Technical Note:

Cornelly: Transitional abstraction licence (transfer and full) application

Published by Stantec UK Limited
March 2019

Document reference:

60743TN1

Report status:

Final

CONFIDENTIAL

New Zealand House, 160-162 Abbey Foregate,
Shrewsbury, Shropshire
SY2 6FD

Telephone: +44 (0)1743 276 100
Facsimile: +44 (01743 248 600

Registered Office:
Stantec UK Ltd
Buckingham Court
Kingsmead Business Park
Frederick Place, London Road
High Wycombe HP11 1JU
Registered in England No. 1188070

Prepared for Tarmac Trading Limited

Document reference: 60743TN1, March 2019

This report has been prepared by Stantec UK Ltd (Stantec) in its professional capacity as environmental specialists, with reasonable skill, care and diligence within the agreed scope and terms of contract and taking account of the manpower and resources devoted to it by agreement with its client and is provided by Stantec solely for the internal use of its client.

The advice and opinions in this report should be read and relied on only in the context of the report as a whole, taking account of the terms of reference agreed with the client. The findings are based on the information made available to Stantec at the date of the report (and will have been assumed to be correct) and on current UK standards, codes, technology and practices as at that time. They do not purport to include any manner of legal advice or opinion. New information or changes in conditions and regulatory requirements may occur in future, which will change the conclusions presented here.

This report is confidential to the client. The client may submit the report to regulatory bodies, where appropriate. Should the client wish to release this report to any other third party for that party's reliance, Stantec may, by prior written agreement, agree to such release, provided that it is acknowledged that Stantec accepts no responsibility of any nature to any third party to whom this report or any part thereof is made known. Stantec accepts no responsibility for any loss or damage incurred as a result, and the third party does not acquire any rights whatsoever, contractual or otherwise, against Stantec except as expressly agreed with Stantec in writing.

	Name	Signature
Author	Kate Brady	
Checked by	Barnaby Harding	
Reviewed by	Barnaby Harding	

Report Reference: 60743TN1rev1
Report Status: Final

Contents

1 Introduction

Cornelly Quarry (the Site) is a limestone quarry situated to the east of the village of South Cornelly, some 0.5 km south of the M4 motorway, 2 km south of Pyle, and some 2 km north/northeast of Porthcawl. The Site is accessed off Hoel Y Splott Road, Bridgend, Wales and is located approximately at post code CF33 4RD. A site location plan is presented as Figure 1.1.

The Site is dewatered in order to facilitate the mining of limestone. The base of the quarry is below water table and hence dewatering water contains both rainfall and groundwater components. A small amount of the dewatered water is used at the Site for a variety of associated processes.

This Technical Note has been prepared by Stantec UK Limited (Stantec) to support Tarmac's application to obtain a transitional route abstraction (transfer) and full (use) licence for the dewatering of Cornelly Quarry and should be read in conjunction with the following application forms presented in Appendix A:

- Form WRH: Application for a transitional water resources licence - Transfer; and
- Form WRH: Application for a transitional water resources licence – Full.

The forms are signed on behalf of Tarmac by Lisa Sumner who is an authorised signatory. A letter of authorisation accompanies the form in Appendix A.

Payment of the combined application fee of £1,635 (£1500 for the transfer component and £135 for the full component) will be paid by credit card.

Per application form question 2.4, invoices should be addressed to;

c/: Ms Sarah Small,
Quorn House,
Meeting Street,
Quorn,
Loughborough,
LE12 8EX
United Kingdom

sarah.small@tarmac.com
Tel: +44 1509 622042

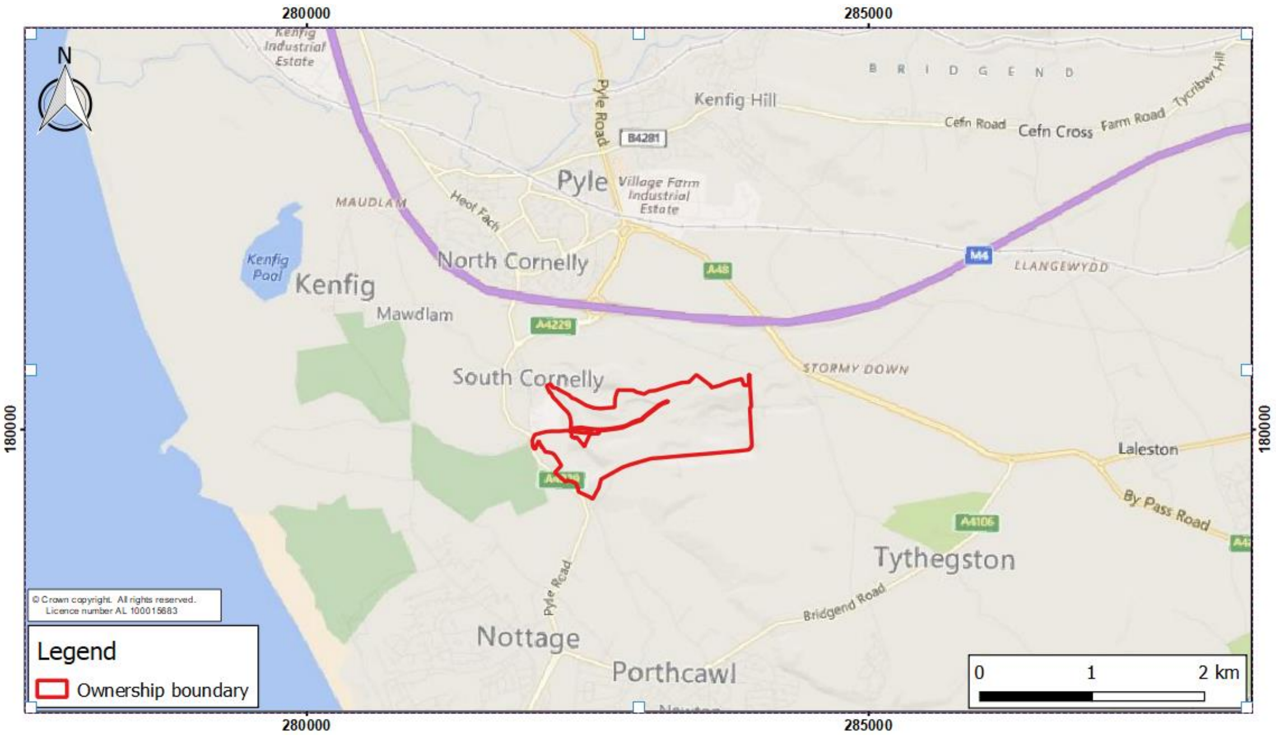
1.1 Background

Cornelly Quarry is the largest quarry in Wales, providing over 1 million tonnes of limestone per year, principally for the steel mill at Port Talbot. It is also an important supplier of aggregates into the local construction industry. The total area covered by existing consents for mineral extraction at the Quarry is approximately 76 ha while the area where mineral extraction is currently undertaken is closer to 38 ha. The main quarry floor is currently at around -3 mAOD. The Site is dewatered by pumping water out of the quarry sump and discharging to the adjacent Grove quarry. Over the next c.37 years, the Quarry will be worked to -75 mAOD.

Planning permission for the Site was granted as part of the Review of Mineral Planning (ROMP) process on 22 December 2016.

Dewatering of the Site has been ongoing for c.30 years and monitoring has been ongoing since 2001.

Figure 1.1 Cornelly location and owner/occupier boundary



1.2 Planning permission

Planning permission for the Site exists in the form of ROMP permission (APP/F6915/X/15/516086), granted on 22 December 2016. A copy of the ROMP permission/decision notice is presented in Appendix B.

1.3 Environmental Impact Assessment

As part of the ROMP process, a voluntary Environmental Impact Assessment (EIA) (SLR 2014) was produced. The impacts identified on the water environment from the proposed development of Cornelly Quarry are, in general, minor.

The main points from the EIA are summarised below and a copy of the most relevant sections is provided in Appendix C.

1. Small predicted hydrogeological effects but no significant hydrogeological impact on Kenfig Pool and Dunes or Merthyr Mawr SSSIs. Cefn Cribwr discounted as no effective hydrological pathway. The nature of the connections and sensitivity of the groundwater levels have been well-constrained through further investigation and integrated numerical modelling.
2. Predicted impacts on the local hydrology are minor. Some effects but no significant impacts predicted for the 24 potentially vulnerable receptors. The likelihood of encountering a significant interconnected fissure at depth has been considered in detail and is concluded to be very low. The implications of encountering such a feature (if one did exist) have been considered by means of modelling which has informed the development of a Water management Plan (WMP) (Appendix D) for the site to tackle this residual uncertainty. The modelling work shows that the

timescales for the effects of encountering such a feature to manifest themselves at key receptors are such that the proposed monitoring would provide sufficient warning to allow effective mitigation to be put in place.

3. Regarding the potential impacts on other groundwater users and water features in the area, see 2.
4. There is no significant risk of saline intrusion predicted.
5. Further deepening of Cornelly Quarry will steepen the hydraulic gradient between adjacent landfills and Cornelly quarry. However, careful consideration of this issue indicates that this does not represent a significant risk. The Water Management Plan includes measures to monitor the quality of water pumped from Cornelly quarry sump.
6. It is not anticipated that the proposed discharge will cause any localised concentration of groundwater flow that could cause washout and hence there are no localised effects on ground stability.
7. It is not anticipated that the proposed discharge will cause any localised concentration of groundwater flow that could cause sinkhole development.

The potential and residual risks have been addressed by means of a monitor and mitigate strategy embedded in the current WMP for the Site. The WMP has previously been subject to extensive consultation with the regulators.

1.4 Collection and review of monitoring data

As required by the WMP for Cornelly, monitoring data are collected from a large number of locations at and around the Site, typically on a monthly basis. Review of these data is presented to the planning authority and Natural Resources Wales (NRW) twice a year in the form of Interim and Annual Reports. These reviews include an assessment of any observed effects of the quarry dewatering on the water environment, breaches of trigger levels, and recommendations for mitigation.

1.5 Report structure

This technical note covers the details required by the application forms and includes:

- Existing water movements and water management at the Site, including abstraction arrangements, water use details, and transfer/discharge details (Section 2); and
- Water balance summary (Section 3).

2 Water Management

2.1 Site water management

Dewatering is required to facilitate efficient extraction of the mineral. During quarrying operations, run-off from the Site and groundwater ingress will accumulate within the lowest section of the active quarry void (the sump), see Figure 2.2. Dewatering occurs to around -3 mAOD.

The Site is governed by the WMP which provides full detail of the monitoring, reporting, and other water management requirements. A copy is provided in Appendix E.

Modelling undertaken for the EIA (SLR, 2014), predicted average off-site pumping rates of 2,670 m^3/d with a quarry base at -30 mAOD (or approximately 15 years into the development) and 2,740 m^3/d at -75 mAOD (or approximately 42 years into the development); demonstrating that inflows are not expected to dramatically increase with depth.

The small predicted change between -30 mAOD and -75 mAOD is due to deepening of the Quarry into a zone in which the permeability is predicted to be very low.

The EIA acknowledged that the predicted rates are off-site rates and do not take into account recirculation that occurs where water is returned from the processing area to the processing lagoon, close to Cornelly Quarry sump. Following the cessation of aggregate washing in 2016, water is no longer returned to the processing lagoon. The occurrence of recirculation has minimal impact on the flows within the aquifer outside the sump and lagoon area but does result in a higher pumping rate from the sump itself. The model implies that, during the period of pumping to date, around 1,500 to 2,000 m^3/d of water has recirculated from Cornelly Quarry lagoon back to the sump. The simulated rate of pumping from Cornelly Quarry sump would therefore be correspondingly higher.

2.2 Abstraction arrangements

The water management arrangement for the Site is presented schematically in Figure 2.1 and Figure 2.2. A more detailed Water Management Drawing (WMD), produced by Tarmac, is provided in Appendix E. Figure 2.3 shows a cross section of the Site now and in the future.

Three submersible pumps (22kW; max flow rate 45 l/s) pump water from the quarry sump, c.15 m up to a further two, ‘Apex’ surface-booster pumps (100kW; max flow rate 50 l/s) in order to drive the water, the c. 40 m, out of the quarry void. This water is transported in a series of overground pipes.

Prior to reaching the processing area, a valve diverts water from the sump into the processing area for use (when required). A meter located on the main discharge line upstream of this valve records the water volume abstracted from the sump before the diversion to the processing area. Unused water is discharged off-site via buried pipes and discharged to the Grove Quarry void located to the west of the Site. A second meter, located on the main discharge line downstream of the valve on the quarry boundary, records the volume of water discharged from Site.

Photos of the Site and infrastructure involved, are provided in Appendix F.

Figure 2.1 Water movements schematic

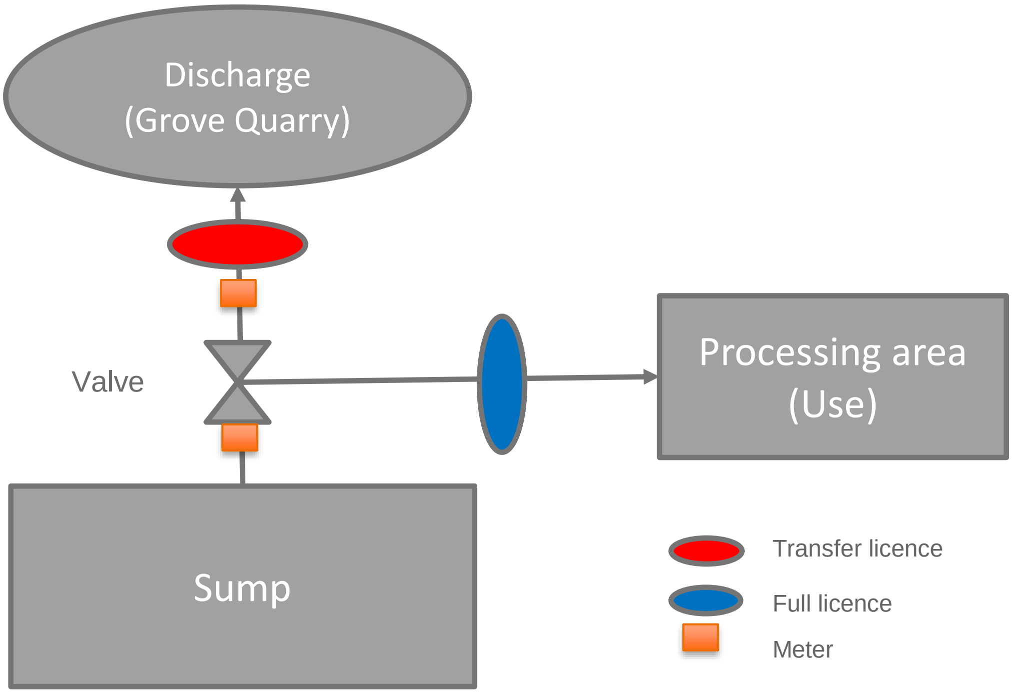


Figure 2.2 Water management plan

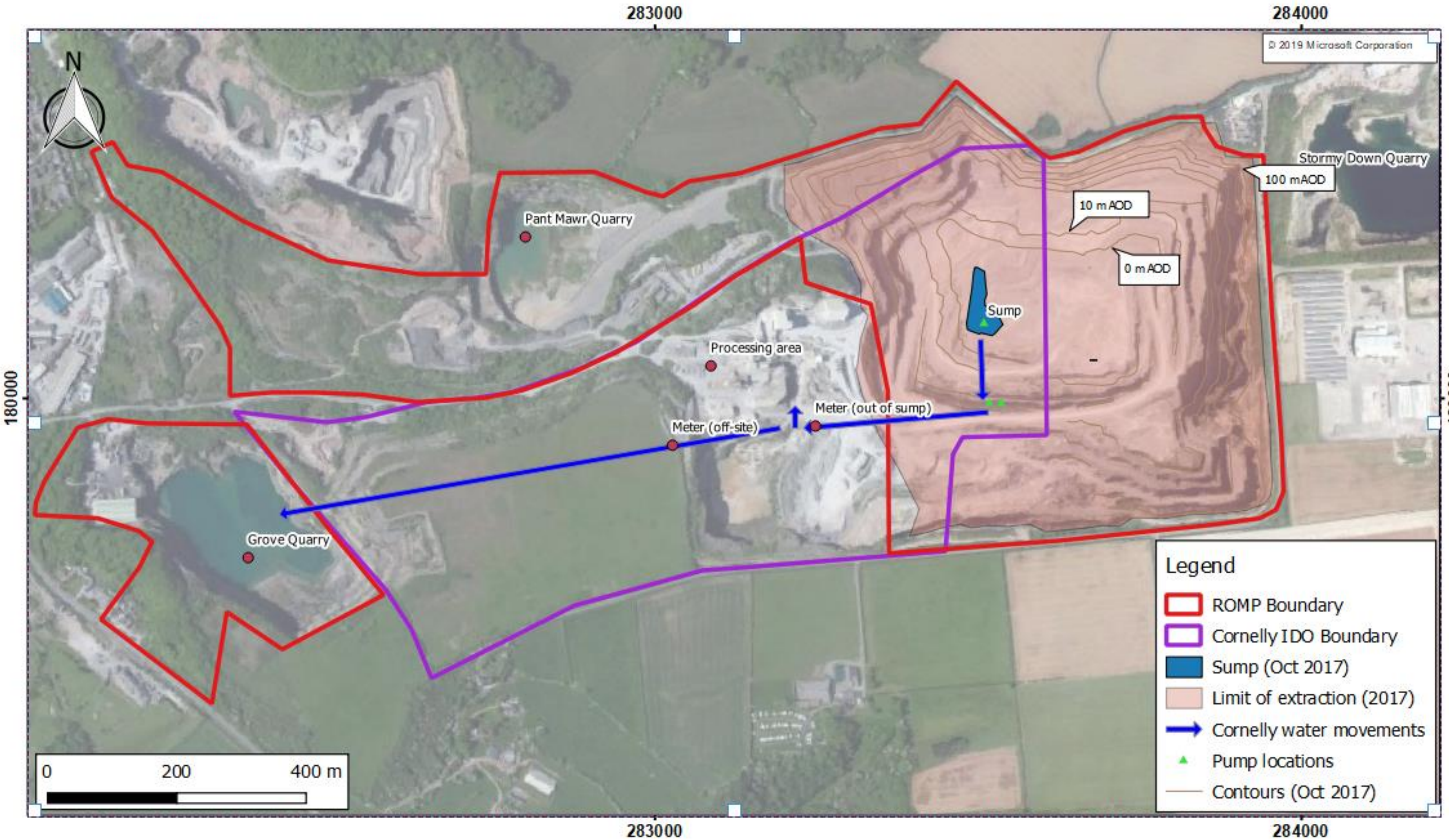
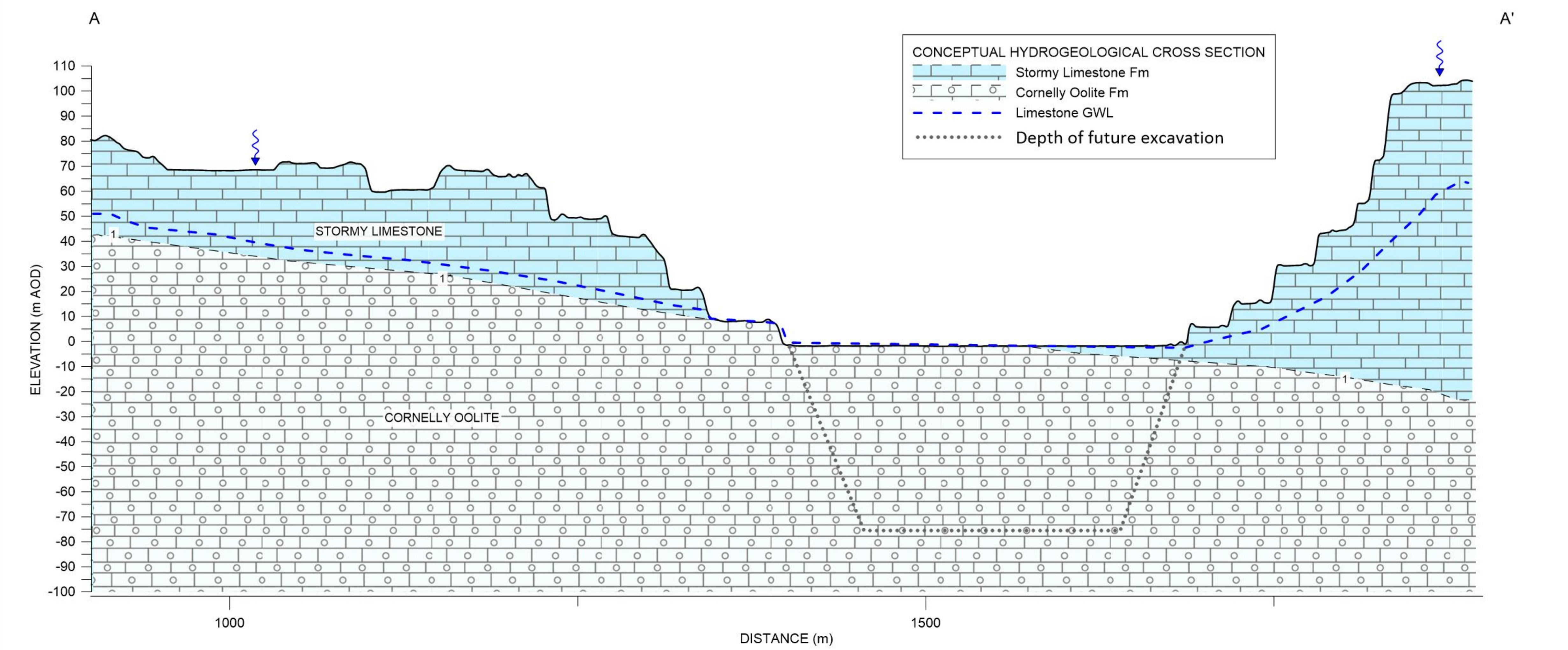


Figure 2.3 Cross section



Cross Section Notes

1. Contacts at depth estimated based on geological mapping

- VERTICAL EXAGGERATION IS 1:6
- CROSS SECTION TOPOGRAPHY FROM NRW LiDAR DATA
- GEOLOGICAL CONTACTS ARE FROM GEOLOGICAL MAPPING
- GROUNDWATER LEVELS ARE FROM MEASURED DATA AT AND AROUND THE SITE

RECHARGE/PERCOLATION*

CROSS SECTION LOCATION

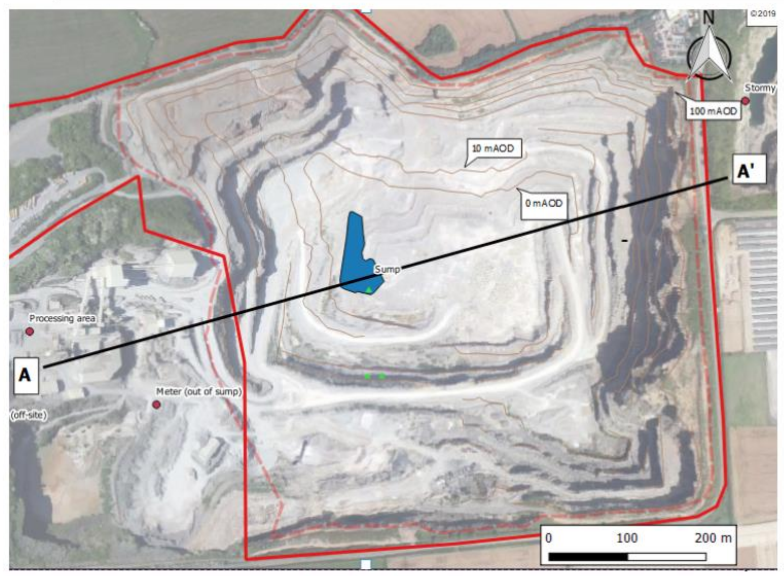


FIGURE 67034TN1 D1 Cornelly Quarry: Conceptual Hydrogeological Cross Section	DATE: *April 2019*	AUTHOR: CDW
	VERTICAL EX.: 1:6	CHECKED: KLB
	PAGE: A3	VERSION: FINAL
	FILE REF: Cornelly Section -3 and -75maod	

2.3 Transfer/ discharge

Water not required for use is discharged off-Site via overground pipe (represented in error as underground on Site Water Management Plan in Appendix E), to Grove Quarry void, c. 1 km west of the Cornelly void, see Figure 2.2. A discharge permit is not held but Tarmac are engaged in pre-application discussions with NRW to ascertain if a discharge permit is required and if so, what kind of discharge it would comprise.

Other options for discharge, as noted in the EIA, are to Pant Mawr Quarry to the north west, Stormy Down Quarry void to the north east or to Processing Lagoon (also known as Cornelly Pond), south of the processing area. No significant discharge has occurred to either Pant Mawr or Stormy Down in the past and discharge is now to Grove Quarry void only. It is noted that historic discharge to the Processing Lagoon/Cornelly Pond is likely to recharge the Cornelly void and have contributed to an element of re-circulation.

Metered volumes for the period 2011 to 2016 are presented. The maximum annual values for transfer were measured in 2014. These are summarised in Table 2.1. The raw data and workings are presented in Appendix G, "Metered Volumes" tab.

Table 2.1 Details of discharge of abstracted water

Discharge location	Location	NGR	Max. discharge (m^3/day)	Max. discharge (l/s)	Permit ID
Grove Quarry	c.1 km west of current extraction area see Figure 2.2	282436, 179811	8,020	278*	TBC

Assuming 8-hour day

2.4 Water use

Abstracted water is used;

- To supply the on-site asphalt plant;
- to supply the on-site concrete plant;
- for dust suppression; and
- for wheel washing (x2).

It is estimated that the concrete plant uses approximately 170 l of water per m^3 of concrete produced. Approximately 100 m^3 of concrete is exported from the Site per day, meaning 17 m^3 of water is used per day.

No water is used in the asphalt plant. Potable and sewage water form separate, closed systems.

Water volumes have been measured upon exit of sump and post processing area since 2001. This gives us an inferred volume of water used at the Site since this time and crucially, during the qualifying period (Jan 2011 – Dec 2017).

During this time, meters were manually read, meaning that measurements are available for varying time periods, but these have been calculated as daily averages (see Appendix G). Finer detail on the usage per process is not metered.

Measured usage for the period January 2011 to December 2017 averaged 2,836 m^3/d, with a maximum use of 8,800 m^3/d. The maximum instantaneous flow rate is 306 l/s.

Table 2.2 Water use statistics at Cornelly Quarry 2011 to 2016

Reference period	Use (m^3/d) Mean	Use (m^3/d) Max	Use (l/s) Mean	Use (l/s) Max
January 2011 to May 2016	2,836	8,800	99	306

In addition to the metered water use, water losses are expected through the quarrying of limestone, with an estimate moisture content of 1% and 1 million tonnes exported per year or 27 m^3/d.

3 Water balance summary

Dewatering is required to facilitate working of the mineral in a dry condition. A transitional route abstraction (transfer) licence is required to continue this work.

Table 3.1 presents the historic (metered) pumping rates for the Site, during the period January 2011 to May 2016. The recordings and workings for which are presented in Appendix G.

These meter readings on which the calculations are based, are submitted on a six-monthly basis to NRW and Bridgend Council in accordance with the WMP.

Table 3.1 Volumes to be abstracted / used

Activity	Maximum (m^3/year)	Maximum (m^3/day)	Max (m^3/hour)	Max instantaneous flow (l/s)
Water use	87,459	8,800	1,100*	306*
Transfer	146,032	8,020	1,003*	278*
Total	1,672,690	11,192	1399*	389*

**assuming an 8-hour day*

The maximum recorded volume of water used in a year was 87,459 m^3 in 2015. This is the maximum recorded volume for a complete year. The maximum recorded volume of water used in a day was 8,800 m^3/d in February 2014. It is not anticipated that water use volumes will increase above those demonstrated.

The maximum recorded transfer in one year was 146,032 m^3 recorded in a single year. It is possible that this was exceeded in other years where full datasets are not available. This value will be greater in wetter years and less in drier ones.

Water levels within the void have been maintained at c.-3 mAOD for many years, as evidenced by the WMD (Appendix E) and topographical survey 2014 (Appendix H).

4 Summary of licencing requirements

Based on the evidence provided above, it is considered that the licencing requirements are as follows:

- Transfer licence – dewatering water:
  - peak instantaneous pumping rate = 278 l/s (or 1003 m^3/hr).
  - maximum dewatering volume (daily) = 8,020 m^3/d.
  - maximum dewatering volume (annual) = 146,032 m^3/year (2014 max as per **Error! Reference source not found.**).

  Note that we would not expect the transfer element to be limited by a numerical limit on flow rates.

- Full licence (consumptive):
  - peak instantaneous pumping rate = 306 l/s (or 1100 m^3/hr).
  - maximum dewatering volume (daily) = 8,800 m^3/d.
  - maximum dewatering volume (annual) = 87,489 m^3/year (2015 max as per Table 2.2).

References

ESI, 2016. Ripon Pennycroft: Hydrogeological Impact Assessment, ESI Ltd, Report reference: 60746R10, December 2016.

SLR, 2014. Environmental Statement Volume 1, Environment Act ROMP Review: Cornelly Quarry.

Appendices

Appendix A

Application forms

Application for a transitional water resources licence

Form WRH

Fill in this form if you are applying for a transitional water resources licence to continue a previously exempt abstraction.

This form is available in both English and Welsh. Please check that this is the latest version of the form available from our website before submitting your application.

Please ensure you use Guidance Note WRH to help you.

All relevant guidance documents can be found on our website.

Contents

1. Application type and fee

1.1 Please select your application type from the list below.

A new transitional water resources full abstraction licence for a previously exempt abstraction	☐
A new transitional water resources transfer licence for a previously exempt abstraction	☑
A variation to an existing full abstraction licence to add a previously exempt abstraction	☐
A variation to an existing transfer licence to add a previously exempt abstraction	☐

1.2 Please indicate the amount and how you wish to pay your application

Amount paid	1500		
Cheque	☐		
Credit or debit card	☑		
BACS transfer	☐	BACS reference number	PRC

2 Applicant and agent details

This is the individual or organisation any resulting licence will be issued to, and must be a legal entity. If you are an agent acting on behalf of an applicant, provide their details here and yours in section 2.2.

2.1 Applicant details

Individual	☐	Public body	☐
Registered company	☑	Organisation or group of individuals	☐
Other	☐	If 'Other', please specify	

Title

First name	
Last name	
Company, charity, body, or trading name (if relevant)	
Registered company or charity number (if relevant)	Tarmac Trading Limited
Address	Portland House
	Bickenhill Lane
	Solihull
	Birmingham
Postcode	B37 7BQ
Telephone - mobile	07740 162027
Telephone - office	01656 746568
Email address	

We will contact you by email unless you tick here. ☐

2.2 Agent details

This is who we will correspond with unless otherwise informed. If you are an agent applying on behalf of an applicant, please include a letter of authorisation from the applicant allowing you to act as signatory,and provide a reference for this document in the box below.

Document reference		
Title	Ms	
First name	Kate	
Last name	Brady	
Company or trading name	Stantec UK Ltd	
Position in company	Senior Consultant	
Address	New Zealand House	
	160 Abbey Foregate	

	Shrewsbury
	Shropshire
Postcode	SY2 6FD
Telephone - mobile	07376 497250
Telephone - office	01743 276117
Email address	kate.brady@stantec.com

We will contact you by email unless you tick here. ☐

2.3 Site operation contact

Please specify who we should contact with regard to your site operation.

Applicant ☑

Agent ☐

Other ☐ Please provide contact details for the operational contact on a separate referenced document, and tell us this reference below.

Document reference

2.4 Abstraction invoices and records contact

Please specify who we should contact for invoices and abstraction records (returns). Please note that these may not be not required for transfer licences.

Invoice address

Applicant ☐

Agent ☐

Other ☑ Please provide contact details for the operational contact on a separate referenced document, and tell us this reference below.

Document reference: c/o Sarah Small, see report 60734TN1

Abstraction records

Applicant ☑

Agent ☐

Other ☐ Please provide contact details for the operational contact on a separate referenced document, and tell us this reference below.

Document reference

3. Site name

3.1 Please provide the site name below:

Site name: Cornelly Quarry

4. Entitlement to apply

4.1 Have you abstracted water between 01 January 2011 and 31 December 2017 for the activity which you are applying to be licensed?

Yes ☑

No ☐ Please see our water abstraction and impounding webpage for further information on the correct applicaton forms.

4.2 What is your connection to the land where the abstraction takes place?

Please provide a map outlining your land ownership/occupation and include all abstractions and discharges where relevant.

Owner ☐

Occupier ☑

Document reference: Figure 1.1 of report 67034TN1

4.3 Do you have a legal right of access to the land where the abstraction take place?

No ☐

Yes ☑ Please provide further detail in the box below. If necessary continue on a separate referenced document, and tell us this reference.

Document reference: ROMP - App B of report 67034TN1

5. Existing licence number(s)

If you are applying to change an existing licence please provide the licence number below.

Licence number(s): n/a

6. Cross border applications

As part of your site operation do you also abstract for a previously exempt activity in England?

No ☑

Yes ☐ Please provide detail of this cross border application in the box below. If possible, provide a reference or application number, or name of an Environment Agency contact with whom the application has been discussed.

Continue on a separate referenced sheet if necessary and tell us the reference for this document.

Document reference:

7. Abstraction details

7.1 Site map

Please provide a map with details of the location(s) you abstract water from (points reaches, or areas). Tell us the reference for this map, below.

Site map reference: See report 67034TN1, Figure 2.2

7.2 Please tell us details about the location(s) you abstract water from (points reaches, or areas) in the tables below.

The abstraction location, name, or reference must be the same as those used on the site map, in question 7.1. If you need more space, please continue on a separate referenced sheet if necessary and tell us the reference for this document

Document reference: Cornelly sump, see report 67034TN1

Table 7. 1 - Surface water abstractions						
Abstraction location name or reference (As labelled on the site map)	Type of location (single point, reach, area)	Source of Supply	First National Grid Reference (12 digits)	Second National Grid Reference (12 digits)	Third National Grid Reference (12 digits)	Fourth National Grid Reference (12 digits)
n/a						

If necessary, continue on a separate sheet and tell us the reference for this document.

Document reference(s)

Table 7. 2 Ground water abstractions										
Abstraction location name or reference (as labelled on map)	Source of Supply	National Grid Reference (12 digit)	Overall depth (metres)	Maximum diameter (millimetres) or area of excavation (square metres)	Screened section (metres below ground level)	Drift geology	Solid geology	Rest pump water level	Pumped water level	Pump Depth
Cornelly sump	Groundwater	283512, 180124	-3.2mAOD	38 ha	n/a	n/a	Carboniferous Limestone:	c.50mAOD	-3.2mAOD	-3.2mAOD

If necessary, continue on a separate sheet and tell us the reference for this document.

Document reference(s) See report 67034TN1

8. Abstraction history and evidence

8.1 Please complete table 8.1 to document that the abstraction(s) and transfer(s) has or have been taking place during the qualifying period.

If necessary, continue on a separate sheet and tell us the reference for this document.

Document reference(s) See App D of report 67034TN1

Table 8.1

Year	Abstraction location name or reference (as labelled on map)	Purpose(s) water used for	Period of abstraction	Maximum quantities abstracted						Means of measurement, or assessment of abstracted quantities	Are these the maximum quantities of water you wish to have licensed? (Yes or No)
			All year, or months, or days (provide specific dates)	Year (cubic metres)	Day (cubic metres)	Hour (cubic metres)	Peak instantaneous flow rate (litres per second)	Maximum number of hours of abstraction per day	Please indicate whether volume is actual (A) or estimated (E)		
01 January 2011 to 31 December 2011											
01 January 2012 to 31 December 2012											
01 January 2013 to 31 December 2013											
01 January 2014 to 31 December 2014	Quarry sump	dewatering	All year	146032	8020	1003	278	24	A	Meter	Yes
01 January 2015 to 31 December 2015											
01 January 2016 to 31 December 2016											
01 January 2017 to 31 December 2017											

8.2 Please complete the table below if you wish a lesser quantity of water to be licensed than that detailed in table 8.1.

If necessary, continue on a separate sheet and provide a reference for this document.

Document reference: n/a

Table 8.2

Abstraction location name or reference (as labelled on map)	Purpose water is used for	Abstraction period	Maximum annual abstraction volume (cubic metres)	Maximum daily abstraction volume (cubic metres)	Maximum hourly abstraction volume (cubic metres)	Maximum number of hours of abstraction per day	Peak abstraction rate (litres per second)

8.3 Do you wish your abstracted quantities to be aggregated?

You can aggregate:

i) across some or all of the abstraction points, or reaches, or areas listed above.

ii) with other abstractions you wish to have licensed through the transitional process.

iii) abstractions you need to have licensed through the standard licensing process.

iv) with existing licences you hold.

No ☐

Yes ☑ Provide details of any proposed aggregation in the box below. If necessary, continue on a separate sheet and provide a reference for this document.

Document reference:

8.4 Please provide a detailed description of how the abstraction(s) has/have taken place

Use the box below to tell us about your abstraction(s). The description should include the following:

- A diagram or schematic of how the activity has been undertaken, using your abstraction point references and including any discharge points
- Details of the structure and equipment involved in the abstraction. This should include dimensions.
- Details of your means of measurement or assessment of abstraction quantities method

If necessary, continue on a separate sheet and tell us the reference for this document.

Document reference: See report 67034TN1

8.5 Please list the evidence you are providing to support your application

Use the box below. The evidence should demonstrate the following:

- That abstraction has taken place at some time during the seven year qualifying period.
- The quantities of water you have abstracted during the qualifying period. For example, records of meter readings, or cropping plans.

If necessary, continue on a separate sheet and provide a reference for this document.

Document reference: See report 67034TN1

9. Discharge details

9.1 Please provide details on any discharge of abstracted water in table 9.1 below and on the map used to show abstraction locations.

If necessary, continue a separate sheet and provide a reference for this document.

Document reference: See report 67034TN1

Table 9.1 - Details of any discharge of abstracted water

Discharge location name or reference (as labelled on map)	National Grid Reference of discharge point (12 digit)	Total volume discharged (cubic metres)	Environmental Permit number for Water Discharge Activity number (if applicable)
Discharge point	282436, 179811	8020m3/d	n/a

9.2 Please provide a description of discharge structures and equipment

See report 67034TN1, pipe outfall to Grove Quarry void.

If necessary, continue a separate sheet and provide a reference for this document.

Document reference: See report 67034TN1

10. Eel considerations

Does your abstraction include measures to safeguard eels?

No ☑

Yes ☐ Provide details below

n/a

11. Trickle Irrigation

If you are applying to licence a trickle irrigation abstraction, do you wish to apply for a Two-Part Tariff agreement with your application?

No ☑

Yes ☐ We will contact you during determination of your application to arrange this agreement.

12. Planned abstractions

12.1 Do you expect to increase the current rate of abstraction for the activity you are applying to have licensed from 01January 2018 onwards or to carry out further new abstractions (both termed 'planned' abstractions) at this site in the future?

No ☐

Yes ☑

12.2 Have you submitted a licence application (s) for any planned abstraction(s) as a result of the Water Act 2003 changes?

No ☑

Yes ☐ Provide a reference number if you have already submitted an application(s) to cover any planned abstractions.

Document reference

13. Other abstractions

Please provide details of any other abstraction(s) (licensed or exempt) that are associated with this application in table 13.1 below.

Table 13.1 - Details of any other abstraction(s) (licensed or exempt) that are associated with this application

National Grid Reference (12 digit) of where you abstract water	Source name and type	Purpose of abstraction	Where do you use the water?	When do you abstract the water?	Is this a pending application, or already licensed? Please provide the application or licence number as appropriate
as this abstraction	Cornelly sump	use	on site	Continiously	pending, accompanies
			see 60734TN1		this application

14. Planning permission

Complete table 14.1 below and provide details of any planning permissions or advice associated with the abstraction you are applying to have licensed where relevant. Provide a copy of any permissions or advice,providing a reference for this document below.

Document reference: Planning permission (ROMP)

Table 14.1 – Planning permission

Abstraction location name or reference (as labelled on map	Is planning permission needed, Yes or No?	Planning permission status (if required)	Have you received any planning advice for the abstraction?
Cornelly Quarry	Yes	Granted (ROMP)	No.

15. Environmental impact assessment(EIA)

Does your application require an EIA under The Water Resources (Environmental Impact Assessment) (England and Wales) Regulations 2003 (as amended)

No ☑

Yes ☐ Please provide a copy of your environmental impact assessment; provide a reference for this assessment below.

Document reference: see Voluntary EIA appnd to 67034TN1

16. Licence duration

Tell us when you wish your abstraction licence to end

Normally abstraction licences are granted for between 6 and 18 years in line with the catchment licence common end date. If you require a shorter or longer duration licence, please provide details and your justification in the box below.

If necessary, continue a separate sheet and provide a reference for this document.

Document reference: See report 67034TN1

Licence should be granted until 2056

17 Declaration and data protection and commercial confidentiality

Data protection:

Please read the guidance carefully for details on who can sign this section and note the information relating to the Data Protection Act 1998, our Public Register and exclusions.

Commercial confidentiality:

Do you think your application should be confidential, and that information should not be placed on the public register?

No ☑

Yes ☐ You must send us supporting information to tell us why. Use the box below or a separate sheet, and tell us the reference you have given this document.

Document reference

Declaration:

By signing below, you are declaring that as far as you know and believe the information given in this form, on any map and in any supporting or additional information is true.

A printed name in the ‘signature’ response box will be treated as the equivalent of an electronic signature.

Title	Ms
First name	Lisa
Last name	Sumner
Position	Technical Manager - Environmental Performance
Today’s date	30/04/2019

Application for a transitional water resources licence

Form WRH

Fill in this form if you are applying for a transitional water resources licence to continue a previously exempt abstraction.

This form is available in both English and Welsh. Please check that this is the latest version of the form available from our website before submitting your application.

Please ensure you use Guidance Note WRH to help you.

All relevant guidance documents can be found on our website.

Contents

1. Application type and fee

1.1 Please select your application type from the list below.

A new transitional water resources full abstraction licence for a previously exempt abstraction	☐
A new transitional water resources transfer licence for a previously exempt abstraction	☑
A variation to an existing full abstraction licence to add a previously exempt abstraction	☐
A variation to an existing transfer licence to add a previously exempt abstraction	☐

1.2 Please indicate the amount and how you wish to pay your application

Amount paid: 1500

Cheque ☐

Credit or debit card ☑

BACS transfer ☐ BACS reference number: PRC

2 Applicant and agent details

This is the individual or organisation any resulting licence will be issued to, and must be a legal entity. If you are an agent acting on behalf of an applicant, provide their details here and yours in section 2.2.

2.1 Applicant details

Individual	☐	Public body	☐
Registered company	☑	Organisation or group of individuals	☐
Other	☐	If 'Other', please specify	

Title

First name	
Last name	
Company, charity, body, or trading name (if relevant)	
Registered company or charity number (if relevant)	Tarmac Trading Limited
Address	Portland House
	Bickenhill Lane
	Solihull
	Birmingham
Postcode	B37 7BQ
Telephone - mobile	07740 162027
Telephone - office	01656 746568
Email address	

We will contact you by email unless you tick here. ☐

2.2 Agent details

This is who we will correspond with unless otherwise informed. If you are an agent applying on behalf of an applicant, please include a letter of authorisation from the applicant allowing you to act as signatory,and provide a reference for this document in the box below.

Document reference		
Title	Ms	
First name	Kate	
Last name	Brady	
Company or trading name	Stantec UK Ltd	
Position in company	Senior Consultant	
Address	New Zealand House	
	160 Abbey Foregate	

	Shrewsbury
	Shropshire
Postcode	SY2 6FD
Telephone - mobile	07376 497250
Telephone - office	01743 276117
Email address	kate.brady@stantec.com

We will contact you by email unless you tick here. ☐

2.3 Site operation contact

Please specify who we should contact with regard to your site operation.

Applicant ☑

Agent ☐

Other ☐ Please provide contact details for the operational contact on a separate referenced document, and tell us this reference below.

Document reference

2.4 Abstraction invoices and records contact

Please specify who we should contact for invoices and abstraction records (returns). Please note that these may not be not required for transfer licences.

Invoice address

Applicant ☐

Agent ☐

Other ☑ Please provide contact details for the operational contact on a separate referenced document, and tell us this reference below.

Document reference: c/o Sarah Small, see report 67034TN1

Abstraction records

Applicant ☑

Agent ☐

Other ☐ Please provide contact details for the operational contact on a separate referenced document, and tell us this reference below.

Document reference

3. Site name

3.1 Please provide the site name below:

Site name: Cornelly Quarry

4. Entitlement to apply

4.1 Have you abstracted water between 01 January 2011 and 31 December 2017 for the activity which you are applying to be licensed?

Yes ☑

No ☐ Please see our water abstraction and impounding webpage for further information on the correct applicaton forms.

4.2 What is your connection to the land where the abstraction takes place?

Please provide a map outlining your land ownership/occupation and include all abstractions and discharges where relevant.

Owner ☐

Occupier ☑

Document reference: Figure 1.1 of report 67034TN1

4.3 Do you have a legal right of access to the land where the abstraction take place?

No ☐

Yes ☑ Please provide further detail in the box below. If necessary continue on a separate referenced document, and tell us this reference.

Document reference: ROMP - App B of report 67034TN1

5. Existing licence number(s)

If you are applying to change an existing licence please provide the licence number below.

Licence number(s): n/a

6. Cross border applications

As part of your site operation do you also abstract for a previously exempt activity in England?

No ☑

Yes ☐ Please provide detail of this cross border application in the box below. If possible, provide a reference or application number, or name of an Environment Agency contact with whom the application has been discussed.

Continue on a separate referenced sheet if necessary and tell us the reference for this document.

Document reference:

7. Abstraction details

7.1 Site map

Please provide a map with details of the location(s) you abstract water from (points reaches, or areas). Tell us the reference for this map, below.

Site map reference	See report 67034TN1, Figure 2.2

7.2 Please tell us details about the location(s) you abstract water from (points reaches, or areas) in the tables below.

The abstraction location, name, or reference must be the same as those used on the site map, in question 7.1. If you need more space, please continue on a separate referenced sheet if necessary and tell us the reference for this document

Document reference	Cornelly sump, see report 67034TN1

Table 7. 1 - Surface water abstractions						
Abstraction location name or reference (As labelled on the site map)	Type of location (single point, reach, area)	Source of Supply	First National Grid Reference (12 digits)	Second National Grid Reference (12 digits)	Third National Grid Reference (12 digits)	Fourth National Grid Reference (12 digits)
n/a						

If necessary, continue on a separate sheet and tell us the reference for this document.

Document reference(s)

Table 7. 2 Ground water abstractions										
Abstraction location name or reference (as labelled on map)	Source of Supply	National Grid Reference (12 digit)	Overall depth (metres)	Maximum diameter (millimetres) or area of excavation (square metres)	Screened section (metres below ground level)	Drift geology	Solid geology	Rest pump water level	Pumped water level	Pump Depth
Cornelly sump	Groundwater	283512, 180124	-3.2mAOD	38 ha	n/a	n/a	Carboniferous Limestone:	c.50mAOD	-3.2mAOD	-3.2mAOD

If necessary, continue on a separate sheet and tell us the reference for this document.

Document reference(s) See report 67034TN1

8. Abstraction history and evidence

8.1 Please complete table 8.1 to document that the abstraction(s) and transfer(s) has or have been taking place during the qualifying period.

If necessary, continue on a separate sheet and tell us the reference for this document.

Document reference(s) See App D of report 67034TN1

Table 8.1

Year	Abstraction location name or reference (as labelled on map)	Purpose(s) water used for	Period of abstraction	Maximum quantities abstracted						Means of measurement, or assessment of abstracted quantities	Are these the maximum quantities of water you wish to have licensed? (Yes or No)
			All year, or months, or days (provide specific dates)	Year (cubic metres)	Day (cubic metres)	Hour (cubic metres)	Peak instantaneous flow rate (litres per second)	Maximum number of hours of abstraction per day	Please indicate whether volume is actual (A) or estimated (E)		
01 January 2011 to 31 December 2011											
01 January 2012 to 31 December 2012											
01 January 2013 to 31 December 2013											
01 January 2014 to 31 December 2014	Quarry sump	dewatering	All year	146032	8020	1003	278	24	A	Meter	Yes
01 January 2015 to 31 December 2015											
01 January 2016 to 31 December 2016											
01 January 2017 to 31 December 2017											

8.2 Please complete the table below if you wish a lesser quantity of water to be licensed than that detailed in table 8.1.

If necessary, continue on a separate sheet and provide a reference for this document.

Document reference: n/a

Table 8.2

Abstraction location name or reference (as labelled on map)	Purpose water is used for	Abstraction period	Maximum annual abstraction volume (cubic metres)	Maximum daily abstraction volume (cubic metres)	Maximum hourly abstraction volume (cubic metres)	Maximum number of hours of abstraction per day	Peak abstraction rate (litres per second)

8.3 Do you wish your abstracted quantities to be aggregated?

You can aggregate:

i) across some or all of the abstraction points, or reaches, or areas listed above.

ii) with other abstractions you wish to have licensed through the transitional process.

iii) abstractions you need to have licensed through the standard licensing process.

iv) with existing licences you hold.

No ☐

Yes ☑ Provide details of any proposed aggregation in the box below. If necessary, continue on a separate sheet and provide a reference for this document.

Document reference:

8.4 Please provide a detailed description of how the abstraction(s) has/have taken place

Use the box below to tell us about your abstraction(s). The description should include the following:

- A diagram or schematic of how the activity has been undertaken, using your abstraction point references and including any discharge points
- Details of the structure and equipment involved in the abstraction. This should include dimensions.
- Details of your means of measurement or assessment of abstraction quantities method

If necessary, continue on a separate sheet and tell us the reference for this document.

Document reference: See report 67034TN1

8.5 **Please list the evidence you are providing to support your application**

Use the box below. The evidence should demonstrate the following:

- That abstraction has taken place at some time during the seven year qualifying period.
- The quantities of water you have abstracted during the qualifying period. For example, records of meter readings, or cropping plans.

If necessary, continue on a separate sheet and provide a reference for this document.

Document reference: See report 67034TN1

9. Discharge details

9.1 Please provide details on any discharge of abstracted water in table 9.1 below and on the map used to show abstraction locations.

If necessary, continue a separate sheet and provide a reference for this document.

Document reference: See report 67034TN1

Table 9.1 - Details of any discharge of abstracted water

Discharge location name or reference (as labelled on map)	National Grid Reference of discharge point (12 digit)	Total volume discharged (cubic metres)	Environmental Permit number for Water Discharge Activity number (if applicable)
Discharge point	282436, 179811	8020m3/d	n/a

9.2 Please provide a description of discharge structures and equipment

See report 67034TN1, pipe outfall to Grove Quarry void.

If necessary, continue a separate sheet and provide a reference for this document.

Document reference: See report 67034TN1

10. Eel considerations

Does your abstraction include measures to safeguard eels?

No ☑

Yes ☐ Provide details below

n/a

11. Trickle Irrigation

If you are applying to licence a trickle irrigation abstraction, do you wish to apply for a Two-Part Tariff agreement with your application?

No ☑

Yes ☐ We will contact you during determination of your application to arrange this agreement.

12. Planned abstractions

12.1 Do you expect to increase the current rate of abstraction for the activity you are applying to have licensed from 01January 2018 onwards or to carry out further new abstractions (both termed 'planned' abstractions) at this site in the future?

No ☐

Yes ☑

12.2 Have you submitted a licence application (s) for any planned abstraction(s) as a result of the Water Act 2003 changes?

No ☑

Yes ☐ Provide a reference number if you have already submitted an application(s) to cover any planned abstractions.

Document reference

13. Other abstractions

Please provide details of any other abstraction(s) (licensed or exempt) that are associated with this application in table 13.1 below.

Table 13.1 - Details of any other abstraction(s) (licensed or exempt) that are associated with this application

National Grid Reference (12 digit) of where you abstract water	Source name and type	Purpose of abstraction	Where do you use the water?	When do you abstract the water?	Is this a pending application, or already licensed? Please provide the application or licence number as appropriate
as this abstraction	Cornelly sump	use	on site	Continiously	pending, accompanies
			see 60734TN1		this application

14. Planning permission

Complete table 14.1 below and provide details of any planning permissions or advice associated with the abstraction you are applying to have licensed where relevant. Provide a copy of any permissions or advice,providing a reference for this document below.

Document reference: Planning permission (ROMP)

Table 14.1 – Planning permission

Abstraction location name or reference (as labelled on map	Is planning permission needed, Yes or No?	Planning permission status (if required)	Have you received any planning advice for the abstraction?
Cornelly Quarry	Yes	Granted (ROMP)	No.

15. Environmental impact assessment(EIA)

Does your application require an EIA under The Water Resources (Environmental Impact Assessment) (England and Wales) Regulations 2003 (as amended)

No ☑

Yes ☐ Please provide a copy of your environmental impact assessment; provide a reference for this assessment below.

Document reference: see Voluntary EIA appnd to 67034TN1

16. Licence duration

Tell us when you wish your abstraction licence to end

Normally abstraction licences are granted for between 6 and 18 years in line with the catchment licence common end date. If you require a shorter or longer duration licence, please provide details and your justification in the box below.

If necessary, continue a separate sheet and provide a reference for this document.

Document reference: See report 67034TN1

Licence should be granted until 2056

17 Declaration and data protection and commercial confidentiality

Data protection:

Please read the guidance carefully for details on who can sign this section and note the information relating to the Data Protection Act 1998, our Public Register and exclusions.

Commercial confidentiality:

Do you think your application should be confidential, and that information should not be placed on the public register?

No ☑

Yes ☐ You must send us supporting information to tell us why. Use the box below or a separate sheet, and tell us the reference you have given this document.

Document reference

Declaration:

By signing below, you are declaring that as far as you know and believe the information given in this form, on any map and in any supporting or additional information is true.

A printed name in the 'signature' response box will be treated as the equivalent of an electronic signature.

Title	Ms
First name	Lisa
Last name	Sumner
Position	Technical Manager - Environmental Performance
Today's date	30/04/2019

TARMAC
A CRH COMPANY

To whom it may concern

12 February 2019

Dear Sirs

Authority to Execute Permit Applications

I, the undersigned, being the Secretary of the Corporate Secretary hereby confirm that:

Sharon Palmer	National Environmental Permitting Manager
Michael Jones	Permitting and Compliance Manager
Lisa Sumner	Permitting and Compliance Manager
Tom Flint	Technical Manager

are each authorised to execute, acting independently, all permit applications, variations, or surrenders on behalf of the Companies in respect of all local authorities.

For the avoidance of doubt, this letter of authority replaces any previous letters of authority provided to your agency in relation to the Companies listed in Appendix 1.

Petershill Secretaries Limited is the corporate secretary of Tarmac Secretaries (UK) Limited. The Companies House link evidencing this is https://beta.companieshouse.gov.uk/company/00532256/officers

Yours faithfully

Andrew Yau
For and on behalf of Petershill Secretaries Limited
Company Secretary of Tarmac Secretaries (UK) Limited

Tarmac Trading Limited Registered in England and Wales. Company No. 453791
Tarmac Cement and Lime Limited Registered in England and Wales. Company No. 66558
Tarmac Services Limited Registered in England and Wales. Company No. 8197397
Registered address for all companies: **Portland House Bickenhill Lane Solihull Birmingham B37 7BQ**

Portland House, Bickenhill Lane
Solihull, Birmingham
B37 7BQ
0845 812 6400

Appendix 1 – the Companies

Company Name	Company Number
Brett Tarmac Limited	03336448
East Coast Slag Products Limited	00330538
GRS Rail Services Limited (formerly known as Northampton Aggregates Limited)	02632166
Solent Aggregates Limited	02730599
Tarmac Aggregates Limited	00297905
Tarmac Building Products Limited	04026569
Tarmac Caledonian Limited	SC176011
Tarmac Cement and Lime Limited	00066558
Tarmac Central Limited	03140596
Tarmac Limited	05560273
Tarmac Northern Limited	03140596
Tarmac Roadstone Limited	00368254
Tarmac Topmix Limited	03132032
Tarmac Trading Limited	00453791
Tarmac Western Limited	01640664
West Lothian Recycling Limited	SC193765

Appendix B

ROMP permission

Lesley Griffiths AC/AM
Ysgrifennydd y Cabinet dros yr Amgylchedd a Materion Gwledig
Cabinet Secretary for Environment and Rural Affairs

Llywodraeth Cymru
Welsh Government

Ein cyf/Our ref A-PAA-25-08-004

Mr Malcolm Lawer
Acting Regional Head of Estates
Tarmac
Portland House,
Bickenhill Lane,
Solihull,
Birmingham,
B37 7BQ

22 December 2016

REVIEW OF OLD MINERAL PERMISSIONS (ROMP)

APPLICATION A CONSISTING OF THE SUBMISSION OF REVISED PLANNING CONDITIONS FOR APPROVAL FOR CORNELLY QUARRY, NEAR SOUTH CORNELLY, BRIDGEND

APPLICATION A IS ONE OF FOUR RELATED APPLICATIONS MADE UNDER THE PLANNING AND COMPENSATION ACT 1991 AND THE ENVIRONMENT ACT 1995, SCHEDULES 13 AND 14

1. Consideration has been given to the report of the appointed Inspector Clive Nield BSc, CEng, MICE, MCIWEM, who held a local inquiry into the four applications for the approval of revised planning conditions under the above legislation. The four applications (applications A-D) were to be considered together because the cases are inextricably linked in terms of working method, environmental impact, water management, monitoring and mitigation, final restoration and after use.

2. The Secretary of State for Wales called in the three ROMP applications for Gaens, Grove and Cornelly quarries under paragraph 13 of Schedule 13 to the 1995 Act and

Bae Caerdydd • Cardiff Bay
Caerdydd • Cardiff
CF99 1NA

Canolfan Cyswllt Cyntaf / First Point of Contact Centre:
0300 0604400
Gohebiaeth.Lesley.Griffiths@llyw.cymru
Correspondence.Lesley.Griffiths@gov.wales

the IDO application for Cornelly and Grove quarry under paragraph 8 of Schedule 14 to that Act. The functions of the Secretary of State in all relevant respects now vest in the Welsh Ministers. The first application to be called in was at Gaens quarry on the 14th May, 1998. The two other ROMP applications for Grove and Cornelly quarries were called in on the 9th July, 1998. The IDO application submitted for Cornelly and Grove quarries was called in on the 11th February, 2010.

3. The ROMP application submitted for Cornelly (Application A) quarry was made by Cambrian Stone (a Tarmac joint venture company). The ROMP application submitted for Grove quarry (Application B) was made by Pioneer Aggregates Ltd. Although the Grove quarry application was originally submitted in the name of Pioneer Aggregates Ltd, the ownership of the quarry changed to the Tarmac Group (Lafarge Tarmac Ltd). At the outset of the public inquiry it was confirmed ownership now lay with Tarmac Trading Ltd. The ROMP application (Application C) submitted in relation to Gaens quarry was made by T.S.Rees Ltd. The IDO application submitted for Cornelly and Grove quarries (Application D) was made by Cambrian Stone Ltd in respect of Grove quarry and Tarmac (South Western) Ltd in respect of Cornelly quarry.

4. The three ROMP applications were not subject to formal environmental impact assessment (EIA) when they were originally submitted but EIA was undertaken voluntarily and Environmental Statements submitted. The IDO application for Cornelly and Grove quarries which, having been submitted much later, fell within the scope of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) regulations 1999 as amended. In 2009, the Town and Country (Environmental Impact Assessment) (Undetermined Reviews of Old Mineral permissions) (Wales) Regulations 2009 formally made EIA a mandatory requirement for the three ROMP applications.

5. Since the three ROMP applications and the voluntary Environmental Statements were submitted, the information contained in Environmental Statements has been substantially updated for each quarry. The latest Environmental Statement for each application contained a new proposed schedule of conditions and updated Water Management Plan. These Environmental Statements were published for consultation on the 26th June 2014 and the public given full opportunity to inspect information. Natural Resources Wales (NRW) has been consulted regularly by all parties and played an important role in seeking to analyse and resolve all matters relating to the water environment, particularly potential effects on the Kenfig/Cynffig Special Area of Conservation (SAC). It also participated fully in the inquiry process.

6. The Inspector's report is published alongside this letter. A note of correction applies to paragraph 135, where reference to "12mm" should be "12cm".

Planning Considerations

7. With regard to the consideration of the proposals against relevant national and local policy it is important to note the principle of mineral extraction at these quarries is already established by the extant planning permissions. Only the submitted conditions are the subject of determination for approval. Nonetheless, policy and guidance in the form of Planning Policy Wales, Minerals Technical Advice Note 1, Mineral Planning Policy Guidance 14 and the Bridgend Local Development Plan (adopted September 2013) has been taken into account in processing the applications.

8. The Inspector's overall conclusions are set out at paragraph's 158-159 of his report which is attached at Annex 3 to this letter. The Inspector recommended that the applications comprising the four sets of conditions be approved. A copy of the conditions is appended to the report of the Inspector at Annex A-D.

9. All four applications will be the subject in the future of further Periodic Reviews every 15 years in accordance with the Environment Act 1995.

10. In the Inspector's view the main issues are the impacts of quarry deepening on the hydrogeological regime between the quarries and the Kenfig/Cynffig SAC located some 2 km to the west. For Gaens quarry, an additional consideration is whether or not future blasting in close proximity to residential properties can be adequately controlled.

11. The Inspector's overall conclusions are there is a level of agreement between the relevant parties to a point where conditions can be applied to address hydrogeological, ecological and amenity matters to an acceptable degree.

<u>Hydrogeological and ecological matters</u>

12. The Inspector recommended at paragraph 153 of his report that the shadow appropriate assessment contained in the Environmental Statements for each application made inadequate provision for the possibility of encountering certain features which could lead to high rates of water flow in the aquifer and the risk, however small, needed a more thorough assessment so that the planning conditions and other measures such as the Water Management Plan would not lead to an adverse effect on the integrity of the Kenfig/Cynffig SAC. He therefore recommended that Welsh Ministers carry out appropriate assessment.

13. An appropriate assessment has been carried out and is contained at annex 2 of this letter and it represents my assessment of hydrogeological and ecological matters with regard to the relevant European protected site. Its considerations are not repeated here, other than to say, on the basis of it being undertaken and the imposition of conditions requiring the adoption of the latest Water Management Plan for each of the quarries, I conclude that there would not be an adverse effect on the

integrity of the Kenfig/Cynffig SAC as a result of the proposed future quarrying operations.

Other matters

14. Other matters to be considered are on-site ecological ones relating to biodiversity enhancements, landscape and visual impact, noise limits, blasting levels, dust controls, highway impacts and the progressive and long term restoration of the sites. I consider the proposals have been given significant and robust analysis against both national and local policy and guidance in relation to all relevant issues and I agree with the Inspector's conclusions that the conditions proposed are capable of effectively controlling these matters.

15. The report of the Inspector at paragraphs 58-62 deals with the matters relating to those conditions which have been agreed by Bridgend Country Borough Council, Tarmac and T.S. Rees Ltd. Several other matters raised by third parties, detailed in paragraphs 115-125 of the Inspector's report, have been considered and conditions, as summarised in paragraphs 126-132 of the Inspector's report, are capable of satisfying those concerns.

16. Of the three quarries, Gaens quarry is located closest to the highest concentration of residential properties in South Cornelly. Dust and blasting vibration levels and a small private water supply have all been the subject of detailed scrutiny and I agree with the Inspector's conclusion of appropriate revised conditions being able to mitigate any adverse effects to an acceptable degree.

17. The conditions set out in the report of the Inspector as at Annexes A-D (pages 39-78) of the Inspectors report have been the subject of open discussion at the public inquiry. I have considered these conditions and subject to the comments and amendments listed below in paragraphs 18-32 I agree they should be approved.

Conditions relating to the duration of the permissions

18. Welsh Ministers have considered the proposed expiry dates of the permissions taking into account Schedule 2.2(1)c of the Planning and Compensation Act 1991 which states inter alia " *the conditions to which an old mining permission is to be the subject must include a condition that the winning and working of minerals or depositing of mineral waste must cease not later than 21st February,2042".*

19. The current conditions seek consent for expiry dates beyond this date and therefore it has been necessary to determine if expiry dates running to a maximum of 2056 (for applications A, B and D) and 2068 (for application C) are acceptable. The overall development programme for each quarry has been informed by environmental

impact assessment and the Environmental Statements set out the projected life of each site based on current production figures and the consented reserves.

20. Firstly, the quarries are strategic ones, providing both aggregate and high purity limestone for the steel industry. Levels of sales and output have been considered over the timescales proposed and although these could be subject to change we do not have any evidence to doubt the longevity of the quarries at this time.

21. Secondly, the prolonged period over which data and environmental information has been collected has resulted in a sophisticated modelling and monitoring framework being in place to control operations at the quarries which includes extensive mitigation and contingency measures. Natural Resources Wales have been involved in the design and approval of these measures and the appropriate assessment shows that there would not be an adverse effect on the integrity of the SAC.

22. Thirdly, the environmental impact assessment and resulting conditions allow for sufficient and appropriate control of impacts of concern to local residents.

23. Having examined these factors the wider socio economic benefits of extending the life of the quarries along with the ability to acceptably control any significant environmental impacts means the balance falls in allowing expiry dates to be extended beyond 2042 on a quarry by quarry basis. For these reasons I consider it appropriate to extend the expiry dates of these permissions.

Other conditions

24. Reference is made in Conditions 11 and 12 to the Water Management Plan which shall be carried out throughout the life of the development. As stated in the report of the Inspector at paragraph 146, the Water Management Plan will need to be implemented beyond the cessation of quarrying operations on the site. Hence, for greater clarity the condition should be revised so that the Water Management Plan is directly linked to the duration of the planning permission and the 5 year aftercare period.

25. Condition 11 should be amended to read:-

"The water management, monitoring, reporting, mitigation and contingency activities set out in the Water Management Plan (WMP) for Cornelly Quarry v5.8 dated 9th November 2015 shall be carried out throughout the duration of the planning permission and the 5 year aftercare period."

26. Condition 12 should be amended to read:-

"In the event that the Minerals Planning Authority requires changes to the WMP, as provided for in the WMP, then the amended water management, monitoring, reporting, mitigation and contingency activities requested by the Minerals Planning

Authority shall be carried for the duration of the planning permission and the 5 year aftercare period."

27. In condition 14, "site glasses" should be replaced with "*sight* glasses".

28. In Condition 19, there is reference to a 2.0 metre high screening bund being constructed with an outer gradient no steeper than 1:2. In practice, such a steep sided bund is likely to be subject to slippage and erosion by heavy rainfall and it would be difficult to establish vegetation with any success. Hence, the gradient of 1:2 should be reduced to 1:3.5.

<u>Additional conditions considered necessary</u>

29. A condition is necessary to require the provision of adequate automated wheel washing facilities to ensure lorries enter onto the public highway in a clean condition. This provides consistency with application C.

30. A new condition number 31 should read:-

"Automatic wheel cleaning facilities, including sprays to clean the wheels, under body and side body of vehicles shall be maintained throughout the operations permitted. Such facilities shall include the provision of a water recycling system to maximise the use of water supplies".

31. There are no conditions in Annex A of the Inspector's report relating to the need for perimeter fencing, gates and warning signs on the perimeter of the site. These measures are considered necessary to ensure the safety of the general public and stock using adjoining farm land. A new condition number 34 should therefore be imposed to read:-

"A minimum 1.3 metre two strand barbed wire stockproof fence should be maintained around the entire site perimeter (with the exception of lockable gates)together with quarry warning signs at 25 metre intervals".

32. Conditions 34-36 should be re-numbered to 35-37.

Formal Decision

33. Subject to the appropriate assessment at annex 1 and the suggested amendments and additions contained in this letter I agree with the Inspector's conclusions and accept his recommendation.

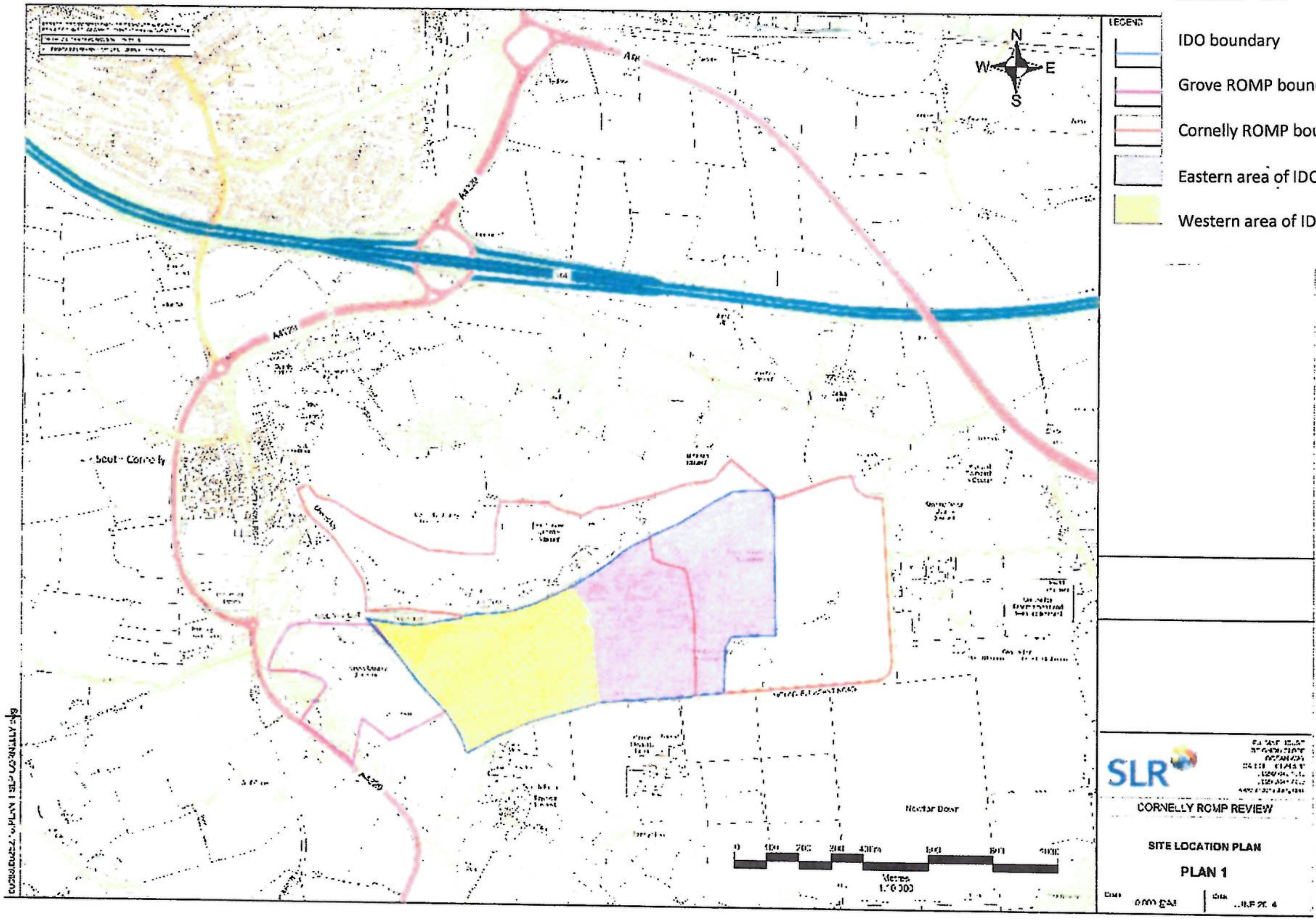
34. For clarity the full set of conditions, as amended, is attached at annex 2. Accordingly, I hereby approve the conditions contained at annex 2 of this letter.

35. This letter, a copy of which has been sent to Bridgend County Borough Council and to those interested persons who appeared at the inquiry, does not convey any approval or consent which may be required under any enactment, bye law, order or regulation other than the application made under paragraph 9 of Schedule 13 of the Environment Act 1995.

Lesley Griffiths

Lesley Griffiths AC/AM
Ysgrifennydd y Cabinet dros yr Amgylchedd a Materion Gwledig
Cabinet Secretary for Environment and Rural Affairs

Cc Mr Graham Jenkins, SLR Consulting



516087, 516088 & 516089

FINAL APPROPRIATE ASSESSMENT UNDER REGULATION 61 (6) THE CONSERVATION OF HABITATS AND SPECIES REGULATIONS 2010, AS AMENDED

1 Introduction

1.1 This Appendix constitutes the Appropriate Assessment carried out by Welsh Ministers under paragraph 61(6) of The Conservation of Habitats and Species Regulations (Habitats Regulations) 2010, as amended, relating to the Review of Old Mineral Planning Permissions (ROMPs) Cornelly, Grove and Gaens quarries and the Periodic Review of Interim Development Order (IDO) Cornelly and Grove quarries, South Cornelly, Bridgend.

1.2 Matters pertaining to the Habitats Regulations were considered by the Inspector at the Public Local Inquiry in November 2015 and summarised in his report at paragraphs 147-154. These matters are noted, including the recommendation that Welsh Ministers undertake an Appropriate Assessment as part of its determination of the applications to satisfy themselves that the applications will not result in adverse effects on the integrity of the Kenfig/Cynffig Special Area of Conservation (SAC).

1.3 This assessment has been undertaken in accord with the guidance contained in TAN 5 Nature Conservation and Planning. TAN 5 states "*If the decision-taker concludes that a proposed development not directly connected with site management is likely to significantly affect a European site or European offshore marine site, they must make an appropriate assessment of the implications of the proposal for the site in view of the site's conservation objectives*".

1.4 In accordance with regulation 61(3) of the Habitats Regulations Welsh Ministers, as the competent authority, must consult with the statutory nature conservation body, in this case Natural Resources Wales (NRW), as part of the Appropriate Assessment. Consultation responses received from NRW in the letter dated 5 July have been incorporated into this assessment.

1.5 Consultation with other parties, including the public, can be undertaken but is not required by the regulations. The publicity and consultation in respect of the Environment Statements and the examination of the cases at the Public Local Inquiry suggest that sufficient opportunity for wider engagement on these applications has been provided and no further consultation has been undertaken.

2 Background

2.1 Determining whether a project is likely to have a significant effect on a European site, either alone or in combination with other plans or projects, can be made at any time during the decision making process. Welsh Ministers recognise the unique circumstances pertaining to these cases and that the collection and submission of relevant information has taken place in an iterative way over a number of years.

2.2 The tacit implication of attaching a shadow appropriate assessment template to the relevant Scoping Decisions, made under the Town and Country Planning (Environmental Impact Assessment) (Undetermined Review of Old Minerals Permissions) (Wales) Regulations 2009 on 4 March 2013, was that it was not possible to exclude the potential of a likely significant effect occurring, on the basis of objective information available at the time.

2.3 Notwithstanding the on-going refinement of the hydrogeological modelling, the collection of monitoring data and the iterative submission of information associated with these proposals, Welsh Ministers consider it necessary to undertake an Appropriate Assessment, under the Habitats Regulations, to satisfy itself that the proposals would not adversely affect the integrity of the Kenfig/Cynfigg SAC.

2.4 The Scoping Directions directly requested that the potential impact of quarrying on Kenfig/Cynffig SAC/SSSIs and Cefn Cribwr Grasslands SAC/SSSIs be included in the Environment Statements for all four applications. More remote SACs such as Blackmill Woodlands were discounted on the basis of no likely significant effect. Other designated sites, both statutory, such as SSSIs, and non-statutory have been considered as part of the environmental impact assessment of the quarry proposals.

2.5 The Cefn Cribwr Grasslands SAC comprises four separate areas of grassland to the north of the group of quarries. It is one of four sites representing ***Molinia* meadows** in south and central Wales, one of the major UK strongholds for this habitat type and this, along with the Marsh fritillary butterfly, represents the qualifying features of the SAC. Whilst the qualifying features of the SAC are dependent on groundwater features they are not dependent on groundwater features that could be affected by dewatering of the Cornelly group of quarries. There is no mechanism by which the quarry proposals could have a significant effect on the SAC, and there is no need to make any further appropriate assessment under the Habitats Regulations in relation to this European site.

2.6 The position for the Kenfig/Cynffig SAC, however, is that the maintenance of the natural hydrological regime of both of its dune systems is critical for the maintenance of the character, composition and condition of the features. For this reason the Kenfig/Cynffig SAC is being taken forward for inclusion in the Appropriate Assessment.

3 Kenfig/Cynffig SAC

3.1 The SAC comprises two discreet areas – the dune fields of Kenfig, including pool and the dunes at Merthyr Mawr.

Designated: December 2004
Area: 1,191.67Ha

3.2 Kenfig is a largely intact dune system with extensive areas of fixed dune vegetation with red fescue *Festuca rubra* and lady's bedstraw *Galium verum* and semi-fixed dune grassland with marram *Ammophila arenaria* and red fescue. There is also a relatively large area of more acidic vegetation dominated by sand sedge Carex *arenaria*, sheep's-fescue *Festuca ovina* and common bent *Agrostis capillaris*.

3.3 It contains one of the largest series of dune slacks in Wales which are species-rich and there are extensive areas of dunes with *Salix repens* ssp. *argentea*, which represent a mature phase in dune slack development. The site is in the central part of the range of this community on the west coast and is a highly representative example of this habitat type.

3.4 Kenfig also contains the most important example of Humid dune slacks in the UK, owing to the extent of the habitat type and the conservation of its structure and function. These calcareous dune slacks are also amongst the most species-rich in the UK, supporting communities dominated by a variety of mosses and a number of rare plants, notably Fen orchid *Liparis loeselii*, for which the site is also selected. Some of the dune slacks on the site are still in the early successional stage of development.

3.5 Kenfig Pool is a shallow lake within the extensive sand dune system of Kenfig, the water chemistry is indicative of a coastal, alkaline lake with a moderate nutrient status with the presence of Chara spp.

3.6 Reasons for Recommendation of SAC:

Humid dune slacks (EU Habitat Code: 2190)
Dunes with *Salix repens* ssp. *argentea* (*Salicion arenariae*) (EU Habitat Code: 2170)
Fixed dunes with herbaceous vegetation ("grey dunes") (EU Habitat Code: 2130)
Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. (EU Habitat Code: 3140)
Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) (EU Habitat Code: 1330)
Petalwort *Petalophyllum ralfsii* (EU Species Code: 1395)
Fen orchid *Liparis loeselii* (EU Species Code: 1903)

3.7 The Conservation Objectives for the Kenfig/Cynffig SAC are set out in the Core Management Plan:

Kenfig/Cynffig SAC (CCW 9th April 2008, map edit February 2013) available at:
https://www.naturalresources.wales/media/672610/Kenfig%20SAC%20management%20plan%2021.4.08%20English.pdf

The management plan describes site condition and Favourable Conservation status. A useful summary is contained within the Applicants' Shadow

Appropriate Assessment (refer to Cornelly Environmental Statement Vol 2D, Appendix 8.3).

4 Brief description of the project

4.1 The Cornelly group of quarries are situated on land south of junction 37 on the M4 between Bridgend and Pyle. They are sited in a ridge of Carboniferous Limestone, on the southern edge of the South Wales syncline, with a ground surface level up to 100m. The land falls steeply to the west and south west, to low rolling ground sloping gently to the sea. The end date for the quarries is 2042.

4.2 Gaens quarry
The area covered by consents for mineral extraction is approximately 13 ha. The most recent known proposals are for a phased extraction scheme to deepen the quarry from approximately 30m AOD to -20m AOD.

4.3 Cornelly quarry
The area covered by consents for mineral extraction is approximately 76 ha. The most recent known proposals are to develop the quarry from approximately 6m AOD (2007) to -75m AOD. Output is about 1 million tonnes per annum. The quarry will be dewatered by pumping to Pant Mawr and/or Grove quarries, or Stormy Down quarry. Pumping to Pant Mawr and/or Grove quarries averaged 1680m^3/day, 2001-06. The western area is covered by an IDO permission subject to the first periodic review, the east is subject to a ROMP review, and newer permissions also overlap the IDO. When dewatering of the quarry ceases, the groundwater is predicted to recover to, variously, 40-45m AOD or approximately 56m AOD, and restoration works would be confined to the levels above 50m AOD.

4.4 Grove quarry
The area covered by consents for mineral extraction is approximately 30 ha. The eastern area is covered by an IDO permission subject to the first periodic review, the west is subject to a ROMP review. The most recent known proposals are to work the quarry to 15m AOD in the IDO area and to -15m AOD in the ROMP area. (0m AOD in the IDO Environmental Statement). It is considered that output would be in the region of 250,000 tonnes per annum. The ROMP area void would be partly filled with overburden from the IDO area (1 million cubic metres). A final water level of approximately 25m AOD is anticipated.

5 Identifying the potential effects on the Kenfig/Cynffig SAC

5.1 It is necessary to identify all possible sources of effects from the project under consideration, or and any other effects likely to arise from other proposed projects or plans, together with all other sources in the existing environment which might act in combination.

5.2 The types of impacts likely to affect aspects of the structure and function of the SAC which are vulnerable to change are considered to be related to water supply and quality. The potential for effect is dependent on pathways between the source (the Cornelly quarries) and the receptors (the SAC). This is influenced both by the geology (particularly the possibility of karst features in the carboniferous limestone), the surface water regime and groundwater levels and flow directions.

5.3 The key SAC features for consideration are the dune slacks and their associated communities (including the dunes with creeping willow) and the fen orchid and petalwort species features which are dependent on water levels for their integrity and Kenfig pool, which could be reduced in size should groundwater levels change reducing the available habitat for chara species.

5.4 The key areas of concern have related to:-

- Outflows from the aquifer
- Conditions at depth in the quarries
- Connection between the limestone aquifer and the dune system at both Kenfig and Merthyr Mawr
- Migration of leachate from the landfills
- Saline intrusion into the aquifer
- Impacts of quarry dewatering and water disposal
- Impacts of quarry recharge

5.5 In worst-case scenarios, it was considered that:-

- draw-down in the groundwater table beneath the SAC would result in a loss of habitat area and lead to a significant and permanent deterioration in habitat condition/loss of species;
- draw-down in the groundwater table could last for the life of the permission and period of water rebound, with some permanent effects as a consequence of the void;
- Changes to the water quality from saline intrusion or alterations to pollution plumes would affect the SACs.

5.6 It is agreed between all parties that the planned quarrying operations are not predicted to have any material impact on water quality in the surrounding areas nor are the operations predicted to cause saline intrusion into the aquifer. Thus, migration of leachate from Stormy West and Tythegston landfill sites, saline intrusion and worst case scenarios associated with such impacts are not considered any further as part of this appropriate assessment.

5.7 The detailed positions for Kenfig dunes and pool and Merthyr Maw dunes are discussed in section 4.2 of the Shadow Appropriate Assessment and Chapter 7 of the Cornelly Environment Statement (Chapter 7; and, Vol 2D Appendix 8.3). Issues of common ground between both sets of applicants and Natural Resources Wales were submitted to the Public Local Inquiry in November 2015.

6 Factors for further detailed assessment

6.1 The process of determining these applications has been the subject of prolonged and detailed scrutiny and it is not considered appropriate to reproduce this at length as part of this assessment. Reference should be made to section 7.2.6 of the Cornelly Environmental Statement and paragraphs 27-28 and pages 36-38 of the Inspectors report which summarises the iterative process and details the most up to date pieces of information and evidence submitted as part of the Inquiry. It is suffice to say that widespread studies and investigations have been carried out in response to hydrogeological concerns and potential impacts on the Kenfig/Cynffig SAC. These have provided data to enable the aquifer to be modelled and forecast data to be derived based on simulation of the proposed future operations.

6.2 The four applications were called in for determination by the Welsh Office and Welsh Ministers in 1998 and 2010 respectively and those called in by the Welsh Office were subsequently transferred to the National Assembly for Wales and to Welsh Ministers. The applications were called in because of potential significant effects on the water environment, with the hydrological information sought still outstanding. The four cases overlap in terms of the area covered and issues raised and it was recommended that all four be considered together by means of a joint Public Inquiry, with a single Inspector considering all planning issues arising, including an integrated approach towards a strategic restoration scheme. For the purposes of the Appropriate Assessment because all quarries could be worked together the assessment was conducted based on the in-combination effects of working at all three quarries.

6.3 Statements of common ground were prepared to inform the Public Local Inquiry. No further assessment of these issues is proposed as part of the Appropriate Assessment.

6.4 The main outstanding issues considered at the Inquiry are summarised by the Inspector at paragraph 133 of his report as:

- confidence in the hydrogeological modelling;
- the impact of further dewatering of the quarries on the Kenfig/Cynffig SAC; and,
- the degree of reliance on the Water Management Plan for the life of the quarries.

6.5 Implicit in these considerations is the determination of an appropriate threshold (level of change) and trigger (an early warning system) for both assessing and being able to avoid an adverse impact in the Kenfig/Cynffig SAC, the effectiveness/robustness of the Water Management Plans to monitor and mitigate any hydrological impacts on the SAC as a result of quarrying and whether or not any risk (albeit small) of rapid groundwater movement as a result of an interception with a karstic feature could be addressed by way of planning condition. These issues will be considered below.

6.6 Level of confidence in the hydrogeological modelling

6.6.1 The conceptual and groundwater models provide a reliable representation of the ground water system around the quarries. The modelling was undertaken to:

- enhance understanding of the degree of potential connectivity between the underlying aquifer and both Kenfig and Merthyr Mawr dune systems and the possible impacts on the designated features of the SAC if the connection between the sites is greater than anticipated,
- to identify the main outflows from the aquifer; and,
- to put in place effective water management options at the quarry.

6.6.2 The hydrogeological model has been used to simulate the future groundwater drawdown circumstances that are likely to occur if and when the quarries (particularly Cornelly) are worked to the maximum depths proposed in the current review applications. Cornelly Quarry is to be worked at greater depths than the other quarries, however, the model has simulated the cumulative effects of all quarries being at their maximum proposed depths.

6.6.3 Modelling of the worst possible case indicates that the maximum change of groundwater levels at the Kenfig/Cynffig SAC attributable to the proposed quarry operations will only be 6mm, however, a 12cm change is forecast if pumping to dewater the quarries were to cease immediately on completion of quarrying in several decades time. However, this could be substantially alleviated if pumping at that time was reduced more gradually and in a controlled manner.

6.6.4 Welsh Ministers are of the opinion that the model represents the best scientific knowledge available and that it provides a sound and reliable representation of the behaviour of the aquifer under normal circumstances. Of key concern, however, has been the uncertainty presented by the heterogeneous nature of the carboniferous limestone and the potential for encountering a karstic feature in the limestone beneath the quarries and the behaviour of the water regime as a consequence of dewatering operations.

6.6.5 There are two specific matters concerning uncertainty in the model over which Natural Resources Wales have consistently expressed doubts relative to the integrity of the site [see paragraphs 29-35 and 93-96, Inspectors Report]. These are:

- That some 69% of the water outflow from the model is not specifically accounted for; and,
- The level of uncertainty due to the possible presence of karst features in the geology below the quarries

6.6.6 The model is based on an extensive dataset comprising over 10 years of monitoring data at 105 monitoring points and the model itself has been developed over 15 years in liaison with Natural Resources Wales and its predecessor bodies. The model has been used to simulate the future drawdown circumstances that are likely to occur if and when the quarries are worked to the maximum depths proposed in the current review applications.

6.6.7 Modelling of the worst possible scenario indicates that the maximum change of groundwater will be 6mm, however, a 12cm change is forecast should pumping to dewater the quarries suddenly cease. However, if the final cessation of pumping was carried out gradually and in a controlled manner, the impact on levels at the SAC would be much lower [paragraph 35 Inspector's Report].

6.6.8 Should karstic features (such features can be typically found in limestone and represent a highly permeable conduit for water within the aquifer) be intercepted as the quarry is deepened and widened the model would not represent the resulting unpredictable flows within the aquifer and groundwater levels at the SAC could be lowered to a degree considered to be of detriment to the SAC and its designated features. It is accepted by all parties that it is inherently difficult to model every possible geological scenario due primarily to the heterogeneous nature of the limestone and a degree of uncertainty about the potential hydrological impacts on the SAC will remain.

6.6.9 It is reasonable to accept that the large proportion of water (69%) unaccounted for in the model is due to general outflow towards the coast, but equally, this could be consistent with the presence of an unknown karstic feature. Evidence was put forward by a leading expert on karst geology which concludes that it is highly unlikely that a substantive karst feature would be encountered below the quarries. Natural Resources Wales agree that the risk is low, but because such a risk cannot be ruled out they consider that the potential for an adverse effect on the Kenfig SAC would remain unless this risk is addressed.

6.6.10 Whilst the model does not cover this possibility, it is considered that any assessment should include acknowledgement of that risk [paragraph 153 Inspector's Report]. Recognition has been given to this issue and it has thus been agreed by all parties that suitable mitigation measures which provide identification, mitigation and contingency, could alleviate the potential for an adverse effect on the SAC. Such measures would need to provide an early warning system to detect potential effects and trigger action necessary to alleviate such effects before any adverse changes could occur.

6.7 Impact of further dewatering and the determination of an appropriate threshold for assessing an adverse impact

6.7.1 It is evident that the qualifying features within the SAC are particularly sensitive to long-term changes in baseline groundwater levels.

6.7.2 A significant proportion of the Petalwort SAC features exist at Merthyr Mawr. However, predicted changes to the flow from Burrows Well as a consequences of quarry operation and at the end of the lives of the quarries would not cause any adverse effects on relevant dune slack features at Merthyr Mawr. The key qualifying features of the SAC which may be affected by long term changes in groundwater levels are the dune slacks, dunes with creeping willow, fen orchid, petalwort and the pond at Kenfig.

6.7.3 This agreed threshold for measuring an adverse effect on the SAC was derived from research by Dr Peter Jones, of the former CCW, in 2004 [see paragraph 97 Inspector's Report]. It concluded that "*even slight sustained changes in mean water level of the order of 10cm (or in some cases even less) would be sufficient to result in undesirable transformations from one community to another*". This criterion was used as the basis for the agreed threshold for assessing whether changes to hydrology predicted by the model were likely to be significant. The agreed criterion provides that a 0.1 metre (10cm) or greater difference between actual and expected mean summer water levels in the sand dunes at Kenfig, sustained for 3 consecutive years, would amount to an adverse effect on the designated features of the SAC.

6.7.4 The dune slacks and the pond at Kenfig are already subject to natural seasonal variations and it is common ground that small changes to summer water levels would be unlikely to be detrimental to the SAC features provided the changes were less than 10cm over 3 consecutive years [paragraph 138 Inspector's Report]. Whilst the natural flora is able to withstand seasonal fluctuations, a sustained 0.1 metre (10cm) reduction in groundwater levels would reduce the size of the zone of ecological interest capable of supporting the protected species and would reduce their resilience. Individual communities of plants would be affected resulting in an adverse effect on the SAC. Therefore, the sensitivity involved gives rise to the need for appropriate early warning systems to be put in place.

6.7.5 Although the advice in the Environment Agency's Ecohydrological Guidelines for Wet Dune Habitats, published in 2010, supports the conclusion that small changes in groundwater levels would not significantly affect the key SAC features it would not be appropriate to use changes in composition of the dune/dune slack communities as an indicator of impacts because a variety of factors reflecting the complex relationship between water behaviour on the site and the condition of the dune and dune slack communities will influence changes. In short the Ecohydrological Guidelines are not sensitive enough as an indicator to pick up changes to individual qualifying SAC features, such as petalwort and fen orchid, because adverse changes to individual features may already be set in train before wider community changes are detected.

6.7.6 The modelling work indicates that the agreed criterion would not be exceeded during normal quarry operations despite substantial increases in depths of working. The model does indicate that an exceedance of the criterion could occur if dewatering pumps were turned off immediately as quarry operations ceased but not if controlled reduction in pumping was carried out instead [paragraph 139 Inspector's Report].

6.7.7 It is agreed by all parties that the application of the 0.1 (10cm) over 3 year criterion is an appropriate mechanism for assessing impacts but that sensitivity criteria at each pathway site should be used to determine whether a significant deviation has occurred otherwise the impact would take effect at the same time as the trigger point was reached and there would be no time for planned mitigation or contingency to take place. In other words, an early warning system is required, which would give an early indication that a 0.1m (10cm) criterion, or greater, change could be anticipated in the future.

6.8 Water management plans and effectiveness of mitigation measures

6.8.1 A key concern of Welsh Ministers is that the mitigation and contingency measures are effective given the sensitivity of the Kenfig/Cynffig SAC to potential changes in groundwater levels. A system of monitoring which documents changes without requiring and securing mitigating action which can avoid adverse impacts would not be acceptable. The agreed Water Management Plan needs to ensure the integrity of the SAC is not affected by identifying any negative effects before they occur and it is critical that any required measures can be implemented in time to prevent such impacts manifesting themselves.

6.8.2 The Water Management Plan (WMP) is a tool to ensure the water environment is protected against the possible effects of changes in groundwater levels resulting from the proposed quarrying activities [paragraph 142 Inspector's Report]. The WMP comprises detailed specification of long term monitoring at an extensive network of monitoring sites, arrangements for annual reporting results, the mechanism to identify deviations from expected water levels which would trigger the need for mitigation or contingency measures and proposals for those possible measures.

6.8.3 The Applicants predict that there will be a lowering of the groundwater levels in the dunes to the west of Kenfig Pool of up to 0.12m (12cm) relative to the baseline i.e. a lowering in excess of the agreed 0.1m (10cm) criterion. It is therefore recognised that if this remains unmitigated the result would be an adverse effect on the dune slacks. The shadow appropriate assessment prepared by the Applicants sets out the ecological impact assessments, and these are also referred to in the ecological/hydrological chapters and appendices of the Environmental Statements. However the shadow assessment makes no reference to the 0.1m (10cm) over 3 year criterion which is now referred to in the final versions of the WMPs.

6.8.4 Until the day before the public inquiry there was a difference between the Applicants and NRW on two matters, namely, the definition of an appropriate 'trigger point' based on the monitoring of groundwater levels at the SAC and whether provisions were required or not for the risks associated with encountering a karstic feature (even though this risk was accepted as being very low) [paragraph 143 Inspector's Report].

6.8.5 Agreement has now been reached in relation to these matters. In the agreed WMP (version 8, paragraphs 4.1.1 and 6.4.2) there is now provision for a network of pathway monitoring sites between the quarries and the SAC, rather than just at the SAC itself. This mechanism enables clear triggers for necessary mitigation measures and the picking up of early warning signs of change.

6.8.6 It is intended that impacts will be measured by reference to site specific trigger levels which are specific to each monitoring site (with allowances for climate based assessment criteria). If these levels are exceeded, and unless it can be demonstrated that the change is either a statistical artefact or not attributable to quarry dewatering at one or more of the quarries within the agreed timeframe, then remedial action will be implemented in accord with sections 7 and 8 of the respective WMP.

6.8.7 Data will be collected by the applicants from November to October during the course of a calendar year with reporting to the regulator, the mineral planning authority (Bridgend County Borough Council) in January. The WMP establishes a suite of flexible mitigation measures that can be required by the mineral planning authority (and on the advice of NRW). In order to ensure long term protection, it is intended that the respective WMPs will cover the entire life of the developments. This will be required by the agreed planning conditions.

6.8.8 The low risk of interception of a karstic feature has been resolved by making provision in the WMPs, along with a supporting planning condition, for changes to be incorporated in the future if found to be necessary to deal with such an incident in the unlikely event that it should occur. These provisions acknowledge the rights of the quarry operator under the Environment Act 1995 that no changes would be made that would prevent quarrying operations or otherwise restrict working rights [paragraph 145 Inspector's Report].

6.8.9 It is only when the final version of the WMPs and the final agreed planning conditions are taken into account that the potential for adverse effects on the SAC can be avoided.

6.8.10 As well as assessing the robustness of the mitigation and contingency measures from the technical and scientific perspective, it is necessary to assess the robustness of the mitigation measures from a practical perspective. Measures should be capable of being implemented. Practically, implementation will depend on the ability to access data at all of the monitoring pathway sites so that any significant deviations can be recorded and appropriate action in the form of alternative mitigation taken as necessary.

6.8.11 The production of monitoring data over recent years from many sources beyond the quarry boundary and the receptor site suggests there is no issue with entering onto third party land. This is not referred to specifically in the Inspector's Report but is vital to the successful implementation of the WMP. It has been confirmed by the applicants that they have access arrangements in place to enable them to maintain the monitoring points on land in the ownership/control of third parties. There are contingency measures in place which provide further reassurance.

6.8.12 Another important issue is the statement in section 2.5 of the WMPs that "*No changes requested by the regulator shall, however, have the purpose or effect of stopping or preventing quarry operations or otherwise restricting working rights within the meaning of the Environment Act 1995*".

6.8.13 Whilst this statement would appear to remove the ultimate restriction on operations if a significant deviation is recorded it also removes the possibility of an adverse impact on the economic viability of the site. If such a restriction were placed on operations in the future, then, in accordance with Minerals Planning Guidance Note 14 the developers would have the opportunity to submit a claim for compensation which the mineral planning authority would have to deal with.

6.8.14 The integrity of the Kenfig/Cynffig SAC must be protected and to address an extreme hydrological impact, such as the interception of a karstic feature, it has been agreed by all relevant parties that it is possible to impose a planning condition that enables an alteration of the planned mitigation and contingency measures in order to address an extreme hydrological impact not foreseen by the hydrogeological modelling. Given the low risk of impact overall, it is reasonable to conclude that as a whole the water management measures contained in the WMP and the necessary planning condition would be capable of overcoming any potential problems.

6.9 <u>In combination assessment</u>

6.9.1 With regard to in-combination effects, TAN 5 advises:
"*In considering the combined effects of other plans and projects it will normally be appropriate to take account of outstanding consents that are not started or fully implemented, ongoing activities or operations that are subject to continuing regulation (such as discharge consents or abstraction licences) and other proposals that are subject to a current application for any kind of authorisation, permission, licence or other consent. The effects of projects which have already been implemented and policies and proposals in adopted and published draft plans should also be included in the in-combination test. Thus, the assessment is not confined to proposals that require planning permission, but includes all plans and projects."*

6.9.2 For the purposes of this assessment, the potential impacts arising from all three quarries, namely Cornelly, Grove and Gaens, have been considered together. This is due to the fact the boundaries abut each other in a tight cluster. All of the historical and current environmental data has been collected and assessed as if the quarries were acting as one operation. With the exception of some historical dewatering from Cornelly to Stormy Down quarry and from Grove quarry to the adjoining old railway cutting water management has largely been contained within the current boundary of the three quarries. Grove quarry has in fact been closed for several years with no dewatering taking place, the accumulated water flooding the void. Some water has been pumped into Grove quarry from Cornelly quarry when the accumulation of water in the water storage areas in Cornelly has reached maximum levels. Hence, the majority of water arising within the quarry voids has been retained within the same geological block.

6.9.3 Two former municipal landfills (dilute and disperse) are located in old quarries to the east and south of Cornelly Quarry. (Stormy West, *sealed, 25m thick, 75m AOD base* and Tythegston *capped, 40m thick, 50m AOD base*). Both landfills contain potential pollutants and the potential of leachate was identified. Stormy Down is now a flooded quarry. It is acknowledged in paragraph 5.6 above that water quality issues would not result in a likely significant effect on the SAC.

6.9.4 There are a number of local licensed abstractions and private water supplies. However, these are not considered to meaningfully combine with the effects of the proposed quarries in a way which could adversely affect the SAC.

6.9.5 In considering the possibility of other in-combination effects it is evident there are no other plans or projects present or proposed in the area which may meaningfully influence or combine to add to the potential effects of the Cornelly group of quarries on the Kenfig/Cynffig SAC. Consequently for the purposes of this appropriate assessment in-combination effects have been limited to the three quarries themselves acting in combination with each other.

7 Integrity Test

7.1 In accordance with Regulation 61(6), Welsh Ministers in considering whether a plan or project will adversely affect the integrity of the SAC, must have regard to the manner in which it is proposed to be carried out or to any conditions.

7.2 The integrity of the site is defined as "*the coherence of its ecological structure and function, across its whole area, which enables it to sustain the habitat, complex of habitats and/or the levels of populations of the species for which it was classified or listed*" (TAN 5). The integrity test can also be considered to be the quality or condition of being whole or complete, or, in a dynamic ecological context as being resilient, with the ability to evolve in ways that are favourable.

7.3 Dune slacks are low-lying areas within dune systems that are seasonally flooded and where nutrient levels are low. They occur primarily on the larger dune systems in the UK, especially in the west and north, where the wetter climate favours their development when compared with the generally warmer and/or drier dune systems of continental Europe. The range of communities found is considerable and depends on the structure of the dune system, the successional stage of the dune slack, the chemical composition of the dune sand, and the prevailing climatic conditions. The Kenfig/Cynffig SAC contains the most important example of Humid dune slacks in the UK, owing to the extent of the habitat type and the conservation of its structure and function.

7.3 The proposed conditions in the applications relating to hydrology and ecology have been agreed by the parties. It is clear that the 0.1m (10cm) change in mean summer groundwater level at the dune slacks is an important criterion even though the sites are subject to higher seasonal variations throughout the year. The qualifying features of the SAC experience natural variation in groundwater levels due to climatic factors and they are adapted to cope with these variable conditions, with the rarer species preferring wetter conditions and the less desirable species (i.e. less desirable compared to safeguarding the rarer species) with which they compete preferring drier conditions. Critically, the natural groundwater fluctuations generally recover or tend back to a stable baseline (of seasonal variation) which supports the special plant communities in the dune slacks.

7.4 If there were to be a sustained fall over several years in the baseline, this would result in a change in the baseline ecology of the dune slacks. The zone of ecological interest capable of supporting the qualifying features would be reduced, affecting the resilience of the dune slack communities because the ability of the species to recover from the background natural fluctuations, especially following drier periods will be diminished. A consequential shift in dune slack communities could result and this would amount to an adverse effect on the integrity of the SAC [paragraphs 99 - 100 Inspector's Report]. The 0.1m (10cm) over 3 years criterion as an agreed measure of adverse effect gives protection to the ecological resilience of the SAC.

7.5 In light of this sensitivity it is the view of Welsh Ministers, therefore, that without the agreed provisions in the WMPs and the imposition of planning conditions the proposed development could adversely affect the integrity of the European site. When the proposed measures and conditions are taken into account any potential adverse effects on the SAC can be ruled out.

7.6 Welsh Ministers consider that the risk of interception of karstic features is extremely low and that the proposed measures and conditions are sufficient to alleviate a potential adverse effect on the integrity of the SAC in this regard and account for the remaining uncertainties associated with the hydrogeological model.

7.8 The conditions relating to the four review applications have been the subject of lengthy discussion and several amendments have been made to address potential impacts. The parties have agreed the final wording of the WMP, along with three conditions required to ensure the WMP (in its present form or a modified form) is implemented over the lives of the quarries and that suitable arrangements are put in place to avoid sudden cessation of pumping at the end of the quarry lives.

7.9 Subject to the provisions of the WMP and the imposition of the agreed planning conditions it is the opinion of Welsh Ministers that the residual uncertainties of the hydrogeological model are adequately covered and that appropriate safeguards are provided for the water environment and the private water supplies in the area. At the same time the WMP now achieves the aim of ensuring that there would be no adverse effect on the integrity of the Kenfig SAC as a result of quarry operations and decommissioning [paragraph 146 Inspector's Report]. Without these agreed conditions, and the associated measures in the Water Management Plans, an adverse effect on the Kenfig/Cynffig SAC cannot be ruled out on the basis of best available scientific evidence.

8 Conclusions

8.1 It is the role of Welsh Ministers, as competent authority in determining these applications, to ensure that the requirements of the Habitats Regulations are met.

8.2 The integrity test is whether there is reasonable scientific doubt, rather than an absolute certainty about the potential for harm to a European site. In this sense an effect would not be adverse if it would not undermine the conservation objectives of the site. Based on the assessment above and the integrity test, it is clear that when taking into account the agreed mitigation and contingency measures Welsh Ministers can be certain that there would not be a sustained change in groundwater levels which would precipitate a loss of qualifying features of the SAC.

8.3 This Appropriate Assessment has sought to summarise the relevant ecological findings, expressly apply the 0.1m (10cm) by 3 year criterion in the context of ecological impacts and evaluate the risks to the SAC in light of proposed conditions. The conclusion of this assessment, subject to the Water Management Plan (version 5.8) for each of the quarries being adopted and implementation being secured by way of the proposed planning conditions, is that Welsh Ministers consider there would not be an adverse effect on the integrity of Kenfig/Cynffig SAC as a result of the proposed future quarrying operations.

Annex 2 Schedule of Planning Conditions: Application A Cornelly

A: DEFINITION OF TERMS

For the purposes of these planning conditions the following words and phrases shall have the meaning given to them below:

"ROMP Area" means the area subject to the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Cornelly Quarry (ref P/97/623), shown outlined in red on Plan 1 accompanying the schedule of planning conditions.

"ROMP Application" means the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Cornelly Quarry (ref P/97/623).

"IDO Area" means the eastern area of the IDO permission ref 53/93/1350 which is the subject of a separate application submitted to Bridgend County Borough Council under the provisions of Schedule 14 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations within the IDO area of Cornelly and Grove Quarries (ref P/09/738/MIN) shown coloured pink on Plan 1 accompanying the schedule of planning conditions.

"Date of Determination" means the date upon which new conditions subsequent to the applications are finally determined, i.e. the date upon which all proceedings on the applications, including appeals to the Secretary of State and the High Court have been determined, and the time period for any further appeal has expired.

"Emergency" means any circumstances in which the operator has a reasonable cause for apprehending injury to persons or serious damage to property.

"Mineral Planning Authority, (MPA)", means Bridgend County Borough Council, or any successor mineral planning authority.

"The Site", means all that land at Cornelly Quarry which is currently within the permitted area of Cornelly Quarry, comprising the "ROMP Area" of Cornelly and Pant Mawr Quarries, shown outlined in red on Plan 1 accompanying the schedule of planning conditions, and the eastern part of the IDO area shown coloured pink on Plan 1 accompanying the schedule of planning conditions.

"2014 ES" means the Environmental Statement (ES) submitted in June 2014 in support of the Cornelly Quarry ROMP application.

"Quarrying operations" means the winning and working of stone from the quarry face, and the operation of the primary crusher/or other mechanical means of stone breaking.

"Temporary operations" means operations associated with soil and overburden stripping, construction of soil storage mounds, construction of site haul roads, construction of soil baffle mounds, and restoration works involving the use of machinery. Temporary operations are to be confined to a period of no more than 8 weeks in a calendar year.

B TIME LIMITS

1. This planning permission shall expire on 31st December 2056.

2. Following the expiry of the planning permission, all extraction, treatment, and stockpiling of minerals shall cease.

3. No later than 12 months following the expiry of the planning permission, or the earlier permanent cessation of winning and working of minerals, all plant, machinery and structures shall be dismantled and removed from the site.

4. No later than 12 months following the expiry of the planning permission, or the earlier permanent cessation of winning and working of minerals, as agreed by both the mineral operator and MPA, the sale and transportation of minerals to and from the site, together with all ancillary manufacturing activities shall cease.

C WORKING PROGRAMME

5. The winning and working of stone and disposal of overburden/quarry waste shall be carried out in accordance with the updated quarry development plan ref numbers C112/097- C112/105 inclusive.

6. The site access shall be surfaced in permanent materials, and the surface maintained in a good state of repair, and kept free of mud/debris at all times.

7. Except in the case of emergency, quarrying operations shall take place only between the hours of 06:00-22:00 Mondays to Saturdays, and at no time on Sundays or Bank Holidays, except for essential maintenance.

   (NB: (i) *For the purpose of this condition, quarrying operations shall be defined as winning and working of stone from the quarry face, and the operation of the primary crusher/or other mechanical means of stone breaking.*

   (ii) *All other items of plant including secondary crushers, screens, sinter mills, asphalt plant, and concrete plant, lie within the 'IDO' area where the hours of working are unrestricted*.)

8. Within the working hours specified in Condition 7, there shall be no drilling operations, or secondary breakage of stone between the hours of 06:00 – 07:00 and 19:00-22:00 hours.

9. Temporary operations, as defined in Section A, shall only be carried out between 08:00 – 19:00 hours Mondays to Fridays.

10. No operations associated with the formation of the Western Pant Mawr Tip illustrated on plans ref C112.102 and C112.104, and formation and subsequent removal of material from bunds/soil storage areas shall be

carried out at the site except between the hours of 08:00 – 17:00 Mondays to Fridays, and 08:00 -13:00 on Saturdays.

D ENVIRONMENTAL PROTECTION

Hydrology and Hydrogeology

11. The water management, monitoring, reporting, mitigation and contingency activities set out in the Water Management Plan (WMP) for Cornelly Quarry v5.8 dated 9th November 2015 shall be carried out for the duration of the planning permission and the 5 year aftercare period.

12. In the event that the Minerals Planning Authority requires changes to the WMP, as provided for in the WMP, then the amended water management, monitoring, reporting, mitigation and contingency activities requested by the Minerals Planning Authority shall be carried out for the duration of the planning permission and the 5 year aftercare period.

13. Prior to the cessation of dewatering, a scheme shall be submitted to and approved in writing by the Minerals Planning Authority setting out proposals for residual pumping during the quarry decommissioning stage. The scheme shall include details of the rates and timescale of residual pumping, and the measures to be taken to monitor the effectiveness of the residual pumping during the defined time period. The scheme shall thereafter be implemented in accordance with the approved scheme.

14. Any facilities for storage of oils, fuels or chemicals on the site shall be sited in impervious bases and surrounded by impervious bund walls. The volume of the bunded compound shall be at least equivalent to the capacity of the tank plus 10%. If there is multiple tankage, the compound shall be at least equivalent to the capacity of the largest tank, or the combined capacity of inter-connective tanks, plus 10%. All filling points, vents, gauges and sight glasses shall be located within the bund. The drainage system of the bund shall be sealed with no discharge to any water course, land or underground strata. Associated pipe-work shall be located above ground and protected from accidental damage.

15. To minimise the risk of groundwater pollution from quarrying and processing operations, the development shall be carried out in accordance with the following requirements:

    - All mobile plant which requires fuel for its operation should be located on hard standing when not in use.
    - All immobile plant which requires fuel for its operation should be located on hard standing. Drip trays should also be appropriately placed under all relevant plant.
    - All refuelling activities should be undertaken on areas of hard standing, taking appropriate care and attention.
    - An incident reporting procedure should be maintained for reporting all site incidents, including pollution events. Emergency responses should be in place in the event of an incident.

- Appropriate spill kits or other means of controlling accidental spills should be made available on site. Adequate training in the use of such equipment should also be provided.
- A maintenance and inspection programme should be followed in order to check the condition of site equipment and provide early warning of any potential leaks or spills.
- Suitable waste management procedures should be followed to prevent surface pollution resulting from any waste products, fuel containers, and chemical drums.
- During site restoration all hazardous plant and equipment should be removed from the quarry.
- The use of herbicides and other related chemicals should be restricted both during quarry working and post restoration. Chemical applications should be made at appropriate times, in suitable quantities, so as to avoid sub surface contamination.

Ecology

16. Within 6 months of the date of determination, an Ecological Mitigation Strategy (EMS) shall be submitted to the MPA for their approval in writing. The EMS shall include the mitigation measures set out in Section 8.7 of the 2014 ES. The EMS shall thereafter be implemented as approved.

17. In addition to the measures to be included in the EMS, in order to minimise disturbance of habitats and interference with species, the development shall be carried out in accordance with the following requirements:

    (i) Calcareous grasslands on the fringes of Cornelly and Pant Mawr Quarries, which would be unaffected by the development scheme, shall be fenced to prevent accidental incursion of vehicles and site personnel;

    (ii) Areas of inaccessible high cliff shall be identified each year, and, subject to operational requirements shall be left undisturbed in order to encourage potential habitat for nesting peregrine falcons;

    (iii) Any large trees or large crevices in undisturbed parts of the quarry shall be inspected for possible bat presence immediately ahead of any tree surgery or quarrying works. Any bats which are identified shall be dealt with in accordance with current legislation and best practice;

    (iv) Clearance of trees and scrub should avoid the main bird nesting season (March to August inclusive);

    (v) Common reptiles encountered during works should be allowed to leave the immediate works area unharmed, and, if necessary, should be assisted by means of capture and release;

    (vi) Dense ruderal and grassland vegetation should be strimmed and raked away at least 24 hours ahead of earthworking, so as to reduce the attractiveness of the area for reptiles, and encourage them to leave;

(vii) Written protocols shall be issued to contractors so that in the event of discovery of bats, nesting birds, badgers or common reptiles, compliance with statutory obligations is ensured.

Landscaping

18. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the beating up and infilling of the existing hedgerow alongside the southern boundary of the ROMP area and IDO area abutting Mount Pleasant Road. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

19. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the construction of a 2.0m high screening bund along the southern boundary of the IDO area of Grove Quarry, abutting Mount Pleasant Road. The scheme should include provision for the bund to be constructed with an outer gradient of no steeper than 1:3.5(v/h) and grass seeded and planted with native trees and shrubs to provide a vegetated visual barrier to views. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

20. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the infilling, widening and strengthening of the hedgerow/woodland belt along the northern boundary of the quarry void. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

21. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the intermediate restoration of the upper faces/benches illustrated on plan ref numbers C112/097- C112/105. The restoration works shall thereafter be implemented in accordance with the approved scheme.

22. Prior to the commencement of construction of the Pant Mawr Quarry Western Tip, shown on plan ref numbers C112.102 and C112.104, a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the landscape treatment of the finished profiles of the tip. The scheme shall include details of grass seeding, tree and shrub planting schedules, and proposals for maintenance of the restored tip area. Any trees, shrubs or hedges which die, are removed or become seriously damaged or diseased within 5 years of planting, shall be replaced in the next planting season with others of a similar size and species, unless otherwise agreed in writing by the MPA. The scheme shall thereafter be implemented in accordance with the approved scheme.

Noise

23. Except for temporary operations, the free-field Equivalent Continuous Noise Level, $L_{Aeq,1\ hour}$ due to operations in the site, shall not exceed the relevant criterion limit specified in Schedule 1 at each nominated dwelling for the periods specified. Measurements taken to verify compliance shall have regard to the effects of extraneous noise and shall be corrected for any such effects.

Schedule 1 Noise Criteria Limits

Location	**07:00-19:00** **Criterion** dB $L_{Aeq,\ T}$	**06:00-07-00** **Criterion** dB $L_{Aeq,\ T}$	**19:00-22:00** **Criterion** dB $L_{Aeq,\ T}$	**22:00-06:00** **Criterion** dB $L_{Aeq,\ T}$
Rock Cottages in South Cornelly	50	42	48	42
Danygraig (Holiday Caravan Camp)	55	45	48	42
Grove Farm House, Grove	55	45	48	42
Sea View, Mount Pleasant Road	50	45	48	42
Manderlay, Stormy Down	55	48	48	42
Ballas Farm	55	48	48	42
Ty Tanglwyst Farm	55	48	48	42
Mount Pleasant Farm	53	45	48	42

24. For temporary operations such as site preparation, soil and overburden stripping, bund formation and removal and final restoration, the free-field noise level due to work at the nearest point to each dwelling shall not exceed 67 dB $L_{Aeq,\ 1\ hour}$. Temporary operations shall not exceed a total of eight weeks in any calendar year for work close to any individual noise sensitive property.

Blasting

25. Except with the written consent of the MPA, or in the case of emergency, blasting operations shall be carried out only between 1000 and 1700 hours Monday to Friday, and only in exceptional circumstances on Saturday and not at all on Sunday and Public/Bank Holidays.

26. Ground vibration as a result of blasting shall not exceed a peak particle velocity of 6mms^{-1} in 95% of all blasts measured over any six month period, and no individual blast shall exceed a peak particle velocity of 10mms^{-1} measured at any vibration sensitive location, which is defined as any residential property in the vicinity of the quarry existing at the Date of Determination. The measurements shall be the maximum of three perpendicular directions taken at the ground surface.

27. All individual blasts shall be designed, managed and implemented to minimise the extent of air overpressure resulting from blasts, having regard to blast design, methods of initiation of blasts, and also as far as practicable to weather conditions prevailing at the time of initiation.

28. Each individual blast shall be monitored by the Operators, to include: provision for recording the details and location of the monitoring station; the location of the blast holes within the Site; weather conditions; specification of the blast in terms of MIC; and total charge weight. Blast monitoring is to be undertaken at the closest sensitive receptor to the blast location or at an alternative location that is requested by the Mineral Planning Authority. Records of blast monitoring shall be made available to the MPA upon request. Any complaints which are received shall be logged against each particular blast. In the event that monitoring indicates that the vibration levels set out in condition 26 above have been exceeded, then the Operator shall inform the MPA within two working days, with written confirmation of the steps to be taken to ensure compliance with condition 26.

29. Blasting times shall be clearly advertised at the Quarry site entrance, and an audible warning shall be sounded prior to any blasting operations taking place, and shall be sounded again immediately after blasting has finished.

30. There shall be no secondary breakage of stone by the use of explosives.

Dust

31. Automatic wheel cleaning facilities, including sprays to clean the wheels, underbody and side body of vehicles shall be maintained throughout the operations permitted. Such facilities shall include the provision of a water recycling system to maximise the use of water supplies.

32 At all times during the carrying out of operations, a water bowser or similar equipment shall be available on site, and be used to minimise the emission of dust from haul roads and access roads within the site, and the processing plant site hard-standings..

33. Measures shall be taken to minimise dust emissions from quarrying operations, in accordance with the following protocol:

- Soils and overburden shall not be handled during extreme dry conditions unless the working areas are first dampened down.
- Drilling of shot holes shall be undertaken using drilling rigs fitted with a suitable dust collection system.

- Site roads within the quarry shall be dampened down as appropriate, in accordance with the requirement of conditions 31 and 32.
- The site entrance road shall be maintained by use of a road sweeper which shall operate as required to maintain the surface of the road free of mud and other detritus.
- All lorries, once loaded, shall be sheeted prior to leaving the site, with the exception of any load carrying only plus 75mm size diameter stone.
- The speed of haulage vehicles at the site will be restricted to 10mph.
- All site vehicles will be fitted with upswept exhausts and radiator fan shields.
- Lorries will be loaded so as to avoid spillages.
- All site traffic will be kept to the designated haul routes
- Any plant spillages will be cleared to avoid accumulations.
- Drop heights will be minimised at loading and discharge points.

Site Security

34. A minimum 1.3 metre high stockproof and two strand barbed wire fence shall be maintained around the entire site perimeter (with the exception of lockable gates) together with quarry warning signs at 25 metre intervals.

Restoration

35 The development shall proceed in accordance with the concept restoration plan ref numbers C112/106 - C112/108 and the details of interim and final restoration treatments, landscaping, and aftercare, set out in Chapter 4.0 of the 2014 ES.

36 Not later than 31st December 2054, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed final restoration scheme, including drawings to illustrate the proposals for the final restoration of the quarry. The final restoration scheme shall be based upon the concept restoration plan ref numbers C112/106 - C112/108, and provide for the site to be restored as a nature conservation bias, with restoration treatment of the benches and faces above the water level which will be formed in the void. The scheme shall include updated predictions of the final rest water level of the lake. The remainder of the site shall be cleared of all plant, machinery, buildings and structures in accordance with the requirements of Condition 3. The restoration scheme shall include details of the final re-profiling works for the site, the soil /soil forming material profiles to be established; tree and shrub planting schedules; seeding, fencing and drainage; and a programme and timetable for the implementation of the works.

37 Not later than 31st December 2054, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed aftercare management plan. The management plan shall be in substantial accordance with the details of the final restoration scheme and the principles of the strategic aftercare management strategy set out in Chapter 4.0 of the 2014 ES.

The Planning Inspectorate
Yr Arolygiaeth Gynllunio

# Adroddiad	# Report
Ymchwiliad a agorwyd ar 10/11/15 Ymweliad â safle a wnaed ar 12/11/15	Inquiry opened on 10/11/15 Site visit made on 12/11/15
gan Clive Nield BSc(Hon), CEng, MICE, MCIWEM, C.WEM	**by Clive Nield BSc(Hon), CEng, MICE, MCIWEM, C.WEM**
Arolygydd a benodir gan Weinidogion Cymru	**an Inspector appointed by the Welsh Ministers**
Dyddiad: 11 Rahgfyr 2015	**Date: 11 December 2015**

Environment Act 1995

Section 96 and Schedules 13 and 14

Review of Old Mineral Permissions (ROMPS) for

Cornelly, Grove and Gaens Quarries

and

Interim Development Order (IDO) Periodic Review for

Cornelly and Grove Quarries

Cyf ffeil/File ref: APP/F6915/X/15/516086, 516087, 516088 & 516089

CONTENTS

Application A: File Ref: APP/F6915/X/15/516086

Site address: Cornelly Quarry, South Cornelly

- The application was called in for decision by the (now) Minister for Environment, Sustainability and Housing, one of the Welsh Ministers, under paragraph 13 of Schedule 13 of the Environment Act 1995, on 29 July 1998.
- The application is made by Cambrian Stone Limited (a Tarmac joint venture company) to Bridgend County Borough Council under paragraph 9 of Schedule 13 of the 1995 Act.
- The application Ref P/97/623/MIN is dated 30 June 1997.
- The application is to determine a scheme of conditions to which the mineral permission for the site is to be subject.
- No specific reason was given for making the direction.
- On the information available at the time of making the direction, and as clarified by subsequent correspondence, the matter on which the Welsh Ministers particularly wish to be informed for the purpose of consideration of the application is the effect of the proposed quarrying operations on the water environment, including the potential for significant effect on the Kenfig Special Area of Conservation.
- The inquiry sat for 3 days on 10-12 November 2015.

Summary of Recommendation: The scheme of conditions, as amended and agreed, be approved.

Application B: File Ref: APP/F6915/X/15/516087

Site address: Grove Quarry, South Cornelly

- The application was called in for decision by the (now) Minister for Environment, Sustainability and Housing, one of the Welsh Ministers, under paragraph 13 of Schedule 13 of the Environment Act 1995, on 29 July 1998.
- The application is made by Pioneer Aggregates Limited under paragraph 9 of Schedule 13 of the 1995 Act to Bridgend County Borough Council.
- The application Ref P/97/618/MIN is dated 26 June 1997.
- The application is to determine a scheme of conditions to which the mineral permission for the site is to be subject.
- No specific reason was given for making the direction.
- The matter on which the Welsh Ministers particularly wish to be informed for the purpose of consideration of the application is the same as for Application A above.

Summary of Recommendation: The scheme of conditions, as amended and agreed, be approved.

Application C: File Ref: APP/F6915/X/15/516088

Site address: Gaens Quarry, South Cornelly

- The application was called in for decision by the (now) Minister for Environment, Sustainability and Housing, one of the Welsh Ministers, under paragraph 13 of Schedule 13 of the Environment Act 1995, on 14 May 1998.
- The application is made by TS Rees Limited under paragraph 9 of Schedule 13 of the 1995 Act to Bridgend County Borough Council.
- The application Ref P/97/85/MIN is dated 27 January 1997.

- The application is to determine a scheme of conditions to which the mineral permission for the site is to be subject.
- No specific reason was given for making the direction.
- The matter on which the Welsh Ministers particularly wish to be informed for the purpose of consideration of the application is the same as for Application A above.

Summary of Recommendation: The scheme of conditions, as amended and agreed, be approved.

Application D: File Ref: APP/F6915/X/15/516089

Site address: Cornelly and Grove Quarries, South Cornelly

- The application was called in for decision by the (now) Minister for Environment, Sustainability and Housing, one of the Welsh Ministers, under paragraph 8 of Schedule 14 of the Environment Act 1995, on 11 February 2010.
- The application is made by Cambrian Stone Limited (in respect of Groves Quarry) and Tarmac (South Western) Limited (in respect of Cornelly Quarry) under paragraph 6 of Schedule 14 of the 1995 Act to Bridgend County Borough Council.
- The application Ref P/09/738 is dated 15 September 2009.
- The application is to determine a scheme of conditions to which the mineral permission for the site is to be subject.
- The reason given for making the direction was that the proposed development raises issues of more than local importance, in particular, issues which may conflict with national planning policy on sites of nature conservation importance.
- The matter on which the Welsh Ministers particularly wish to be informed for the purpose of consideration of the application is the same as for Application A above.

Summary of Recommendation: The scheme of conditions, as amended and agreed, be approved.

Preamble

1. This report includes brief descriptions of the sites and surrounding area, relevant planning policies, the gist of the representations made, my appraisal and conclusions, and my recommendations. Document references are shown in brackets, and in my conclusions the numbers in square brackets indicate the relevant paragraphs of the report. Details of the people who took part in the public inquiry and comprehensive lists of documents are attached at the end of the report. The recommended planning conditions are attached as annexes.

Procedural and Background Matters (ES Volume 1 – Core Document CD2.2)

2. The Planning and Compensation Act 1991 introduced a requirement that quarries benefitting from Interim Development Order (IDO) permissions (i.e. predating the 1948 Act) should be subject to a review to allow the original planning conditions to be updated and replaced with new modern conditions to control future quarrying and restoration. This process was duly followed for the Cornelly/Grove Quarries IDO

permission (which covers part of each quarry – see figures in Appendices 1 & 2 of Doc 16.3), and the former Mid Glamorgan County Council issued an updated schedule of conditions on 21 September 1994 (see Appendix 1.1 in Environmental Statement (ES) Volume 2D - Core Document CD2.6).

3. The Environment Act 1995 introduced a process of periodic reviews of old mineral permissions at 15 year intervals in order to ensure that the planning conditions continue to reflect up to date standards and requirements. Schedule 14 sets out the procedures for the periodic review of IDO permissions, and the current application for the Cornelly/Grove Quarries IDO (Application D) is in accordance with these requirements.

4. Schedule 13 of the Act covers the process for periodic reviews of old mineral planning permissions granted after 1948 (known as ROMP reviews), and Applications A, B and C above (for Cornelly, Grove and Gaens Quarries respectively) are made under this Schedule. All 4 of the permissions will fall due for further periodic review of conditions in 15 years time.

5. The 3 ROMP applications were not formally subject to environmental impact assessment when they were made. However, when requested by the (then) Welsh Office, Environmental Statements were subsequently submitted voluntarily for each application. An Environmental Statement was submitted with the 4th application, the Cornelly/Grove IDO Periodic Review, which falls within the scope of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (SI 1999/293) as modified by the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 2000 (2000/3295). In 2009 the Welsh Government enacted the Town and Country Planning (Environmental Impact Assessment) (Undetermined Reviews of Old Mineral Permissions) (Wales) Regulations 2009, and these apply to the 3 ROMP applications.

6. More recently, the environmental information submitted for all 4 applications has been reviewed, and new Environmental Statements were submitted for each case in June 2014 (Core Documents CD2, 3, 4 & 5, each comprising several volumes as detailed in Document 2). These represent the most up to date application documents and include proposed schedules of conditions and Water Management Plans for each quarry. These ESs were advertised in accordance with the legislation.

7. During the course of the preparations for the public inquiry and at the inquiry itself these schedules of proposed conditions and Water Management Plans have been subject to some variation (as agreed between the Applicants, the Council and NRW). As explained by Tarmac's agent in its letter to PINS (Document 25), public advertisement of this varied environmental information is adequately covered by advertisement of the public inquiry itself, where the varied information is open to public scrutiny.

8. Although the Grove Quarry application was originally submitted in the name of Pioneer Aggregates Limited, its ownership now lies within the Tarmac group, and in recent years the 3 Cornelly and Grove applications have been pursued by Lafarge Tarmac Limited. However, at the opening of the inquiry it was reported that the responsible company is now Tarmac Trading Limited.

9. Natural Resources Wales (and its predecessor organisations) has been consulted regularly by both Welsh Government (and its predecessors) and by the Applicants over the period since the applications were first made and, of course, NRW is a statutory consultee for any appropriate assessment under the Habitats Regulations. In view of the importance attached to the possible effects of future quarrying operations on the water environment, including effects on the nearby Kenfig Special Area of Conservation, NRW has participated fully (as a Rule 6 party) in the procedures for the public inquiry and in the public inquiry itself.

Sites and Surroundings (ESs Volume 1 – CD2.2, CD3.2, CD4.2 & CD5.2)

10. The 3 quarries in question are grouped on land to the east and south-east of South Cornelly and to the south of junction 37 of the M4 motorway (see site location plans at Appendix 1 of Document 16.3 for Cornelly and Grove Quarries and in Volume 3 of the Gaens Quarry ES, Core Document CD5.7, for Gaens Quarry). Cornelly is the largest of the 3 quarries and is bounded by Grove Quarry to the west, Mount Pleasant Road to the south and east, Heol-y-Splot to the north-west with Gaens Quarry beyond, and open countryside towards the motorway to the north. The aerial photographs at Documents 34.1 & 34.2 provide an excellent appreciation of the quarry and its surroundings. I have annotated them to show the M4 motorway and arrows pointing towards the north. The quarry site covers an area of almost 79 hectares, of which the extraction area equates to some 48 hectares.

11. Grove Quarry lies to the west of Cornelly Quarry and is not currently in operation. It is currently one of the disused/former quarries to which water from Cornelly Quarry is pumped (see location plan at Appendix 1 of Document 16.3). It is bounded by Heol-y-Splot to the north with the disused Pant Mawr Quarry beyond and an industrial estate to the north-west, by Cornelly Quarry to the east, and by Porthcawl Road (A4229) to the west and south, which links Porthcawl to the motorway. The Grove ROMP area covers some 12.4 hectares and the Cornelly/Grove IDO area almost 48 hectares, although the total extraction area proposed for Grove Quarry amounts to between 18 and 19 hectares.

12. Gaens Quarry is situated due east of the settlement of South Cornelly with a high ridge between the quarry and nearby houses. The disused/former Pant Mawr Quarry lies to the south-east, and to the north and east there is largely open countryside with Ty Tanglwyst Farm beyond the northern boundary. The ROMP area constitutes some 12.7 hectares of which 11 hectares have been disturbed for extraction (see location plan at ES Volume 3 – CD5.7)

13. The quarries are located on a broad upland limestone plateau ranging in level between 80 m and 108 m AOD, the higher level being at the eastern end of Cornelly Quarry. The surrounding land falls away in all directions. There are 2 internationally designated nature conservation sites within 2 km of the quarries: the Kenfig Special Area of Conservation (SAC) to the west-north-west; and the Cefn Cribwr Grasslands SAC to the north (see the Ecological Designations map, Figure 8.1, in Appendix 8.2 of the ES (Volume 2D) – Core Document CD2.6). The same map shows the locations of Sites of Special Scientific Interest, National Nature Reserves and Sites of Importance for Nature Conservation.

Planning Policy (Documents 16.1 & 17.1, and Volume 1 of each of the ESs {Core Documents CD2.2, CD3.2, CD4.2 & CD5.2})

14. Although the principle of mineral development at these quarries has already been established by the extant planning permissions, development plan and national policies provide guidance on environmental controls and operational practices that need to be enshrined in up to date planning conditions. At the national level Minerals Planning Policy Wales (MPPW) establishes a series of sustainable aims for mineral development, including provision for an adequate supply of minerals whilst protecting landscape features and the environment.

15. Paragraph 34 lists the key issues to be considered when assessing the impact of mineral development: access and traffic generation; noise; control of dust, smoke and fumes; blasting controls; land drainage and impact on groundwater resources; visual intrusion; impact on sites of nature conservation, historic and cultural importance; and provisions for restoration, aftercare and after-use. Planning conditions are appropriate on most of these matters.

16. Minerals Technical Advice Note 1: Aggregates (MTAN1) provides more detailed advice on delivering the policies of MPPW. It includes specific advice on measures to reduce the impacts of quarrying and on planning conditions. The advice on blasting vibration limits and controls, noise limits, dust control measures, landscape and visual impact, site management and restoration proposals is particularly relevant to these applications.

17. Although published in 1995, "Minerals Planning Guidance 14: Environment Act 1995 – review of mineral planning permissions" is also relevant as it gives advice on both the statutory procedures to be followed for such applications and the approach to be adopted to the preparation and consideration of updated planning conditions in the review process.

18. The adopted development plan is the Bridgend Local Development Plan, which was adopted in September 2013. It does not make specific reference to reviews of old mineral permissions but contains policies for general environmental protection covering similar issues to those listed above in MTAN1.

Quarry Proposals (Documents 16.1 & 17.1)

19. Each application includes detailed proposals for working the quarries over the next few decades (see the application plans contained in the ESs: Cornelly ROMP, Groves ROMP and Cornelly/Grove IDO Review in Volume 4 (Core Documents CD 2.8, CD3.8 and CD4.8 respectively); and Gaens ROMP in Volume 3 (Core Document CD5.7). Detailed working proposals are described in Section 3 of Volume 1 of each ES (Core Documents CD2.2, CD3.2, CD4.2 & CD5.2). Whilst working would progress into areas not already quarried in due course (though only within the permission boundaries, of course), the key development feature so far as possible effects on the groundwater environment are concerned is increased depths of working.

20. Cornelly Quarry is currently worked down to a level of about 0 m AOD, and the application proposal is to go to -75 m AOD. This would yield reserves of between 42m

and 45m tonnes which, at the present working rate of about 1m tonnes per year, would take an estimated 42 years (i.e. to 2056).

21. The application proposals for Grove Quarry and Gaens Quarry would involve much shallower maximum depths (-15m AOD for Grove and -20m AOD for Gaens). The resource at Grove Quarry would amount to about 12m tonnes, and it has been estimated that at about 250,000 tonnes per year it would have a notional timescale of some 48 years. However, for consistency with Cornelly Quarry, the proposal is also based on a working life of 42 years.

22. Gaens Quarry has a current output of about 150,000 tonnes per year, and the estimated reserve amounts to some 8m tonnes. This equates to an operational term of about 53-54 years (i.e. to 2068).

23. The quarried limestone is primarily used as an aggregate in the construction industry. However, some 50% of the output of Cornelly Quarry is used to produce sinter, a fine crushed limestone which is an essential constituent in the production of iron and steel (for the removal of impurities). The chemical purity of the limestone is essential for this use, and suitable limestone reserves are only found at a small number of quarries in the UK. The importance of the limestone reserve is reflected in the fact that Tata, the owners of Port Talbot Steelworks, are also the freehold owners of Cornelly Quarry.

Case for Tarmac

The material points are:

Hydrogeological Modelling and Monitoring (Document 14.1)

24. Quarrying operations require dewatering of the working area, which lowers the local water table. As quarrying operations go deeper, the water table is lowered even further and there is potential for this hydrogeological effect to encompass a wider area. Cornelly is the deepest of the quarries, and it is proposed to deepen it further over the coming decades. Thus the dewatering of that quarry has the most significant effect and has been investigated in considerable detail. However, the cumulative effect of dewatering all 3 quarries at the same time has also been investigated.

25. It is pertinent that the water removed from the quarries is not lost to the aquifer below but merely redistributed. At present water from Cornelly Quarry is pumped to the adjoining Grove Quarry (which is currently disused). In the past it has been pumped to the disused Pant Mawr Quarry to the north-west of Cornelly or to the disused Stormy Down Quarry to the east (see site location plan at Appendix 1 of Document 16.3). When it was operating Grove Quarry was pumped periodically to a disused railway cutting to the west. Any surplus water from Gaens Quarry goes to the northern quarry sump.

26. Hydrogeological concerns were raised at the time of the original applications, and extensive and widespread studies and investigations have been carried out over many years to address them. These have provided data to enable the aquifer to be modelled and to provide forecast data based on simulation of the proposed future operations.

27. The process started with investigation of the local hydrogeology: conditions at depth below the quarries; the hydraulic connection between the limestone and the dune systems at Kenfig and Merthyr Mawr; the identification of the main outflows from the aquifer; and the feasibility of water management options at the quarries. This led to development of the conceptual model, including the geological and hydrogeological frameworks and the water balance and boundaries, which is a tool for communicating understanding of the groundwater systems at the site. The model has been iteratively refined over the past 15 years in liaison with NRW (and its predecessors), and it is common ground that it represents the best scientific knowledge available and is a robust basis for assessing and managing the risks to the local water environment.

28. The next step was development of a groundwater model based on the conceptual model, and again this has been an iterative process with calibration against the extensive baseline dataset of groundwater levels and flows. Data has been collected (and continues to be collected) from some 105 local monitoring locations, the most extensive hydrometric dataset around any quarry in the UK. The sensitivity of the groundwater model has also been tested. As more data has been collected over the years (most of the datasets go back more than 10 years) the understanding and confidence in the groundwater model has increased, including the groundwater storage, the directions and rates of groundwater flow and connections within and between geological formations.

29. In the Statements of Common Ground between the Applicants and NRW (Documents 18.1 & 18.2) it is confirmed that NRW agrees with both the methods and results of the Applicants' hydrogeological impact assessments. However, NRW has expressed doubts on 2 particular matters. The first is that some 69% of the water outflow from the model is not specifically accounted for. However, this is believed to be due to general flows to the south and west towards the sea and is not considered to affect the understanding of the links between the quarries and the Kenfig SAC. The second is the level of uncertainty due to the possible presence of karst features in the geology below the quarries.

30. Karst features are highly permeable discontinuities that could provide conduits for high groundwater flows if intercepted by quarrying activities. A study carried out by the British Geological Society (BGS) for the National Assembly for Wales in 2000 (Core Document CD6.1) advised that karst features would be likely to exist beneath the quarry floor and, if encountered by deeper quarrying, could be reactivated and produce substantial water flows into the quarry. NRW's concerns are based on that report and on its own guidance document, Hydrogeological Impact Appraisal for Dewatering Abstractions, dated 2007, in which Appendix 3 deals specifically with Karst (Core Document CD6.21). However, more recent investigations have been carried out for the Applicants and indicate a far more positive picture.

31. Investigations carried out in 2003 and updated in 2013 (Appendix H of ES Volume 2A - Core Document CD2.3) included detailed surveys of the exposed quarry faces and 1000 metres of borehole records, substantially more data than available to the BGS in 2000. The conclusion was that the present phase of karst development only extended downwards about 40 metres from the surface, i.e. to about 60 m AOD, coincident with the pre-dewatered level of the water table. The study also showed that there is little

evidence of any substantive karst conduit network. Rather, due to the very high frequency of dilated joints, the dewatered saturated zone appears to be characterised by diffuse fracture flow, and so is more amenable to reliable groundwater modelling than most karstic aquifers.

32. Taken together with the relatively low pumping rates experienced at Cornelly Quarry, even though the groundwater level is drawn down by some 60 metres, and the steep gradients found in groundwater levels in the area, this suggests that there is a very low probability of encountering significant zones of enhanced permeability (i.e. active karst conduits) as the quarry is deepened further. This contradicts the conclusions of the BGS assessment in 2000 which are now considered by Tarmac to be incorrect.

33. The findings of these studies should be given considerable weight as they were carried out by Professor Peter Smart who is one of the UK's leading experts on karst geology. It is also pertinent that Professor Smart was one of the authors of the karst chapter in the other document referred to by NRW, the 2007 guidance document on Hydrogeological Impact Appraisal for Dewatering Abstractions (Core Document CD6.21). The Applicants are of the view that, on the basis of Professor Smart's conclusions, a high level of confidence can be placed in the modelling work and that NRW's view that there remains a degree of uncertainty due to the possibility of encountering karst features is misplaced.

34. The key criterion so far as effects on the Kenfig SAC is concerned is the water level regime in the dune slacks (as explained below). The hydrogeological model has been used to simulate the effects of deepening the quarries and to assess the potential impacts on the dune slack groundwater levels. Although a range of simulations have been carried out, the most illustrative is modelling the situation of maximum water table drawdown at the quarries. This shows a worst case prediction of a 6 mm change in general water level at the Kenfig SAC, a prediction accepted by NRW in the Statements of Common Ground (Documents 18.1 & 18.2). It should also be born in mind that this assessment is based on an instantaneous change of water levels at the quarries rather than a gradual change over several decades, a very precautionary approach.

35. In contrast, the modelling predicts a maximum water level change of 12 cm at the SAC if pumping at the quarries were stopped suddenly at the maximum excavated depths (without any mitigation measures). However, if the final cessation of pumping was carried out gradually and in a controlled manner, the impact on levels at the SAC would be much lower. This is one of the matters dealt with in the Water Management Plan.

Water Management Plan (Documents 14.1, 18.1 & 18.2)

36. At the opening of the inquiry the Applicants and NRW announced that they had reached agreement on the wording of the Water Management Plan (Documents 19.1-19.6), which is to be incorporated by agreed conditions, and that compliance with the WMP would ensure there would be no adverse effect on the SAC. Up to that time, whilst there was little between the parties, it had not been possible to reach complete agreement.

37. The WMP is a tool for protecting the water environment and local private water supplies. It consists of: quarry pumping arrangements; requirements for long-term future monitoring of the extensive network of monitoring sites; requirements for review and reporting of the data each year, including overview by the Council (in conjunction with NRW); the mechanism for identifying whether a deviation from the specified assessment criteria (trigger levels) has occurred, the cause and significance of that deviation, and what adjustments should be made; planned mitigation measures, such as changes to the destinations for quarry pumping or modification or compensation arrangements for an affected private water supply; and contingency measures should unpredicted events occur. (Document 19.1)

38. Prior to agreement being reached there were 2 significant matters between the parties. The first was about how to identify a trigger event at the SAC receptor site. It is common ground that the measure to be adopted for a significant effect on the integrity of the SAC (see below) should be a 0.1 m drawdown in summer water levels over a 3 year period, and the Applicants had taken this to be an appropriate trigger for identification of the need for mitigation measures. However, NRW's view was that the trigger should 0.1 m change over just one year as, if that drawdown were to occur over a 3 year period, there would already have been a significant impact on the SAC.

39. However, that impasse has been overcome by specifying changes in levels at pathway monitoring sites as the measures to trigger actions, and this is the approach adopted in the final WMPs. The hydrogeological model has been used to assess appropriate deviations from the expected norms at each of the identified intermediate pathway sites equivalent to a deviation of 0.1 m at the SAC (see Table 1 in Document 22). It can be seen that these are substantially greater than any deviations expected at those monitoring sites under normal circumstances and so would be readily apparent. A further advantage of this approach is that it would give advance warning of possible impacts at the SAC itself as there would be delays of several years between identifying deviations at these sites and the effect reaching the SAC (see last columns on Table 1). Thus there would be adequate time to take mitigation or contingency measures to ensure the criterion of 0.1 m deviation over 3 years for significant harm to the SAC was avoided.

40. The second key issue was the degree of precaution to be allowed for in the contingency measures, as NRW was concerned about the risk of encountering karst features. The Applicants did not want to entertain any provisions within the WMP that might have the effect of stopping or restricting quarrying operations or otherwise restricting working rights, as the Act makes provision for any such constraints to be applied by means of special Modification Orders, which come with provisions for financial compensation to the quarry operator. This matter has been resolved by including within the WMP an acknowledgement (in paragraph 2.5) that *"the WMP may need to be revised from time to time"* and that *"No changes ……… shall, however, have the purpose or effect of stopping or preventing quarry operations or otherwise restricting working rights within the meaning of the Environment Act 1995"*.

41. The final position now is that all parties agree that the contingency measures in version 5.8 of the WMP are adequate and that the WMP as a whole provides the necessary

assurance to safeguard the water environment (and hence the SAC features) and private water supplies in the area from significant harm.

Effect on Special Area of Conservation (Document 15.1)

42. This section is headed in the singular as it is only the effects on the Kenfig SAC that need to be considered in any detail. The Cefn Cribwr Grasslands SAC (to the north of the quarries), which has purple moor grass (*Molinia*) meadows and the marsh fritillary butterfly as qualifying features, is not dependent on groundwater features that could be affected by dewatering of the Cornelly group of quarries. Consequently there is no mechanism by which the quarry proposals could have a significant effect on the SAC, and there is no need to make any further appropriate assessment under the Habitats Regulations. That is common ground with NRW.

43. The Kenfig SAC is made up of 2 discrete areas, the Kenfig dunes (and pond) and the Merthyr Mawr dunes (see the Ecological Designations map, Figure 8.1, in Appendix 8.2 of the ES (Volume 2D) – Core Document CD2.6). The key features for consideration are the dune slacks, which are dependent on water levels for their integrity. Dune slacks are damp or wet hollows left between the dunes where the groundwater reaches or approaches the surface of the sand. Their most distinguishing feature is a seasonally fluctuating water table which usually reaches a maximum in winter and spring and a minimum in summer, and vegetation development is strongly associated with the average depth and seasonal fluctuation of the water table. (Document 14.1)

44. Kenfig Pool is also identified as a qualifying SAC feature and any reduction in groundwater levels could reduce the size of the pool and the available habitat for the qualifying species (the benthic vegetation of *Chara* species). It is common ground with NRW that an appropriate measure of significant impact on both types of SAC features would be a change in summer groundwater levels of 0.1 m over a rolling 3 year period. This is based on studies of the Kenfig dune slacks carried out by Peter Jones of CCW and reported in a short paper in 2004 (Core Document CD6.25). He reported that dune slack communities were differentiated by their summer water regimes and that differences as small as 10 cm (i.e. 0.1 m) separated many communities. He recommended that, pending further research, 10 cm be adopted as an interim figure to aid impact assessment.

45. The groundwater modelling work has demonstrated that, even at the depth of quarrying proposed several decades ahead, the impact of quarry operations on summer groundwater levels at the SAC would be considerably less than 10 cm and would not have any significant effect on the integrity of the SAC. The Statements of Common Ground between the Applicants and NRW (Documents 18.1 & 18.2) record agreement that, subject to implementation of the WMP (v5.8), there would be no adverse impact on the integrity of the SAC. There is also agreement that the 0.1 m criterion provides the necessary degree of resilience.

46. Although not given much weight by NRW, consideration has also been given to the advice in the Environment Agency's Ecohydrological Guidelines for Wet Dune Habitats, published in 2010 (Core Document CD6.22). The guidelines state that their purpose is to *"provide a generic tool to help conceptualise wetlands and inform assessments of whether vegetation communities associated with European-designated wet dune*

features should be considered at risk of being out of regime. For example, they may be used for the purposes of impact assessments for new consents under the Habitats Directive or more generally". In view of the organisations and authors involved in preparing the guidelines and the use of the Kenfig SAC as one of the underlying case studies, it is reasonable to take these into account in assessing impacts on the SAC in this case.

47. Table 3.1 of the Guidelines details water table conditions for defining the different types of humid dune slack habitats, and these further support the conclusion that changes to the water level regime of less than 0.1 m would be insufficient to move any of the dune slack habitats in the SAC from one sub-category to another or to adversely affect the benthic vegetation of *Chara* species in the Kenfig Pool.

Appropriate Assessment (Documents 15.1 & 31 and Core Document CD2.6)

48. The Applicants are of the opinion that appropriate assessment under the Habitats Regulations is unnecessary for Kenfig SAC as it is straightforward for the competent authority (in this case the Welsh Ministers) to decide that the project is not *"likely to have a significant effect on a European site"* (the test in paragraph 61(1) of the Habitats Regulations) and would not *"adversely affect the integrity of the European site"* (the test in paragraph 61(5) of the Regulations). Thus further assessment is not considered to be necessary. This view is reached in the light of the recent Supreme Court judgement in *Regina (Champion) v North Norfolk District Council and another [2015] UKSC 52* (Court of Appeal decision is at Document 32.1 and Supreme Court decision is at Document 32.2) and in full knowledge of the well known *Waddenzee* judgement (*Landelijke Vereniging tot Behoud van de Waddenzee v Staatsscretaris van Lanbouw (Coöperatieve Producentenorganisatie van de Nederlandse Kokkelvisserji UA intervening) (Case C-127/02) EU:C:2004:482; [2005] All ER (EC) 354; [2004]ECR I-7405, ECJ*).

49. The Applicant's barrister has included a summary of the key points taken from the Supreme Court judgement at Appendix 1 of his closing statement (Document 31) but further highlighted the following principles:

- No decision has yet been made by the Welsh Ministers on whether appropriate assessment is needed or not, and so it can still make that decision.
- It is now common ground amongst the parties, including NRW, that, with the provisions of the WMP and agreed conditions, the proposals would not have a significant effect on the SAC.
- As all of the information is available, including NRW's agreement, to enable the Welsh Ministers to be able to be confident that the SAC would be protected at this initial stage, no further appropriate assessment is required.
- The Regulations and Directive do not set out any formal requirements for the content or form of an appropriate assessment.
- It would be perfectly lawful for the Welsh Ministers to conclude that appropriate assessment is not required as it is already able to reach a positive conclusion on the

test in paragraph 61(5) of the Regulations, i.e. that the project would not *"adversely affect the integrity of the European site"*.

50. However, notwithstanding this position, if the decision maker considers it necessary to carry out an appropriate assessment, the information required is provided in the shadow appropriate assessment (SAA) at Appendix 8.3 of the ES Volume 2D (Core Document CD2.6). Section 2 of the SAA sets out the assessment process and explains that for the first step, the decision as to whether appropriate assessment is needed or not, the term "likely" is taken in its broadest meaning as "capable", i.e. "is the project capable of having a significant effect on the SAC". Thus the likelihood of an effect needs only to be very low to trigger the need for an appropriate assessment.

51. Section 3 of the SAA describes the qualifying interests of the Kenfig SAC and their criteria for favourable conservation status, and Section 4 carries out the first step review concluding that "it is not possible to rule out the likelihood that the quarrying operations will have a significant effect on the (Kenfig) European site". The same section rules out at this step the possibility of affecting the Cefn Cribwr Grasslands SAC. Sections 5 and 6 of the SAA then go on to identify what features of the SAC might be affected by changes in the water level regime and what those predicted effects might be.

52. The key habitats are identified as the dune slacks, which are hollows within the dune systems that form between the dune ridges, where the plant species are adapted to the seasonally changing groundwater levels and are therefore sensitive to any long-term alteration of such cycles. These include petalwort and fen orchid, 2 rare plant species which are qualifying features of the SAC in their own right. The other relevant SAC feature is the Kenfig Pool with a benthic vegetation of *Chara* species, a form of algae that resembles land plants and is commonly known as stonewarts.

53. The SAA makes reference to the Ecohydrological Guidelines for Wet Dune Habitats, published by the Environment Agency in May 2010 (Core Document CD6.22), which provide guidance on the range of water table conditions required to sustain the various types of dune slack habitats and which identify the summer maximum values as the most relevant, as they represent the period when the water table is at its seasonal lowest. The extensive groundwater modelling carried out by the Applicants has predicted a maximum change in groundwater level due to the proposed quarrying of only 6 mm at both the dunes and Kenfig Pond. Such a change would be insufficient to shift any of the dune slack habitats from one sub-category into another. It would also be much lower than the 0.1 m change criterion adopted by NRW, based on Peter Jones' research work reported in 2004 (see Core Document CD6.25).

54. The only predicted exception to this is that during decommissioning of the quarries, if the quarry dewatering pumps were completely turned off and this coincided with a drought, a fall in groundwater levels by as much as 0.12 m could occur. Whilst it is marginal whether this would be sufficient to materially affect the dune slack habitats, it would exceed the 0.1 m change prescribed by NRW. However, it could be substantially alleviated if residual pumping were continued for a period after quarrying ceased, and this could be ensured by applying appropriate planning conditions, as agreed with NRW in the Statements of Common Ground (Documents 18.1 & 18.2) and the Version 5.8 WMP (Documents 19.1-19.6).

55. NRW has continued to express concern about risks associated with possible interception of a highly permeable karst feature and, whilst the risk is very low, it cannot be completely ruled out. However, as explained above, this small risk can be adequately covered by the inclusion of contingency measures in the WMP and appropriate planning conditions, as agreed with NRW and described in the Statements of Common Ground. Paragraph 61(6) of the Habitats Regulations says that *"In considering whether a plan or project will adversely affect the integrity of the site, the authority must have regard to the manner in which it is proposed to be carried out or to any conditions or restrictions subject to which they propose that the consent, permission or other authorisation should be given"*. Thus the appropriate assessment takes into account the safeguards contained in the WMPs and proposed planning conditions. The assessment has also taken into account the in-combination effects of all of the quarries operating at the same time.

56. Section 7 of the SAA reaches the conclusion that, taking account of the WMPs and proposed planning conditions, there would be no adverse effect on the integrity of the SAC arising from the proposed continuation of quarrying or the recovery stage after decommissioning. NRW agrees with this conclusion (see Statements of Common Ground at Documents 18.1 & 18.2).

57. The information provided is sufficient to enable the Welsh Government to carry out an appropriate assessment if it considers it necessary to do so.

Other Matters (Document 16.1)

58. There is common ground between Tarmac and the Council on all other matters (Document 3), and it is agreed that the proposed planning conditions can provide appropriate controls or mitigation measures on all of the following matters:

- on-site ecological matters, including the potential for biodiversity enhancements in the restoration scheme;
- landscape and visual impact, with additional screen planting in certain locations;
- noise limits at sensitive properties around the sites in accordance with current standards;
- blast vibration limits at sensitive properties in accordance with current standards;
- dust control measures to avoid potential impact on neighbouring land uses and amenity (in addition to controls included in the PPC permits);
- highway impact issues; and
- progressive restoration and long-term restoration of the sites.

59. The Environmental Statements have considered all of these matters and concluded that none significantly affect the abilities to continue to mine the quarry reserves. This assessment has been guided by the relevant national and development plan policies. National policy recognises that mineral extraction can only take place where the mineral is found to occur, that its extraction is a temporary operation (albeit often over many years), and that any adverse effects on amenity and the environment need to be

mitigated to acceptable levels. The proposed planning conditions would achieve these requirements.

60. Several matters have been raised by interested third parties, though the limited number of such responses also gives a clear indication that the presence of the quarries is generally well accepted in the local community, which recognises the benefits they bring, and of the well managed nature of the Cornelly and Grove quarries.

61. Some of the third party comments seem to relate to Gaens Quarry rather than the Cornelly and Grove Quarries, and TS Rees responds to these. However, some general matters warrant comment. Firstly, there are concerns about dust. Comprehensive air quality and dust studies have been carried out to inform the Environmental Statements, including dust monitoring. The studies concluded that national air quality standards would not be exceeded and that planning condition controls are capable of minimising dust emissions to within acceptable levels for amenity purposes.

62. Another party was concerned about possible effects of lowered groundwater levels on their farm borehole. All water supply boreholes in the area have been included in the groundwater modelling studies, and the conclusion for the borehole concerned (at Ty Tanglwyst Farm to the north of the quarries) is that any effects will be negligible. However, the borehole will be monitored on a monthly basis (using data loggers) as part of the monitoring regime enshrined in the WMP and would be subject to mitigation measures should unforeseen circumstances arise. The WMP makes provision for modification of private boreholes, the provision of an alternative mains water supply or financial compensation for loss of the supply should such an event arise.

Proposed Conditions (Documents 3, 16.1 & 18.1)

63. Finally, some mention of the proposed conditions is needed. These reflect the recommendations for mitigation measures emanating from the various technical studies for the ESs and up to date national guidance. The 1995 Act requires applicants to submit a schedule of conditions for consideration, and proposals were submitted with the original applications. However, these have been reviewed in the light of the latest ESs (June 2014) and discussions with the Council, and sets of proposed conditions for each of the applications are included as appendices to the Statement of Common Ground agreed with the Council (Document 3). In addition, several conditions have been agreed with NRW on hydrogeological matters (see Statement of Common Ground – Document 18.1). The proposed conditions are considered to satisfy the 6 tests for conditions set out in Welsh Government Circular 16/2014, The Use of Planning Conditions for Development Management.

64. The proposed schedule of noise criteria limits in the noise condition warrants particular explanation. This adopts noise limits measured at noise sensitive properties of 55 dB $L_{Aeq,\ 1\ hour}$ for daytime hours (0700-1900 hours) and 42 dB $L_{Aeq,\ 1\ hour}$ for night-time hours (2200-0600 hours). However, following the discussion on conditions held during the inquiry, Tarmac agrees that a lower daytime limit of 50 dB $L_{Aeq,\ 1\ hour}$ should be adopted for Cornelly Quarry at Rock Cottages and Sea View, properties that otherwise enjoy a relatively quiet background noise environment (Closing Statement – Document 31).

65. The schedule includes compromise noise limits for the intermediate hours 0600-0700 and 1900-2200 hours. At present there are no restrictions on site working hours, and these are intended to provide a constructive compromise to reflect recent working practices. When the applications were made MPG11 (Minerals Planning Guidance: The Control of Noise at Surface Mineral Workings), issued in 1993 by the DOE and the Welsh Office, was extant and included the following advice:

"35. In some local circumstances, it may be appropriate for an evening period, typically 1900-2200 hours, and/or a dawn period, typically 0600-0700 hours, to be defined. If evening and/or dawn periods are to be defined, depending on local circumstances, limits modified from those indicated at paragraph 34 should be set." (Paragraph 34 specified the 42 and 55 dBA limits referred to above.)

66. Although MPG11 is no longer extant and MTAN1 makes no mention of these evening and dawn periods, this is the approach taken in this case. The Council agrees with this approach, and it is commended as a compromise that is beneficial to local amenity. The limits proposed for 0600-0700 hours are the lowest achievable, being set at 42, 45 or 48 dBA at different properties. The limit proposed for 1900-2200 hours is 48 dBA (a correction of the figures included in the sets of conditions attached to the Statement of Common Ground).

67. Updated schedules of planning conditions for the 3 Tarmac applications, taking into account the discussion on conditions held at the inquiry, were submitted on the final day of the inquiry (Documents 26.1-26.6).

Case for TS Rees

The material points are:

Hydrogeology and Special Area of Conservation

68. TS Rees relies on the same case as put forward above for Tarmac in respect of the hydrogeological modelling and monitoring, effect on the SAC, Water Management Plan and appropriate assessment. The specialist evidence submitted on these matters was prepared on behalf of both Tarmac and TS Rees.

Appropriate Assessment (Document 30)

69. TS Rees supports Tarmac's contention that appropriate assessment under the Habitats Regulations is unnecessary, though if it is carried out, all of the information necessary is available in the shadow habitats regulations assessment (available in the Gaens ROMP Environmental Statement at Appendix 6.9 in Volume 2D - Core Document CD5.6) and in the wider ES. In support of the shadow assessment, NRW is of the opinion that, subject to the controls and provisions provided by the WMP and related planning conditions, there would be no adverse effect on the integrity of the Kenfig SAC due to quarry operations (see Statement of Common Ground – Core Document CD18.2).

70. Like Tarmac, TS Rees refers to the recent Supreme Court judgement on *Regina (Champion) v North Norfolk District Council and another [2015] UKSC 52* (Document 32.2). That judgement includes the following comments: *"there is nothing in the*

language of the Habitats Directive to support a separate stage of "screening" in any formal sense" (paragraph 37); *"there is no suggestion that this imposes any separate legal obligation analogous to EIA screening"* (38); the issue *"ultimately rests on the judgement of the authority"* (41); and *"the competent authority, in common with their expert consultees, were satisfied that any material risk of significant effects on the SAC had been eliminated. Although this was expressed by the officers as a finding that no appropriate assessment under article 6(3) was required, there is no reason to think that the conclusion would have been any different if they had decided from the outset that appropriate assessment was required, and the investigation had been carried out in that context"* (42).

71. In the current case the issues are not being considered at an early stage in the decision making process but at the final stage when the simple question is "having regard to the totality of the known information, including that from NRW, is there likely to be a significant effect on the integrity of the SAC?" If the answer is "no", then there is no need for further appropriate assessment.

Blasting and Vibration (Documents 17.1 & 17.3)

72. As recorded in the Statement of Common Ground (Document 4), there is only one area of disagreement with the Council, the appropriate controls needed for blasting operations in parts of the site near to sensitive properties, particularly the residential properties, 1 and 2 Rock Cottages (see plan at Appendix 1 of Document 17.1 or Receptor Location R9 on the Receptor Locations Plan at Appendix 10.2 of ES Volume 2D – Core Document CD5.6).

73. TS Rees has proposed a suite of conditions to ensure adequate control of blasting operations at the quarry following a thorough assessment of potential impacts on the amenity of residents nearby (see Chapter 9 of the Gaens Quarry ES – Core Document CD5.2, and the Schedule of Conditions in the Statement of Common Ground – Document 4). These are in accordance with the latest good practice and follow the standards for vibration set out in Minerals Technical Advice Note (Wales) 1: Aggregates (MTAN1). However, the Council is seeking to further constrain the use of blasting in the part of the site nearest to Rock Cottages, following a single regrettable incident in 2009.

74. In October 2009 a single blasting operation some 125 m from Rock Cottages caused levels of vibration measured at the properties in excess of the permitted levels (and the levels now proposed in the planning conditions). An investigation of the incident was carried out by a specialist consultant who concluded that the charges had been properly designed and implemented, and the incident was attributed to some geological discontinuity. Some 40 blasts have been carried out at the quarry since that time without any exceedance of the permitted vibration levels, though these have all been further away from the properties concerned.

75. To safeguard against this in the future the Council is now arguing for a buffer zone to be defined so that blasting would not be able to be employed nearer to Rock Cottages. Clearly that would not be acceptable to the Applicant as it would effectively sterilise a substantial part of the quarry reserves, and any condition along those lines would not be reasonable or necessary, 2 of the 6 tests prescribed for planning conditions.

Furthermore, it would not be reasonable to sterilise the mineral within the buffer zone without serving a notice as a prelude to compensation, as allowed for in the 1995 Act. The ROMP provisions provide a safeguard that the new schedule of conditions should not prejudice to an unreasonable degree either the economic viability of the quarry or its asset value. If they would, then a modification notice must be issued, and provisions for compensation would follow. (See paragraph 80 onwards in Minerals Planning Guidance 14: Environment Act 1995: review of mineral planning permissions – Core Document CD1.5).

76. At Gaens Quarry, there is no need for such a restriction. In the first place, it is not planned that the area of quarry concerned would be worked until Phase 3 of the proposed quarry operations, i.e. for another 25-30 years (and this is covered by one of the proposed conditions). By that time the quarry will have been subject to at least one and possibly even 2 further reviews of conditions and methods for the winning and working of minerals may have evolved by then.

77. Furthermore, rather than prohibit normal operational techniques completely, it would be entirely reasonable to require some assurance that any blasting proposed in that part of the quarry could be carried out without causing unacceptable levels of vibration. This could be done by the operator carrying out more detailed investigations of the localised geology to minimise uncertainty and to put forward for the Council's approval specific proposals and designs for any future blasting work in the area closer to Rock Cottages. This could be achieved by a suitable additional condition broadly along the lines of the condition put forward by the Council at the public inquiry (see Document 20).

78. It is not appropriate for the Council to be too involved in the day-to-day management of the quarry. However, it is entirely reasonable for it to wish to be convinced that any blasting could be carried out without harm to the amenity of nearby residents. The production of a suitable report in due course, based on detailed investigation of the geology in that part of the quarry, would aim to demonstrate that the limits for vibration at nearby residential properties could be achieved so that the minerals in that part of the quarry could be successfully worked using carefully designed charges. It is agreed that it would also be reasonable to require the operator to give advance warning of all such blasts so that they could be suitably monitored.

Other Matters of Concern to Third Parties (Documents 4 & 17.1)

79. Several other matters have been raised by local residents. The first is the possibility of groundwater drawdown affecting a water supply borehole at Ty Tanglwyst Farm to the north of the quarry (see map at Appendix 1 of Document 17.1). The hydrogeological modelling has indicated that, even at the proposed increased depths of quarrying, the effects on water levels in this borehole are expected to be negligible. Indeed, some small rise in level is expected as a result of the proposed water management arrangements.

80. Furthermore, the borehole will continue to be monitored regularly in accordance with the WMP and any changes in water level not expected, bearing in mind the climatic conditions, would trigger intervention and mitigation measures if needed. These trigger conditions are defined in the WMP, and the measured data would be subject to annual

review by the planning authority (advised and assisted by NRW). These various measures will safeguard the borehole or, should an extreme unforeseen event occur, make provision for an alternative supply and/or compensation.

81. With regard to dust, the site would be subject to controls under both the planning permission and the environmental permit. The current planning permission does not include any such conditions. The proposed new conditions would follow national good practice guidelines to minimise the incidence of dust, and studies have been carried out to identify all potential sources of dust at the site, including the access road and internal haul roads which are the main sources of dust generation. Compliance with the proposed new conditions will minimise dust emissions and satisfactorily address the amenity concerns raised by local residents.

82. The access road for Gaens Quarry is from Porthcawl Road and is close to residential properties. HGV vehicles travel in and out of the site regularly throughout the working day with potential for generating noise and dust. However, it is not proposed to increase the rate of quarrying or the number of HGVs travelling in and out of the site each day. So there will be no increase in noise. As for dust, a condition is proposed for lorries to be sheeted prior to leaving the site as part of the measures for minimising dust generation.

83. Overall, the proposed schedule of conditions will provide proper control of site operations with the aim of minimising all impacts on local amenity, providing environmental protection and nature conservation, and making proper provision for landscaping and long-term restoration of the site.

Case for Bridgend CBC

The material points are:

84. The Council defers to Natural Resources Wales in respect of the hydrogeological matters and effects on the SAC. It puts forward no evidence on these matters itself.

General Planning Matters (Documents 3, 4 and 10)

85. The Council has agreed all matters with Tarmac in respect of the applications for Cornelly and Grove Quarries. The Statement of Common Ground (Document 3) includes schedules of agreed conditions for each of the 3 applications.

86. The Council has also agreed all matters with TS Rees in respect of Gaens Quarry except the need for additional conditions to limit the risks of blasting causing excessive levels of vibration in the part of the quarry nearest to Rock Cottages. The Statement of Common Ground (Document 4) includes a schedule of agreed conditions for the Gaens Quarry application, subject only to reservations in respect of Condition 20 on ground vibration limits. On all other matters the Council accepts the conclusions of the ES and that the proposed conditions would provide adequate control of the mineral working development.

Blasting at Gaens Quarry (Documents 11.1 & 11.2)

87. There have been several incidents in the past when blasting operations at the quarry have given rise to levels of vibration considered to cause nuisance to nearby residential

properties. An abatement notice was served on the Company in 1994 and was re-served in July 2006 as a result of complaints received by the Council. The 2006 notice was served to ensure that the latest advice on acceptable levels of vibration, as contained in MTAN1, was used by the operator in the design of future blasting. However, in October 2009 these levels were exceeded in a blast conducted at a location some 125 m from Rock Cottages (see map at Appendix 1 of Document 17.1 for locations of nearby sensitive properties). MTAN1 advises that vibration should not exceed 6 mm/s in 95% of all blasts measured over a 6 months period and that no individual blast should exceed 10 mm/s. The 2009 blast was measured well in excess of the latter, and a formal caution was subsequently served on the Company.

88. The boundary for the Gaens Quarry ROMP site passes within 15 metres of Rock Cottages, and the Council is highly sceptical that blasting could be acceptably employed for mineral working that close to the properties when a blast 125 m away is capable of causing such excessive levels of vibration. Investigations into the 2009 incident confirmed that the blast had been properly designed and executed, and the only plausible explanation seems to be that the excessive vibration was due to some unexpected geological transmission path.

89. The quarry operator has not carried out any blasting within 125 m of Rock Cottages since that incident, and the Council's initial approach to the current ROMP application was that a buffer zone should be established to protect the nearest sensitive properties from risks of excessive vibration. However, in the light of the Applicant's evidence, the Council has put forward suggested additional conditions (Document 20) requiring a specialist expert investigation and report to demonstrate the feasibility of blasting in that part of the quarry before further mineral working is carried out there, assurance that individual blasts have been appropriately designed and advance warning of any such blasts.

90. Provided conditions along these lines are included, the Council is in agreement with the full schedule of proposed conditions.

Case for Natural Resources Wales

The material points are:

91. Natural Resources Wales (and its predecessor bodies) has been consulted by and has provided advice to the Welsh Government (and its predecessors) on a regular basis since the applications were called in. Over that period it has also provided advice to the Applicants in regard to the hydrogeological modelling work and possible implications for the SAC. Full agreement was reached with the Applicants shortly before the opening of the public inquiry and is reflected in agreed Statements of Common Ground with each Applicant (Documents 18.1 & 18.2) and the agreed Water Management Plan (Documents 19.1-19.6).

Hydrogeological Modelling (Documents 12.1, 12.2, 18.1 & 18.2)

92. It is agreed that the hydrogeological modelling carried out by the Applicants through their conceptual and groundwater models, as explained in detail in the ESs, is sound and based on over 10 years monitoring over a wide network of locations. In the ordinary course of events NRW is satisfied that it provides a reliable representation of

the groundwater system around the quarries. However, a degree of uncertainty remains in respect of 2 matters.

93. The first uncertainty is about the potential hydrogeological impacts on the Kenfig SAC due to the generally heterogeneous nature of the carboniferous limestone aquifer in which the quarries are situated and the possibility of encountering a highly permeable karstic feature within the aquifer as the bases of the quarries are lowered. Karstic features are formed during geological periods when there is significant groundwater flow through the rock. The limestone is dissolved by rainfall, soil water and groundwater, which are all slightly acidic, so that enlarged fractures are created, and these form highly permeable conduits for groundwater flow. Whilst they are usually surrounded by much larger volumes of low permeable limestone, if quarry excavation encounters a karstic feature, significant groundwater flow can occur.

94. The Environment Agency's research report, Hydrogeological Impact Appraisal for Dewatering Abstractions (Core Document CD6.21), advises: *"given the high vulnerability of karstified aquifers and the considerable difficulties in predicting the effects of groundwater abstractions in them, the precautionary principle indicates that groundwater systems developed in these rock types should be considered as karstified until this is proven not to be the case"*. The British Geological Society report prepared in 2000 for the (then) National Assembly for Wales (Core Document CD6.1) advised that karstic features are likely to exist beneath the quarry floors and, although Professor Peter Smart's report for the Applicants in 2013 (Appendix H of ES Appendix 7.1 (Volume 2A) - Core Document CD2.3) expresses more confidence about not encountering such features, a degree of uncertainty still remains.

95. The second matter is the degree of uncertainty in the water balance calculations. Some 69% of the aggregate water discharge from the aquifers within the study area has not been accounted for or fully analysed. The Applicants believe this to be on account of wide dispersion of flows towards the coast but it could also be caused by a more highly concentrated discharge via, for example, submarine springs, which would be consistent with the presence of highly permeable karstic features. This raises further doubts about the possibility of encountering such features.

96. Thus, whilst NRW agrees with the conclusions of the Applicants' hydrogeological assessments which indicate that the probability of intercepting a highly permeable karstic feature with potential to cause an adverse effect on the Kenfig SAC is extremely low, the modelling cannot completely rule out the risk and the consequent impacts on the SAC as a result of deepening (and widening) the quarries.

Effect on Special Area of Conservation (Documents 13.1, 13.2, 18.1 & 18.2)

97. The protected features at the Kenfig SAC are highly sensitive to even small changes in the groundwater level regimes, even though levels vary considerably with the seasons. All parties accept the conclusions in Peter Jones 2004 paper, The Influence of Hydrological Processes upon the Structure and Composition of Dune Slack Vegetation, (Core Document CD6.25), which was based on many years of extensive research into the hydrological conditions of the Kenfig SAC. The paper's conclusion that *"even slight sustained changes in mean water level of the order of 10 cm (or in some cases even less) would be sufficient to result in undesirable transformations from one community*

to another" provides the basis for an agreed quantitative threshold for a likely adverse impact on the ecology of the SAC. The agreed threshold is set out in the Statements of Common Ground and provides that a 0.1 m or greater difference between actual and expected mean summer water levels in the dune slacks, sustained for 3 consecutive years, would amount to an adverse effect on the ecology of the SAC.

98. Contrary to Tarmac's suggestion, NRW has not changed its position on this definition for an adverse impact on the SAC. Its suggestion that a 0.1 m variation over just one year should act as a trigger within the water management regime was aimed at ensuring that a potential adverse effect on the SAC (i.e. 3 consecutive years) would be addressed before it occurred. If the trigger had been set at 0.1 m variation over 3 consecutive years it would have been too late as, by definition, the adverse effect would have already occurred. However, this point has now been addressed to NRW's satisfaction by the "early warning system" now provided for in the WMP by using changes at the pathway monitoring sites as triggers.

99. The 0.1 m change in mean summer groundwater level at the dune slacks is an important criterion even though the sites are subject to higher seasonal variations throughout the year (see sketches at Document 21). The SAC features experience natural variation in groundwater levels due to climatic factors and they are adapted to cope with these variable conditions, with the rarer species preferring wetter conditions and the less desirable species (i.e. less desirable in terms of safeguarding the rarer species) with which they compete preferring drier conditions. Critically, the natural groundwater fluctuations generally recover or tend back to a stable baseline (of seasonal variation) which supports the special plant communities in the dune slacks.

100. NRW's concern is that, if there were a sustained 0.1 m fall over several years in the baseline, it would result in a change in the baseline ecology of the dune slacks. A sustained 0.1 m reduction between actual and expected mean summer water levels would reduce the size of the zone of ecological interest capable of supporting the protected species and would reduce their resilience. Effectively, it would increase the time taken for the feature species to recover from the background natural fluctuations, particularly following drier periods. A baseline change of 0.1 m caused by the quarry activities would be likely to produce a shift in the dune slack communities from one type of community to another and so would amount to an adverse effect on the integrity of the SAC. This is the basis for adopting a 0.1 m change over 3 consecutive years as the agreed measure of adverse effect on the integrity of the SAC.

101. In the light of this level of sensitivity, whilst it is accepted that quarrying operations are unlikely to result in a significant hydrological event, the agreed mitigation and contingency measures contained within the WMP are necessary to remedy any unexpected events, and this needs to be reinforced by several conditions.

Water Management Plan (Documents 13.1, 13.2, 18.1, 18.2 & 19.1-19.6)

102. The parties have now reached agreement on the content and provisions of the WMP, the purpose of which is to ensure that the quarry operations do not cause any adverse effect on the integrity of the SAC attributes. The WMP sets up a framework for monitoring the groundwater network and for mitigation measures if unexpected changes occur. Water levels will be measured at pathway sites, i.e. sites between the

quarries and potential receptors at the SAC, in order to provide early warning of potential impacts, as well as at monitoring points at the SAC itself. This will allow time for suitable mitigation measures to be implemented before harm is caused to the SAC.

103. The impacts at each monitoring point will be measured by reference to site specific trigger levels (with allowances for climate based assessment criteria, i.e. to reflect what is expected as a result of climatic variations). If these triggers or criteria are exceeded and the discrepancy is attributed to dewatering operations at the quarries, then appropriate remedial action will be required. The trigger levels will be set at precautionary values to provide an early indication of changes in the groundwater regime and an early indication of a potential for groundwater level reductions of the order of 0.1 m at the SAC dune slacks. Any significant deviations would trigger the need for mitigation measures to avoid significant effects on the SAC.

104. The WMP includes an annual timetable for the collection and reporting of the monitoring data, and the latest version of the WMP now requires data collected between November and October of the next year to be reported in the following January so that any deviation in the critical summer water levels can be identified at the earliest possible opportunity. Sections 7 and 8 of the WMP establish a suite of flexible mitigation measures and contingency measures which may be required to ensure there is no impact on the SAC.

105. In addition to the WMP several conditions are also needed (and have been agreed in the Statements of Common Ground) to secure the implementation of the WMP for the life of the development, though it should be emphasised that none of the requirements of the WMP or the conditions would have the purpose or effect of preventing quarrying or otherwise restricting working rights within the meaning of the 1995 Act. It is agreed that risks to the SAC can be adequately addressed by way of the proposed planning conditions.

106. It is common ground that the conditions are necessary to secure the implementation of the WMP and to ensure there is no adverse impact on the integrity of the SAC. The WMP includes provision for alteration of the planned mitigation measures and contingency measures in order to address extreme hydrological impacts which the hydrogeological modelling has not foreseen or made provision for. Together with the agreed additional planning conditions (see section 4 of the Statements of Common Ground), the WMP now adequately addresses the residual uncertainties of the model.

Appropriate Assessment (Documents 13.1, 13.2, 18.1 & 18.2)

107. Regulation 61 of the Conservation of Habitats and Species Regulations 2010 requires the decision maker to consider whether appropriate assessment of the development's impact on the SAC is required. NRW's view is that it is required as, until agreement was reached just before the opening of the inquiry on the need for conditions to secure the implementation of the WMPs and because the measures contained within the WMP are necessary to safeguard the integrity of the SAC, the possibility of causing harm to the SAC could not previously be ruled out. In addition, without those additional measures, a groundwater level change of more than 0.1 m was predicted to occur at the SAC during the quarry decommissioning phase (i.e. when pumping ceased), which would have a significant impact on the SAC. Until agreement was reached with the

Applicants shortly before the opening of the public inquiry, NRW was not satisfied that the identified risks to the SAC and the residual uncertainty in the model had been suitably addressed, such that the risk remained that the schemes would adversely affect the integrity of the SAC. Only when the proposed conditions are taken into account can the likely effects be ruled out. These factors need to be considered through the process of appropriate assessment.

108. The Applicants are of the opinion that appropriate assessment is not necessary and have referred to the recent Supreme Court judgement on *Regina (Champion) v North Norfolk District Council and another [2015] UKSC 52* to support that contention. However, NRW does not agree with that argument for several reasons.

109. Firstly, *Champion* is not authority for this contention as it did not deal directly with this matter. It addressed 2 specific issues: the correct approach to the timing of EIA screening: and whether or not and to what extent mitigation measures may be taken into account in EIA screening. The only mention of Habitats Regulation 61 is: *"It is said to be common ground that mitigation measures may be considered as part of the process of appropriate assessment once it has been decided following screening that appropriate assessment should be carried out"*, which provides clear support for the approach advocated by NRW. Whilst there is no formal screening stage in appropriate assessment, unlike Environmental Impact Assessment, there is a clear distinction between the requirements of regulations 61(1) and 61(5), the one requiring consideration of whether the plan or project is "likely to have a significant effect on the protected site", and the other whether the plan or project will "adversely affect the integrity of the site".

110. Secondly, *Champion* is distinguishable from the current applications as in that case the conditions being considered were not "necessary" to eliminate the risk of an adverse effect on a European site. The Supreme Court took the view that in that case the Council had applied the conditions for purposes of reassurance rather than as a necessity to safeguard the SAC. That is different from the current applications where the conditions (and WMP provisions) are necessary to ensure there would be no adverse effect on the dune slacks of the SAC, and that is common ground amongst the parties. In the light of this distinction and the fact that the Supreme Court did not specifically address the issue of mitigation measures in the context of the Habitats Regulations, the ruling in *Champion* cannot be read across to the current applications.

111. Thirdly, there is also a good policy reason for NRW's view that appropriate assessment needs to be carried out. Some of the applications under consideration have taken 18 years to reach a public inquiry during which time a considerable amount of work has been carried out and extensive paperwork has been generated. A clear appropriate assessment would bring this to a conclusion so far as the requirements of the Habitats Regulations are concerned and would avoid the need for any interested party to follow a paper chase should they wish to be satisfied it had been properly addressed.

112. As for the appropriate assessment itself, all parties agree that there is sufficient information for it to be carried out and on what the conclusion of the assessment should be. There is sufficient information in the shadow appropriate assessment contained within the ESs at Appendix 8.3 (Volume 2D – Core Document CD2.6), within

the wider ESs and in the WMP. The appropriate assessment should summarise the ecological findings, expressly apply the 0.1 m over 3 consecutive years criterion in the context of the ecological impacts, and evaluate the risks to the SAC in the light of the agreed conditions and WMP provisions.

113. No special procedure or particular form is prescribed for an appropriate assessment, and it is NRW's view that, given the extensive assessment work already carried out, the appropriate assessment can be a simple and straightforward process. It may be said that the best appropriate assessment may be quite brief. As to the conclusion, NRW's view is that, provided the WMP (version 5.8) for each of the quarries is adopted and their implementation is secured by way of the proposed conditions, there is unlikely to be any risk of an adverse impact on the Kenfig SAC as a result of the proposed quarrying operations. Consequently, there is no reason on hydrological or ecological grounds why the applications should not be approved.

114. Finally, the Cefn Cribwr Grasslands SAC warrants mention. NRW agrees with the Applicants' assessment that there is no mechanism by which the quarry proposals could possibly have a significant effect on this SAC and there is no need for any further assessment.

Other Third Party Representations

115. Two local residents gave evidence at the public inquiry, Messrs Peter Vincent and Clive Tranter, and a letter was handed in from Mr & Mrs Nicholas (local residents). In addition, letters were received before the inquiry from Mr Rhys Lougher (a local farmer), Ms Janet Roberts (local resident) and Cadw.

The material points are:

116. Mr Vincent is a member of the local residents association and of the quarries liaison committee and spoke to a written statement (Document 23). He lives at Rock Cottages which, together with the houses at Railway Terrace, are the houses closest to Gaens Quarry. An attractive escarpment and wooded area lies between Rock Cottages and the quarry. It is subject to a tree preservation order and is believed to be a site of special scientific interest due to its ancient woodland and rare plants. It should not be disturbed by quarrying too close to it.

117. The immediate vicinity of Rock Cottages used to be a small medieval settlement called Tomsville. It has the remains of a small medieval chapel, Ty Capel, and ancient human remains have been found in the gardens. The Glamorgan-Gwent Archaeological Trust has carried out a dig there.

118. The prospect of blasting in the part of the quarry nearest to these properties is of great concern. Problems have been experienced on several occasions in the past, with reported cracks to walls, floors and ceilings and damage to wall tiles and crockery. The most recent incident was only about 2 years ago. Many residents find the blasting incidents disturbing and, even, frightening, and they affect elderly residents, animals and property values (in terms of their attractiveness).

119. Problems are also experienced with dust, and this is particularly keen in dry weather with an easterly wind. Cars, windows and steps become coated in dust, and doors and

windows cannot be left open. Effects on heath are also of concern, and many residents suffer bronchial and chest complaints.

120. Mr Tranter lives at Ty Maen House (see plan at Appendix 1 of Document 17.1), a Grade II listed building in the village. A blast about 2 years ago caused a considerable shock, shook the house and caused tiles to fall off the bathroom wall. Mr Tranter reported it to the Council.

121. Mr & Mrs Nicholas live at Railway Terrace (see plan at Appendix 1 of Document 17.1) and handed in a letter to the inquiry (Document 24). Whilst attention has been given to effects on Rock Cottages and other properties, Railway Terrace seems to have been barely recognised, yet it is one of the nearest groups of houses to the proposed extension of Gaens Quarry (i.e. the north-western part of the quarry where little working has been carried out in recent years). Problems are already experienced with high levels of noise and dust, and these will get worse. The South Cornelly Nursing Home is just to the rear of Railway Terrace and is also affected.

122. Disturbance due to blasting has also been a serious issue, and the Council has visited many times to carry out monitoring of blast vibrations, though often abortively when blasting has not been carried out as advised. The effects of blasting operations seem to be quite variable, sometimes affecting one property and sometimes another, presumably due to inconsistent geological features. Mineral Development Policy ENV11 (of the Bridgend Local Development Plan) sets a list of criteria to be met by mineral developments. Many of these would certainly be breached by the proposed extension of Gaens Quarry.

123. Mr Lougher farms Ty Tanglwyst farm to the north of Gaens Quarry (see plan at Appendix 1 of Document 17.1), and is concerned about possible effects on his water supply borehole. A sustainable water source is essential to the running of his dairy farm, which employs 16 people. It requires a substantial volume of water and, if this had to be purchased from the public water undertaking, would involve significant extra costs to the business, which might make it unviable. As the quarry workings go deeper and more groundwater is pumped out to facilitate this, Mr Lougher is concerned about the borehole running dry.

124. Ms Roberts lives in South Cornelly close to the entrance to Gaens Quarry and is concerned about dust. Every day she has to wipe dust off the clothes line and outside furniture, and it even affects furniture inside the house. Since moving to the area she has suffered from a chest complaint for which a diagnosis is awaited.

125. Finally CADW has responded to a consultation invitation under its role associated with designated historic assets. It advises that there are 2 Grade II listed buildings nearby in South Cornelly: Ty Maen, a Mid 17th Century 2-bay house; and the garden gateway at Ty Maen. As the applications relate only to reviews of the planning conditions within the existing quarry site boundaries they would not have a significant visual impact on the setting or character of these listed buildings. The proposals would not impact on any designated assets or raise issues of more than local importance in relation to the historic environment.

Conditions

126. Towards the end of the public inquiry I held an open discussion on conditions, considering the detailed wording and terms of each of the proposed conditions. Some are common to all 4 schedules but others are specific to each application. The schedules considered comprised those contained in the Statements of Common Ground with the Council (Documents 3 & 4), those in the Statements of Common Ground with NRW (Documents 18.1 & 18.2) and, for Gaens Quarry, the extra conditions on blasting put forward by the Council (Document 20).

127. The time limits for each case reflect the anticipated life of the mineral asset at the present rate of working, and the other conditions in Section B would ensure clearance of the site at that time. The conditions in Section C, Working Programme, would ensure future operations are carried out in accordance with the development plans detailed in the Environmental Statements and that working hours would reflect current good practice guidelines (and current practices at each quarry), subject to some limited compromise to take into account the current, largely unfettered controls applied to the quarries.

128. The rest of the conditions, Section D, provide controls for environmental protection. The first group cover hydrology and hydrogeology, and it was agreed that the draft condition on compliance with the Water Management Plan (WMP) should be replaced by the 3 conditions in the NRW Statements of Common Ground, which would ensure: compliance with the WMP throughout the life of the development; compliance with any future amended version of the WMP for the remaining life of the development; and provision for a residual pumping scheme during the eventual decommissioning stage.

129. Two conditions are included to safeguard general ecological matters, followed by a group of conditions specific to each quarry for improved landscaping measures (such as boundary screening). Those are followed by conditions on noise limits, which generally follow the advice in MTAN1, except that compromise limits are set for early morning and evening work where such hours of work are normal practice at those quarries (and currently not otherwise regulated). Corrections were agreed to the schedule for those quarries in respect of the noise limits for the evening period (1900-2200 hours), as incorrect higher limits had been included in error. In addition, it was agreed that the daytime noise limits would be reduced to 50 dB $L_{Aeq\ 1\ hour}$ for the properties Rock Cottages and Sea View for consistency amongst the quarries and to reflect the quiet background noise levels at these properties.

130. Each schedule then includes a group of conditions to control blasting, which reflect good practice and the advice in MTAN1. In addition, for Gaens Quarry it was agreed that 3 extra conditions should be included to address the concerns about the feasibility of using blasting in the part of the quarry close to Rock Cottages. These cover the carrying out of geological investigations and submission of a report to demonstrate that blasting is feasible in this area without causing unacceptable levels of vibration at the nearby residential properties, the submission of blast design details in advance of any such blasting in that area, and the provision of 24 hours notice for any blasting in the quarry as a whole.

131. Each schedule then includes conditions to ensure good practice is followed in measures to control and minimise the generation of dust, and finally several conditions aimed at ensuring restoration of the quarries when the winning and working of minerals eventually ceases, with reference to the proposed schemes in the Environmental Statements, including landscaping and aftercare arrangements.

132. Following the discussion on conditions, both Applicants have helpfully provided revised schedules of conditions to reflect the agreed changes (Documents 26.1-26.3 as plain versions for the 3 Tarmac applications for Cornelly and Grove Quarries, Documents 26.4-26.6 as tracked-change versions of those, and Document 27 for the TS Rees application for Gaens Quarry). It is common ground that these schedules of conditions address the matters intended by the 1995 Act and that they meet the tests for planning conditions set out in the conditions Circular (WGC 016/2014, The Use of Planning Conditions for Development Management).

Conclusions

[The numbers in square brackets indicate the relevant paragraphs of the report.]

133. In my view the main considerations in these applications are: the degree of reliance that can be placed on the Applicants' hydrogeological modelling; the likely effect of further dewatering of the quarries on the Kenfig Special Area of Conservation (SAC); the degree of reliance that can be placed on the Water Management Plan for the life of the quarries; and whether or not one can have confidence that future quarry operations would not adversely affect the integrity of the Kenfig SAC. For Gaens Quarry an additional consideration is whether or not future blasting in the part of the quarry closest to residential properties can be adequately controlled to avoid unacceptable levels of vibration at those sensitive properties. [13]

Hydrogeological Modelling

134. The aquifer model produced by the Applicants is based on an extensive dataset comprising over 10 years monitoring data at some 105 local monitoring points, the most extensive hydrometric dataset around any quarry in the UK. The model has been developed over a period of almost 15 years in liaison with Natural Resources Wales and it predecessor bodies using iterative techniques as the dataset has increased and the understanding of the behaviour of the aquifer has improved. It represents the best scientific knowledge available, and it is common ground that it provides a sound and reliable representation of the behaviour of the aquifer under normal circumstances. [9, 26-28, 91, 92]

135. It has been used to simulate the future groundwater drawdown circumstances that are likely to occur if and when the quarries (and particularly Cornelly Quarry) are worked down to the maximum depths proposed in the current applications. The proposal is to excavate Cornelly Quarry to a considerably greater depth than the other quarries. However, the modelling has also simulated the cumulative effects of all quarries being at their maximum proposed depths. Modelling of the worst possible case indicates that the maximum change of groundwater levels at the Kenfig SAC attributable to the proposed quarry operations will be only about 6 mm, though a 12 mm change is forecast if pumping to dewater the quarries were to cease immediately on completion of quarrying in several decades time. However, this could be substantially alleviated if pumping at that time was reduced more gradually and in a controlled manner. These model results are accepted by NRW as reasonable representations for assessment of potential effects on the SAC. [19-21, 24, 25]

136. The only difference between the parties is in the assessment of the risks of encountering a karstic feature (i.e. a highly permeable conduit for water within the aquifer) as the quarries are deepened. If this were to occur the model would not be representative of the resulting unpredictable flows within the aquifer, and there would be a risk of lowering groundwater levels at the SAC to a degree detrimental to the SAC. NRW's concerns are based on the well accepted likelihood of karstic features being present in limestone rocks, the conclusion to this effect in the BGS study carried out for the (then) National Assembly for Wales in 2000, and the large proportion of outflow water unaccounted for (69%) in the hydrogeological model. Although the Applicants'

explanation that this is due to general outflow towards the coast is perfectly reasonable, NRW submits that it could also indicate the presence of a highly concentrated discharge somewhere, which could be consistent with the presence of an unknown karstic feature. [29, 30, 93-95]

137. In response, the Applicants have provided evidence based on a detailed study carried out by Professor Peter Smart, one of the UK's leading experts in karst geology, the conclusion of which is that substantive karstic features are highly unlikely to be encountered below the quarries. NRW accepts this assessment but argues that the risk cannot be completely ruled out. I draw the same conclusion. Whilst I consider there to be a high level of confidence in the modelling work carried out and in the reliability of the model under normal circumstances, one cannot entirely rule out the risk of a highly permeable karstic feature being encountered. However, as explained below, this risk can be managed by the proposed Water Management Plan. [30-33, 94, 96]

Effect on Special Area of Conservation

138. Putting that risk to one side for the time being, it is common ground that small changes in groundwater levels would be unlikely to be detrimental to the SAC provided the changes to summer water levels were less than 10 cm over 3 consecutive years. The key qualifying features of the SAC that might be affected by long-term changes in groundwater levels are the dune slacks and the pond at Kenfig. These already experience natural seasonal variations in groundwater levels but longer term changes would cause changes to the baseline ecology and harm to key features. [43, 44, 97, 99, 100]

139. The measure of 10 cm change to summer levels over 3 consecutive years is based on the results of studies on the Kenfig dunes carried out by Peter Jones of the former CCW and reported in 2004; it is not in dispute. The modelling work indicates that this measure would not be exceeded during normal quarry operations despite substantial increases in depths of working. The model also indicates that a slight exceedance could occur if dewatering pumps were turned off immediately quarry operations ceased but not if controlled reduction in pumping was carried out instead. This could be ensured by a suitable planning condition. [34, 35, 44, 45, 54, 97, 99]

140. The Applicants have also taken into account the advice in the Environment Agency's Ecohydrological Guidelines for Wet Dune Habitats, published in 2010, which were intended to be used for assessments of this sort. These describe the different types of dune slack habitats and provide further support for the conclusion that the small changes in groundwater levels due to quarrying operations predicted by the modelling work would not significantly affect the key SAC features. I consider these provide valuable confirmation of the assessment based on the simple criterion of 10 cm change over 3 years. [46, 47, 53]

141. The only circumstances not covered by the modelling results are, of course, the unlikely possibility of a karstic feature being encountered. However, the WMP makes provision for this scenario. Thus it is common ground that, subject to implementation of the measures in the WMP and to appropriate conditions, the proposed quarry operations would be highly unlikely to have an adverse impact on the designated features of the SAC. I agree with that conclusion. [45, 98, 101]

Water Management Plan

142. The Water Management Plan (WMP) is a tool to ensure the water environment (and hence the SAC) and local private water supplies are adequately protected against possible effects of the changes in groundwater levels resulting from future quarry operations. It comprises detailed specification of long-term monitoring at an extensive network of monitoring sites, arrangements for annual reporting of results, the mechanism to identify deviations from expected water levels which would trigger the need for mitigation or contingency measures, and proposals for those possible measures. [37]

143. Until the day before the public inquiry there was a difference between the Applicants and NRW on 2 matters: definition of an appropriate "trigger point" based on the monitoring of groundwater levels at the SAC and whether provisions were required or not for the risks associated with encountering a karstic feature (even though this risk was accepted as being very low). However, these differences have now been resolved. [36, 38, 102]

144. The "trigger point" issue has been resolved by adopting a network of pathway monitoring sites (i.e. sites part of the way between the quarries and the SAC), rather than relying on monitoring data only at the SAC itself, and defining triggers at each site based on the degree of deviation from the expected groundwater levels. Not only will this method provide clear and agreed triggers to identify the need for mitigation measures to avoid harm to the integrity of the SAC, but it will also provide a much earlier warning to ensure mitigation measures were carried out in good time. [39, 102-104]

145. The karstic feature issue has been resolved by making provision in the WMP, along with a supporting condition, for changes to be incorporated in the WMP in the future if found to be necessary to deal with such an incident in the (agreed) highly unlikely event of it occurring. The provisions also acknowledge the rights of the quarry operators under the 1995 Act that no changes would be made that would prevent quarrying operations or otherwise restrict the working rights without the formal issue of a notice involving compensation to the operators. [40, 98, 105]

146. The parties have now agreed the detailed wording of the WMP, along with 3 conditions required to ensure the WMP (in its present form or a modified form) is implemented over the lives of the quarries and that suitable arrangements are put in place in due course to avoid sudden ceasing of pumping at the end of the quarry lives. Subject to the provisions of the WMP and the planning conditions, it is now common ground that the residual uncertainties of the hydrogeological model are adequately covered and that appropriate safeguards are provided for the water environment and the private water supply boreholes in the area. The WMP now achieves its aim of ensuring that the water environment is safeguarded against any significant detrimental effects arising from quarry operations. [41, 62, 79, 80, 106, 123]

Appropriate Assessment

147. The parties disagree on whether or not appropriate assessment under the Conservation of Habitats and Species Regulations 2010 is required but are in agreement that there is sufficient information available for such an assessment and that, whether or not a formal assessment is carried out, the proposed schemes (including the provisions included in the WMP and in planning conditions) will not adversely affect the integrity of the SAC. [48, 69, 107]

148. In arguing that appropriate assessment is not required the Applicants have made reference to the recent *Champion* judgement (*Regina (Champion) v North Norfolk District Council and another [2015] UKSC 52*). They submit that, as the Regulations do not specify a formal screening stage (unlike EIA) or any requirements for the content or form of an appropriate assessment, the matter rests on the judgement of the competent authority (in this case the Welsh Ministers). Furthermore, as all of the information needed is available, the decision maker is able to take into account the proposed mitigation measures and reach the conclusion that the project (or cumulative projects) would not *"adversely affect the integrity of the European site"*, the test prescribed in Regulation 61(5) of the Regulations. In *Champion* the Court took the view that, in the circumstances of that case, it would have made no difference if the conclusion that significant effects on the SAC had been eliminated had been reached at the initial stage or after formal appropriate assessment. Thus it is submitted that in the current case a positive conclusion can be reached on the initial assessment, and it would be perfectly lawful not to go on to any formal appropriate assessment. [48, 49, 70, 71, 108]

149. NRW disagrees with this interpretation and argues that: firstly, *Champion* does not deal directly with assessment under the Habitats Regulations as its primary issues are in connection with EIA screening, and so it cannot be relied upon for interpretation of the Habitats Regulations; secondly, that the circumstances of that case were quite different from the current ones as the decision maker did not rely on conditions being necessary to eliminate the risk of adverse effects on the SAC; and thirdly, that some formal record is needed in the current case to ensure any interested party did not have to follow a paper chase extending over 18 years to be satisfied the Regulations had been properly considered. Furthermore, it is established in law, principally in the *Waddenzee* judgement (*Landelijke Vereniging tot Behoud van de Waddenzee v Staatsscretaris van Lanbouw (Coöperatieve Producentenorganisatie van de Nederlandse Kokkelvisserji UA intervening) (Case C-127/02) EU:C:2004:482; [2005] All ER (EC) 354; [2004]ECR I-7405, ECJ*), that there is a clear difference between the tests in Regulation 61(1) and 61(5). Regulation 61(1) says that an appropriate assessment must be made if the project *"is likely to have a significant effect on a European site"*, whereas Regulation 61(5), which refers to the results of an assessment uses the test *"that it will not adversely affect the integrity of the European site"*. [107-111]

150. In practical terms it makes little difference whether the assessment is carried out at the initial stage and concludes that no further appropriate assessment is required or if it is decided that appropriate assessment is required and then the assessment is carried out at that stage. It is a matter for the competent authority, in this case the

Welsh Ministers, to decide whether appropriate assessment is required or not. In my view, it would be prudent to rely on the well accepted conclusions of the *Waddenzee* judgement than to accept the questionable comparability and relevance of the *Champion* judgement. The *Waddenzee* judgement, in essence, provides guidance that the initial question to be considered under Regulation 61(1) is whether there is a "possibility" of having a significant effect on the SAC, whilst the subsequent appropriate assessment should then take into account any mitigation or control measures before reaching a conclusion under Regulation 61(5). This leads me to the conclusion that appropriate assessment is required.

151. It is common ground amongst the parties that, in this case, an appropriate assessment can be a relatively simple and straightforward process. It is agreed that the information needed is contained in the Applicants' helpful shadow appropriate assessment in the ESs, subject only to it making clearer reference to the key criterion that summer groundwater levels at the SAC should not change relative to normally expected levels by more than 0.1 m due to quarrying operations over 3 consecutive years. This measure has been taken into account in the shadow appropriate assessment but it is not explicitly stated. [50, 57, 112, 113]

152. The shadow appropriate assessment describes the qualifying interests of the Kenfig SAC, the concept of "favourable status", the features that might be affected by changes to the groundwater level regime, the appropriate measure for assessing whether or not they would be adversely affected, and the results of the hydrogeological modelling which indicates worst case changes in water levels due to quarrying activities. The shadow appropriate assessment then concludes that the quarrying would not have an adverse effect on the integrity of the SAC. [50-52, 56, 113]

153. I agree with that conclusion so far as normal circumstances are concerned. However, the shadow assessment makes inadequate provision for the possibility of encountering a highly permeable karstic feature, which could lead to high rates of water flow in that part of the aquifer, and it is considered that a more thorough assessment should include acknowledgement of that risk (albeit agreed by all parties as being very small) and recognition that measures now contained in the WMP and planning conditions will provide adequate identification, mitigation and contingency measures to ensure there would be no adverse effect on the SAC should that occur. The Appellants and NRW all advise that an appropriate assessment will be able to conclude that the proposed quarrying schemes will not adversely affect the integrity of the Kenfig SAC. I reach the same conclusion, though clearly it is the Welsh Ministers who are required to carry out the appropriate assessment as part of their decision making process. Of course, that assessment will be further informed by NRW in its capacity as "the appropriate nature conservation body" which Regulation 61(3) requires the decision maker to consult for purposes of the assessment. [55, 113]

154. For completeness, mention is also made of the Cefn Cribwr Grasslands SAC to the north of the quarries. All parties are agreed that there is no mechanism by which the quarry proposals could possibly have a significant effect on this SAC and that no further appropriate assessment is required for it. This is also described in the Applicants' shadow appropriate assessment in the ESs. [42, 114]

Blasting at Gaens Quarry

155. Finally, I turn to the matter of blasting at Gaens Quarry, which seems to have a history of events of concern to nearby residents. The Council has referred to a particular incident in 2009 when high levels of vibration were experienced at nearby sensitive properties despite subsequent investigations finding nothing obviously wrong with the design or implementation of the blast. That blasting was carried out about 125 metres away from the nearest properties, and work has been moved further away since that incident. Nevertheless, the quarry operator intends to return to that part of the quarry in due course, though probably not for another 25-30 years, and the Council maintains that improved measures are likely to be needed when that occurs. [72-74, 76, 87-89, 118, 120, 122]

156. The Council's initial approach was to prescribe a buffer zone to prevent quarry operations, or at least the use of blasting, in the part of the quarry closest to sensitive residential properties. However, that would sterilise the minerals within the buffer zone and conflict with the provisions in the 1995 Act to avoid imposing conditions that unreasonably prejudice the economic viability or asset value of the quarry. Restrictions of that sort should be the subject of a modification notice with consequent implications for compensation. Thus the parties have agreed an alternative approach. [75]

157. One of the conditions now proposed would require the quarry operator to carry out more detailed investigations of the geology in that part of the quarry in order to demonstrate the feasibility of blasting without generating levels of vibration in excess of the permitted standards. It would also required detailed design of the charges to be subject to approval by the Council. This is a reasonable approach and, in view of the problems experienced in the past, a necessary one. It is not intended to return to work that part of the quarry for another 25-30 years, during which time the quarry will have been subject to at least one and maybe 2 further periodic reviews of conditions. Nevertheless, I consider it appropriate to apply this condition now to provide the necessary assurance and certainty. [16, 76-78, 89, 90, 130]

Overall Conclusions

158. Several other matters have been raised by local residents, and it is important that appropriate controls are applied to address these various amenity matters. The proposed schedules of conditions include conditions aimed at making suitable provisions for these controls in line with latest good practice methods and procedures. I conclude that the proposed conditions would be reasonable in this respect. Furthermore, the conditions proposed for wider environmental protection and long-term restoration would meet modern standards, and I consider all of the conditions would meet the 6 tests prescribed for conditions in the Welsh Government Circular on planning conditions. In addition, none would invoke a need for formal notification of degradation of the operators' rights or the asset values. [15, 17, 18, 58-61, 63-67, 73, 81-83, 85, 86, 117, 119, 121, 124-129, 131, 132]

159. In reaching these conclusions I have taken into account the Environmental Statements (ESs) submitted in support of each application and all other environmental information submitted since. The latter has been adequately publicised through the public inquiry procedures. The Water Management Plans (WMPs) were included and

explained in the ESs. However, they were revised shortly before the inquiry to reflect improved arrangements for monitoring and mitigation measures (based on pathway monitoring), as agreed between the Applicants and NRW. These do not alter the fundamental nature of the WMPs, and it is not considered any interested party would be prejudiced by the changes. NRW, of course, are familiar with the changes. Accordingly, I do not consider any further public advertisement is necessary to meet the requirements of EIA legislation. [5-7]

Recommendations

160. Before determining these applications for approval of conditions, the Welsh Ministers have to consider whether or not appropriate assessment is required under the Habitats Regulations. I recommend that appropriate assessment be carried out.

Application A: Cornelly Quarry ROMP

161. I recommend that the schedule of conditions in Annex A of this report be approved.

Application B: Grove Quarry ROMP

162. I recommend that the schedule of conditions in Annex B of this report be approved.

Application C: Gaens Quarry ROMP

163. I recommend that the schedule of conditions in Annex C of this report be approved.

Application D: Cornelly and Gaens IDO Periodic Review

164. I recommend that the schedule of conditions in Annex D of this report be approved.

Clive Nield

Inspector

APPEARANCES

FOR THE LOCAL PLANNING AUTHORITY:

Ms Nicola Gandy, MSc, MRTPI	Principal Planning Officer, Development Control, Bridgend County Borough Council.
She gave evidence and called:	
Ms Helen Williams	Senior Environmental Health Officer, Public Protection, Bridgend CBC.

FOR NATURAL RESOURCES WALES:

Ms Sarah Sackman of Counsel	Instructed by Geldards LLP (Mr Charles Felgate, Partner).
She called:	
Dr Rob Low, BSc(Hon), MSc, CGeol, FGS	Director, Rigare Limited (Groundwater and Wetland Science Consultant).
Mr Kerry Rogers, BSc (Hon)	Ecologist, specialising in Habitats Regulations Assessment, NRW.

FOR APPLICANT, TARMAC:

Mr Richard Humphreys QC	Instructed by Nabarro LLP (Mr Christopher Bowes, Partner).
He called:	
Mr Michael Streetly, BA(Hon), MSc, CGeol, FGS	Director, ESI Limited (Water Resource Hydrogeology Consultant).
Mr Stuart Lowther, BA, MSc, CEnv, MCIEEM	Managing Director, Atmos Consulting Limited (Environmental Consultancy).
Mr Graham Jenkins, BA(Hon), MRTPI, MIQ	Technical Director, SLR Consulting Limited.

FOR APPLICANT, TS REES:

Mr Hugh Richards of Counsel	Instructed by TS Rees Ltd.
He called:	
Mr Will Ryan, BA(Hon), BTP, MRTPI	Technical Director, SLR Consulting Limited.

INTERESTED PERSONS:

Mr Peter Vincent	Local resident, representing South Cornelly Residents Association.
Mr Clive Tranter	Local resident.

DOCUMENTS

1 Letter of Notification and list of persons notified.

2 Schedule of Core Documents comprising:

- CD1.1-CD1.9: Guidance, Regulations and Policy;
- CD2.1-CD2.9: Cornelly Romp Application Documents, including Environmental Statement Volumes;
- CD3.1-CD3.9: Grove ROMP Application Documents, including Environmental Statement Volumes;
- CD4.1-CD4.9: Cornelly Grove IDO Periodic Review Application Documents, including Environmental Statement Volumes;
- CD5.1-CD5.8: Gaens ROMP Application Documents, including Environmental Statement Volumes;
- CD6.1-CD6.25: Other Documents.

3 Statement of Common Ground between Tarmac and Bridgend CBC in respect of Cornelly and Grove Applications, including Schedules of Proposed Planning Conditions.

4	Statement of Common Ground between TS Rees and Bridgend CBC in respect of Gaens Application.
5.1-5.2	Draft Statement of Common Ground between Tarmac and Natural Resources Wales, dated 14/9/15 with comments dated up to 1/10/15 (version 5.4): clean version and version with tracked changes.
6	Opening Statement on behalf of Tarmac Trading Ltd.
7	List of Appearances on behalf of Tarmac Trading Ltd.
8	Opening Statement on behalf of TS Rees Ltd.
9	Opening Statement on behalf of Natural Resources Wales.
10	Nicola Gandy's Statement of Evidence.
11.1-11.2	Helen Williams' Statement of Evidence with Appendices and Rebuttal Statement.
12.1-12.2	Rob Low's Proof of Evidence with Appendices and Rebuttal Proof of Evidence.
13.1-13.2	Kerry Rogers' Proof of Evidence with Appendices and Rebuttal Proof of Evidence.
14.1-14.7	Michael Streetly's Proof of Evidence, Summary of Proof of Evidence, Appendices A-C, Appendix D, Appendix E, Appendix F and Rebuttal Statement.
15.1-15.2	Stuart Lowther's Proof of Evidence (with Appendix) and Rebuttal Proof of Evidence.
16.1-16.5	Graham Jenkins' Proof of Evidence, Summary of Proof of Evidence, Appendices, Rebuttal Proof of Evidence re Dr Rob Low and Rebuttal Proof of Evidence re Graham Rogers.
17.1-17.3	Will Ryan's Proof of Evidence, Summary Proof of Evidence and Rebuttal Proof of Evidence.
18.1-18.2	Final Statements of Common Ground between Tarmac and NRW and between TS Rees and NRW, submitted at opening of Inquiry.
19.1-19.6	Water Management Plans for Cornelly, Grove and Gaens Quarries, v5.8 dated 9 November 2015: clean versions and versions with tracked changes, submitted at opening of Inquiry.
20	Additional conditions suggested by Bridgend CBC concerning blasting at Gaens Quarry.

21	Sketches of relationships between water table variations and zone of ecological interest, submitted by NRW (Mr Rogers).
22	Technical Note on Anticipated Responses at Pathways, submitted by Tarmac (Mr Streetly).
23	Peter Vincent's statement of evidence and attachments.
24	Letter submitted by Mr & Mrs D Nicholas, local residents.
25	Copy of letter from SLR to PINS, dated 24 September 2015, concerning advertisement of revised Water Management Plans, submitted by Tarmac.
26.1-26.6	Updated Schedules of Planning Conditions for Cornelly and Grove Quarries ROMPs and Cornelly/Grove Quarries IDO Review (plain and tracked versions for each), reflecting discussion on conditions held during Inquiry, submitted by Tarmac at close of Inquiry.
27	Updated Schedule of Planning Conditions for Gaens Quarry ROMP, reflecting discussion on conditions held during Inquiry, submitted by TS Rees at close of Inquiry.
28	Closing Statement on behalf of Bridgend CBC.
29	Closing Statement on behalf of Natural Resources Wales.
30	Closing Statement on behalf of TS Rees Ltd.
31	Closing Statement on behalf of Tarmac Trading Ltd.
32.1-32.2	Judgements referred to by parties in Closing Submissions: Court of Appeal judgement on R (on the application of Champion) v North Norfolk DC *[2013] EWCA Civ 1657 and [2014] Env. L.R. 23*; and Supreme Court judgement on same *[2015] UKSC 52*.
33.1-33.3	Plans of Kenfig Dunes used for site visit.
34.1-34.2	Aerial photographs of Cornelly Quarry used for site visit.

ANNEX A - CORNELLY QUARRY ROMP (REF: 516086)

RECOMMENDED SCHEDULE OF PLANNING CONDITIONS

A: DEFINITION OF TERMS

For the purposes of these planning conditions the following words and phrases shall have the meaning given to them below:

i. "ROMP Area" means the area subject to the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Cornelly Quarry (ref P/97/623), shown outlined in red on Plan 1 accompanying the schedule of planning conditions.

ii. "ROMP Application" means the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Cornelly Quarry (ref P/97/623).

iii. "IDO Area" means the eastern area of the IDO permission ref 53/93/1350 which is the subject of a separate application submitted to Bridgend County Borough Council under the provisions of Schedule 14 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations within the IDO area of Cornelly and Grove Quarries (ref P/09/738/MIN) shown coloured pink on Plan 1 accompanying the schedule of planning conditions.

iv. "Date of Determination" means the date upon which new conditions subsequent to the applications are finally determined, i.e. the date upon which all proceedings on the applications, including appeals to the Secretary of State and the High Court have been determined, and the time period for any further appeal has expired.

v. "Emergency" means any circumstances in which the operator has a reasonable cause for apprehending injury to persons or serious damage to property.

vi. "Mineral Planning Authority, (MPA)", means Bridgend County Borough Council, or any successor mineral planning authority.

vii. "The Site", means all that land at Cornelly Quarry which is currently within the permitted area of Cornelly Quarry, comprising the "ROMP Area" of Cornelly and Pant Mawr Quarries, shown outlined in red on Plan 1 accompanying the schedule of planning conditions, and the eastern part of the IDO area shown coloured pink on Plan 1 accompanying the schedule of planning conditions.

viii. "2014 ES" means the Environmental Statement (ES) submitted in June 2014 in support of the Cornelly Quarry ROMP application.

ix. "Quarrying operations" means the winning and working of stone from the quarry face, and the operation of the primary crusher/or other mechanical means of stone breaking.

x. "Temporary operations" means operations associated with soil and overburden stripping, construction of soil storage mounds, construction of site haul roads, construction of soil baffle mounds, and restoration works involving the use of machinery. Temporary operations are to be confined to a period of no more than 8 weeks in a calendar year.

B TIME LIMITS

1. This planning permission shall expire on 31st December 2056.
2. Following the expiry of the planning permission, all extraction, treatment, and stockpiling of minerals shall cease.
3. No later than 12 months following the expiry of the planning permission, or the earlier permanent cessation of winning and working of minerals, all plant, machinery and structures shall be dismantled and removed from the site.
4. No later than 12 months following the expiry of the planning permission, or the earlier permanent cessation of winning and working of minerals, as agreed by both the mineral operator and MPA, the sale and transportation of minerals to and from the site, together with all ancillary manufacturing activities shall cease.

C WORKING PROGRAMME

5. The winning and working of stone and disposal of overburden/quarry waste shall be carried out in accordance with the updated quarry development plan ref numbers C112/097- C112/105 inclusive.
6. The site access shall be surfaced in permanent materials, and the surface maintained in a good state of repair, and kept free of mud/debris at all times.

7. Except in the case of emergency, quarrying operations shall take place only between the hours of 06:00-22:00 Mondays to Saturdays, and at no time on Sundays or Bank Holidays, except for essential maintenance.

   (NB: (i) *For the purpose of this condition, quarrying operations shall be defined as winning and working of stone from the quarry face, and the operation of the primary crusher/or other mechanical means of stone breaking.*

   (ii) *All other items of plant including secondary crushers, screens, sinter mills, asphalt plant, and concrete plant, lie within the 'IDO' area where the hours of working are unrestricted*.)

8. Within the working hours specified in Condition 7, there shall be no drilling operations, or secondary breakage of stone between the hours of 06:00 – 07:00 and 19:00-22:00 hours.

9. Temporary operations, as defined in Section A, shall only be carried out between 08:00 – 19:00 hours Mondays to Fridays.

10. No operations associated with the formation of the Western Pant Mawr Tip illustrated on plans ref C112.102 and C112.104, and formation and subsequent removal of material from bunds/soil storage areas shall be carried out at the site except between the hours of 08:00 – 17:00 Mondays to Fridays, and 08:00 -13:00 on Saturdays.

D ENVIRONMENTAL PROTECTION

Hydrology and Hydrogeology

11. The water management, monitoring, reporting, mitigation and contingency activities set out in the Water Management Plan (WMP) for Cornelly Quarry v5.8 dated 9th November 2015 shall be carried out throughout the life of the development.

12. In the event that the Minerals Planning Authority requires changes to the WMP, as provided for in the WMP, then the amended water management, monitoring, reporting, mitigation and contingency activities requested by the Minerals Planning Authority shall be carried out for the remaining life of the development.

13. Prior to the cessation of dewatering, a scheme shall be submitted to and approved in writing by the Minerals Planning Authority setting out proposals for residual pumping during the quarry decommissioning stage. The scheme shall include details of the rates and timescale of residual pumping, and the measures to be taken to monitor the effectiveness of the residual pumping during the defined time period. The scheme shall thereafter be implemented in accordance with the approved scheme.

14. Any facilities for storage of oils, fuels or chemicals on the site shall be sited in impervious bases and surrounded by impervious bund walls. The volume of the bunded compound shall be at least equivalent to the capacity of the tank plus 10%. If there is multiple tankage, the compound shall be at least equivalent to the capacity of the largest tank, or the combined capacity of inter-connective tanks, plus 10%. All filling points, vents, gauges and site glasses shall be located within the bund. The drainage system of the bund shall be sealed with no discharge to any water course, land or underground strata. Associated pipe-work shall be located above ground and protected from accidental damage.

15. To minimise the risk of groundwater pollution from quarrying and processing operations, the development shall be carried out in accordance with the following requirements:

- All mobile plant which requires fuel for its operation should be located on hard standing when not in use.
- All immobile plant which requires fuel for its operation should be located on hard standing. Drip trays should also be appropriately placed under all relevant plant.
- All refuelling activities should be undertaken on areas of hard standing, taking appropriate care and attention.
- An incident reporting procedure should be maintained for reporting all site incidents, including pollution events. Emergency responses should be in place in the event of an incident.
- Appropriate spill kits or other means of controlling accidental spills should be made available on site. Adequate training in the use of such equipment should also be provided.
- A maintenance and inspection programme should be followed in order to check the condition of site equipment and provide early warning of any potential leaks or spills.
- Suitable waste management procedures should be followed to prevent surface pollution resulting from any waste products, fuel containers, and chemical drums.
- During site restoration all hazardous plant and equipment should be removed from the quarry.
- The use of herbicides and other related chemicals should be restricted both during quarry working and post restoration. Chemical applications should be made at appropriate times, in suitable quantities, so as to avoid sub surface contamination.

Ecology

16. Within 6 months of the date of determination, an Ecological Mitigation Strategy (EMS) shall be submitted to the MPA for their approval in writing. The EMS shall include the mitigation measures set out in Section 8.7 of the 2014 ES. The EMS shall thereafter be implemented as approved.

17. In addition to the measures to be included in the EMS, in order to minimise disturbance of habitats and interference with species, the development shall be carried out in accordance with the following requirements:

    (i) Calcareous grasslands on the fringes of Cornelly and Pant Mawr Quarries, which would be unaffected by the development scheme, shall be fenced to prevent accidental incursion of vehicles and site personnel;

    (ii) Areas of inaccessible high cliff shall be identified each year, and, subject to operational requirements shall be left undisturbed in order to encourage potential habitat for nesting peregrine falcons;

    (iii) Any large trees or large crevices in undisturbed parts of the quarry shall be inspected for possible bat presence immediately ahead of any tree surgery or quarrying works. Any bats which are identified shall be dealt with in accordance with current legislation and best practice;

    (iv) Clearance of trees and scrub should avoid the main bird nesting season (March to August inclusive);

    (v) Common reptiles encountered during works should be allowed to leave the immediate works area unharmed, and, if necessary, should be assisted by means of capture and release;

    (vi) Dense ruderal and grassland vegetation should be strimmed and raked away at least 24 hours ahead of earthworking, so as to reduce the attractiveness of the area for reptiles, and encourage them to leave;

    (vii) Written protocols shall be issued to contractors so that in the event of discovery of bats, nesting birds, badgers or common reptiles, compliance with statutory obligations is ensured.

Landscaping

18. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the beating up and infilling of the existing hedgerow alongside the southern boundary of the ROMP area and IDO area abutting Mount Pleasant Road. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

19. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the construction of a 2.0m high screening bund along the southern boundary of the IDO area of Grove Quarry, abutting Mount Pleasant Road. The scheme should include provision for the bund to be constructed with an outer gradient of no steeper than 1:2 (v/h) and grass seeded and planted with native trees and shrubs to provide a vegetated visual barrier to views. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

20. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the infilling, widening and strengthening of the hedgerow/woodland belt along the northern boundary of the quarry void. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

21. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the intermediate restoration of the upper faces/benches illustrated on plan ref numbers C112/097- C112/105. The restoration works shall thereafter be implemented in accordance with the approved scheme.

22. Prior to the commencement of construction of the Pant Mawr Quarry Western Tip, shown on plan ref numbers C112.102 and C112.104, a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the landscape treatment of the finished profiles of the tip. The scheme shall include details of grass seeding, tree and shrub planting schedules, and proposals for maintenance of the restored tip area. Any trees, shrubs or hedges which die, are removed or become seriously damaged or diseased within 5 years of planting, shall be replaced in the next planting season with others of a similar size and species, unless otherwise agreed in writing by the MPA. The scheme shall thereafter be implemented in accordance with the approved scheme.

Noise

23. Except for temporary operations, the free-field Equivalent Continuous Noise Level, $L_{Aeq,1\ hour}$ due to operations in the site, shall not exceed the relevant criterion limit specified in Schedule 1 at each nominated dwelling for the periods specified. Measurements taken to verify compliance shall have regard to the effects of extraneous noise and shall be corrected for any such effects.

Schedule 1 Noise Criteria Limits

Location	**07:00-19:00** **Criterion** dB $L_{Aeq,\ T}$	**06:00-07-00** **Criterion** dB $L_{Aeq,\ T}$	**19:00-22:00** **Criterion** dB $L_{Aeq,\ T}$	**22:00-06:00** **Criterion** dB $L_{Aeq,\ T}$
Rock Cottages in South Cornelly	50	42	48	42
Danygraig (Holiday Caravan Camp)	55	45	48	42
Grove Farm House, Grove	55	45	48	42
Sea View, Mount Pleasant Road	50	45	48	42
Manderlay, Stormy Down	55	48	48	42
Ballas Farm	55	48	48	42
Ty Tanglwyst Farm	55	48	48	42
Mount Pleasant Farm	53	45	48	42

24. For temporary operations such as site preparation, soil and overburden stripping, bund formation and removal and final restoration, the free-field noise level due to work at the nearest point to each dwelling shall not exceed 67 dB $L_{Aeq,\ 1\ hour}$. Temporary operations shall not exceed a total of eight weeks in any calendar year for work close to any individual noise sensitive property.

Blasting

25. Except with the written consent of the MPA, or in the case of emergency, blasting operations shall be carried out only between 1000 and 1700 hours Monday to Friday, and only in exceptional circumstances on Saturday and not at all on Sunday and Public/Bank Holidays.

26. Ground vibration as a result of blasting shall not exceed a peak particle velocity of 6mms^{-1} in 95% of all blasts measured over any six month period, and no individual blast shall exceed a peak particle velocity of 10mms^{-1} measured at any vibration sensitive location, which is defined as any residential property in the vicinity of the quarry existing at the Date of Determination. The measurements shall be the maximum of three perpendicular directions taken at the ground surface.

27. All individual blasts shall be designed, managed and implemented to minimise the extent of air overpressure resulting from blasts, having regard to blast design, methods of initiation of blasts, and also as far as practicable to weather conditions prevailing at the time of initiation.

28. Each individual blast shall be monitored by the Operators, to include: provision for recording the details and location of the monitoring station; the location of the blast holes within the Site; weather conditions; specification of the blast in terms of MIC; and total charge weight. Blast monitoring is to be undertaken at the closest sensitive receptor to the blast location or at an alternative location that is requested by the Mineral Planning Authority. Records of blast monitoring shall be made available to the MPA upon request. Any complaints which are received shall be logged against each particular blast. In the event that monitoring indicates that the vibration levels set out in condition 26 above have been exceeded, then the Operator shall inform the MPA within two working days, with written confirmation of the steps to be taken to ensure compliance with condition 26.

29. Blasting times shall be clearly advertised at the Quarry site entrance, and an audible warning shall be sounded prior to any blasting operations taking place, and shall be sounded again immediately after blasting has finished.

30. There shall be no secondary breakage of stone by the use of explosives.

Dust

31. At all times during the carrying out of operations, a water bowser or similar equipment shall be available on site, and be used to minimise the emission of dust from haul roads and access roads within the site, and the processing plant site hard-standings..

32. Measures shall be taken to minimise dust emissions from quarrying operations, in accordance with the following protocol:

    - Soils and overburden shall not be handled during extreme dry conditions unless the working areas are first dampened down.
    - Drilling of shot holes shall be undertaken using drilling rigs fitted with a suitable dust collection system.
    - Site roads within the quarry shall be dampened down as appropriate, in accordance with the requirement of condition 31.
    - The site entrance road shall be maintained by use of a road sweeper which shall operate as required to maintain the surface of the road free of mud and other detritus.
    - All lorries, once loaded, shall be sheeted prior to leaving the site, with the exception of any load carrying only plus 75mm size diameter stone.
    - The speed of haulage vehicles at the site will be restricted to 10mph.
    - All site vehicles will be fitted with upswept exhausts and radiator fan shields.
    - Lorries will be loaded so as to avoid spillages.
    - All site traffic will be kept to the designated haul routes
    - Any plant spillages will be cleared to avoid accumulations.
    - Drop heights will be minimised at loading and discharge points.

Restoration

33 The development shall proceed in accordance with the concept restoration plan ref numbers C112/106 - C112/108 and the details of interim and final restoration treatments, landscaping, and aftercare, set out in Chapter 4.0 of the 2014 ES.

34. Not later than 31st December 2054, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed final restoration scheme, including drawings to illustrate the proposals for the final restoration of the quarry. The final restoration scheme shall be based upon the concept restoration plan ref numbers C112/106 - C112/108, and provide for the site to be restored as a nature conservation bias, with restoration treatment of the benches and faces above the water level which will be formed in the void. The scheme shall include updated predictions of the final rest water level of the lake. The remainder of the site shall be cleared of all plant, machinery, buildings and structures in accordance with the requirements of Condition 3. The restoration scheme shall include details of the final re-profiling works for the site, the soil /soil forming material profiles to be established; tree and shrub planting schedules; seeding, fencing and drainage; and a programme and timetable for the implementation of the works.

35 Not later than 31st December 2054, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed aftercare management plan. The management plan shall be in substantial accordance with the details of the final restoration scheme and the principles of the strategic aftercare management strategy set out in Chapter 4.0 of the 2014 ES.

ANNEX B - GROVE QUARRY ROMP (REF: 516087)

RECOMMENDED SCHEDULE OF PLANNING CONDITIONS

A: DEFINITION OF TERMS

For the purposes of these planning conditions the following words and phrases shall have the meaning given to them below:

i. "ROMP Area" means the area subject to the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Grove Quarry (ref P/97/618), shown outlined in purple on Plan 1 accompanying the schedule of conditions.

ii. "ROMP Application" means the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Cornelly Quarry (ref P/97/618).

iii. "IDO Area" means the western area of the IDO permission ref 53/93/1350 which is the subject of a separate application submitted to Bridgend County Borough Council under the provisions of Schedule 14 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations within the IDO area of Cornelly and Grove Quarries (ref P/09/738/MIN), shown coloured yellow on Plan 1 accompanying the schedule of conditions.

iv. "Date of Determination" means the date upon which new conditions subsequent to the applications are finally determined, i.e. the date upon which all proceedings on the applications, including appeals to the Secretary of State and the High Court have been determined, and the time period for any further appeal has expired.

v. "Emergency" means any circumstances in which the operator has a reasonable cause for apprehending injury to persons or serious damage to property.

vi. "Mineral Planning Authority, (MPA)", means Bridgend County Borough Council, or any successor mineral planning authority.

vii. "The Site", means all that land at Grove Quarry which is currently within the permitted area of Grove Quarry, comprising the "ROMP Area" shown outlined in purple on Plan 1 accompanying the schedule of conditions and the western part of the IDO area shown coloured yellow on Plan 1 accompanying the schedule of conditions.

viii "2014 ES" means the Environmental Statement (ES) submitted in June 2014 in support of the Grove Quarry ROMP application.

ix. "Temporary operations" means operations associated with soil and overburden stripping, construction of soil storage mounds, construction of site haul roads, construction of soil baffle mounds, and restoration works involving the use of machinery. Temporary operations are to be confined to a period of no more than 8 weeks in a calendar year.

A TIME LIMITS

1. The MPA shall be given 7 days notice in writing prior to a resumption of quarrying operations at Grove Quarry.

2. This planning permission shall expire on 31st December 2056.

3. Following the expiry of the planning permission, all extraction, treatment, and stockpiling of minerals shall cease.

4. No later than 12 months following the expiry of the planning permissions, or the earlier permanent cessation of winning and working of minerals, all plant, machinery and structures shall be dismantled and removed from the site.

5. No later than 12 months following the expiry of the planning permission, or the earlier permanent cessation of winning and working of minerals, as agreed by both the mineral operator and MPA, the sale and transportation of minerals to and from the site, together with all ancillary manufacturing activities shall cease.

B WORKING PROGRAMME

6. The winning and working of stone and disposal of overburden/quarry waste shall be carried out in accordance with the updated quarry development plan ref numbers G057/016 to G057/019.

7. The site access shall be surfaced in permanent materials, and the surface maintained in a good state of repair, and kept free of mud/debris at all times.

8. The winning and working of stone from the quarry faces, and operation of a primary crusher, shall take place only between the hours of 07:00 - 19.00 Mondays to Fridays and 07.00 – 13.00 on Saturdays, and at no time on Sundays or Bank Holidays, except for essential maintenance or otherwise agreed in writing by the MPA.

9. Temporary operations, as defined in Section A, shall only be carried out between 08:00 – 19:00 hours Mondays to Fridays.

C ENVIRONMENTAL PROTECTION

Hydrology and Hydrogeology

10. The water management, monitoring, reporting, mitigation and contingency activities set out in the Water Management Plan (WMP) for Grove Quarry v5.8 dated 9th November 2015 shall be carried out throughout the life of the development.

11. In the event that the Minerals Planning Authority requires changes to the WMP, as provided for in the WMP, then the amended water management, monitoring, reporting, mitigation and contingency activities requested by the Minerals Planning Authority shall be carried out for the remaining life of the development.

12. Prior to the cessation of dewatering, a scheme shall be submitted to and approved in writing by the Minerals Planning Authority setting out proposals for residual pumping during the quarry decommissioning stage. The scheme shall include details of the rates and timescale of residual pumping, and the measures to be taken to monitor the effectiveness of the residual pumping during the defined time period. The scheme shall thereafter be implemented in accordance with the approved scheme.

13. Any facilities for storage of oils, fuels or chemicals on the site shall be sited in impervious bases and surrounded by impervious bund walls. The volume of the bunded compound shall be at least equivalent to the capacity of the tank plus 10%. If there is multiple tankage, the compound shall be at least equivalent to the capacity of the largest tank, or the combined capacity of inter-connective tanks, plus 10%. All filling points, vents, gauges and site glasses shall be located within the bund. The drainage system of the bund shall be sealed with no discharge to any water course, land or underground strata. Associated pipe-work shall be located above ground and protected from accidental damage.

14. To minimise the risk of groundwater pollution from quarrying and processing operations, the development shall be carried out in accordance with the following requirements**:**

- All mobile plant which requires fuel for its operation should be located on hard standing when not in use.

- All immobile plant which requires fuel for its operation should be located on hard standing. Drip trays should also be appropriately placed under all relevant plant.

- All refuelling activities should be undertaken on areas of hard standing, taking using appropriate care and attention.

- An incident reporting procedure should be maintained for reporting all site incidents, including pollution events. Emergency responses should also be in place in the event of an incident.

- Appropriate spill kits or other means of controlling accidental spills should be made available on site. Adequate training in the use of such equipment should also be provided.

- A maintenance and inspection programme should be followed in order to check the condition of site equipment and provide early warning of any potential leaks or spills.

- Suitable waste management procedures should be followed to prevent surface pollution resulting from any waste products, fuel containers, and chemical drums.

- During site restoration all hazardous plant and equipment should be removed from the quarry.

- The use of herbicides and other related chemicals should be restricted both during quarry working and post restoration. Chemical applications should be made at appropriate times, in suitable quantities, so as to avoid sub surface contamination.

Ecology

15. Within 6 months of the date of determination, an Ecological Mitigation Strategy (EMS) shall be submitted to the MPA for their approval in writing. The EMS shall include the mitigation measures set out in Section 8.7 of the 2014 ES. The EMS shall thereafter be implemented as approved.

16. In addition to the measures to be included in the EMS, in order to minimise disturbance of habitats and interference with species, the development shall be carried out in accordance with the following requirements:

    (i) Areas of inaccessible high cliff shall be identified each year, and, subject to operational requirements shall be left undisturbed in order to encourage potential habitat for nesting peregrine falcons;

(ii) Any large trees or large crevices in undisturbed parts of the quarry shall be inspected for possible bat presence immediately ahead of any tree surgery or quarrying works. Any bats which are identified shall be dealt with in accordance with current legislation and best practice;

(iii) Clearance of trees and scrub should avoid the main bird nesting season (March to August inclusive);

(iv) Common reptiles encountered during works should be allowed to leave the immediate works area unharmed, and, if necessary, should be assisted by means of capture and release;

(v) Dense ruderal and grassland vegetation should be strimmed and raked away at least 24 hours ahead of earthworking, so as to reduce the attractiveness of the area for reptiles, and encourage them to leave;

(vi) Written protocols shall be issued to contractors so that in the event of discovery of bats, nesting birds, badgers or common reptiles, compliance with statutory obligations is ensured.

Landscaping

17. The limits of quarrying within the ROMP area shall be confined to the areas illustrated on plan ref numbers G057/016 to G057/019. No quarrying operations shall take place within the woodland area along the western side of the ROMP area beyond the defined limit of quarrying.

18 Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the beating up and infilling the existing hedgerow alongside the southern boundary of the IDO area abutting Mount Pleasant Road. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

19. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the construction of a 2.0m high screening bund along the southern boundary of the IDO area of Grove Quarry, abutting Mount Pleasant Road. The scheme should include provision for the bund to be constructed with an outer gradient of no steeper than 1:2 (v/h) and grass seeded and planted with native trees and shrubs to provide a vegetated visual barrier to views. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

20. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the infilling and strengthening of the woodland belt along the lower sections of the wooded northern flank of the IDO area along the Heol y Splot corridor. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

21. Prior to the commencement of operations in Phase b (plan ref G057/017) a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the intermediate restoration of the upper faces/benches illustrated on plan ref numbers G057/016 to G057/019. The restoration works shall thereafter be implemented in accordance with the approved scheme.

Noise

22. Except for temporary operations, the free-field Equivalent Continuous Noise Level, $L_{Aeq,1\ hour}$ due to operations in the site, shall not exceed the relevant criterion limit specified in Schedule 1 at each nominated dwelling for the periods specified. Measurements taken to verify compliance shall have regard to the effects of extraneous noise and shall be corrected for any such effects.

Schedule 1 Noise Criteria Limits

Location	**07:00-19:00** **Criterion** dB $L_{Aeq,\ T}$
Rock Cottages in South Cornelly	55
Danygraig (Holiday Caravan Camp)	55
Grove Farm House, Grove	55
Sea View, Mount Pleasant Road	55
Manderlay, Stormy Down	55
Ballas Farm	55
Ty Tanglwyst Farm	55
Mount Pleasant Farm	53

23. For temporary operations such as site preparation, soil and overburden stripping, bund formation and removal and final restoration, the free-field noise level due to work at the nearest point to each dwelling shall not exceed 67 dB $L_{Aeq, 1 hour}$. Temporary operations shall not exceed a total of eight weeks in any calendar year for work close to any individual noise sensitive properties.

Blasting

24. Except with the written consent of the MPA, or in the case of emergency, blasting operations shall be carried out only between 1000 and 1700 hours Monday to Friday, and only in exceptional circumstances on Saturday and not at all on Sunday and Public/Bank Holidays.

25. Ground vibration as a result of blasting shall not exceed a peak particle velocity of $6mms^{-1}$ in 95% of all blasts measured over any six month period, and no individual blast shall exceed a peak particle velocity of $10mms^{-1}$ measured at any vibration sensitive location, which is defined as any residential property in the vicinity of the quarry existing at the Date of Determination. The measurements shall be the maximum of three perpendicular directions taken at the ground surface.

26. All individual blasts shall be designed, managed and implemented to minimise the extent of air overpressure resulting from blasts having regard to blast design, methods of initiation of blasts, and also as far as practicable to weather conditions prevailing at the time of initiation.

27. Each individual blast shall be monitored by the Operators, to include: provision for recording the details and location of the monitoring station; the location of the blast holes within the Site; weather conditions; specification of the blast in terms of MIC; and total charge weight. Blast monitoring is to be undertaken at the closest sensitive receptor to the blast location or at an alternative location that is requested by the Mineral Planning Authority. Records of blast monitoring shall be made available to the MPA upon request. Any complaints which are received shall be logged against each particular blast. In the event that monitoring indicates that the vibration levels set out in condition 25 above have been exceeded, then the Operator shall inform the MPA within two working days, with written confirmation of the steps to be taken to ensure compliance with condition 25.

28. Blasting times shall be clearly advertised at the Quarry site entrance, and an audible warning shall be sounded prior to any blasting operations taking place, and shall be sounded again immediately after blasting has finished.

29. There shall be no secondary breakage of stone by the use of explosives.

Dust

30. At all times during the carrying out of operations, a water bowser or similar equipment shall be available on site, and be used to minimise the emission of dust from haul roads and access roads within the site, and the processing plant site hard-standings.

31. Measures shall be taken to minimise dust emissions from quarrying operations, in accordance with the following protocol:

    - Soils and overburden shall not be handled during extreme dry conditions unless the working areas are first dampened down;
    - Drilling of shot holes shall be undertaken using drilling rigs fitted with a suitable dust collection system;
    - Site roads within the quarry shall be dampened down as appropriate, in accordance with the requirement of conditions 30;
    - The site entrance road shall be maintained by use of a road sweeper which shall operate as required to maintain the surface of the road free of mud and other detritus.
    - All lorries, once loaded, shall be sheeted prior to leaving the site, with the exception of any load carrying only plus 75mm diameter size stone.
    - The speed of haulage vehicles at the site will be restricted to 10mph.
    - All site vehicles will be fitted with upswept exhausts and radiator fan shields.
    - Lorries will be loaded so as to avoid spillages.
    - All site traffic will be kept to the designated haul routes
    - Any plant spillages will be cleared to avoid accumulations.
    - Drop heights will be minimised at loading and discharge points.

Restoration

32. The development shall proceed in accordance with the concept restoration plan ref numbers G057/020 - G057/021 and the details of interim and final restoration treatments, landscaping, and aftercare, set out in Chapter 4.0 of the 2014 ES.

33. Not later than 31st December 2054, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed final restoration scheme, including drawings to illustrate the proposals for the final restoration of the quarry. The final restoration scheme shall be based upon the concept restoration plan ref numbers G057/020 - G057/021, and provide for the site to be restored as a nature conservation bias, with restoration treatment of the benches and faces above the water level which will be formed in the void. The scheme shall include updated predictions of the final rest water level of the lake. The remainder of the site shall be cleared of all plant, machinery, buildings and structures in accordance with the requirements of condition 4. The restoration scheme shall include details of the final re-profiling works for the site, the soil /soil forming material profiles to be established; tree and shrub planting schedules; seeding, fencing and drainage; and a programme and timetable for the implementation of the works.

34. Not later than 31st December 2054, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed aftercare management plan. The management plan shall be in substantial accordance with the details of the final restoration scheme and the principles of the strategic aftercare management strategy set out in Chapter 4.0 of the 2014 ES.

ANNEX C - GAENS QUARRY ROMP (REF: 516088)

RECOMMENDED SCHEDULE OF PLANNING CONDITIONS

A: Definition of Terms

For the purposes of these planning conditions the following words and phrases shall have the meaning given to them below:

i. "ROMP Area" means the area subject to the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Gaens Quarry;

ii. "ROMP Application" means the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Gaens Quarry;

iii "Date of Determination" means the date upon which new conditions subsequent to the applications are finally determined, i.e. the date upon which all proceedings on the applications, including appeals to the Secretary of State and the High Court have been determined, and the time period for any further appeal has expired;

iii. "Emergency" means any circumstances in which the operator has a reasonable cause for apprehending injury to persons or serious damage to property;

iv. "Mineral Planning Authority, (MPA)", means Bridgend County Borough Council, or any successor mineral planning authority;

v. "The Site", means all that land at Gaens Quarry which is currently within the permitted area of Gaens Quarry, comprising the "ROMP Area"; and

vi. "2014 ES" means the Environmental Statement (ES) submitted in June 2014 in support of the Gaens Quarry ROMP application.

B: Time Limits

Duration

1. The planning permission hereby granted shall expire on the 6th January 2068.

2. On the expiry of the planning permission, all extraction, processing and stockpiling of minerals shall cease and not recommence.

3. No later than 12 months following the expiry of the planning permissions, or the earlier permanent cessation of winning and working of minerals, all plant, machinery and structures shall be dismantled and removed from the site.

4. No later than 12 months following the expiry of the planning permission, or the earlier permanent cessation of winning and working of minerals, the sale and transportation of minerals to and from the site, together with all ancillary manufacturing activities shall cease.

C: Working Programme

5. The winning and working of stone shall be carried out in accordance with the updated quarry development plan ref numbers 3782/02 to 3782/05 inclusive.

6. The sole means of vehicular access to and from the site shall be from Porthcawl Road as defined on Plan Ref. No. 3782/01: Existing Layout.

7. The site access shall be surfaced in permanent materials, and the surface maintained in a good state of repair, and kept free of mud/debris at all times.

8. Except in emergencies to maintain safe quarry working the following shall apply:

    a. No quarry operations, other than water pumping, the servicing/maintenance of plant, and environmental monitoring, shall be carried out at the site except between the following times:

        i. 0600 – 2200 hours Monday to Friday; and
        ii. 0600 – 1600 hours Saturday;

    b. No operations other than environmental monitoring and water pumping at the site shall take place on Sundays or public/bank holidays.

    c. No operations for the formation and subsequent removal of material from bunds/soil storage areas shall be carried out at the site except between the following times:

        i. 0800 – 1800 hours Monday to Friday; and
        ii. 0800 – 1300 hours on Saturdays.

    d. Deliveries and collection of aggregates shall only be made between the following times:

       0700 – 1900 hours Monday to Friday
       0700 – 1300 hours Saturday with no deliveries/collections on Sundays or Public /Bank Holidays

e. Within the working hours specified above, temporary operations shall only be carried out between 0800 - 1900 hours Monday to Fridays.

D: Environmental Protection

Hydrology & Hydrogeology

9. The water management, monitoring, reporting, mitigation and contingency activities set out in the Water Management Plan (WMP) for Gaens Quarry v5.8 dated 9th November 2015 shall be carried out throughout the life of the development.

10. In the event that the Minerals Planning Authority requires changes to the WMP, as provided for in the WMP, then the amended water management, monitoring, reporting, mitigation and contingency activities requested by the Minerals Planning Authority shall be carried out for the remaining life of the development.

11. Prior to the cessation of dewatering, a scheme shall be submitted to and approved in writing by the Minerals Planning Authority setting out proposals for residual pumping during the quarry decommissioning stage. The scheme shall include details of the rates and timescale of residual pumping, and the measures to be taken to monitor the effectiveness of the residual pumping during the defined time period. The scheme shall thereafter be implemented in accordance with the approved scheme.

12. Any facilities for storage of oils, fuels or chemicals on the site shall be sited in impervious bases and surrounded by impervious bund walls. The volume of the bunded compound shall be at least equivalent to the capacity of the tank plus 10%. If there is multiple tankage, the compound shall be at least equivalent to the capacity of the largest tank, or the combined capacity of inter-connective tanks, plus 10%. All filling points, vents, gauges and site glasses shall be located within the bund. The drainage system of the bund shall be sealed with no discharge to any water course, land or underground strata. Associated pipe-work shall be located above ground and protected from accidental damage.

13. Measures shall be taken to minimise the risk of groundwater pollution from quarrying operations, in accordance with the following protocol:

- All mobile plant using fuel should be located on hard standing when not in use;
- All immobile plant using fuel should be located on hard standing. Drip trays should also be appropriately placed under all relevant plant;
- All refuelling activities should be undertaken on areas of hard standing, using appropriate care and attention;

- An incident reporting procedure should be maintained for reporting all site incidents, including pollution events. Suitable emergency responses should also be in place in the event of an incident.
- Appropriate spill kits or other means of controlling accidental spills should be made available on site. Adequate training in the use of such equipment should also be provided;

- A maintenance and inspection programme should be followed in order to check the condition of site equipment and provide early warning of any potential leaks or spills;

- Suitable waste management procedures should be followed to prevent surface pollution resulting from any waste products, fuel containers, chemical drums;

- During site restoration all permanent plant and equipment should be removed from the quarry;

- The use of herbicides and other related chemicals should be restricted both during quarry working and post restoration. Chemical applications should be made at appropriate times, in suitable quantities, so to avoid sub surface contamination.

Nature Conservation

14. Measures shall be taken to minimise disturbance of habitats and interference with species, in accordance with the following protocols:

    a. Any large trees or large crevices in undisturbed parts of the quarry shall be inspected for possible bat presence immediately ahead of any tree surgery or quarrying works. Any bats which are identified shall be dealt with in accordance with current legislation and best practice;

    b. Clearance of trees and scrub should avoid the main bird nesting season (March to August inclusive);

    c. Common reptiles encountered during works should be allowed to leave the immediate works area unharmed, and, if necessary, should be assisted by means of capture and release;

    d. Dense ruderal and grassland vegetation should be strimmed and raked away at least 24 hours ahead of earthworking, so as to reduce the attractiveness of the area for reptiles, and encourage them to leave; and

    e. Written protocols shall be issued to contractors so that in the event of discovery of bats, nesting birds, badgers or common reptiles, compliance with statutory obligations is ensured.

Landscape

15. Within 12 months of the date of determination of this submission a scheme shall be submitted to and agreed in writing by the MPA detailing the fencing out of Tree Preservation Order woodland adjoining the western boundary of the site. The scheme shall be implemented as agreed in accordance with a timetable to be agreed.

16. Within 12 months of the date of determination of this submission a scheme of landscaping shall be submitted to and approved by the MPA. Such a scheme shall provide for:

    a. The landscaping of all peripheral areas of the quarry which would help to screen quarrying operations from adjoining land/settlement and enhance landscape/wildlife interests. Details such as the cultivation of soils, spacing, density and species shall be provided together with the need for protective tree shelters/rabbit guards as appropriate;

    b. Infill, widening and strengthening of the woodland belt along the western boundary of the proposed quarry void (adjacent to Lamb Row and Rock Cottages as well as adjacent to the weighbridge and offices);

    c. The progressive landscaping of quarry benches where possible; and

    d. All trees, shrubs and hedges planted in accordance with the approved scheme shall be maintained and any plants which within 5 years of planting die, are removed or become seriously damaged or diseased shall be replaced in the next planting season with others of a similar size and species.

    All planting shall be carried out in accordance with the approved scheme within the first planting season following the date of its approval.

17. A stockproof fence, minimum height 1.30 metres, with appropriate warning signs, shall be maintained around the entire perimeter of the site.

Noise

18. Except for temporary operations, the free-field Equivalent Continuous Noise Level, $L_{Aeq,1\ hour}$ due to operations in the site, shall not exceed the relevant criterion limit specified in Schedule 1 at each nominated dwelling for the periods specified. Measurements taken to verify compliance shall have regard to the effects of extraneous noise and shall be corrected for any such effects.

Schedule 1 Noise Criteria Limits

Location	06:00-07-00 Criterion dB $L_{Aeq, T}$	07:00-19:00 Criterion dB $L_{Aeq, T}$	19:00-22:00 Criterion dB $L_{Aeq, T}$	22:00-06:00 Criterion dB $L_{Aeq, T}$
Rock Cottages	42	50	48	42
Sea View, Mount Pleasant Road	45	50	48	42
Ty Tanglwyst Farm	42	55	48	42
Cornelius Close	42	55	48	42

19. For temporary operations such as site preparation, soil and overburden stripping, bund formation and removal and final restoration, the free-field noise level due to work at the nearest point to each dwelling shall not exceed 67 dB $L_{Aeq, 1 hour}$. Temporary operations shall not exceed a total of eight weeks in any calendar year for work close to any individual noise sensitive properties.

Blasting

20. Except with the written consent of the MPA, or in the case of emergency, blasting operations shall be carried out only between 1000 and 1700 hours Monday to Friday, and only in exceptional circumstances on Saturday and not at all on Sunday and Public/Bank Holidays.

21. Ground vibration as a result of blasting shall not exceed a peak particle velocity of 6mms-1 in 95% of all blasts measured over any six month period, and no individual blast shall exceed a peak particle velocity of 10mms-1 measured at any vibration sensitive location, which is defined as any residential property in the vicinity of the quarry existing at the Date of

Determination. The measurements shall be the maximum of three perpendicular directions taken at the ground surface. The monitoring locations shall be agreed with the MPA.

22. No blast shall be undertaken closer than 125m of Rock Cottages until a report has been submitted to and approved in writing by the MPA to demonstrate how the vibration limits specified in Condition 21 will be met. The report shall be carried out by a qualified vibration consultant and shall include the following information:

    a) the predicted vibration levels of the nearest sensitive receptor taking into account the Council's vibration results measured as a PPV on the 5th October 2009 at a proximity of 125m from the blast area which were:
    - Longitudinal 14.4mm/s
    - Vertical 10.8mm/s
    - Transverse 21.6 mm/s; and

    b) the design of the blast and the Maximum Instantaneous Charge (MIC) that will be required to achieve the limits specified in Condition 21.

23. A minimum of 24 hrs notice shall be given to the MPA of any blasting that is to be carried out within the Quarry that is closer than 125m to Rock Cottages together with details of the proposed blast design.

24. A minimum of 24 hrs notice shall be given to the MPA of all blasting at the Quarry.

25. All individual blasts shall be designed, managed and implemented to minimise the extent of air overpressure resulting from blasts. Such effort shall have regard to blast design, methods of initiation of blasts, and also as far as practicable to weather conditions prevailing at the time of initiation.

26. Each individual blast shall be monitored by the Operators, to include provision for recording the details and location of the monitoring station; the location of the blast holes within the Site; weather conditions; specification of the blast in terms of MIC; and total charge weight. Records of blast monitoring shall be made available to the MPA upon request. Any complaints which are received shall be logged against each particular blast. In the event that monitoring indicates that the vibration levels set out in condition 21 above have been exceeded, then the Operator shall inform the MPA within two working days, with written confirmation of the steps to be taken to ensure compliance with condition 21.

27. Blasting times shall be clearly advertised at the Quarry, and an audible warning shall be sounded prior to any blasting operations taking place, and shall be sounded again immediately after blasting has finished.

28. There shall be no secondary breakage of stone by the use of explosives.

Dust

29. Automatic vehicle cleaning facilities, including sprays to clean the wheels, underbody and side body of vehicles shall be maintained throughout the operations permitted. Such facilities shall include the provision of a water recycling system to maximise the use of water supplies.

30. At all times during the carrying out of operations, a water bowser or similar equipment shall be available on site, and be used to minimise the emission of dust from haul roads within the site.

31. Measures shall be taken to minimise dust emissions from quarrying operations, in accordance with the following protocol:

- Soils and overburden shall not be handled during extreme dry conditions unless the working areas are first dampened down;
- Drilling of shot holes shall be undertaken using drilling rigs fitted with a suitable dust collection system;
- All lorries, once loaded, shall be sheeted prior to leaving the site, with the exception of any load carrying only plus 75mm size stone.
- The speed of haulage vehicles at the site will be restricted to 10mph.
- All site vehicles will be fitted with upswept exhausts and radiator fan shields.
- Lorries will be loaded so as to avoid spillages.
- All site traffic will be kept to the designated haul routes
- Any plant spillages will be cleared to avoid accumulations.
- Drop heights will be minimised at loading and discharge points.

Archaeology

32. At least 12 months in advance of the commencement of extraction from Phase 3 (as per Drawing 3782/04) a programme of archaeological investigation and recording in accordance with a written scheme of investigation shall be carried out by the developer. The written scheme of investigation shall be submitted to and approved in writing by the MPA, and implemented within 6 months of the date of the approval.

33. At least 14 days notice of the commencement of any soil stripping programme shall be given to the MPA and the developer shall afford access at all reasonable times to archaeologists nominated by the MPA who shall be allowed to observe the excavations and record items of interest and finds.

Restoration

34. The development shall proceed in accordance with the concept restoration plan ref numbers M13.128b.D.012 and 011 and the details of interim and final restoration treatments, landscaping, and aftercare, set out in the 2014 ES.

35. Not later than 6th January 2067, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed final restoration scheme, including drawings to illustrate the proposals for the final restoration of the quarry. The final restoration scheme shall be based upon the concept restoration plan ref numbers M13.128b.D.012 and 011, and provide for the site to be restored as a nature conservation bias, with restoration treatment of the benches and faces above the water level which will be formed in the void. The scheme shall include updated predictions of the final rest water level of the lake. The remainder of the site shall be cleared of all plant, machinery, buildings and apparatus in accordance with the requirements of Condition 3. The restoration scheme shall include details of the final re-profiling works for the site, the soil /soil forming material profiles to be established; tree and shrub planting schedules; seeding, fencing and drainage; and a programme and timetable for the implementation of the works.

36. Not later than 6th January 2067, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed aftercare management plan. The management plan shall be in substantial accordance with the details of the final restoration scheme and the principles of the strategic aftercare management strategy set out in Chapter 3.0 of the 2014 ES.

ANNEX D - CORNELLY AND GROVE QUARRIES IDO REVIEW

RECOMMENDED SCHEDULE OF PLANNING CONDITIONS

A: DEFINITION OF TERMS

For the purposes of these planning conditions the following words and phrases shall have the meaning given to them below:

i. "IDO Area" means the IDO permission ref 53/93/1350 which is the subject of an application submitted to Bridgend County Borough Council under the provisions of Schedule 14 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations within the IDO area of Cornelly and Grove Quarries (ref P/97/738/MIN), shown outlined in blue on Plan 1 accompanying this schedule of conditions.

ii. "The eastern IDO area" means that part of the IDO permission ref 53/93/1350 which lies within Cornelly Quarry, and which is shown coloured pink on Plan 1 accompanying this schedule of conditions.

iii. "The western IDO area" means that part of the IDO permission ref 53/93/1350 which lies within Grove Quarry, and which is shown coloured yellow on Plan 1 accompanying this schedule of conditions.

iv "Grove ROMP Area" means the western area of Grove Quarry which is subject to a separate application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations within the ROMP area of Grove Quarry (ref P/97/618), shown outlined in purple on Plan 1 accompanying this schedule of conditions.

v "Grove ROMP Application" means the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Grove Quarry (ref P/97/618).

vi "Cornelly ROMP Area" means the eastern and northern areas of Cornelly Quarry area subject to the application submitted to

Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Cornelly Quarry (ref P/97/623), shown outlined in red on Plan 1 accompanying this schedule of conditions.

vii "Cornelly ROMP Application" means the application submitted to Bridgend County Borough Council under the provisions of Schedule 13 of the Environment Act 1995 for a Review of the planning conditions regulating quarrying operations at Cornelly Quarry (ref P/97/623).

viii "Date of Determination" means the date upon which new conditions subsequent to the applications are finally determined, i.e. the date upon which all proceedings on the applications, including appeals to the Secretary of State and the High Court have been determined, and the time period for any further appeal has expired.

ix "Emergency" means any circumstances in which the operator has a reasonable cause for apprehending injury to persons or serious damage to property.

x "Mineral Planning Authority, (MPA)", means Bridgend County Borough Council, or any successor mineral planning authority.

xi. "2014 ES" means the Environmental Statement (ES) submitted in June 2014 in support of the Cornelly and Grove Quarries IDO Review application.

xii. "Quarrying operations" means winning and working of stone from the quarry face, and the operation of the primary crusher/or other mechanical means of stone breaking.

xiii. "Temporary operations" means operations associated with soil and overburden stripping, construction of soil storage mounds, construction of site haul roads, construction of soil baffle mounds, and restoration works involving the use of machinery. Temporary operations are to be confined to a period of no more than 8 weeks in a calendar year.

B TIME LIMITS

1. Quarrying operations within the eastern and western IDO areas shall be completed by 31st December 2056.
2. Following the completion of quarrying operations in the eastern and western IDO areas, all extraction, treatment, and stockpiling of minerals shall cease.

3. No later than 12 months following the completion of quarrying operations in the eastern and western IDO areas, or the earlier permanent cessation of winning and working of minerals, all plant, machinery and structures shall be dismantled and removed from the site.

4. No later than 12 months following the expiry of the planning permission, or the earlier permanent cessation of winning and working of minerals, as agreed by both the mineral operator and MPA, the sale and transportation of minerals to and from the IDO area, together with all ancillary manufacturing activities shall cease.

C WORKING PROGRAMME

5. Unless otherwise approved in writing by the MPA, the winning and working of stone and disposal of overburden/quarry waste shall be carried out in the eastern IDO area in accordance with the updated quarry development plan ref numbers C112/097 - C112/105, and in the western IDO area in accordance with the updated quarry development plan ref numbers G057/016 - G057/019.

6. The site accesses to Cornelly and Grove Quarries shall be surfaced in permanent materials, and the surface maintained in a good state of repair, and kept free of mud/debris at all times.

7. Within the eastern IDO area, quarrying operations shall take place only between the hours of 06:00 - 22:00 Mondays to Saturdays, and at no time on Sundays or Bank Holidays, except for essential maintenance or otherwise agreed in writing by the MPA.

   (NB (i) *For the purpose of this condition, quarrying operations shall be defined as winning and working of stone from the quarry face, and the operation of the primary crusher/or other mechanical means of stone breaking.*

   (ii) *The hours of operation for all other items of plant within the eastern IDO area, including secondary crushers, screens, sinter mills, asphalt plant, and concrete plant, are unrestricted in terms of hours of working*).

8. Within the working hours specified in Condition 7, there shall be no drilling operations, or secondary breakage of stone between the hours of 06:00 – 07:00 and 19:00 - 22:00 hours.

9. Within the western IDO area, quarrying operations shall take place only between the hours of 07:00 - 19.00 Mondays to Fridays and 07.00 – 13.00 on Saturdays, and at no time on Sundays or Bank Holidays, except for essential maintenance or as otherwise agreed in writing by the MPA.

10. No operations associated with the formation and subsequent removal of material from bunds/soil storage areas shall be carried out at the site except between the hours of 08:00 – 17:00 Mondays to Fridays, and 08:00 - 13:00 on Saturdays.

11. Temporary operations, as defined, shall only be carried out between 08:00 – 19:00 hours Mondays to Fridays.

D ENVIRONMENTAL PROTECTION

Hydrology and Hydrogeology

12. The water management, monitoring, reporting, mitigation and contingency activities set out in the Water Management Plans (WMPs) for Cornelly Quarry v5.8 and Grove Quarry v5.8 dated 9th November 2015 shall be carried out throughout the life of the development.

13. In the event that the Minerals Planning Authority requires changes to the WMPs, as provided for in the WMPs, then the amended water management, monitoring, reporting, mitigation and contingency activities requested by the Minerals Planning Authority shall be carried out for the remaining life of the development.

14. Prior to the cessation of dewatering, a scheme shall be submitted to and approved in writing by the Minerals Planning Authority setting out proposals for residual pumping during the quarry decommissioning stage. The scheme shall include details of the rates and timescale of residual pumping, and the measures to be taken to monitor the effectiveness of the residual pumping during the defined time period. The scheme shall thereafter be implemented in accordance with the approved scheme.

15. Any facilities for storage of oils, fuels or chemicals on the site shall be sited in impervious bases and surrounded by impervious bund walls. The volume of the bunded compound shall be at least equivalent to the capacity of the tank plus 10%. If there is multiple tankage, the compound shall be at least equivalent to the capacity of the largest tank, or the combined capacity of inter-connective tanks, plus 10%. All filling points, vents, gauges and site glasses shall be located within the bund. The drainage system of the bund shall be sealed with no discharge to any water course, land or underground strata. Associated pipe-work shall be located above ground and protected from accidental damage.

16. To minimise the risk of groundwater pollution from quarrying operations, the development shall be carried out in accordance with the following requirements**:**

- All mobile plant which requires fuel for its operation should be located on hard standing when not in use.
- All immobile plant which requires fuel for its operation should be located on hard standing. Drip trays should also be appropriately placed under all relevant plant.
- All refuelling activities should be undertaken on areas of hard standing, taking appropriate care and attention.
- An incident reporting procedure should be maintained for reporting all site incidents, including pollution events. Emergency responses should also be in place in the event of an incident.
- Appropriate spill kits or other means of controlling accidental spills should be made available on site. Adequate training in the use of such equipment should also be provided.
- A maintenance and inspection programme should be followed in order to check the condition of site equipment and provide early warning of any potential leaks or spills.
- Suitable waste management procedures should be followed to prevent surface pollution resulting from any waste products, fuel containers, and chemical drums.
- During site restoration all hazardous plant and equipment should be removed from the quarry.
- The use of herbicides and other related chemicals should be restricted both during quarry working and post restoration. Chemical applications should be made at appropriate times, in suitable quantities, so to avoid sub surface contamination.

Ecology

17**.** Within 6 months of the date of determination, an Ecological Mitigation Strategy (EMS) shall be submitted to the MPA for their approval in writing. The EMS shall include the mitigation measures set out in Section 8.7 of the 2014 ES. The EMS shall thereafter be implemented as approved.

18. In addition to the measures to be included in the EMS, in order to minimise disturbance of habitats and interference with species, the development shall be carried out in accordance with the following requirements:

(i) Calcareous grasslands on the fringes of Cornelly and Pant Mawr Quarries, which would be unaffected by the development scheme, shall be fenced to prevent accidental incursion of vehicles and site personnel;

(ii) Areas of inaccessible high cliff shall be identified each year, and, subject to operational requirements shall be left undisturbed in order to encourage potential habitat for nesting peregrine falcons;

(iii) Any large trees or large crevices in undisturbed parts of the quarry shall be inspected for possible bat presence immediately ahead of any tree surgery or quarrying works. Any bats which are identified shall be dealt with in accordance with current legislation and best practice;

(iv) Clearance of trees and scrub should avoid the main bird nesting season (March to August inclusive);

(v) Common reptiles encountered during works should be allowed to leave the immediate works area unharmed, and, if necessary, should be assisted by means of capture and release;

(vi) Dense ruderal and grassland vegetation should be strimmed and raked away at least 24 hours ahead of earthworking, so as to reduce the attractiveness of the area for reptiles, and encourage them to leave;

(vii) Written protocols shall be issued to contractors so that in the event of discovery of bats, nesting birds, badgers or common reptiles, compliance with statutory obligations is ensured.

Landscaping

19. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the beating up and infilling the existing hedgerow alongside the southern boundary of the Cornelly ROMP area and western IDO area abutting Mount Pleasant Road. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

20. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the construction of a 2.0m high screening bund along the southern boundary of the western IDO area abutting Mount Pleasant Road. The scheme should include provision for the bund to be constructed with an outer gradient of no steeper than 1:2 (v/h) and grass seeded and planted with native trees and shrubs to provide a vegetated visual barrier to views. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

21. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the infilling, widening and strengthening of the hedgerow/woodland belt along the northern boundary of the eastern IDO area. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

22. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the infilling and strengthening of the woodland belt along the lower sections of the wooded northern flank of the western IDO area along the Heol y Splot corridor. The scheme shall include proposals for the timescale for implementation of the works, which shall thereafter be implemented in accordance with the approved scheme.

23. Within 6 months of the date of determination a scheme shall be submitted to the MPA for their approval in writing setting out proposals for the intermediate restoration of the upper faces/benches illustrated on plan ref numbers C112/097- C112/105. The restoration works shall thereafter be implemented in accordance with the approved scheme.

Noise

24. Except for temporary operations, the free-field Equivalent Continuous Noise Level, $L_{Aeq,1\ hour}$ due to operations in the eastern IDO area shall not exceed the relevant criterion limit specified in Schedule 1 at each nominated dwelling for the periods specified. Measurements taken to verify compliance shall have regard to the effects of extraneous noise and shall be corrected for any such effects.

Schedule 1 Noise Criteria Limits: Eastern IDO Area

Location	**07:00-19:00** **Criterion** dB $L_{Aeq, T}$	**06:00-07-00** **Criterion** dB $L_{Aeq, T}$	**19:00-22:00** **Criterion** dB $L_{Aeq, T}$	**22:00-06:00** **Criterion** dB $L_{Aeq, T}$
Rock Cottages in South Cornelly	50	42	48	42
Danygraig (Holiday Caravan Camp)	55	45	48	42
Grove Farm House, Grove	55	45	48	42
Sea View, Mount Pleasant Road	50	45	48	42
Manderlay, Stormy Down	55	48	48	42
Ballas Farm	55	48	48	42
Ty Tanglwyst Farm	55	48	48	42
Mount Pleasant Farm	53	45	48	42

25 Except for temporary operations, the free-field Equivalent Continuous Noise Level, $L_{Aeq,1\ hour}$ due to operations in the western IDO area shall not exceed the relevant criterion limit specified in Schedule 2 at each nominated dwelling for the periods specified. Measurements taken to verify compliance shall have regard to the effects of extraneous noise and shall be corrected for any such effects.

Schedule 2 Noise Criteria Limits: Western IDO Area

Location	07:00-19:00 Criterion dB $L_{Aeq, T}$
Rock Cottages in South Cornelly	55
Danygraig (Holiday Caravan Camp)	55
Grove Farm House, Grove	55
Sea View, Mount Pleasant Road	55
Manderlay, Stormy Down	55
Ballas Farm	55
Ty Tanglwyst Farm	55
Mount Pleasant Farm	53

.

26. For temporary operations such as site preparation, soil and overburden stripping, bund formation and removal and final restoration, the free-field noise level due to work at the nearest point to each dwelling shall not exceed 67 dB $L_{Aeq, 1 hour}$. Temporary operations shall not exceed a total of eight weeks in any calendar year for work close to any individual noise sensitive properties.

Blasting

27. Except with the written consent of the MPA, or in the case of emergency, blasting operations shall be carried out only between 1000 and 1700 hours Monday to Friday, and only in exceptional circumstances on Saturday and not at all on Sunday and Public/Bank Holidays.

28. Ground vibration as a result of blasting shall not exceed a peak particle velocity of $6mms^{-1}$ in 95% of all blasts measured over any six month period, and no individual blast shall exceed a peak particle velocity of $10mms^{-1}$ measured at any vibration sensitive location, which is defined as any residential property in the vicinity of the quarry existing at the Date of Determination. The measurements shall be the maximum of three perpendicular directions taken at the ground surface.

29. All individual blasts shall be designed, managed and implemented to minimise the extent of air overpressure resulting from blasts, having regard to blast design, methods of initiation of blasts, and also as far as practicable to weather conditions prevailing at the time of initiation.

30. Each individual blast shall be monitored by the Operators, to include provision for recording the details and location of the monitoring station; the location of the blast holes within the Site; weather conditions; specification of the blast in terms of MIC; and total charge weight. Blast monitoring is to be undertaken at the closest sensitive receptor to the blast location or at an alternative location that is requested by the Mineral Planning Authority. Records of blast monitoring shall be made available to the MPA upon request. Any complaints which are received shall be logged against each particular blast. In the event that monitoring indicates that the vibration levels set out in condition 28 above have been exceeded, then the Operator shall inform the MPA within two working days, with written confirmation of the steps to be taken to ensure compliance with condition 28.

31. Blasting times shall be clearly advertised at the Cornelly and Grove Quarries, and an audible warning shall be sounded prior to any blasting operations taking place, and shall be sounded again immediately after blasting has finished.

32. There shall be no secondary breakage of stone by the use of explosives.

Dust

33. At all times during the carrying out of operations, a water bowser or similar equipment shall be available within the IDO area, and be used to minimise the emission of dust from haul roads and access roads within the site, and the processing plant site hard-standings.

34. Measures shall be taken to minimise dust emissions from quarrying operations, in accordance with the following protocol:
    - Soils and overburden shall not be handled during extreme dry conditions unless the working areas are first dampened down;

- Drilling of shot holes shall be undertaken using drilling rigs fitted with a suitable dust collection system;
- Site roads within the quarry shall be dampened down as appropriate, in accordance with the requirement of condition 33;
- The site entrance road shall be maintained by use of a road sweeper which shall operate as required to maintain the surface of the road free of mud and other detritus.
- All lorries, once loaded, shall be sheeted prior to leaving the site, with the exception of any load carrying only plus 75mm diameter stone.
- The speed of haulage vehicles at the site will be restricted to 10mph.
- All site vehicles will be fitted with upswept exhausts and radiator fan shields.
- Lorries will be loaded so as to avoid spillages.
- All site traffic will be kept to the designated haul routes
- Any plant spillages will be cleared to avoid accumulations.
- Drop heights will be minimised at loading and discharge points.

Restoration

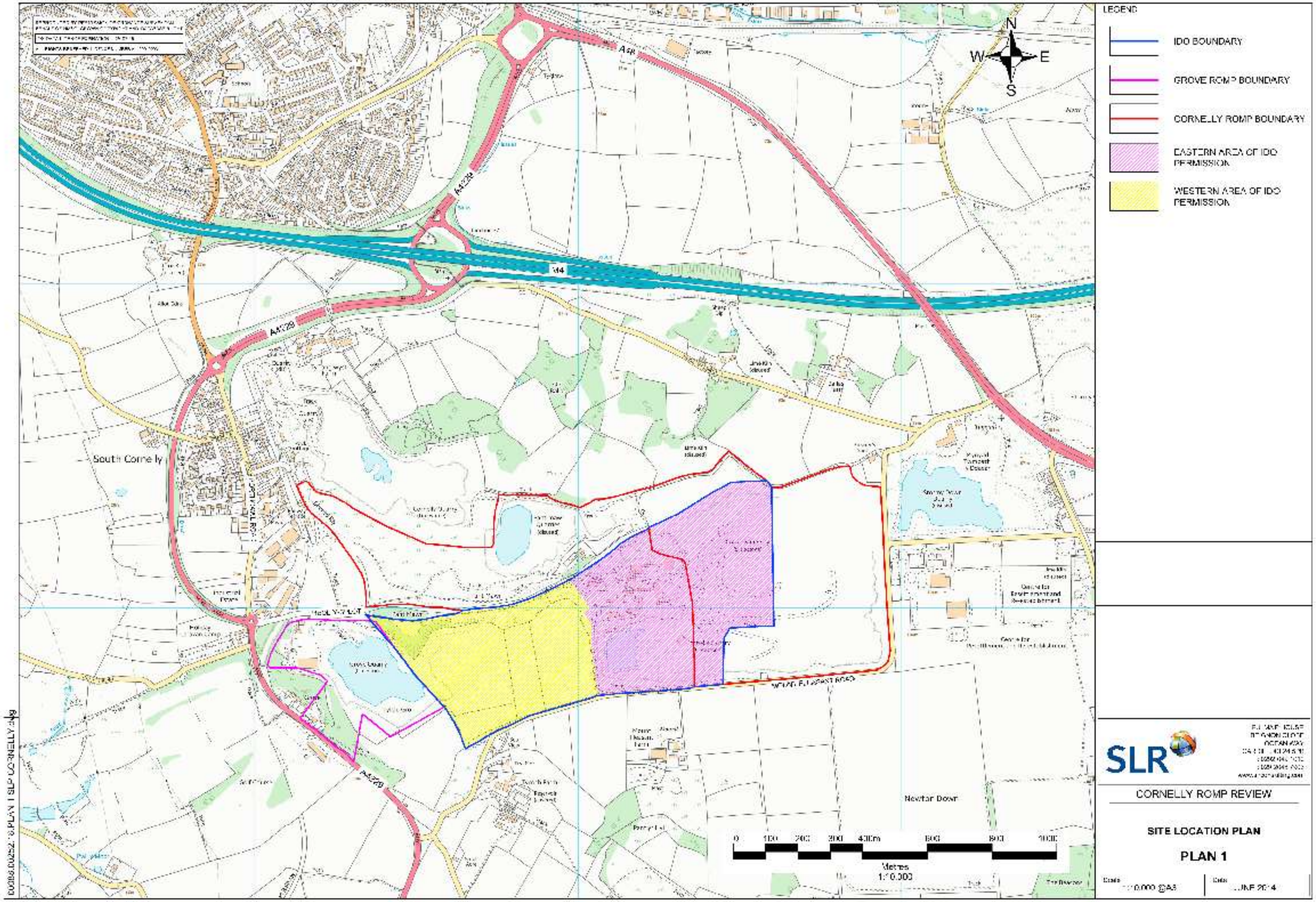
35 The development shall proceed in accordance with the concept restoration plan ref numbers C112/106 - C112/108 for the eastern IDO area and Cornelly ROMP area, and plans G057/020 - G057/021 for the western IDO area and Grove ROMP area, and the details of interim and final restoration treatments, landscaping, and aftercare, set out in Chapter 4.0 of the 2014 ES.

36. Not later than 31st December 2054, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed final restoration scheme, including drawings to illustrate the proposals for the final restoration of the quarry. The final restoration scheme shall be based upon the concept restoration plan ref numbers C112/106 - C112/108 for the eastern IDO area and plan ref numbers G057/020 - G057/021 for the western IDO area, and provide for the site to be restored as a nature conservation bias, with restoration treatment of the benches and faces above the water level

which will be formed in the void. The scheme shall include updated predictions of the final rest water level of the lake. The remainder of the site shall be cleared of all plant, machinery, buildings and structures in accordance with the requirements of Condition 3. The restoration scheme shall include details of the final re-profiling works for the site, the soil /soil forming material profiles to be established; tree and shrub planting schedules; seeding, fencing and drainage; and a programme and timetable for the implementation of the works.

37 Not later than 31st December 2054, or the expiry of six months following the permanent cessation of the winning and working of minerals, whichever is the sooner, the Operator shall submit for the written approval of the MPA, a detailed aftercare management plan. The management plan shall be in substantial accordance with the details of the final restoration scheme and the principles of the strategic aftercare management strategy set out in Chapter 4.0 of the 2014 ES.

ANNEX E – Plan 1 referred to in Definition of Terms in Annexes A, B and D for Cornelly and Grove Quarries


LEGEND
IDO BOUNDARY
GROVE ROMP BOUNDARY
CORNELLY ROMP BOUNDARY
EASTERN AREA OF IDO PERMISSION
WESTERN AREA OF IDO PERMISSION
N
S
E
W
M4
A48
A4229
South Cornelly
Newton Down
SLR
CORNELLY ROMP REVIEW
SITE LOCATION PLAN
PLAN 1
Metres
1:10,000
JUNE 2014

Appendix C

Environmental Impact Assessment (relevant sections)

CORNELLY QUARRY

ENVIRONMENT ACT ROMP REVIEW
ENVIRONMENTAL STATEMENT
VOLUME 1

June 2014

ENVIRONMENTAL STATEMENT

VOLUME 1

ENVIRONMENT ACT ROMP REVIEW:

CORNELLY QUARRY

Client: Lafarge Tarmac Ltd
Job no. 407.00088.00252
Document title: Environmental Statement Volume 1
Status: Final
Date: 16 06 14

Ref: ES

CONTENTS

CONTENTS

TABLES (within ES Volume 1)

CONTENTS

FIGURES (within ES Volume 1)

CONTENTS

APPENDICES (ES Volumes 2A – 2D)

APPLICATION PLANS (ES Volume 4)

CORNELLY

CONTENTS

1.0 INTRODUCTION

1.1 Preamble

Cornelly Quarry is a limestone quarry situated to the east of the village of South cornelly, some 0.5 km south of the M4 motorway, 2km south of Pyle, and some 2km north/northeast of Porthcawl. A plan illustrating the location of the quarry is produced as figure 1.01.

This Environmental Statement (ES) sets out the results of an Environmental Impact Assessment (EIA) of the effects of quarrying and related activities at Cornelly Quarry. The EIA has been undertaken in support of an exercise to update and modernise the planning conditions which control and regulate activities at the quarry (required by the Environment Act 1995). It does not relate to proposals to extend the quarry into areas which do not currently enjoy the benefit of planning permission: it merely considers the environmental effects of continuing the existing permitted quarrying activities, with the EIA and ES providing a context for the drafting of updated planning conditions.

1.2 Background

Cornelly Quarry has been in operation since the late 19th century. The formal planning history dates back to 1948 when the quarry was registered with an Interim Development Order (IDO) Permission. Since 1948 there have been 9 further planning permissions for the winning and working of limestone as easterly extensions to the original Cornelly Quarry. The boundaries of the original IDO permission and subsequent permissions are illustrated on figure 1.2, with the permissions listed in table 1.1.

Table 1-1 Cornelly Quarry Planning Permissions

Permission ref	Description	Date Granted
S516	Extension of Quarry	08.11.1949
S841	Quarry Extension	17.11.1949
S4533	Quarrying of Limestone	07.10.1952
S6695	Quarrying	07.05.1954
S8852	Quarrying	12.09.1955
S12315	Quarry Extension	09.05.1958
S14553	Diversion of Road	23.02.1960
S17471	Quarrying	06.07.1962
P19(Z1009)	Quarrying	17.03.1967
53/93/1350	Approval of IDO Conditions	21.09.1994

The IDO area straddles the boundary between Cornelly Quarry and Grove Quarry situated to the west. Grove Quarry also benefits from planning permissions for westerly extensions to the original IDO area granted in 1950 and 1956 (ref S30 and S10617). The Grove Quarry planning permission areas are also illustrated on figure 1.2, and are discussed further in this introductory chapter.

1.3 Legislative Requirements

1.3.1 Planning and Compensation Act 1991

The Planning and Compensation Act 1991 imposed a requirement that quarries which benefited from IDO permissions should be formally registered. They should then be the subject of a review to allow the original planning conditions to be updated and replaced with new modern conditions controlling future quarrying and restoration. This process was duly followed, and the Cornelly / Grove IDO permission was registered by the former Mid Glamorgan County Council in June 1992 (ref 53/92/0308).

On 21st September 1994, the former Mid Glamorgan County Council issued an updated schedule of planning conditions to apply to the permitted IDO area ("Decision Notice"). A copy of the Decision Notice (ref 53/93/1350) is produced as Appendix 1.1 (within ES Volume 2D).

The plan accompanying the Decision Notice (ref 53/93/1350/A) is produced as Figure 1.02. The plan reflected the historical and then current working practices whereby the original planning permission had been sub-divided into two discrete operational areas. The areas are depicted on the plan as a 'pink area' at Cornelly Quarry and a 'yellow area' at Grove. These areas are hereafter referred to in this ES as the Cornelly IDO area and the Grove IDO area.

The Decision Notice related to the full extent of the 'red line' IDO permitted area, and incorporated conditions which were relevant to the full area. This included requirements to submit schemes to provide details of the way in which the Quarry would be worked, and measures to control noise, blast vibration, dust, surface and groundwater, treatment of soils, woodland management and landscaping, and the general principles of restoration and aftercare. Separate conditions were imposed relating to the hours of working within the respective 'pink' and 'yellow' areas.

As noted above, at the time of issuing the Decision Notice, the permitted area was in two separate operational areas and land ownerships, with the eastern 'pink' area in the ownership of Wimpey Minerals Limited/ Cambrian Stone/ Corus Ltd, and the western 'yellow' area at Grove in the ownership of Pioneer Aggregates Ltd. Separate schemes were thus submitted by Wimpey Minerals and Pioneer Aggregates to discharge the conditions relating to their respective quarry areas.

The scheme associated with the Cornelly IDO area formed part of the wider Cornelly quarry operation, and similarly, the scheme submitted for the Grove IDO area formed part of the wider Grove quarry. The submitted schemes for the respective areas were not approved prior to the introduction of the related review requirements of the Environment Act 1995, and have been held in abeyance pending the determination of the Cornelly and Grove Environment Act 'ROMP applications' for the respective quarries, as discussed below.

1.3.2 Environment Act 1995

Periodic Reviews

The Environment Act 1995 introduced a process of Periodic Reviews of mineral permissions at 15 year intervals. This is designed to ensure that planning conditions imposed as part of an Initial Review do not become outdated with the passage of time, and to more generally ensure that conditions reflect up to date standards and requirements. The required 15 year Periodic Review application to update the September 1994 IDO Initial Review was duly submitted in September 2009. The application remains undetermined, as discussed below.

ROMP Reviews

The registration and updating of IDO permissions, required by the Planning and Compensation Act 1991, represented the first stage in the review and updating of historical mining permissions. The Environment Act 1995 introduced a procedure of reviewing planning permissions granted after 1948, with a phased approach of requiring reviews of permissions granted between June 1948 and April 1969 as 'Phase 1', followed by a review of permissions granted between April 1969 and February 1982 as 'Phase 2'. All permissions are then to be the subject of reviews at 15 year intervals. This process of a 'Review of Old Mining Permissions' is commonly referred to by the term 'ROMP Review'.

In addition to the original IDO permission, Cornelly Quarry benefits from a series of planning permissions for extensions to the original permitted area, granted between 1949 and 1967. These permissions are illustrated on Figure 1.2 and are listed in table 1.1. Grove Quarry also benefits from additional planning permissions for extensions granted in 1950 and 1956. These additional permitted quarrying areas at Grove are also illustrated on Figure 1.2.

As a result, in addition to the IDO Review procedures, both quarries became subject to the parallel ROMP Review requirements relating to those areas of the quarry covered by permissions granted subsequent to the original IDO permission. ROMP applications were duly submitted to Bridgend County Borough Council (BCBC) in June 1997 by Cambrian Stone (Tarmac) in relation to Cornelly Quarry, and by Pioneer Aggregates in relation to Grove Quarry. Both applications were accompanied by statements in support of the application, and schedules of proposed updated planning conditions relating to the respective quarries.

1.3.3 'Call in' of ROMP Applications

Discussions were held between the quarry operators and the Planning Authority, BCBC relating to the content of the proposed conditions but, prior to a conclusion of those discussions and the determination of the applications, they were formally 'called-in' by the Welsh Office (now Welsh Government [WG]) for their determination (letters from the Welsh Office dated 29th July 1998 and 13th August 1998). A ROMP application relating to the nearby Gaens Quarry operated by TS Rees Ltd was also 'called-in' by the Welsh Office (letter dated 14th May 1998).

1.3.4 Voluntary ES's

On 13th August 2000 the National Assembly for Wales (now WG) requested the Applicants (Cambrian Stone (a Lafarge Tarmac Compan) re Cornelly; Hanson Aggregates re Grove (following their acquisition of Grove Quarry); and TS Rees Ltd re Gaens Quarry to voluntarily undertake an EIA in support of the ROMP applications, on the basis of their view that the "the "*development would be likely to have significant effects on the environment, because of its nature, size and location, having regard, in particular and inter alia, to the following points:*

(a) the potential impact of quarrying on Kenfig Pool and Dunes SSSI a site of European importance being a candidate Special Area of Conservation;

(b) the potential impact of quarrying on the hydrology and hydrogeology of the area;

(c) the likely impact from further quarrying of the migration of leachate and landfill gas;

(d) the likely effect on the visual amenities of the area;

(e) the likely impact on flora and fauna in the locality;

(f) the scale of traffic likely to be generated and the likely effect on the environment;

(g) the likely impact of noise from sources associated with the development and its likely effects on the local population;

(h) the likely impact on ground and air vibration on nearby properties and utilities including the reservoir at Ty Coch,and local residents;

(i) the likely effects of dust levels on the local population, flora and fauna;

(j) the likely environmental effects of the closure of Heol y Splot;

(k) the likely effects of quarrying on the archaeological value of the site;

(l) the likely implications of quarrying on the stability of surrounding land."

Tarmac confirmed their willingness to cooperate with that request in relation to the Cornelly ROMP application (letter dated 2nd September 2000). In November 2000, Tarmac acquired Grove Quarry from Hanson following which Tarmac confirmed that they would also be willing to cooperate with undertaking an EIA in support of the Grove ROMP application. Tarmac further confirmed that the Grove EIA would be undertaken in parallel with the similar EIA to be undertaken for the ROMP Review at Cornelly Quarry.

Following further discussions with representatives of the Assembly, it was apparent that the key element of the EIAs related to the hydrological/hydrogeological implications of quarrying in the Cornelly area, both as individual quarries (including the nearby Gaens Quarry, in separate ownership), and cumulatively. The Applicants therefore concluded that they should concentrate on the hydrological/hydrogeological aspects of the EIA as a first phase, and to then address the remaining environmental topics as a second phase. All matters would then be brought together as part of the ESs. The Applicants further concluded that they should initially concentrate on the hydrogeological implications of developments at Cornelly Quarry in view of the size and proposed working depth of that quarry. The approach to an environmental impact assessment for Cornelly Quarry could then be applied to an impact assessment for Grove Quarry (and Gaens Quarry).

An ES in support of the Cornelly Quarry ROMP application was submitted to the Assembly on 13th August 2004 accompanied by a detailed hydrogeological assessment and a Water Management Plan (WMP) designed to regulate water discharge. The ES was accompanied by a schedule of further updated planning conditions which had been informed by the results of the EIA and ES.

Following the submission of the ES, additional information was requested by the Environment Agency (EA) and Countryside Council for Wales (CCW) relating to the hydrogeological effects of the development, and the originally submitted WMP. Extensive discussions were then held with the EA and CCW, and further hydrogeological studies were undertaken. This culminated in the preparation of an updated WMP, which was submitted to the Assembly on 19th September 2007. Copies were also circulated to interested parties, including the EA and CCW.

An ES in support of the Grove Quarry ROMP application was submitted to the Assembly in February 2008. The EIA was undertaken as a separate study which considered the specific environmental issues relating to Grove Quarry, but which drew upon the wider hydrogeological impact assessment and WMP plan which had been prepared for Cornelly Quarry (ref updated WMP September 2007). This sought to ensure a common approach to hydrological and hydrgeological issues.

Discussions on the content of the Cornelly es (2004) and Grove ES (2008), and in particular the hydrogeological issues and WMP continued throughout 2008 and 2009, and a substantial measure of agreement emerged regarding the technical matters. However, prior to the final resolution of the outstanding matters, the WG introduced new regulations relating to ROMP applications which, for varying reasons, had become "stalled", with the regulations designed to bring closue to the respective reviews. Whilst the Cornelly and Grove applications were not "stalled" in the way defined (given the voluntary ESs which had been submitted and substantial progress which had been made towards determination) they were nevertheless embraced by the requirements of the new regulations.

1.3.5 Stalled ROMP EIA Regulations 2009

The Regulations introduce an express requirement for EIAs to be undertaken in relation to 'stalled reviews', where such EIAs and ESs would update and replace any voluntary ES's which had been submitted. The Regulations also introduce a formal timetable for the completion and submission of the formal ESs which is designed to bring closure to the 'stalled' process.

The requirements are set out in The Town and Country Planning (Environmental Impact Assessment) (Undetermined Reviews of Old Mineral Permissions) (Wales) Regulations 2009/3342, which came into force on 8th January 2010, referred to as the Stalled ROMP EIA Regulations 2009.

The Stalled ROMP EIA Regulations 2009 set out a procedure and series of steps which must be followed, which include:

- the ability for Planning Authorities or the Welsh Ministers to request information from Applicants on the development to be undertaken (step1);
- the issuing of a 'scoping opinion' / 'scoping direction' by the Planning Authority or the Welsh Ministers confirming the issues which should be addressed as part of the EIA (step 2);
- the setting of a timescale for the completion of a draft ES (step 2.2);
- the undertaking of a pre-consultation check of the draft ES to ensure that it is satisfactory in terms of presentation and content (step 3);
- either requests for a revision to the ES or, if the ES is deemed to be acceptable in terms of presentation and content, progress to a public consultation stage (step 4);
- public consultation can be associated with requests for the provision of further information (steps 5 and 6); and
- ultimately the determination of the application and the issuing of the final schedule of updated conditions (step 7).

The preparation and submission of this draft ES represents 'Step 3'. The draft ES is to be the subject of a pre-consultation check by the Welsh Ministers to ensure that it is presented in an appropriate form and that it contains the information required by the Scoping Direction prior to formal public consultation.

1.4 The Scope of the EIA

The Stalled ROMP EIA Regulations 2009 require the WG, in cases which have been called in by the Welsh Ministers, to issue a "Scoping Direction" setting out the issues which should be addressed as part of an EIA, and confirming the timescale in which the EIA should be undertaking and a draft ES submitted (Regulation 14 – step 2). In order to assist this exercise, the WG requested confirmation from the Applicants of the environmental information which was presently available, noting the 2004 voluntary ES and related post submission discussions and information. WG also sought advice from the Environment Agency and CCW (now Natural Resources Wales [NRW]) on information which is available, and issues which they considered should be included within the Scoping Direction. In order to further assist the process, the WG issued a draft Scoping Direction for comment by the Applicants and regulatory bodies. Following receipt of the consultation responses, a formal Scoping Direction was issued on 4th March 2013. A copy of the Scoping Direction is produced as Appendix 1.2 to the ES (within ES Volume 2D).

Scoping Directions of the same date (4th September 2013) have been issued in similar terms in relation to the Grove and Gaens ROMP applications. In addition, and to ensure consistency, the WG have issued a formal request for additional information to be submitted in support of the September 2009 Cornelly/Grove IDO Periodic Review application which remains undetermined (reference Regulation 19 of theTown and Country Planning (Environmental Impact Assement)(England and Wales) Regulations 1999/293 ("EIA Regulations 1999")). The requested information seeks to ensure consistency with the required content of the Cornelly and Grove ROMP Review ESs. It has been agreed with the WG that, again for consistency purposes, a new IDO Periodic Review ES will be produced in a similar format to the new Cornelly and Grove ROMP ESs, rather than rely upon additional information to support to the 2009 ES. Correspondence to this effect is produced as Appendix 1.3 (ES Volume 2D).

The Scoping Directions (and Regulation 19 request relating to the IDO Periodic Review application) set out specific requirements under a series of environmental and amenity headings. The Stalled ROMP EIA Regulations 2009 require the Welsh Ministers to "*check whether the content and extent of the information included in the draft Environment Statement appears to be consistent with the relevant Scoping Direction*" (reference Regulation 18 (5). The Applicants have ensured that each issue is fully addressed as part of the EIA and this ES and, for ease of reference, a detailed table has been prepared which identifies the issues raised in the Scoping Direction, the way in which the issues have been addressed as part of the EIA, and the reference within the ES (reference table 1.2).

1.5 The Cornelly Group of Quarries ES's

The Cornelly Group of Quarries comprises Cornelly Quarry, Grove Quarry, and Gaens Quarry. The respective ROMP and IDO applications for the quarries will be supported by separate updated EIAs and new ESs as follows:

(i) Cornelly Quarry ROMP Review ES 2014, which will replace the 2004 voluntary ES;
(ii) Grove Quarry ROMP Review ES 2014, which will replace the 2008 voluntary ES;
(iii) Cornelly/Grove IDO Periodic Review ES 2014 which will replace the 2009 ES; and
(iv) Gaens Quarry ROMP Review ES 2014 (to be separately prepared and submitted on behalf of TS Rees Ltd.

The approach to undertaking EIA's and preparing ES's in support of the respective applications has recognised the inter-relationships between the quarries in terms of historical planning permission boundaries, and the potential cumulative/in-combination environmental effects arising from the concurrent operation of the quarries. In particular, the scope of the assessments has recognised that it would be inappropriate and artificial to attempt to isolate individual IDO and ROMP permitted areas from the overall quarries, particularly in the context of the need for EIA's to consider the totality of a project. In terms of Cornelly Quarry, the boundaries of the planning permission area illustrated on figure 1.2 confirm that:

(i) The boundaries of the areas covered by the ROMP Review overlap with the eastern area of the Cornelly/Grove IDO permission: and

(ii) The processing plant and access to Cornelly Quarry which are relied upon for processing and distributing reserves from the ROMP area lie outside the ROMP area, within the eastern part of the IDO permitted area.

This reinforces the need to consider the quarry development projects as a comprehensive exercise. The approach to the respective EIA's and content of the ES's is thus as follows:

(i) The Cornelly Quarry ROMP ES considers the environmental effects of the full extent of the Cornelly Quarry development area, comprising the ROMP permitted areas in the eastern part of the quarry; the operations in the northern Pant Mawr area; and the associated quarrying, processing and ancillary operations in the Cornelly part of the IDO permitted area. It also considers the cumulative/in-combination effects of operating Cornelly Quarry in conjunction with Gaens Quarry (as at present), and in conjunction with a resumption of operations at the currently mothballed Grove Quarry.

(ii) The Grove Quarry ROMP ES considers the effects of quarrying and processing operations within the Grove ROMP area, when activities resume at the currently mothballed quarry, but also an extension of the ROMP area eastwards into the permitted Grove IDO area. It also considers the cumulative/in-combination effects of operating Grove Quarry in conjunction with Cornelly Quarry and Gaens Quarry.

(iii) The Cornelly/Grove IDO Periodic Review ES considers the effects of the full quarry development schemes at both Cornelly and Grove quarries, given that the Cornelly part of the IDO permission forms an integral component of the operations at Cornelly Quarry, and the Grove part of the IDO permission will be worked in conjunction with the Grove ROMP area, as an extension to it. The EIA also considers the cumulative/in-combination effects of operating Cornelly and Grove quarries in conjunction with Gaens quarry.

(iv) The Gaens Quarry ROMP ES considers the effects of the quarrying and processing operations at Gaens, but also the cumulative/in-combination effects of operating Gaens quarry in conjunction with Cornelly and Grove quarries.

One final consequence of the delay in determining the ROMP Review applications is that the schemes of working submitted by Pioneer and Tarmac in relation to the discharge of conditions imposed on the original 1994 IDO Initial Review have been held in abeyance, pending the determination of the ROMP Review application. However, in practical terms, the requirements to discharge conditions imposed on the 1994 IDO First Review have been overtaken by events via the preparation and submission of updated quarry development schemes set out in the respective ES's, and, in particular, via the 2009 IDO Periodic Review application, and the updated IDO 2014 ES, which now forms part of the overall package of proposals.

1.6 The EIA and ES

1.6.1 Context

It is apparent from the nature of a review of planning conditions that planning permission for quarrying at Cornelly already exists. The principle of quarrying is therefore not an issue for reconsideration as part of the Review, unless the environmental effects are deemed to be of such significance that the existing planning permissions should be formally modified or revoked. If that were to occur then compensation would be payable to the Applicants for the loss of the mineral asset.

1.6.2 Purpose of the ES

In this context, the primary purpose of the ES is to assist in identifying environmental effects, and to use that information to (i) devise measures to minimise the environmental effects through an updated design of the quarry development scheme and / or via specific mitigation/ attenuation measures; and (ii) provide for the measures to be enshrined in up to date planning conditions which regulate ongoing quarrying in a way which is reflective of the EIA.

1.6.3 Technical Studies

The content of the EIA and respective technical studies has been informed by the Scoping Direction referred to in section 1.4 above. In order to address the topics, the Applicant has commissioned a number of specialist consultants to deal with the identified issues, namely:

- Landscape and Visual Impact and Restoration Design – Pleydell Smithyman;
- Hydrology and Hydrogeology – ESI Ltd;
- Ecology – Atmos Consulting Ltd;
- Noise – WBM;
- Blast Vibration – Vibrock;
- Air Quality - SLR Consulting Ltd.
- Traffic – Hurlstone Partnership;
- Cultural Heritage – Andrew Josephs Associates

In addition, technical inputs on geology, phased quarry development, working practices and operational mitigation measures have been prepared by in-house expertise available to the Applicant.

The EIA and preparation of the ES has been coordinated by SLR Consulting. SLR is a member of the Institute of Environmental Assessment and Management with an awarded 'Quality Mark', and has specialist capability in mineral planning.

1.7 Format of the ES

The ES has been prepared to fulfil the requirements set out in the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 regarding the content of environmental statements (Schedule 4). However, more specifically in the context of the ROMP Review application, the ES has been prepared to adhere to the advice set out in the 'Guidance on Regulations Applying Environmental Impact Assessment to Stalled Reviews of Conditions attached to Old

Mineral Planning Permissions in Wales (2009)', issued by WG to accompany the 2009 'Stalled ROMP Regulations'.

Paragraph 197 of the Guidance Note lists the main characteristics of an ES which should:

(a) Provide a clear structure;

(b) Include a table of contents;

(c) Describe the way in which the EIA fits into the procedural requirements;

(d) Read as a single document;

(e) Be concise, comprehensive and objective;

(f) Be written in an impartial manner;

(g) Include a full description of the development proposals;

(h) Make use of illustrations, photographs and other graphics to support the text;

(i) Use consistent terminology, with a glossary;

(j) Reference information sources;

(k) Have a clear explanation of complex issues;

(l) Contain a good description of the methods used for the study of each environmental topic;

(m) Cover each environmental topic in a way which is proportionate to its importance;

(n) Provide evidence of good consultation (if any);

(o) Include a discussion of alternatives;

(p) Make a commitment to mitigation and monitoring; and

(q) Has a non technical summary which does not contain technical jargon.

The ES has been prepared to reflect these requirements. It has a clear structure (discussed below), and reads as a concise single document (d and e). It is sub-divided into a number of sections and Chapters, namely:

1.0 **Introduction** which sets out the background of the preparation of the ES, the procedural requirements, and the underlying purpose of the Review of planning conditions.

Part I: Baseline Studies.

2.0 **The site and its surroundings**, which provides a summary baseline description of the site drawn from the more detailed consideration of the baseline set out in the individual technical assessment chapters.

Part II: The Quarry Development Scheme

3.0 **The quarry development**, which describes the details of the updated phased quarry development scheme and the alternatives which have been considered (items g and o).

4.0 **The Restoration Strategy**, which provides a description of the concept for the restoration of the overall site upon cessation of quarrying.

Part III: Environmental Effects

5.0 - 13.0 **Environmental effects and mitigation measures**, which describes, in detail, the likely significant effects of the development under the sub-headings of landscape/visual effects; hydrology / hydrogeology; ecology; noise; blast vibration; air quality; traffic; and cultural heritage, which fully reflect the content of the Scoping Direction (items k, l, m, n, and p).

Part IV: Planning Policy

14.0 **Planning Policy considerations**, which analyses the planning policy issues against which the development can be considered, and which provides a further context for the drafting of planning conditions.

Part V: Summary and Conclusions

15.0 **Summary of Environmental Issues**, which draws upon the content of preceding chapters in identifying issues which require control via planning conditions, and which cross refers to an updated schedule of conditions prepared by the Applicant (item p).

16.0 **Conclusions and Planning conditions**, which provides a general overview of the EIA, and the schedule of updated planning conditions produced as Annex1 to the ES. Chapter 16.0 also includes a glossary of technical terms used in the ES.

1.8 Submitted Documents

The ES seeks to provide an objective account of the likely significant effects of the overall proposed development (item f above). The aims of the statement are to:

- Describe the baseline conditions at the site against which changes and effects can be assessed.
- Describe the details of the respective elements of the overall scheme.
- Consider the potential environmental effects of the development.
- Describe the measures which are available to mitigate those effects.
- Assess the likely effectiveness of the mitigation measures.
- Draw conclusions which will assist in the drafting of up-to-date planning conditions controlling the ongoing operations at the quarry.

The ES (Volume 1) draws together the inputs from the specialist technical consultants who have undertaken the EIA, and cross-refers to a number of background documents and technical appendices prepared by the consultant team, which have been bound into ES Volumes 2A – 2D.

The ES reproduces a series of figures which have been prepared by the EIA project team as part of their inputs into the ES. These are reproduced within the respective chapters of the ES and follow the chapter numbering sequence of the ES, such that, for example, figures within Chapter 1.0 are numbered 1.1 – 1.2 etc. A full list of figures is provided within the contents schedule of the ES (items b and h of 1.7 above). The figures which have been produced in support of the Landscape and Visual Impact Assessment are produced within Volume 4 of the overall submission. These have been numbered as Figures 1 - 9 inclusive, and are also listed within the contents schedule of the ES.

A Non-Technical Summary of the ES has been prepared as a separate document (Volume 3) as a means of enabling the findings and conclusions of the ES to be more readily understood (item q of 1.7 above).

Finally, the quarry development and restoration plans are produced within Volume 4, and represent the development which has formed the subject of the EIA (item g of 1.5 above).

1.9 Planning Conditions

The purpose of the Review is to formulate a schedule of updated planning conditions which reflect modern standards and controls, and which provide (i) detailed controls over on-going operations for the 15 year Review period; and (ii) a context for subsequent Periodic Reviews by confirming the longer term intentions for the development of the quarry, and the final restoration strategy (ref Environment Act 1995).

The ROMP Review procedure place the initial onus on the Applicants to propose an updated schedule of planning conditions. A schedule of proposed planning conditions was duly submitted in 1997 with the original Cornelly Quarry ROMP application. The schedule was updated in 2004 at the time of submission of the voluntary ES, where the updated conditions were informed by the recommendations and conclusions of the 2004 ES. The schedule of conditions has been further updated, partly to reflect the 10 year passage of time berween 2004 and 2014, but also, consistent with the principles of the 2004 schedule, to reflect the recommendation of the updated 2014 ES regarding mitigation measures, and the way in which those mitigation measures can be translated into planning conditions.

The ES also includes a review of planning policy, noting that there have been substantial changes since the original application in 1997, and the analysis of planning policy set out in the voluntary 2004 ES. Particular reference has been paid to the way in which planning policy and advice can inform the drafting of up to date planning conditions.

The Welsh Ministers in relation to called in applications, are not obliged to accept the planning conditions proposed by the Applicant, and they are entitled to impose different conditions or additional conditions. However, where the Welsh Ministers determine conditions different from those submitted by the Applicant and the effect of the new conditions, other than restoration or aftercare, as compared with the effect of the exisitng conditions is to impose a restriction on working rights, then Applicants whose interests have been adversly effected by the restrictions will be entitled to claim compensation (reference Schedule 13, Paragraph 15 of the Environment Act 1995).

The updated conditions proposed by the Applicant are produced as Annex 1 to the ES, and the rationale behind the conditions is summarised in Chapter 15.0 of the ES. The updated conditions are considered to represent a positive and constructive approach to devising an environmental sensitive operation and to regulating the devleopment by modern, up to date planning controls. In those terms, as was the case with the 2004 ES, the exercise associated with the EIA has been of positive value in preparing specific conditions which reflect the conclusions and recommendations of the EIA.

Table 1.2 Scoping Compliance Schedule

SCOPING ISSUE	RESPONSE	ES REFERENCE
Description of Cornelly Quarry		
Description of the site as existing, with particular reference to topography and landscape, geology, exsiting nature conservation resources, and designations in the wider area (ref para 4)	Summary description set out in Chapter 2.0 with detailed descriptions of the baseline sections in the baseline sections of the topic chapters	Application site description – Chapter 2.0 Topography and Landscape Baseline – Section 6.4 Geology – Section 7.4 Nature Conservation resources and designations– Section 8.5
Description of Quarry Development Scheme		
Layout of the proposed operations, existing plant, phasing and rate of extraction, and direction of quarry workings based upon up to date topographic survey (ref para 5)	Description of quarry development scheme set out in Chapter 3.0, with quarry development plans produced within Volume 4, including up to date topographic survey plan ref C112/-04	Quarry development scheme described in section 3.3, with confirmation of anticipated rate of extraction. Processing plant described in section 3.5
Geology		
Superficial, bedrock and structural setting of the site in a sub regional and local context, based upon previous investigations and data (ref para 6).	Description of the regional geology (solid and superficial) and local geology set out in Chapter 7.0 and supporting Appendix 7.1	ES Section 7.4.2 provides a summary of the regional geology, local geology and structure. Detailed geological description provided in Appendix 7.1 of ES Volume 2A.
Hydrology / Hydrogeology		
Updated and refined conceptual model to underpin assessment of potentail impac on Kenfig and Cefn Cribwr Grasslands SAC and Swansea Southern Carboniferous Limestone grioundwater (Water Framework Directive) body (re para 7).	Conceptual model has been updated in the light of consultation with NRW (and previously EA and CCW) and the large amount of data collected and studies undertaken since the development of the original 2003 conceptual model (ESI, 2003b)	Updated and refined conceptual model summarised in section 7.4.5, and produced in full as Appendix 7.1 within ES Volume 2A.
Specific issues to be addressed are:	All potential hydrological and hydrogeological issues addressed in ES Chapter 7.0 and supporting Appendixes 7.1 – 7.5 produced within	

(i) Potential impact on the Kenfig and Cefn Cribwr Grasslands SAC / SSSI; (ii) Potential impact on the hydrology and hydrogeology of the area including the possibility of intercepting a 'highly permeable feature'; (iii) Potential impacts on the Kenfig SAC and the hydrology of the dune system and Kenfig Pool, including the nature of the hydraulic connection between the dune sands and the underlying sand and gravel aquifer at Kenfig; (iv) Potential impacts on other groundwater users and water features in the area; (v) Potential for quarry dewatering to introduce saline intrusion into the aquifer; (vi) Likely impact from further quarrying on the migration of leachate and landfill gas; (vii) Likely impact of quarrying on the stability of adjoining land; and (viii) Evaluation of the potential surface lowering and sinkhole collapse (ref para 8).	ES Volumes 2A – 2C. Potential indirect hydrogeological effects on the Kenfig SAC provide a context for the assessment of potential indirect ecological effects, addressed in ES Chapter 8.0	(i) ES sections 7.6.2; 7.7.2;and 7.8.2 re Kenfig SAC, and 7.5.1 and Appendix 7.1 (2.4.2) re Cefn Cribwr SAC (ii) Possibility of intercepting a 'highly permeable feature' discussed in ES sections 7.5.2 and 7.6.5 (iii) Hydraulic connection discussed in section 7.4.6, and detailed in appendices 7.1 and 7.3 (iv) Other groundwater receptors discussed in sections 7.6.1, 7.6.3 (Cornelly) 7.7.1, 7.7.3,(confirmed quarry impacts) and (7.8.1 and 7.8.3 (restoration) (v) Saline intrusion discussed in sections 7.6.4 (Cornelly), 7.7.4 (combined quarry impacts) and 7.8.4 (restoration) (vi) Leachate migration discussed in sections 7.6.4 (Cornelly), 7.7.4 (combined quarry impacts) and 7.8.4 (restoration) (vii) Stability discussed in sections 7.6.4 (Cornelly), 7.7.4 (combined quarry impacts) and 7.8.4 (restoration) (viii) Sinkhole / stability discussed in sections 7.6.4 (Cornelly), 7.7.4 (combined quarry impacts) and 7.8.4 (restoration)
ES should include a refinement of the Water Managament Plan, with a description of water management measures linked to proposed works and quarry decomissioning, with a monitoring residual programme and a description of any actions to be taken to prevent and / or reverse any impacts (ref para 9).	Refined Water Management Plan (WMP) produced as Appendix 7.6 (ES Volume 2C) and discussed in ES section 7.10, which includes description of water management disposal options and contingency measures.	ES section 7.10 and Appendix 7.6 of ES Volume 2C.

In relation to future quarry development, potential effects to be considered include: • Effects on groundwater levels and flows and loss of groundwater resources; • Derogtion of groundwater abstraction wells and boreholes; • Impact on surface watercourses and wetlands; • Saline intrusion caused by changes in groundwaer flow paths; • Subsidence and settlements caused by falling groundwater levels; • Water flows and proposed discharge points; and Limit and duration of an impacts (ref para 10).	All effects considered, and categorised as: a. General effects on groundwater levels and flows; b. Potential effects on water levels at Kenfig SAC/SSSI's; c. Potential effects on water levels and flows at other potentially vulnerable receptors; and d. Other potential effects on water quality and settlement	Effects assessed in section 7.6 (Cornelly quarry only); 7.7 (combined quarry development); and 7.8 (restoration).
Ecology / Biodiversity		
Potential indirect impacts of operation on Kenfig SAC, including impacts in combination with Grove and Gaens Quarries (ref para 11).	Potential indirect impacts on Kenfig SAC considered with reference to qualifying features of the SAC; the conservation objectives; potential effects at Kenfig Dunes and Merthyr Mawr during quarrying (combined operations) and at restoration.	ES Section 8.6.5 and Appendix 8.3 (ES Volume 2D) which comprises a 'Shadow Appropriate Assessment'
Potential indirect impacts on the hydrology of Cefn Cribwr Grasslands SAC (ref para 12).	Cefn Cribwr grasslands SAC not dependant on groundwater systems affected by dewatering at Cornelly, Grove and Gaens.	ES section 7.5.1 and 8.6.5, and Appendix 7.1 (section 2.4.2)
Presence of any protected species and extent to which they may be affected, based upon updated surveys (ref para 13).	Ecological study updates previous studies undertaken in 2003 and 2008/2009, with new surveys undertaken in 2013/2014	Survey findings set out in section 8.2.4; evaluation in 8.5.4; and impact assessment in 8.6.8

Likely significant effects and necessary mitigation on: • Non statutory nature coneservation sites / SINC's • UK and Bridgend BAP habitats and species; • CROW Act and NERC Act species (ref para 14).	Full references to statutory and non statutory designated nature conservation sites, protected habitats and species included as part of the ecological assessment, with consideration of potential effects and recommendations for mitigation measures.	ES sections 8.4; (legal considerations); 8.5 (evaluation); 8.6 (impact assessment) and 8.7 (mitigation measures)
Blasting		
Blast vibration assessment having regard to advice in MTAN1, proximity of nearby properties sensitive to vibration, baseline data and mitigation measures (ref para 15).	Detailed blast vibration assessment undertaken, noting the advice in MTAN1 and other guidance; the nearby blast vibration sensitive properties ; baseline data derived from ongoing monitoring and a specific production blast, and recommendations for planning conditions.	ES Chapter 10.0
Air Quality / Dust		
Dust assessment having regard to the advice in MTAN1, with cross references to other dust and emmission controls which are in place. Assessment to set out baseline data and identify mitigation measures (ref para 16).	Air quality assessment refers to the advice in MTAN1; the controls in place via the Environmental Permit; baseline data derived from monitoring and other sources, and recommendations for mitigation measures.	ES Chapter 11.0
ES should refer to detailed controls set out in the PPC Permit, and any additional dust control measures which should be imposed as conditions. Assessment should include cumulative impacts (ref para 17).	Cross reference made to the Environmental Permit (ref no. 071/02) and the detailed controls which are in place. General additional 'dust control protocol' suggested as an additional condition.	ES Chapter 11.0; sections 11.10 (Permit); 11.14 (planning conditions); and 11.10 (cumulative impacts)
Noise		
Noise assessment to be carried out in accordance with the advice in MTAN1, and should identify mitigation measures.	Noise assessment undertaken in accordance with MTAN1, but also drawing upon advice in TAN11 and general comments in MPG11 and NPPF	ES Chapter 9.0

	(England). No specific mitigation measures deemed to be required.	
Background L90 noise levels to be established, and assessment should identify noise limits for daytime, night-time and other appropriate periods, and identify any mitigation measures which may be necessary to comply with the noise limits (ref para 19).	Background noise levels established from updated surveys undertaken in November 2013. Noise limits suggested for day time, night time and early morning/evening periods. Ongoing development able to comply with noise limits set for the defined periods without additional mitigation measures.	ES sections 9.4.1 and 9.4.2 (existing noise levels); 9.5 (site noise limits) and 9.6 (calculated site noise levels and noise mitigation)
Landscape and Visual		
Targeted and proportional assessment to describe and analyse visual and landscape effects of current and proposed operations; effects of longer term restoration; and identification of mitigation measures.	Detailed LVIA undertaken in accordance with *Guidance for Landscape and Visual Assessment : 3rd Edition*	ES Chapter 6.0
Transport		
Description of future traffic movements and impact on local road network, proposals for traffic management and other mitigation measures. Assessment should identify traffic flows on A4229 and component of HGV traffic associated with Cornelly Quarry (ref para 21).	Traffic study describes the existing highway infrastructure, traffic flows based on a classified turning count on A4229/Smokey Cottage roundabout on 22nd October 2013; highway safety; highway capacity and impacts and mitigation measures.	ES Chapter 12.0
Restoration		
Assessment of restoration proposals for the site, prposed after uses, progressve restoration, and proposals for integration intothe surrounding land. Consideration to be given to restoration in combination with Grove and Gaens Quarries (ref para 22).	Restoration strategy set out in ES Chapter 4.0, with the concept restoration scheme for Cornelly shown on plans C112.106-108 within Volume 4. The plans show the restoration scheme for Cornelly in conjunction with the restoration schemes for Grove and Gaens Quarries.	ES Chapter 4.0 and plans C112/106-108 (Volume 4)

Alternatives		
Detailed consideration of alternatives not appropriate for Review application, but consideration of alternative development options should be assessed.	Brief overview of alternatives set out in ES Chapter 3.0, reflecting the requirements of the Scoping Direction.	ES Section 3.9
Cumulative Impact		
Cumulative impact of the hydrogeological, visual, landscape, environmental, ecological and biodiversity effects of the operation and restoration of Cornelly in combination with Grove and Gaens Quarries, including combined effects of restoration (para 24).	Cumulative effects of the development at Cornelly Quarry, in conjunction with a resumption of operations at Grove, and a continuation of operating at Gaens addressed in all ES Technical Chapters	LVIA - section 6.8 Hydrogeology - sections 7.7 and 7.8 Ecology – section 8.9 Noise – section 9.7.1 Blast Vibration – section 10.11 Air Quality – section 11.12 Transportation – section 12.8 Cultural Heritage – section 13.11
Difficulties in compiling information		
Any difficulties in compiling the required information should be stated in the ES (ref para 25).	Difficulties in compiling the required information/survey limitations are identified where appropriate. This has only applied to certain ecological survey limitations	

Figure 1-1 Site Location

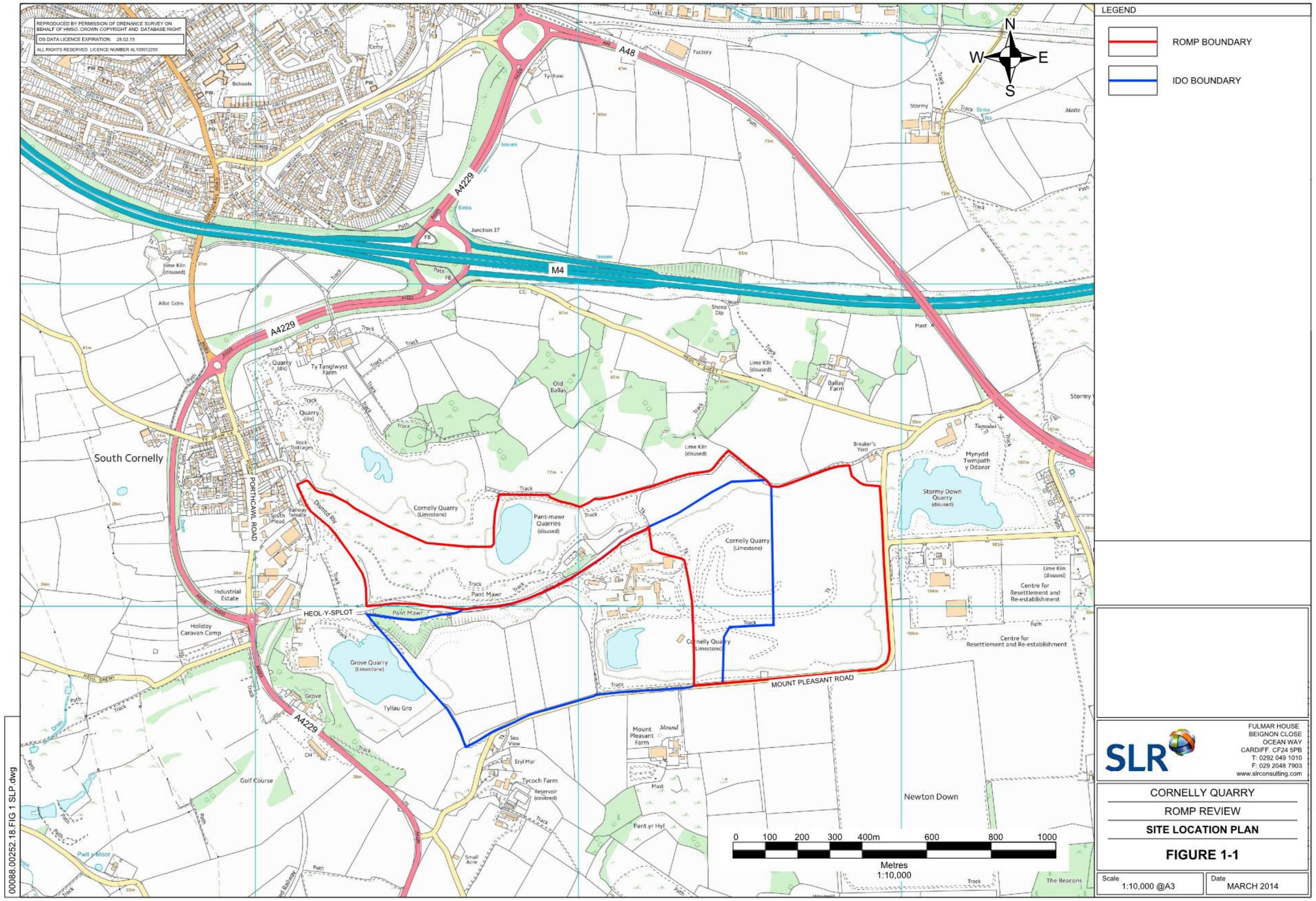
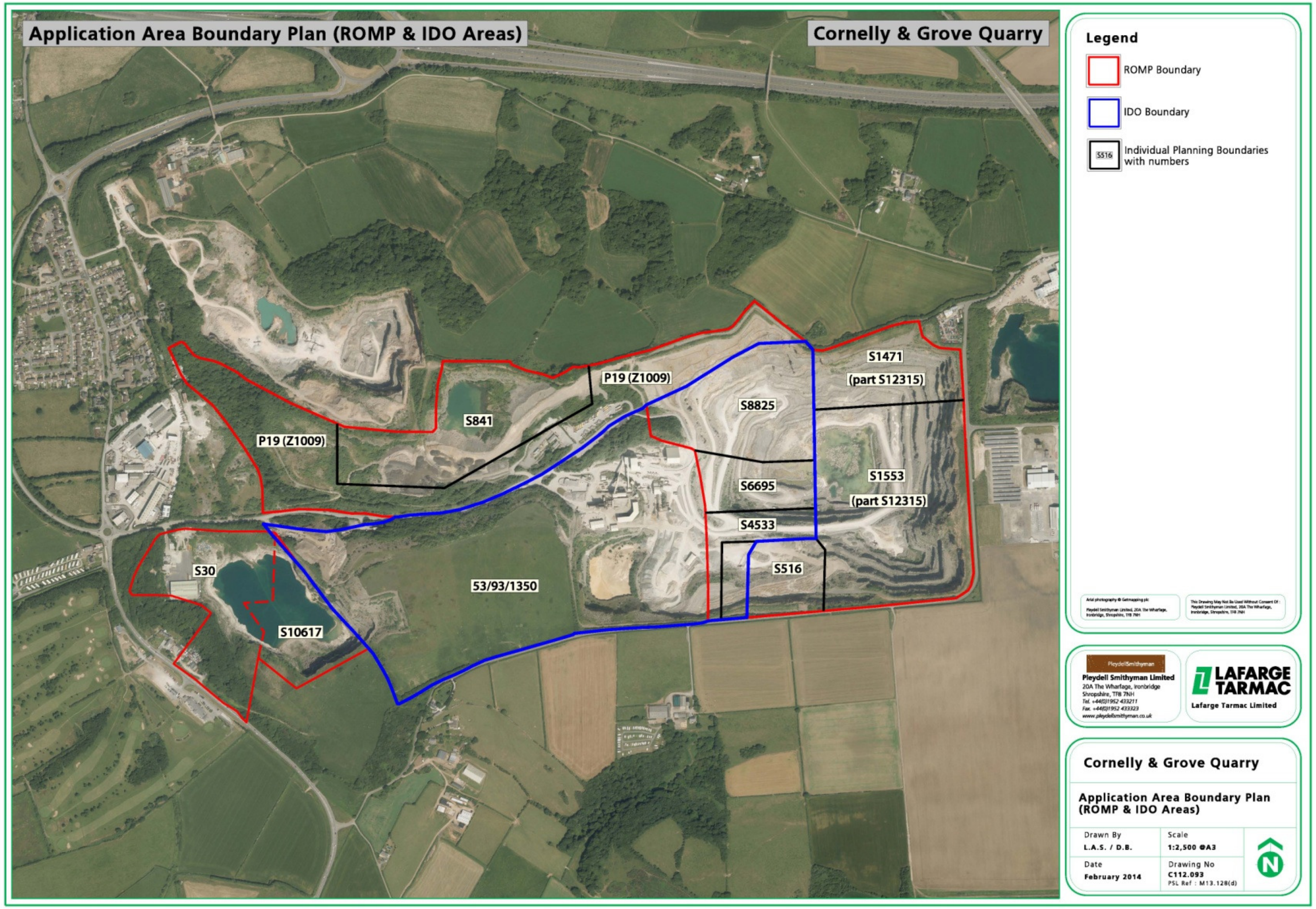


Figure 1-2 Planning History



Part (I)

Baseline Information

2.0 THE APPLICATION SITE

2.1 Application Site

The application site which is the subject of the Cornelly Romp Review is shown on plan ref C112.OOO93. It covers the extent of the planning permissions granted between 1949 and 1967 (ref table 1.1 and figure 1.2).

In practical terms, for the reasons set out in Chapter 1.0 the EIA has considered the totality of the quarry development scheme including quarrying, processing and related operations which are integral to the overall development but which lie outside the boundaries of the ROMP Review application site (i.e. the IDO area).

The description of the baseline conditions at Cornelly Quarry have therefore been undertaken in this wider context. It also reflects the requirements of the Scoping Direction to cover a description of 'Cornelly Quarry, site and environment' (ref para 4 and 5).

This Chapter provides a summary of the key findings of the baseline assessments undertaken as part of the individual technical studies. The summary serves as a context for the description of the development scheme set out in Chapter 3.0 and the restoration strategy in Chapter 4.0.

It also serves as an introduction to the much fuller description of baseline conditions set out in the individual technical topic chapters as referred to in section 2.11 below.

2.2 Site Location

Cornelly Quarry is situated on an upland plateau of land situated some 0.5 km south of the M4 motorway; some 0.5km east of the village of South Cornelly in terms of the operational area (although the boundary of the ROMP application site abuts the outskirts of the village; and some 1.5km north east of Porthcawl (ref figure 1.1).

It is bounded to the north east by Heal y Splot; to the south and east by Mount Pleasant Road (and a link road between Mount Pleasant Road and Heol y Splot; to the west by Grove Quarry, and to the north west by Gaens Quarry.

The Cornelly ROMP area relates to the central and eastern area of Cornelly Quarry and land to the north and north-west at Pant Mawr. The ROMP area includes the majority of the quarry development area, but not the western extremity which includes the plant site and access which is covered by a separate IDO permission. The Pant Mawr area generally comprises ancillary land used for HGV parking, water management (Pant Mawr Lagoon), stocking, and an area which has been partly backfilled with quarry waste (and which will be over-tipped as part of the proposed development – the Western Pant Mawr Tip).

The total area of Cornelly Quarry that falls within the ROMP Review totals some 64.33 ha. The IDO permission, as it physically relates to Cornelly Quarry equates to some 14.43 ha. The proposed future extraction area at Cornelly, which lies fully within the ROMP/IDO boundaries, equates to some 48.21ha.

2.3 Landscape Context

The quarry is located in a broad upland plateau area, ranging between the 80m and 108m AOD. The eastern boundary of the site represents a local high point (Newton Down) with the plateau gently rising in a series of small undulations to the northeast to 108m AOD at Stormy Down. Further eastwards the landform remains at a similar level before falling gently away towards Lalestron/Trelales due east and Tythegston to the southeast as a series of small valley features. These valleys are occupied by both local and national road networks (A48 linking Bridgend with Pyle).

To the north beyond Stormy Down the land falls away more rapidly towards the Afon Fach valley, a tributary of the main incised valley of Afon Cynffig further to the west which drains into the Bristol Channel between Margam Moors and Kenfig Dunes. The M4 motorway corridor cuts through the edge of this escarpment, bisecting Stormy Down in two. The town of Pyle extensively occupies the valley where these two rivers meet, as well as the lower lying hillocks that surround these valleys.

To the west, the land initially falls away gently to some 80m AOD, bisected by a small narrow valley that links into the main incised valley of Afon Cynffig further to the north, or small valleys that drain away towards the sea to the south of Sker Point. The valley feature itself is occupied by a small minor road (Heol y Splot) which now forms the main access into both Cornelly and Grove quarries. Originally this road linked with Mount Pleasant Road to the east of the site, but is now cut off as the northern half of the quarry has worked through the line of the road (ref: formal Road Closure Order 2007).

This lower lying upland area immediately to the west of Cornelly Quarry is occupied by Grove Quarry to the south of the central valley feature and Gaens and Pant Mawr Quarry to the north. The landform immediately to the southwest of Grove Quarry falls away steeply as a wooded escarpment the toe of which is defined by the carriageway of the A4229 and a small group of dwellings. Grove Quarry is currently inactive, whilst Gaens Quarry is active, and has been so for many decades.

The southern and south eastern boundary of the main quarry void is defined by Mount Pleasant Road which links the A4229 north of Porthcawl with the A48 to the northeast of the site, as well as with Tythegston to the southeast. The north eastern boundary is defined by Stormy Down Quarry.

As a consequence of the location of the quarry within this upland plateau area, in conjunction with the surrounding topographical features, Cornelly Quarry is generally well screened and enclosed by the existing landform and vegetation within the general landscape setting. However, as described earlier, the location of Mount Pleasant Road abutting the site to the south and east and the proximity of the quarry faces allows relatively open, if somewhat intermittent views both into the quarry void as well as the large structures associated with the processing plant. Again, due to the sloping landform to the west along with the presence of the central valley feature, the upper parts of these large structures also occupy a prominent skyline position from certain locations to the west of the site.

Cornelly Quarry is not located within any nationally designated landscape (i.e. a National Park (NP) or an Area of Outstanding Natural Beauty (AONB)). There are no UNESCO World Heritage Sites (WHS), Ramsar, or Special Protected Areas (SPA) within 10km of the site boundary. However, a number of Special Landscape Areas, Historic Landscape Areas, Special Areas of Conservation (SAC), Scheduled Ancient Monuments, Site's of Special Scientific Interest, National and Local Nature Reserves, Site of Important Nature Conservation, Historic Parks and Gardens, Listed Buildings, areas of Ancient Woodland and Long Distance Recreational Routes are present within a 3km radius of Cornelly Quarry, which has been defined as the Study Area for the purposes of the Landscape and Visual Impact Assessment (LVIA) set out in Chapter 6.0 of the ES.

2.4 Visual Amenity

Computer generated 'zones of theoretical visibility (ZTV's) have been produced to ascertain the potential visual envelope of both the current situation as well as that of the proposed future development in context to Cornelly Quarry, as well as Grove and Gaens Quarries. These studies, verified and updated by field work, concluded that landscape and visual effects are restricted by the presence of strong mature woodland blocks associated with the central valley feature and the western perimeters of the site, plus the location and orientation of the active quarry faces. Potentially this visual envelope also extends to the northwest to include parts of North Cornelly/Pyle, as well as to the southwest to include the northern outskirts of Porthcawl (Nottage).

To the west, due to the rising landform, visual receptors in close proximity to the site (100-200m) do not receive direct visual effects associated with the mineral extraction or processing, although they do experience indirect effects associated with vehicle movements to and from the quarry joining onto the A4229 Pyle Road via the roundabout with Hoel-y-Splot Road (forming the main access to the quarry).

Further to the west, views progressively open up to include the upper sections of the processing plant and parts of the eastern quarry face. Due to the location of the processing facilities set down within the quarry, in conjunction with the main valley feature associated with Heol y Splot

Road, views into Cornelly Quarry and in particular the processing facilities are severely restricted to an acute angle due west of the site.

Field work undertaken concluded that visual receptors could be categorised into three main zones (Zones 1 to 3), shown on figure 6.10 within ES Volume 4).

2.4.1 Short distance views < 100m

Zone 1 is associated with receptors that gain views towards the site from less than 100m from the northern, eastern and southern boundaries of the Cornelly ROMP application site within the Newton Down plateau and the site entrance to the west. These receptors include:

- Users of Mount Pleasant Road, a minor road that links the A4229/B4283 Pyle Road to the A48 at Stormy Down;
- Users of Hoel-y-Splot Road, a closed road that partly links footpaths to the north of the site with the Hoel-y-Sheet Road;
- Users of the footpath network that partly traverse the western half of the site as well as running along the northern boundary to the east;
- Receptors that work within the Stormy Down Research and Production Centre, immediately to the east of the site or the auto salvage garage on the northeastern corner of the site;
- Receptors that work within the South Cornelly Trading Estate that gain access from Hoel-y-Splot Road, including the Esso Petrol Station.

2.4.2 Medium distance views within 1km

Zone 2 is associated with receptors that gain views towards the site from the north generally within 1km of the site, although long distance views are possible from up to 4.0km away. These receptors include:

- Residential properties/farmsteads along Hoel-y-Sheet Road that links Hoel-y-Splot Road with the B4283 Porthcawl Road to the south of Pyle including Balas Farm and Balas Cottages;
- Users of Hoel-y-Sheet Road that links Hoel-y-Splot Road with the B4283 Porthcawl Road to the south of Pyle;
- Users of the footpath network that traverse the northern half of the Newton Down plateau including crossing over the M4 motorway where it is in cutting, as well as the southwestern section of Stormy Down open access land;
- Users and residents along the B4281 Seaview Road between Kenfig Hill and Cefn Cribwr including Pen-y-castell;
- Users of the open access land/playground to the southwest of Cefn Cribwr.
- Users of the various roads and residents within the southern half of North Cornelly/Pyle.

2.4.3 Distant views from 2km – 4km

Zone 3 is associated with receptors that gain views towards the site from the west/southwest within 2.0km of the site, although longer distance views are possible from up to 4.0km away. These receptors include:

- Users of the B4283 Porthcawl/Pyle Roads and the A4229 by-pass in the vicinity of South Cornelly;
- Various dwellings within the southern section of South Cornelly;
- Various dwellings associated with the northern outskirts of Porthcawl (Nottage).
- Various dwellings associated with the southern outskirts of North Cornelly.
- Users of the Heol Drewi, Moor Lane, West Road and Heol y Broom road and the local footpath network within 2km of the site.
- Users of the various Golf Clubs/Courses including Grove, Pyle and Kenfig and Royal Porthcawl, as well as Penymynydd Country Club/Sandville Court,;

- Users of the various local footpath networks and public open space greater than 2km from the site including the Wales Coastal Path, Kenfig Sands, Sker Point and Rest Bay.
- Various isolated dwellings, farmsteads and caravan parks within the locality, including Parc Newydd Farm, Sker Court, Westerleys, Pentwyn, Penycae, Waun-y-mer, Sker Cottages, Ty'r-ychen, Sker House, Kenfig Caravan Park and South Cornelly Holiday Caravan Park, plus various unnamed dwellings;

The effects on landscape and visual amenity are considered in detail in Chapter 6.0 of the ES.

2.5 Ecology

There are no designated nature conservation sites within the ROMP area. Two internationally designated sites are within 2km – **Kenfig Special Area of Conservation (SAC) 1.9**km north-west and **Cefn Cribwr Grasslands SAC** 1.4km north. A further six nationally designated Sites of Special Scientific Interest (SSSIs) are present within a 2 km radius (five including the component SSSIs of the above SACs) and **Stormy Down SSSI** 500m east.

One National Nature Reserve is present approximately 1.7km north-west - **Kenfig Pool and Dunes National Nature Reserve (NNR)**.

There are twenty non-statutory designated Sites of Importance for Nature Conservation (SINCs) within approximately 2km of the ROMP area. The closest 'Cornelly Quarry' SINC lies within the ROMP area immediately to the north of the minor B-road named 'Heol y Splot'. Further details on the habitats and/or species present within these sites are presented along with the evaluation of their nature conservation interest in Section 7.6 of Chapter 7.0.

Extended Phase I habitat surveys for the Cornelly ROMP Review were initially carried out during 2nd -11th July 2003, and the Cornelly ROMP, Grove ROMP and Cornelly / Grove IDO Review areas were subsequently surveyed / resurveyed in early September 2008 (Cornelly) and March-May 2009 (Grove). Habitats, plants (and incidental sightings of animal species) across the site and survey area were noted during scoping and updated survey visits for breeding birds, great crested newts and bats between May and July 2013. These findings were verified and updated with additional information from a Phase I habitat survey undertaken in January 2014.

The habitats within the Cornelly ROMP area were predominantly classified as artificial rock exposure - quarry and quarry spoil, with two areas of dense scrub in the north and south western corners. Immediately adjacent to the ROMP area, arable farmland was extensive to the south east and scattered to the west, with pockets of broadleaved semi-natural woodland to the north and south west.

Areas of woodland are variably present within the survey area, with pockets in Pant Mawr and Grove Quarries, but none surrounding the operational Cornelly Quarry.

Narrow strips of planted broadleaved trees were present on-site within Pant Mawr Quarry – along the roadside north of Heol y Splot, and a more extensive area in the north-west corner.

Dense scrub was extensive across the survey area, in particular in Pant Mawr and Grove Quarries and around the margins of the operational Cornelly Quarry. It has also colonised many of the artificial bunds.

Areas of bare ground were colonised by short ephemeral species and mosses in the less disturbed parts of the survey area – in the west of Pant Mawr Quarry on-site and off-site in Grove Quarry.

Areas of semi- and unimproved calcareous grassland were present within the survey area. On-site, very few areas of grassland remained intact and the unimproved calcareous grassland was limited to small pockets in the north of Pant Mawr, which were being encroached by scrub.

Hedgerows were limited in the survey area (ref Figure 7.1), with two short sections present, both of which were on-site. One hedgerow was located between the Cornelly Quarry south west quary lagoon lagoon and semi-improved grassland off-site on an artificial bund and was dominated by scattered hawthorn backed by a post and wire fence. The other hedgerow was adjacent to a track and formed the southern site boundary. It supported a comparatively greater number of species such as hawthorn, sycamore, hazel and gorse, but was gappy in nature.

Six waterbodies were recorded within the survey area; three on-site within the Cornelly Quarry ROMP area (waterbodies 1, 3 and 6), two within Grove Quarry ROMP area (waterbodies 4 and 5) and one within the Grove IDO review area (waterbody 2), which were all within 250m of the Cornelly ROMP area. These included standing water in quarry voids, silted lagoons, washing ponds and a seasonal pond. All were surveyed as part of the great crested newt habitat assessment.

Excavated rock faces were present throughout the survey area, with disused faces in Pant Mawr and Grove, and an active quarry face within Cornelly.

In addition to the rock faces, exposed bare rock was also a common feature in the survey area.

The habitats present within the site and survey area were assessed for their potential to support roosting and foraging bats. Opportunities for roosting are limited, but the mosaic of habitats within the quarry are likely to provide suitable foraging habitat for bats.

Otter and water vole are not considered to be present, based upon the nature of the habitats and lack of connecting watercourses. Dormouse are similarly not considered to be present based upon the nature of the habitats and lack of food sources.

There are no badger setts within the site, but peripheral areas are used for foraging.

There is no evidence of the presence of great crested newts in the waterbodies on site, and they are generally unsuitable for this species. However, palmate newt and common toad are present.

Two species of reptile have been confirmed present within the survey area – slow worm and common lizard.

The peripheral habitats present within the survey area support a wide range of birds during the breeding season, some of which are widespread and others concentrated in specific habitat types. These included one species, peregrine falcon, specifically protected under the Wildlife and Countryside Act 1981 (as amended), which is a probable breeder in the operational quarry on site as well as the adjoining Grove Quarry.

Full details of the ecology baseline and impact assessment are presented in Chapter 7.0 of the ES, including consideration of potential indirect effects on features within the designated nature conservation areas (notably the Kenfig SAC).

2.6 Geology

A detailed description of the geology can be found in Appendix G of Appendix 7.1 (ES Volume 2A). A summary is provided below.

2.6.1 Regional Geology

Solid Geology

The key solid geology formations are:

- Triassic Mercia Mudstone: Coarse grained, conglomeratic marginal facies (aquifer) and distal mudstone facies (non aquifer);
- Carboniferous Limestone: A variable sequence of limestones, shales and sandstones. The most layered, shaley units are concentrated at the top and bottom of the sequence. The main limestones worked at the quarries comprise the Cornelly Oolite and Stormy Limestone (Cornelly and Grove) and the overlying Oxwich Head Limestone (Gaens quarry).

The mapped extent of these strata and associated cross sections from the BGS (2000) are shown on Figure 3.1 and 3.2 respectively in Appendix 7.1.

The Carboniferous Limestone which is worked by the quarries forms the main aquifer in the area, and is classified as a Major Aquifer by NRW for the purposes of groundwater protection. The Carboniferous Limestone forms the higher plateau around the quarries.

Other formations form minor aquifers (e.g. the blown sand deposits at Kenfig and the Triassic Mercia Mudstone Marginal Facies) or non-aquifers (e.g. the Mercia Mudstone (undifferentiated) and the estuarine clays and silts at Kenfig).

The major unconformity between the Carboniferous strata and the overlying Triassic deposits is a significant feature of the local geology. The exposure of the limestone to erosion and karstification during this period is discussed below and in Appendices G and H of Appendix 7.1.

The Carboniferous strata dip to the north at 0 to 40^{o} exposing progressively younger strata to the north. The sequence is also disrupted by the north west - south east Newton Fault and associated splays. To the north, the sequence is truncated by the east-west Triassic Boundary Fault which downthrows Triassic Mudstones and Upper Carboniferous Coal Measures strata.

Superficial Geology

The superficial deposits in the study area are shown on Figure 3.3 of Appendix 7.1. The main units of significance at outcrop are:

- Blown sands: The dune fields at Kenfig and Merthyr Mawr comprise loose, fine-grained sand with shell debris.
- Estuarine clays and alluvium (organic rich clays and silts with beds of peat) underlies the blown sands at Kenfig. At Merthyr Mawr a thin 1-3 m thick clay layer underlies the Blown Sands.
- Till: Much of the area around Pyle is underlain by relatively impermeable Diamicton and gravelly, clayey sand.
- Glaciofluvial deposits. Predominantly sand and gravel forming a minor aquifer. This underlies the estuarine clays at Kenfig. In places this lies directly on the Triassic marginal facies or Carboniferous Limestone thus providing a potential pathway between the main aquifer system and groundwater in the superficial deposits.

2.6.2 Local Geology

Kenfig

A schematic diagram of the evolution of Kenfig Pool is shown in Figure 3.4 of Appendix 7.1 (BGS, 2000).

The nature of the superficial deposits in this area is of critical importance to the understanding of the degree of connection between the Blown Sand hydrological system and that of the underlying Triassic and Carboniferous strata. This in turn has implications for the potential for dewatering at the Cornelly, Grove and Gaens quarries to affect groundwater levels at Kenfig. The superficial geology around Kenfig was the focus of much of the geological and geophysical investigations carried out as part of the current assessment and has been the subject of detailed discussions between ESI and the regulators. Wherever possible uncertainties have been resolved by investigation but the remaining residual uncertainties have been taken through to sensitivity analysis on the predictive model runs.

A detailed review of the local geology presented in Appendix G of Appendix 7.1 concludes that the low permeability estuarine clays and alluvium is present throughout the main area in which the overlying Blown Sands are saturated. The estimated thickness of this layer and the lateral extent of saturated Blown Sands are shown on Figure 3.5 of Appendix 7.1.

Merthyr Mawr

Within the SAC, Blown Sand overlies Friar's Point Limestone over most of the area. In the west there is a small area of subcrop of Mercia Mudstone Marginal Facies and in the east, around Candlestone Stream, there is a small outcrop of Brofiscin Oolite Formation and Barry Harbour Limestone Formation. Beneath the Mean High Water line the outcrop is predominantly marine beach deposits of sand with some outcrop of limestone in the west. A strip of Tidal Flat Deposits follows the line of the River Ogmore.

The main area of humid dune slacks within the Blown Sand is in the southern and eastern part of the SSSI. In the north the dunes overlie a step in the underlying limestone, roughly parallel with the coastline. In this area the dunes are considered to be 'dry' with no active dune slacks. Limestone has also been observed cropping out in a number of places along this step (BGS, 1:10,000 geology maps).

Borehole logs and augering have demonstrated the occurrence of a 1-3 m thick clay layer separating the sands from the underlying limestone in the central part of the dune system (south of the step in topography). Beneath the sand in the west, gravels are present, rather than clay: gravel workings west of Burrows Well confirm this. Gravel was also encountered close to the Candleston Stream channel and to the River Ogmore in the east.

The low elevation of the top of the limestone indicates the presence of a possible buried channel associated with the River Ogmore.

2.6.3 Structure

The locations of key faults in the area are shown on the solid geology map (Figure 3.1 of Appendix 7.1) and on cross sections through the area (Figure 3.2 of Appendix 7.1). The study area lies on the southern edge of the South Wales syncline. Cornelly Quarry lies on the northern limb of the Candleston Anticline, a subsidiary fold in this system.

The most prominent structural feature in the area is the north west - south east trending Newton Fault which down throws Triassic strata to the south west. A series of NNW-SSE trending cross faults, which include the Morfa Fault, link into the Newton Fault to the west of the quarries. South of the quarries, the Newton Down Fault Zone comprises a complex set of east-west reverse faults. The east-west Kenfig and Triassic Boundary Faults act as opposing normal faults which downthrow Triassic and Jurassic strata in a trough to the north of the quarries.

2.7 Hydrology

2.7.1 Rainfall

The NRW has provided data for the rainfall stations at:

- Margam (SS808856, about 4 km to the north of the quarries) for the period February 1991 to June 2013,
- Cefn Cribwr (SS856838, about 3 km to the north east of the quarries) for the period January 1981 to January 2009; and
- Schwyll from December 1991 to June 2013.

Long term average rainfall at Margam is 1149 mm/a with 1996 being the driest year in the 22 year sequence (845 mm) and 2012 being the wettest (1655 mm). The very wet sequence of months from April 2012 onwards affects most of the recent water level records.

2.7.2 Stream Flows

Available stream flow data for the area are described in Appendix J of Appendix 7.1.

The main surface water flows of interest relate to the two large springs in the area:

- The large, perennial springs at New Mill Farm have been identified as an important feature of the local hydrology and flow measurements have been made on numerous occasions over the last ten years (Appendix J). The spring complex comprises a main spring (20 – 70 l/s, 1,700 to 6,000 m3/d) sourced from underlying Triassic strata and numerous other smaller seeps and springs in this general area. The total gain in the reach around the springs is around 190 l/s (16,400 m3/d) although some of this is derived from the surface water catchment of the reach.
- A flume and data logger have been installed by Lafarge-Tarmac on Burrows Well, the Carboniferous Limestone spring that rises in the middle of Merthyr Mawr dunes (Appendix J). The data show that the spring is ephemeral with flows up to 350 l/s (30,000 m^3/d) but more typically around 50 l/s (4,300 m^3/d).

In addition to these flows, there is some surface water flow in the dune slacks at Kenfig during high groundwater level conditions (Jones, 1993).

However, this all recharges to the Blown Sands to the west rather than flowing to the coast.

2.8 Hydrogeology

2.8.1 Formations and their Properties

Two types of aquifer are present in the study area: porous medium aquifers, in which flow is distributed relatively evenly throughout the whole formation (e.g. the Blown Sands of the sand dune systems) and karstic aquifers in which flow occurs almost entirely through solution enhanced fissures or conduits (e.g. the Carboniferous Limestone and Triassic Marginal Facies).

2.8.2 Groundwater Levels

Groundwater levels have been monitored by Lafarge-Tarmac, the NRW and staff at the Nature Reserves at nearly 60 sites in the area (Figure 5.1 of Appendix 7.1) over the last decade with some sites having up to 16 years of data. This forms an exceptional baseline for the assessment of the impacts of the quarries.

2.8.3 Conceptual Model

The Cornelly Group of quarries work Carboniferous Limestone that forms part of a wider, inter-connected aquifer system extending over an area of around 25 km^2 (see Figure 6.1 of Appendix 7.1). This is bounded by the River Kenfig to the north, the River Ogmore to the south, by various faults to the north east and by the coast to the south and west.

The Carboniferous Limestone forms the main, karstic aquifer in this area but is overlain by permeable, layered and possibly karstic, Triassic strata to the west and south. The Blown Sands at Kenfig and Merthyr Mawr form minor aquifers that have a degree of connection with the underlying Carboniferous/Triassic aquifers (described in more detail below).

The main directions of groundwater flow within these aquifers are illustrated on Figure 6.1 of Appendix 7.1. These are derived from a range of evidence described in the preceding sections of this report.

The main discharge point for groundwater in this area is to the ~10 km of coastline that forms the western and southern boundaries of the area (83%). As these discharges are effectively immeasurable, this introduces an element of uncertainty in the overall water balance for the catchment. Apart from these coastal discharges, groundwater also emerges:

- At the large springs at New Mill Farm. This groundwater has a strong hydrochemical signature from the Triassic strata.
- Within the Blown Sand dunes at Kenfig and in Kenfig Pool. The hydrochemistry of Kenfig Pool suggests that this water is almost entirely sourced from the Blown Sands, with small amounts of flow from ephemeral springs to the east.
- At the large spring at Burrows Well which emerges from the Carboniferous Limestone in the middle of Merthyr Mawr and flows through some dune slacks, eventually soaking back into the sands before reaching the sea.
- Pumping from Cornelly Quarry (and occasionally from Grove and Gaens Quarries).

The following sections describe the conceptual model of some of the key parts of this system in more detail.

Cornelly Group of Quarries

Cornelly is the largest quarry in the group and, as it has been extensively worked and dewatered, it is the one about which the most information is available. The most striking aspect of the groundwater system at Cornelly Quarry is how little abstraction and drawdown effect there is and how stable it has been since detailed monitoring started in ~2001: over a period of ~30 years groundwater levels have been reduced by a total of around 60 m over an area of around 0.5 km^2 and yet the average inflows to the quarry sump are only ~3,500 m^3/d - equivalent to a catchment area of around 1.3 km^2. Monitoring of groundwater levels in the area confirms that drawdown has extended over a limited area.

The low transmissivity of the aquifer in this area is due to a combination of stratigraphical, structural and erosion/dissolution processes:

- The Cornelly Oolite worked at Cornelly Quarry is a thickly bedded, oolitic limestone which is likely to be less prone to karstification than units with numerous mudstone horizons;
- The strata within the quarry are generally horizontal with little faulting. The extensive north-south jointing is largely infilled with clayey material;
- This area forms a high plateau with little opportunity for chemically aggressive runoff from adjacent strata which might enhance/reactivate karst;
- The karst re-activation that has occurred is limited to the zone near the natural position of the water table. The current sump elevation is well below this.

The conclusion of the palaeokarst review carried out for this study (Appendix H of Appendix 7.1) was that the present phase of karst development/re-activation extends down about 40 m from the surface. There is little evidence for integration of the dispersed recharge from the unsaturated zone within a substantive karst conduit network. Rather, due to the very high frequency of dilated joints, the dewatered saturated zone appears to be characterised by diffuse fracture flow. Taken together, this suggests that there is a low probability of the further deepening of Cornelly Quarry encountering significant zones of enhanced permeability at depth.

Although the karst survey was extended to the adjacent quarries in 2013, the extent of active karst in Gaens and Grove Quarries is less clear as these quarries are smaller and have not been worked to such depths. There may be a higher risk of encountering permeable features at depth in these quarries although, because the quarries are smaller and will not be worked to as great a depth as at Cornelly, the significance of these is expected to be somewhat reduced.

A schematic cross section east-west through Cornelly and Grove quarries and then north westward to Kenfig illustrates some of the points made above and also links this to the groundwater flow systems between the quarries and Kenfig (Figure 6.2 of Appendix 7.1). It can be seen that the groundwater gradients to the west of the Newton Fault are generally flatter than to the east, implying a much lower transmissivity in the latter area.

New Mill Springs

New Mill Springs form an important discharge point for the northern part of the Carboniferous Limestone/Triassic aquifer system. The springs have a strong hydrochemical signal indicating that the groundwater has flowed through the Triassic strata (Appendix L of Appendix 7.1). The total gain in the River Kenfig in this area is consistent with a catchment area of 8.8 km^2 (ESI, 2003).

Kenfig Pool and Dunes

The groundwater system at Kenfig comprises three aquifers: the Blown Sand dunes, and the underlying glaciofluvial gravels and Carboniferous/Triassic aquifers. Figure 6.3 of Appendix 7.1 shows a schematic east-west cross section of the conceptual model of the area.

The eastern boundary of the saturated Blown Sand has been estimated by Jones, 1993 (see Figure 3.3 of Appendix 7.1). It follows the eastern boundary of Kenfig Pool northwards to the remains of Kenfig castle and south west out to Sker point. Directly beneath the sands a sequence of low permeability estuarine clay deposits extends across the majority of the site from beneath Kenfig Pool to the coast (as confirmed by borehole logs and geophysical surveys). This horizon limits the hydraulic connection between the sands and the underlying aquifers.

Contours by Jones, 1993 based on a very extensive monitoring network of dip tubes, show the presence of a groundwater high north west of Kenfig Pool (Figure 3.3 of Appendix 7.1). The majority of groundwater within the sand aquifer flows westwards, down gradient from this high towards the coast, with a smaller amount of flow north to the River Kenfig and south east to Kenfig Pool. Groundwater level and hydrochemical data imply that recharge from rainfall over the site provides the great majority of flow in the system.

Beneath the estuarine clay, the underlying gravels form a minor, confined aquifer. Groundwater level fluctuations are much larger in the gravels than within the Blown Sands and the hydraulic gradient is downwards except in very wet periods (Figure 5.3 of Appendix 7.1). The latter fact implies that the gravel aquifer discharges to the coast rather than upwards through the sands. There will be some downwards leakage from the sands to the gravels, however, the contrast in the behaviour of groundwater levels in the Blown Sands and gravels in the immediate vicinity of Kenfig Pool provides a clear indication that these two aquifers are not well connected.

Groundwater levels in the gravels show similar, if subdued, trends compared to boreholes completed in the underlying/adjacent Triassic strata. This may imply a degree of connection between these groundwater systems.

Borehole N is the nearest borehole completed in the Triassic strata to the dunes. It has groundwater levels which are almost always below those in the nearby Kenfig Pool. Groundwater levels in Borehole A (also completed in the Triassic about 300 m to the south west) are also lower than the pool in summer. This implies that this aquifer system discharges to the coast rather than upwards through the sands. There is a mapped area of Triassic strata on the beach to the west of Kenfig pool and this may be the main discharge point.

Merthyr Mawr

There are two distinct hydrogeological units at Merthyr Mawr – the blown sand superficial deposits at surface (within which the dune slacks form) and the underlying Carboniferous Limestone. A degree of hydraulic separation between the two units is afforded by a clay layer which appears to be present across the majority of the site and is typically more than 0.5 m thick. Clay may be absent in the west toward the SAC boundary and in what may be a buried channel next to the Ogmore River. A schematic of the conceptual model is shown in Figure 6.4 of Appendix 7.1.

The Blown Sand aquifer is split into two topographic levels with an area at lower elevation, within which the dune slacks form, adjacent to the sea and an area at higher elevation further inland. The elevation step between the two is coincident with a step in the underlying limestone which can be seen cropping out where the Blown Sand thins along this line. North of this, the Blown Sands are considered to be largely dry and the text below focusses on the southern half of the site where the slacks occur.

Although there are no co-located monitoring locations in the limestone and sand, comparison of the closest monitoring locations suggests that limestone water levels are generally below those in the sand. Due to the low storage of the limestone, groundwater levels are significantly more variable than the sands aquifer and therefore there are times when the limestone aquifer water levels are higher than the sand levels and the gradients are reversed (i.e. when Burrows Well discharges).

In the area to the south of Burrows Well, water levels are affected by the discharge of limestone groundwater levels into the Blown sands which causes large areas to pond, possibly on a shallow clay layer in this area (SWS, 2010). When the spring stops flowing, these water levels drop rapidly by three or more metres (e.g. piezometer D7) i.e. the groundwater system in this area is not typical of dune slacks more generally.

There are three main inputs to the groundwater system in the sands: direct recharge, runoff from less permeable catchments to the north east and intermittent flow from the underlying Carboniferous Limestone that discharges at Burrows Well. Flow from this large, ephemeral spring floods several dune slacks to the south before soaking back into the sands. Groundwater in both the sands and limestone is likely to flow southwards towards the sea.

2.9 Access and Traffic

The site is accessed via Heol y Splot, which extends approximately 1.25km from the roundabout junction with the A4229 and Porthcawl Road to the west. Heol y Splot generally rises gradually along its length from the roundabout to the west and follows a series of gentle bends. Heol y Splot is now a cul-de-sac following a formal road closure in 2007 which enabled quarrying operations to take place through the alignment of the former highway as part of the implementation of the existing quarrying planning permissions (ref Table 1.1). Heol y Splot thus predominantly serves as an access route to Cornelly Quarry (and Grove Quarry), and is not used as a ‘through route’ by members of the public.

The main site entrance to Cornelly Quarry lies on the south side of Heol y Splot, with a secondary entrance to the concrete plant and stockyard at the eastern end of Heol y Splot, just before the road closure / cul de sac position. Opposite the secondary entrance there is an entrance to a HGV parking area located on the north side of Heol y Splot. Both accesses are one-way entry points to the respective areas to the north and South of Heol y Splot.

The remaining western section of Heol y Splot between the quarry entrances and the A4229 roundabout was subject to a comprehensive scheme of improvements in 1997, including localised widening, realignment, resurfacing and the provision of passing bays.

Egress from the concrete plant and stocking yard is via the main site exit point, which is located approximately 250m to the west of the concrete plant / stock yard entrance. The main entrance to Cornelly Quarry is approximately 35m to the southwest of the egress point, separated by a traffic island which forms part of the quarry traffic management scheme.

Forward visibility for drivers turning right into the main access towards oncoming traffic travelling westbound along the eastern section of Heol y Splot is good, as is visibility in both directions for drivers emerging from the main egress. Both locations incorporate barriers to prevent unauthorised use. Immediately to the west of the site access there is a segregated sheeting areas for drivers.

Between the main site egress and entrance to the concrete plant/stocking yard there is an employees and contractors' car park on the south side of Heol y Splot. Visibility to the left for emerging drivers is good but the view to the right is restricted by vegetation. However, this restriction is acceptable as there are no access points to the east which would result in vehicles approaching the car park access from that direction (i.e. the right of emerging drivers).

A HGV parking area is situated on the northern side of Heol y Splot, with an entrance opposite the concrete plant / stocking are entrance, and an egress opposite the employees / contractors car park entrance. No entry signs are provided to prevent access to the HGV parking area at the egress point. . The HGV egress also benefits from good visibility.

Immediately to the west of the HGV parking area entrance and adjacent to it is an access to a range of buildings with a surrounding yard area used for plant maintenance. This two-way access essentially benefits from the same visibility provision as the neighbouring egress from the HGV parking area.

Continuing west along Heol y Splot there is another access/egress to land to the north within the Pant Mawr area of the quarry, opposite the main entrance to the processing plant area to the south. The access primarily serves a stocking area.

At the eastern end of Heol y Splot, the road joins the A4229 at the Smokey Cottage roundabout. Porthcawl Road, South Cornelly is the northern approach, Heol y Splot is the eastern approach, and the A4229 forms the southern and western approaches.

To the south of the roundabout the A4229 continues to Porthcawl. The route is a single carriageway with a nominal width of 7.6m on the approach to the junction, which widens to an entry width of 8.5m divided into two traffic lanes at the roundabout itself. There are bus stops located on both sides of the route and an access to Grove Golf Club on the west side of the route. The A4229 is lit for approximately 0.5km to the south of the junction, and a pedestrian footway is provided along the east side of the carriageway towards Porthcawl.

The western approach to the roundabout is the continuation of the A4229 northwards. Although leaving the junction to the west, the carriageway curves to head north then northeast forming a bypass around South Cornelly before reaching another four-arm roundabout where Porthcawl Road crosses the A4229 to the north of the village, approximately 2km distant.

The bypass is a single carriageway route with a nominal width of 7.3m and is subject to the national speed limit of 60 mph for such routes. It is unlit beyond the roundabout junctions and has no other accesses or junctions along its length. It is a Clearway where stopping is prohibited, as are pedestrians; although the sign confirming the latter when leaving Smokey Cottage roundabout has almost faded completely. The entry width at the roundabout is 7.4m divided into two traffic lanes.

The roundabout on the northern side of South Cornelly is also lit and has a diameter of approximately 50m, beyond which the A4229 continues northeast towards M4 Motorway Junction 37, which is 0.7km distant. The A4229 link to the M4 Motorway is constructed to dual carriageway standard with the opposing 7.3m wide carriageways providing two traffic lanes in each direction. The route is also a Clearway, although lay-bys are provided on both sides immediately to the north of the junction. The route is also subject to the national speed limit of 70 mph on dual carriageway sections.

The M4 Motorway Junction 37 is a grade-separated interchange that provides entry and egress to/from the M4 for westbound and eastbound traffic.

The A4229 is classified as a Strategic Road and also a Principal Road in the local route hierarchy, and as such is effectively the preferred corridor for HGV traffic travelling to or from the area.

2.10 Cultural Heritage

No designated assets of cultural heritage importance lie within the Site.

Four scheduled monuments lie within 2km of the Site's boundary, comprising Mynydd Herbert Round Barrow; Stormy castle; Dan-y-graig house; and Nottage inscribed stone, at distances of between 950m and 1600m from the site boundary.

Fourteen sites (or former sites) lie within a 1km study area, but none lie within the ROMP application area.

There are no Listed Buildings within the boundaries of the site, but six listed buildings lie within 2km of the site's boundary.

There are no World Heritage Sites, Heritage Coasts, Historic Landscapes, Parks and Gardens of Special Historic Interest or Registered Battlefields within 2km of the Site.

2.11 ES Baseline

The above summary of baseline conditions represents a brief overview of the much more detailed consideration of current circumstances set out in the environmental impact assessment chapters, notably:

- Chapter 6.0: landscape and visual baseline (section 6.4);
- Chapter 7.0: geology, hydrology and hydrogeology baseline (sections 7.4);
- Chapter 8.0: ecology baseline (section 8.2.3 and 8.5);
- Chapter 9.0: noise baseline (section 9.4);
- Chapter 11.0: air quality baseline (section 11.5);
- Chapter 12.0: transportation (section12.3); and
- Chapter 13.0: cultural heritage (section 13.4 – 13.6).

However, this Chapter 2.0 provides a brief outline of current circumstances as a context for the description of the quarry development and restoration scheme which is described in the following chapters 3.0 and 4.0.

Part (II)

The Quarry Development Scheme

3.0 THE PROPOSED DEVELOPMENT

3.1 Introduction

As noted in Chapter 1.0, the boundaries of the planning permissions which comprise the Cornelly ROMP Review area include land within the central and eastern area of the existing quarry, together with the lateral northern extension area at Pant Mawr (ref figure 1.2). The western area of the quarry, including the existing silt lagoon, processing plant and future western development of the quarry lie within the eastern part of the IDO permitted area.

At the outset of the ROMP Review process, it was recognised that it would be artificial and inappropriate to attempt to produce separate quarry development schemes for the respective ROMP and IDO areas since, in practice, Cornelly Quarry is worked as a single operational unit within the defined overall ROMP and IDO boundaries. Thus, the quarry development scheme which accompanied the original 1997 Cornelly Quarry ROMP application set out details of quarry development for the quarry development scheme covering the ROMP and IDO areas which was anticipated at that time.

In 2004, the Applicants updated the quarry development scheme to accompany the submission of the 2004 voluntary ES. This comprised plans showing the quarry development at year 1 (2003), year 2-3 and year 4-5 (to July 2008), together with a year 10 plan (2013), and year 20 plan (2023). The final quarry configuration shown on the originally submitted 1997 quarry layout plan was unchanged, showing a final layout involving a westward development into part of the plant site (IDO area) and a quarry floor at -75m AOD.

For consistency, the same set of quarry development plans for 'year 10' – 2013, 'year 20', 2023, and the final quarry development plans accompanied the 2009 IDO Periodic Review application, where the eastern part of the IDO permission forms part of the Cornelly Quarry development area. However, the Scoping Direction requires the plans to be updated based upon an up to date topographic survey, and the phasing and layout of proposed future operations (from 2014) (re para 5). A topographic survey was undertaken in December 2013, and the quarry development plans have been re-drawn based upon the current circumstances at the quarry. The phased development scheme is discussed in the sub sections below, but the nature and principles of the development scheme have not materially changed: the scheme is still based upon the initial development of the quarry northwards to the approved limits of extraction at Pant Mawr, and the progressive deepening of the quarry to -15, -30, -45, -60 and -75, together with the lateral development of the quarry westwards through part of the current plant site.

The quarry development scheme is depicted on plans which show the quarry development in years 1 - 5; 5 - 10; 10 - 15; 15 – 30 and 30 – 42 (ref plans C112/094 – 115 Inclusive, produced within ES Volume 4. The key focus of the current ROMP Review will be on years 0 – 15, following which, based upon current legislative requirements, there will be a need for a Periodic ROMP Review which will consider the quarry development for the next 15 years, and any changes to the development scheme proposed at that time, and any revised conditions which are deemed to be appropriate at that time. It follows that environmental effects of the ongoing development post year 15 can be re-assessed as part of that process. However, the current submission has not sought to confine the development scheme or the impact assessment to the initial 15 year period. The submission includes a development scheme for the full quarry development, and the effects of that full development scheme have been assessed as part of the EIA and reported in this ES.

However, there are certain aspects of the development scheme which cannot be finalised at his stage. Notably this relates to the processing plant site. The quarry development scheme indicates that during the year 15 – year 30 phase, the eastern area of the plant site will be removed to allow access to the reserves situated beneath the plant site. The quarry will then be developed in a westerly direction, and ultimately will progress through the full extent of the current plant site. These operations will take place towards the end of the year 15 – year 30 period (from circa year 25), and a location to accommodate the processing plant will be identified and assessed at that stage.

The quarry development scheme has been based upon an assumed annual output of 1m tonnes per annum. The quarry development scheme which is shown would yield reserves of between 42m and 45m tonnes. At the assumed 1 m tonnes per annum, the scheme is based upon a conservative 42 year development programme. The proposed planning conditions have thus been updated to provide an end date of 2056 for the completion of quarrying operations.

3.2 Existing Quarry: (Figure 3.1 which reproduces plan C112.094)

The current circumstances of the quarry are illustrated on the overview plan ref C112.094 and the topographic survey plans '095 (Cornelly East) and '096 (Cornelly West). Because of the scale of the quarry, and the need to produce plans at a readable size, these and the subsequent phased quarry development plans have been produced for the East and West areas of Cornelly, with an overlap between the two plans.

The main features of the current Cornelly quarry are the main quarry void which has developed down to a base of -3m AOD compared to a quarry rim along the southern boundary of between 92 and 100m AOD. The existing quarry is thus circa 100m deep. The quarry is being developed northwards into the Pant Mawr area, through the former alignment of Heol y Splot which was formally stopped up by a Closure Order issued in 2007. Quarry waste / reject rock from the upper face of the Pant Mawr area is being disposed of in a quarry waste tip to the east in the Pant Mawr area.

The processing plant lies on the western side of the Cornelly quarry void, and the main components of the plant are described in section 3.5 below.

A historic quarry tip is situated within the Cornelly quarry void in the southern area of the site, and that material will be removed and repositioned during the year 15 – 30 development phase to release reserves currently present beneath the tip. The existing south west silt lagoon will also be repositioned during that period.

3.3 Quarry Development Scheme

3.3.1 Stage 1: 0 - 5 years (Figures 3.2 and 3.3, which reproduce plans C112.097 - 98)

Stage 1 of the development shown in plans C112.097 - .098 broadly comprises the working of the northern quarry faces towards their final positions, along with the development of a new sinking in the quarry floor to -15m AOD.

Initially, overburden consisting of heavily clay-contaminated limestone will be stripped, in two phases, from the upper level of the Pant Mawr Extension area. This material will be drilled and blasted, and removed via dump trucks on a campaign basis, and placed in the Pant Mawr quarry area, forming the new tip platform shown in plan no *C112/098.* Removal of the overburden will allow access to the reserves in the north-eastern Heol y Splot area, and the remainder of the reserves in the Pant Mawr extension area. The total amount of overburden to be removed equates to approximately 200,000m^3.

The final profile of the Pant Mawr Quarry Tip will be such that an open water body is maintained as part of the water management system in the north west of the Pant Mawr void, and the upper surface of the tip levelled for use as a stocking area.

Following the first eastern phase of overburden removal, access can be gained to the upper level of the Heol y Splot area. This area will be quarried in unison with the main production faces in the Pant Mawr extension area. The upper level of this area is constrained by a narrow access corridor, due to historical quarry development, and variable quality limestone horizons. The unison working will allow the development to proceed in a timely, safe manner, whilst also allowing removal of any clay contaminated horizons that may be found, and supplementing the full production requirements for the site. As development proceeds, the second phase of overburden will be removed so that production from the Pant Mawr Extension area can continue.

Faces will be worked, by means of drilling and blasting to break up the rock mass, followed by loading into dump trucks by an excavator for transport to the primary crushing facility for onward processing.

During this time, a new sinking will be developed in the quarry floor, to a depth of -15m AOD. This sinking will be used for water management, maintaining a dry quarry floor, and providing clean limestone reserves to supplement production from the upper faces.

Due to variations in the chemistry of the limestone beds quarried in Cornelly Quarry, it is preferable to have access to a number of working faces at any one time to provide material of suitable specification for the end uses of the limestone in steel manufacture, coated-stone road surfacing, and ready-mix concrete.

Once the upper level has been quarried out from the Heol y Splot area, regular production can proceed from the lower levels, with access being gained from each level of the Pant Mawr Extension area. Final faces will be formed along the northern boundary of the Heol y Splot area, at an angle of approximately 10°-15° from the vertical, with rock-trap benches retained at elevation intervals no greater than 15m apart. The final bench widths will be between 7.5m to 10m wide, depending on the assessment of individual rock faces and the risks of rock fall from these faces.

The exact individual bench and face profiles will be determined at each level by the rock mass structure in each area. Where possible, faces will be aligned with naturally occurring discontinuities (joints) in the rock mass to leave stable faces. Where this is not possible, a best-fit approach is taken.

The use of advanced 'smooth' blasting techniques will be employed to ensure the optimum face angle is achieved, and the risks of rock fall are reduced. Presently, 'pre-splitting', where closely spaced boreholes are used to perforate the rock mass along the final face position, has been employed in areas of the quarry to produce a smooth face profile, and it is anticipated that this technique will be used where new final face positions are reached, depending on the integrity of the rock mass structure.

During this period, waste derived from the production process, up to 100,000m³, will be tipped in the southern tipping area and Pant Mawr Quarry tip.

The total extraction shown for this stage is 5,000,000 saleable tonnes.

3.3.2 Stage 2: 5 – 10 years (Figures 3.4 and 3.5, which reproduce plans C112.099 - 100)

During the second stage of working shown on plans C112/099 - 100 final faces will be formed in the north western corner (the Pant Mawr Extension area) and the south eastern area (the 'Pinnacle area'), and a new sinking will be developed in the quarry floor to -30m AOD.

Faces will be worked as above, by means of drilling and blasting to break up the rock mass, followed by loading into dump trucks by an excavator for transport to the primary crushing facility for onward processing.

During the development of the 'Pinnacle area', the existing haul route into the base of the quarry will be removed, and a new route developed along the toe of the final faces. This new route will form the main access in to the base of the quarry, and will remain in this position for the duration of the development. The ramped sections of the route will be formed at a smooth gradient no steeper than 1-in-10 in order to reduce fuel usage and tyre-wear.

In a similar fashion to that described above, the 'Pinnacle area' will be worked in unison with the Pant Mawr Extension area, to balance the slower production areas in the Pinnacle area, with the more easily won stone in the north west.

Following development of the new haul route, a new sinking to -30m AOD will be excavated in the north eastern corner of the quarry floor, forming the quarry sump and access to the next development level.

During this period, waste derived from the production process, up to 100,000m³, will be tipped in the Pant Mawr Quarry Tip or via the commencement of the new Western Pant Mawr Tip (ref plan C112/104).

The total extraction shown for this stage is 5,000,000 saleable tonnes.

3.3.3 Stage 3: 10 – 15 years (Figures 3.6 and 3.7, which reproduce plans C112. 101 - 102)

Stage 3 sees the further development of the -30m AOD level

The initial development work required in this third stage, from year 10 onwards involves working back the historic haul route areas in the south west of the quarry, from elevations between 20m AOD and -3m AOD. Once these have been worked back to their interim final position, the -15m AOD and the -30m AOD levels can be worked from an east to west direction, with all material hauled out of the excavation along the new southern haul ramp.

During this period, waste derived from the production process, up to 100,000m³, will be tipped in the Western Pant Mawr Tip. This landform will be constructed on the historic tipping area to the north of the western end of the Heol y Splot road. It will be constructed starting at the western end, towards the east, by means of forming a screening boundary bund along the outer edge, with material tipped in layers and compacted to create the final landform.

The total extraction shown for this stage is 5,000,000 saleable tonnes.

3.3.4 Stage 4: 15 – 30 years (Figures 3.8 and 3.9, which reproduce plans C112. 103 - 104)

The fourth stage, covering approximately 15 years of development, principally comprises deepening the eastern side of the quarry to -75m AOD, and, at the latter part of the stage, the relocation of the processing plant to access the reserves in the west.

Extraction of mineral in the base of the quarry will continue during the initial phases of this stage, during which time the current existing South Tip will be partially relocated into the far south western corner of the quarry. A new landscaped tip will be formed on top of the historic silt lagoons, which once completed at the end of the quarry development scheme will tie in the original ground level surrounding the quarry.

Once this tip has been relocated, there will be sufficient space within the lower levels to develop the quarry to the maximum working depth of -75m AOD. This mineral in the southern and lower faces will provide approximately 11,500,000 saleable tonnes, following which the reserves beneath the plant site will need to be accessible. Access to the -60m AOD and -75m AOD levels will be via constructed rock-fill ramps, as the final ramp profiles for these levels will be completed as part of the following stage.

During this time, production waste of up to 300,000m³ will either be stored in the relocated southern tip or formed into a low lying tip against the eastern faces at the base of the quarry (see next stage).

Prior to full working out of the southern and lower faces, and following the relocation of the processing plant, the upper level of the plant site area will be stripped. It is anticipated that a significant volume of waste material and overburden, in the region of 250,000m³, may need to be removed to the tip.

Following stripping of the plant site, working of the limestone reserves beneath will continue by mean of excavation and loading up the newly formed upper haul route. A series of temporary ramps and haul routes are likely to be required during this stage, and would be integrated into a number of subsidiary phase designs to detail the order of extraction in the areas worked in this stage.

In total, this stage represents extraction of approximately 15,000,000 saleable tonnes.

3.3.5 Stage 5: 30 - 42 years (Figure 3.10 which reproduces plan C112. 105)

Stage 5 involves working back of all levels between +40m AOD and -75m AOD to their final positions in the west.

Following the removal of the plant site and overburden from the western flank of the quarry, the full exposed reserve can be exploited. These benches would be worked via a series of connected haul routes and ramps, leading down to the main ramp starting in the base of the quarry. On retreat from each level, the roadways will be removed, allowing full access to the reserves beneath.

Production waste derived from working this mineral, of approximately 300,000m^3, will be placed in the southern tip, until such time that the final landform is created, following which all further waste will be placed in a tip structure against the eastern faces in the base of the quarry.

In total, this stage represents extraction of approximately 15,000,000 saleable tonnes.

3.4 Pant Mawr Western Quarry Tip (Figures 3.7 and 3.9)

Quarry waste, in the form of clay, reject rock and weathered rock/overburden is currently disposed of within (i) the southern Cornelly Quarry tip, along the southern edge of the quarry void, and (ii) in the south area of the Pant Mawr void. The Pant Mawr quarry tip will reach capacity in circa 10 years, and a new quarry waste disposal area will be required. This will consist of a new quarry tip which will be created in the western area of Pant Maw, on previously disturbed/partly tipped land.

The location is illustrated on Figure 3.7, which shows the locAtion of the western area of the tip, which will then be developed eastwards to create the final landform shown on Figure 3.9.

The tip will be constructed with an outer western flank with tipping then taking place on the innder side within Operators proposals from north to east.

3.5 Processing Plant

Excavated rock from the quarry face is transported by dump truck to a primary crusher, located at the western edge of the quarry, within the IDO area. That primary crusher building contains a feed hoper and a rotary impact primary crusher.

3.5.1 Primary Crusher Building

Undersized scalping material falling through the primary feeder is conveyed to a washing plant where minus 40mm scalps are sized and washed in a barrel screen to produce minus 40mm scalps and a range of washed aggregate products. Primary stone is reduced to a minimum 150mm product by the crusher at a maximum output of 1,000 tonnes per hour.

The primary stone is discharged onto conveyors with oversize aggregate returned from the washing plant. It then enters the sinter plant building and is screened to produce a minus 150mm plus 40mm product and a minus 40mm product.

3.5.2 Sinter Plant Building

The minus 150mm plus 40mm aggregates are conveyed to a 35,000 tonnes covered reclaimable sinter plant stockpile. The material is drawn from the underground recovery feeders under the stockpile into the sinter building for further size reduction by a crusher to minus 10mm. This material is lifted by an enclosed elevator to a separate crusher for further reduction. The final minus 3mm sinter product selected by the screen is lifted by an enclosed vertical elevator transfer conveyor into one each of two elevated storage silos of 1,000 tonnes capacity. The silos are arranged in line in an enclosed loading bay for loading into road going lorries which transport the sinter to the steel works at Port Talbot.

3.5.3 Main Screen House Building

The minus 40mm limestone, produced at the sinter building, goes to the new main screen house, which has two screening units over integral storage bins, which separate the final aggregates into sized products of 40mm, 28mm, 20mm, 10mm, 6mm and 3mm. The limestone is then transferred to a vehicle load out system either for sale from site, for transport into the asphalt plant stocking area, or to the concrete batch area.

The screen house building and integral aggregate storage bins are fully enclosed within a dust containing sheeted building. The vehicle load out is sheeted both sides and suppression sprays are installed to eliminate emissions.

3.5.4 Roadstone Coating Plant

The process involves the operation of a Parker Asphalt Coating Plant which is a totally enclosed unit and capable of producing 250,000 tonnes per annum of coated material.

Various grades of aggregates, steel and blast furnace slag and sand are transferred from storage bays to four sided and roofed cold feed bins from which they are conveyed into a sealed rotary drier. The sealed rotary drier is fired by a burner.

The dried and heated aggregates are discharged from the drier and lifted by an enclosed bucket elevator into a sealed screening unit to be sized into six separate hot bins. The various aggregate sizes in the hot bins are weighed into a four tonne capacity paddle mixer where bitumen and filer are added. The bitumen is stored in four 50,000 litre capacity vertical heated tanks and the filler in four 50 tonne capacity silos mounted at high level within the mixing tower.

The vertical hot elevator, screening unit, hot bins and weigh gear within the mixing tower and the rotary drier are connected via ductwork to a dust collection plant.

The dust collected by the filter is stored in hoppers, fitted with high and low level alarms before being pneumatically conveyed either back into the plant process or removed from site via tanker.

3.5.5 Environmental Permit

The processing plant and roadstone plant are regulated by an Environmental Protection Act 1990 Permit, the most recent of which was issued by Bridgend County Borough Council in May 2011. A copy of the Permit is produced as Appendix 3.1 (ES Volume 2D). The Authorisation sets out 90 detailed conditions relating to emission limits, emission controls, fuel oil controls; monitoring; record keeping; sampling provision, notifications of defined events; general materials handling and specific requirements for storage silos, hoppers and screens; materials handling for mobile crushing and screening plant; transport and loading; roadways, chimney vents and process exhausts, staff training and supervision, and general good practice maintenance and use of plant and equipment. This represents a detailed schedule of requirements which is discussed further in the Air Quality Chapter 11.0 in terms of the effectiveness of the controls and the relationship to planning conditions which might be imposed to supplement or re-enforce these existing requirements.

3.6 Hours of Operation

The IDO First Review imposed separate hours of working restrictions on Cornelly Quarry (the ‘pink area’) and Grove Quarry (the ‘yellow area’) – figure 1.2. The hours of operation relating to Cornelly Quarry are:

> *“The winning and working of stone from the quarry faces and operation of the primary crusher shall take place only between 6:00 am and 1:00 am Monday to Saturday and at no time on Sundays or Statutory Public /Bank Holidays except for essential maintenance or otherwise agreed in writing by the Mineral Planning Authority”.*

It should be noted that this condition related to the actual quarrying of stone, and it does not place hours of working restrictions on processing or the use of the other items of plant.

A similar condition was proposed by the Applicants as part of the original ROMP application, but with additional restrictions, as follows:

(i) Except in the case of emergency the wining and working of stone from the quarry faces and operation of the primary crusher shall take place only between 6:00 am and 1:00 am Monday to Saturday and at no time on Sundays or statutory public/bank holidays except for essential maintenance or otherwise agreed in writing by the Mineral Planning Authority.

(ii) No operations for the formation and subsequent removal of material from bunds/soil storage areas shall be carried out the site except between the following times:

08:00 – 17:00 hours Monday to Friday
08:00 – 13:00 hour Saturdays

(iii) The operation of all other plant including the sinter mills, aggregate screening plant, lime plant and asphalt plant will be unrestricted.

NB: For the purposes of the condition, quarrying operation shall be defined as wining and working of stone from the quarry face, the haulage of stone from the face and the operations of the primary crusher/or other mechanical means of stone breakage.

In practise, the quarrying operations are generally undertaken with the hours of 6:30/7:00 am to 4:00 pm Monday to Friday, and occasionally on Saturday morning. The extended periods from 6:00 am to 7:00 am and 5:00 pm to 01:00 am are only utilised very occasionally during particular surges in demand. No complaints have been received relating to operations carried out in those extended periods.

Following further discussions with BCBC as part of the preparation of the IDO Periodic Review application, further revisions have been proposed to the hours of working restrictions, which impose additional constraints on certain operations. These revisions are set out below, and would apply to the ROMP area, as defined in the condition. The proposed condition is reproduced within the schedule of conditions produced as Annex 1 to the ES.

"Except in the case of emergency (defined as circumstances in which the Operator has a reasonable cause for apprehending injury to persons, or serious damage to property), the winning and working of stone from the quarry faces, and operation of the primary crusher, shall take place only between the hours of 06:00-22:00 Mondays to Saturdays, and at no time on Sundays or Bank Holidays, except for essential maintenance or otherwise agreed in writing by the MPA.

(NB (i) For the purpose of this condition, quarrying operators shall be defined as winning and working of stone from the quarry face, and the operation of the primary crusher/or other mechanical means of stone breaking.

(ii) All other items of plant including secondary crushers, screens, sinter mills, asphalt plant, and concrete plant, lie within the 'IDO' permitted area where the hours of working are unrestricted by virtue of permission ref 53/93/1350.)

Within the working hours, specified in Condition [X], there shall be no drilling operations, or secondary breakage of stone between the hours of 06:00 – 07:00 and 19:00-22:00 hours.

No operations associated with the formation of the western Pant Mawr Tip, and formation and subsequent removal of material from bunds/soil storage areas shall be carried out at the site except between the hours of 08:00 – 17:00 Mondays to Fridays, and 08:00 -13:00 on Saturdays".

The noise implications of working to these limits are considered in Section 9.0 of the ES.

3.7 Output and Traffic Movements

The quarry is principally geared towards the production of sinter, for use in the steel works at Port Talbot. Indeed Tata are the freehold owners of the quarry. Recent output has typically averaged between 1.2 and 1.4 million tonnes per annum, of which some 50% comprises sinter.

The processing operations concentrate on producing +40mm stone for use in the sinter manufacturing process, with the remainder essentially a by-product of that process. However, this by-product represents a quality source of primary aggregate, which is used in the construction industry, notably via the on-site roadstone and concrete batching plants. This contrasts with historical practices whereby the majority of stone not suitable for sinter production was disposed of as "waste" on the 'IDO' land between Cornelly and Grove Quarries. More specifically, the aggregate is used to supply concrete plants both on site and in the general locality and the concrete blockworks at South Cornelly.

The Applicants are aware of objectives set out in Mineral Planning Policy Wales and Minerals Technical Advice Note (Wales (1): Aggregates (referred to in more detail in Chapter 15.0 of the ES), which seek to encourage the efficient use of minerals, and to maximise the potential use of secondary aggregate where appropriate. To that end, the operation is geared towards the production of sinter and single sized aggregate, rather than less sustainable low specification applications such as bulk fill. Moreover, as part of a comprehensive and integrated approach to local mineral supply of both primary and secondary resources, the Applicant is actively involved in the production and marketing of secondary aggregate (blast furnace slag) from the Port Talbot Steel Works.

Access to the quarry is derived off Heol y Splot, and its roundabout junction with the A4229. The westbound carriageway of Heol y Splot was substantially improved in 1997 with widening, re-surfacing, re-alignment, and provision of passing bays. All traffic utilises that route, with the exception of very occasional deliveries of ready-mix concrete which previously ran in an easterly direction along Heol y Splot. However such movements will be precluded by the closure of part of Heol y Splot. The concrete batching plant at Cornelly Quarry is the subject of a separate planning permission which does not impose any restrictions on vehicle movements or routing.

Sinter to the steel works is conventionally transported in articulated lorries with a carrying capacity of between 22 and 23 tonnes. Product from the asphalt plant is conventionally transported in vehicles with average capacities of 16 tonnes, with dry aggregate sales using vehicles with average load sizes of 18 tonnes.

The majority of movements travel north from the South Cornelly roundabout along the A4229 to the M4 junction 37, and are distributed to markets from there. In the case of sinter, the quarry is very well located, with access along the M4 to Port Talbot Steel Works at junction 38 of the M4, some 5km to the north west.

The effects of these traffic movements on the highway network of the local area are considered in Chapter 12.0 of the ES.

3.8 Water Management

The quarry is diverted via a sump, from where water is currently pumped to the water filled void within Grove Quarry. From there, water is discharged to a sink hole within a former railway cutting north west of Grove Quarry.

Historically, water has also been pumped to the lagoon within Pant Mawr Quarry, and this remains an operational water management option.

Full details of the future water management proposals are set out in the Water Management Plan produced as Appendix 7.6 (within Volume 2C), and described further in Section 7.10 of the ES.

3.9 Alternatives

It is conventional practice in undertaking an EIA to consider the principal alternatives to the development, although such an exercise is not mandatory in all cases. This assists the determining authority in their consideration of whether planning permission should be granted. If the principle is acceptable then it provides a further opportunity to review the alternative means of undertaking the development.

The starting point in the consideration of the ROMP Review application is the established fact that planning permission exists for the extraction of minerals from the Romp site, and from the remainder of the site covered by the IDO permission. The principle of the development has therefore been established by virtue of those extant planning permissions. The purpose of the current exercise is to allow the EIA to inform the process of updating the planning conditions which should regulate and control the on-going quarrying operation. The issue of whether the development should continue should only be reconsidered in extreme cases, where an EIA indicates a potential environmental impact of such significance that the planning permission should be modified or revoked. Compensation would then become payable to the developer.

In those circumstances, and in the context of the conclusions of this EIA (reference section 17 0 of the ES), it has not been deemed appropriate or necessary to undertake a detailed analysis of hypothetical alternatives to a continuation of quarrying at Cornelly. This is further recognised in the Scoping Direction which notes that "*as the current application is for a review of conditions, detailed consideration of alternative sites and materials is not appropriate*" (ref para 23). However, the significance of Cornelly as a supplier of limestone sinter to the Tata Steelworks in Port Talbot is important as part of an overview of the development, and a consideration of alternative sources of supply. The quarry benefits from geographical proximity to the steelworks and is able to consistently produce sinter to meet strict chemical composition requirements. Other limestone quarries in South Wales do not have the capacity, or the necessary plant and infrastructure to produce the sinter product in the desired volumes, with consistency of supply, necessary for continuity of production for the steelworks.

Whilst there may be hypothetical alternative sources of supply in England, it would not be in the interest of sustainability to encourage long distance bulk transportation of such material unless there were compelling and overriding reasons to discontinue quarrying at Cornelly. The results of the EIA do not suggest that quarrying of Cornelly should cease.

The Scoping Direction also notes that there are other options for the development of the quarry including quarrying to shallower depths (ref para 23). The principal 'alternative' in terms of a quarry development scheme is thus to deepen the quarry to shallower depths than the -75 metres AOD confirmed in the submitted quarry development plans.

The environmental effects of quarrying to -75 metres AOD have been considered as part of the studies of hydrogeological impact and indirect ecological effects. Based upon the content of the hydrogeological impact assessment, no significant adverse effects have been predicted to arise from quarrying to those depths. In those circumstances, the Applicants conclude that there is no reason to terminate quarrying at an arbitrary level above -75 metres AOD. Indeed, to do so, would not be in the interests of sustainable minerals planning as a result of the unnecessary sterilisation of reserves which would occur.

.

Figure 3-1 Existing Quarry

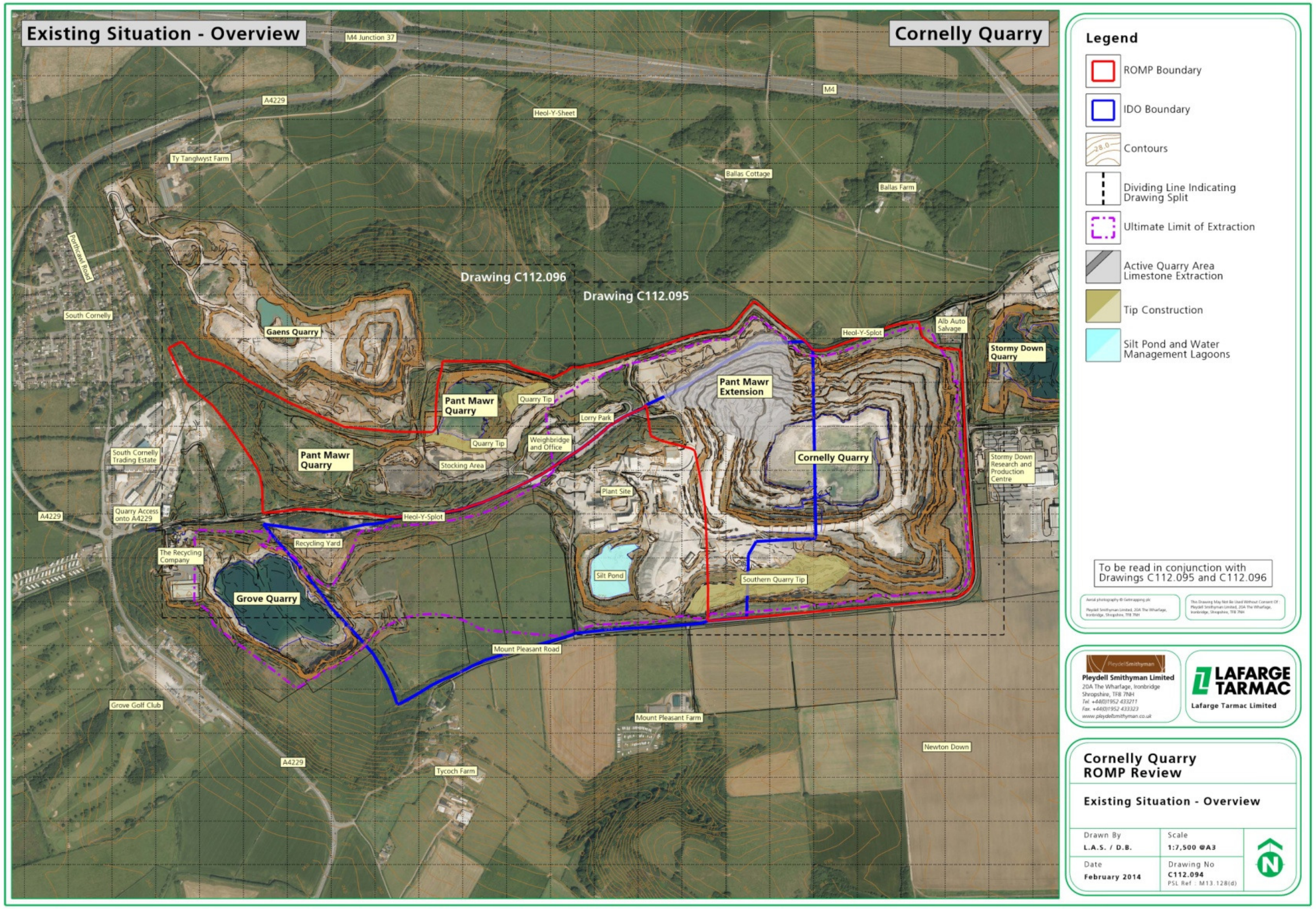


Figure 3-2 Stage 1: 1 – 5 years Cornelly East

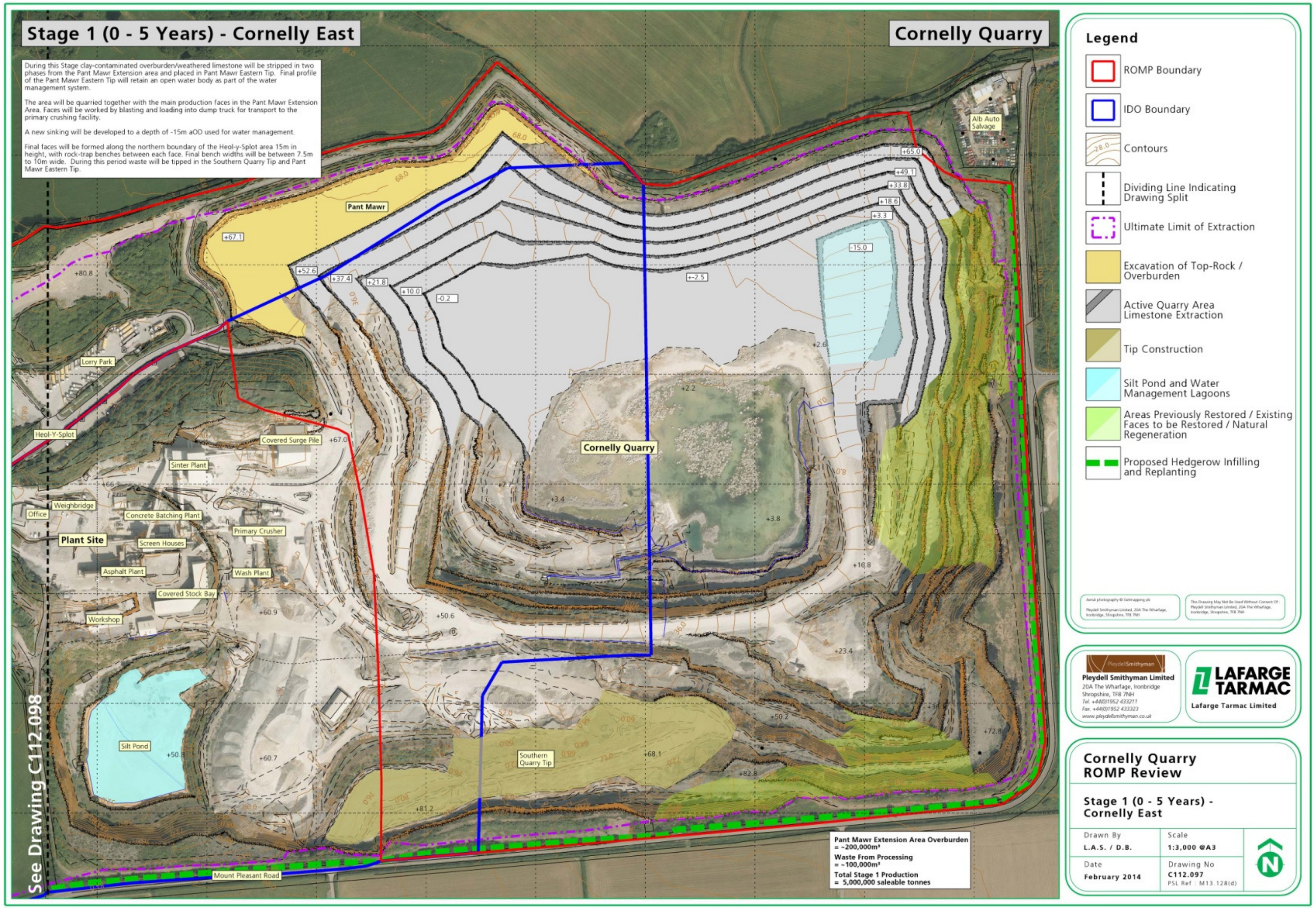


Figure 3-3 Stage 1: 1 – 5 years Cornelly West

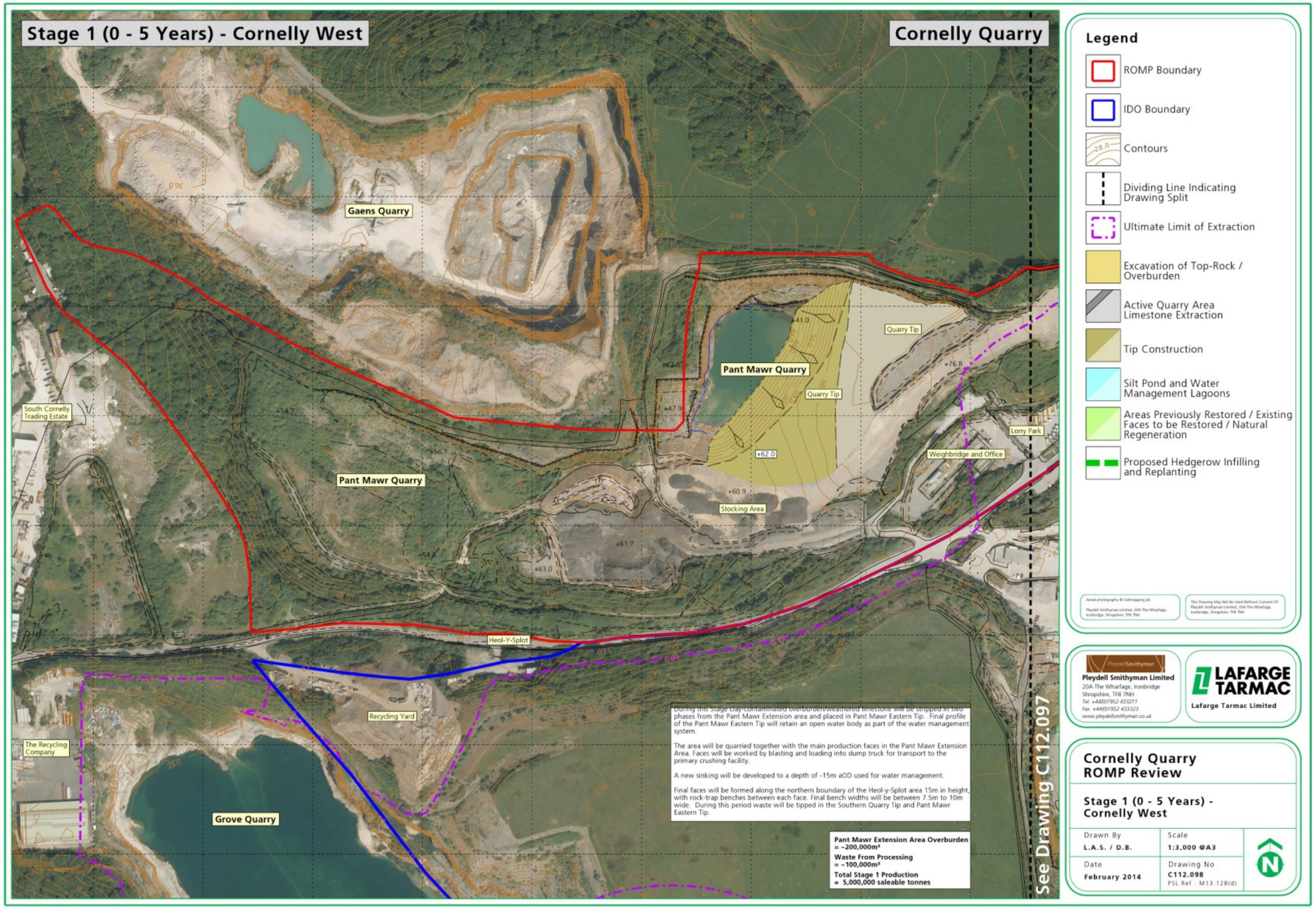


Figure 3-4 Stage 2: 5 – 10 years Cornelly East

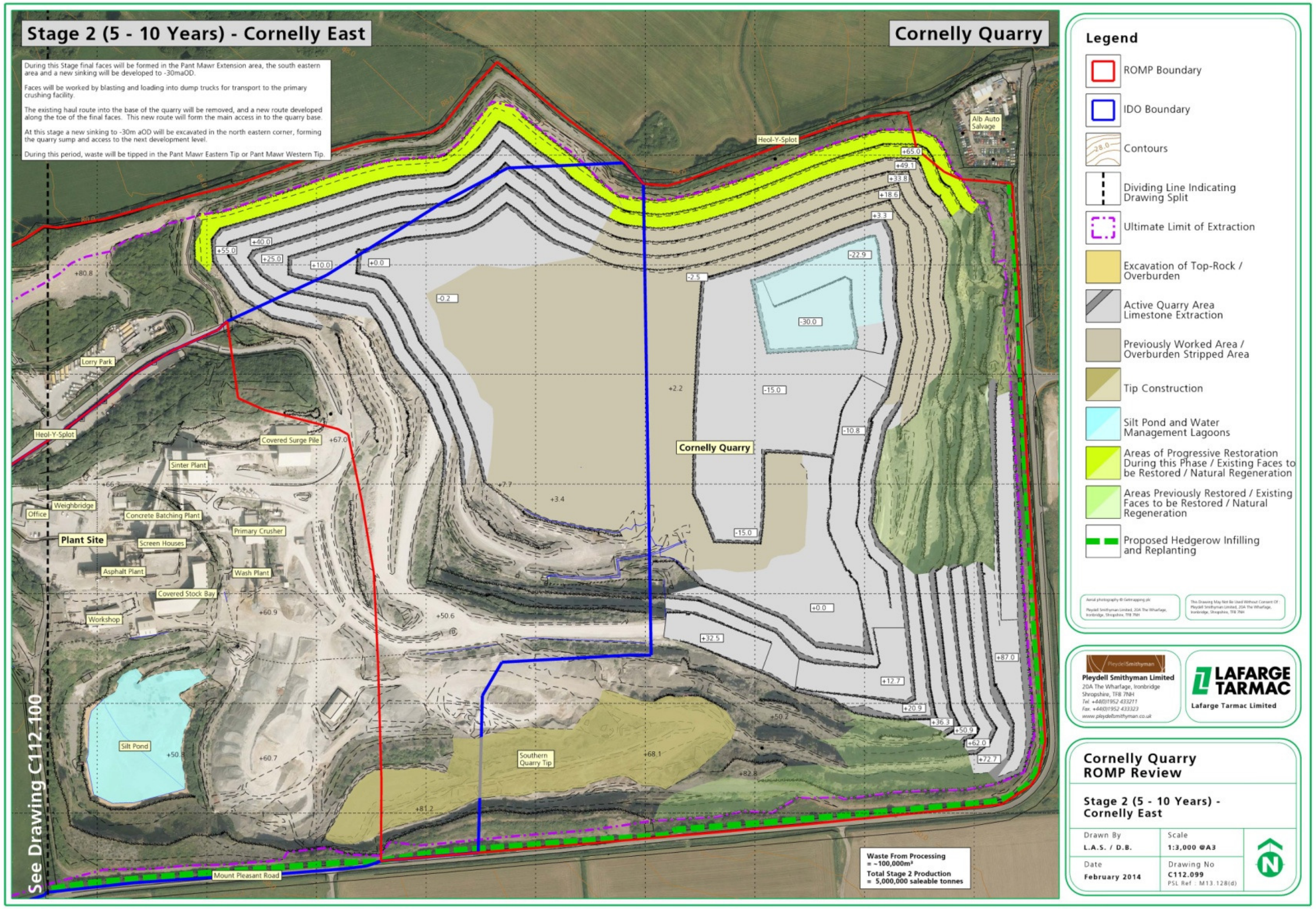


Figure 3-5 Stage 2: 5– 10 years Cornelly West

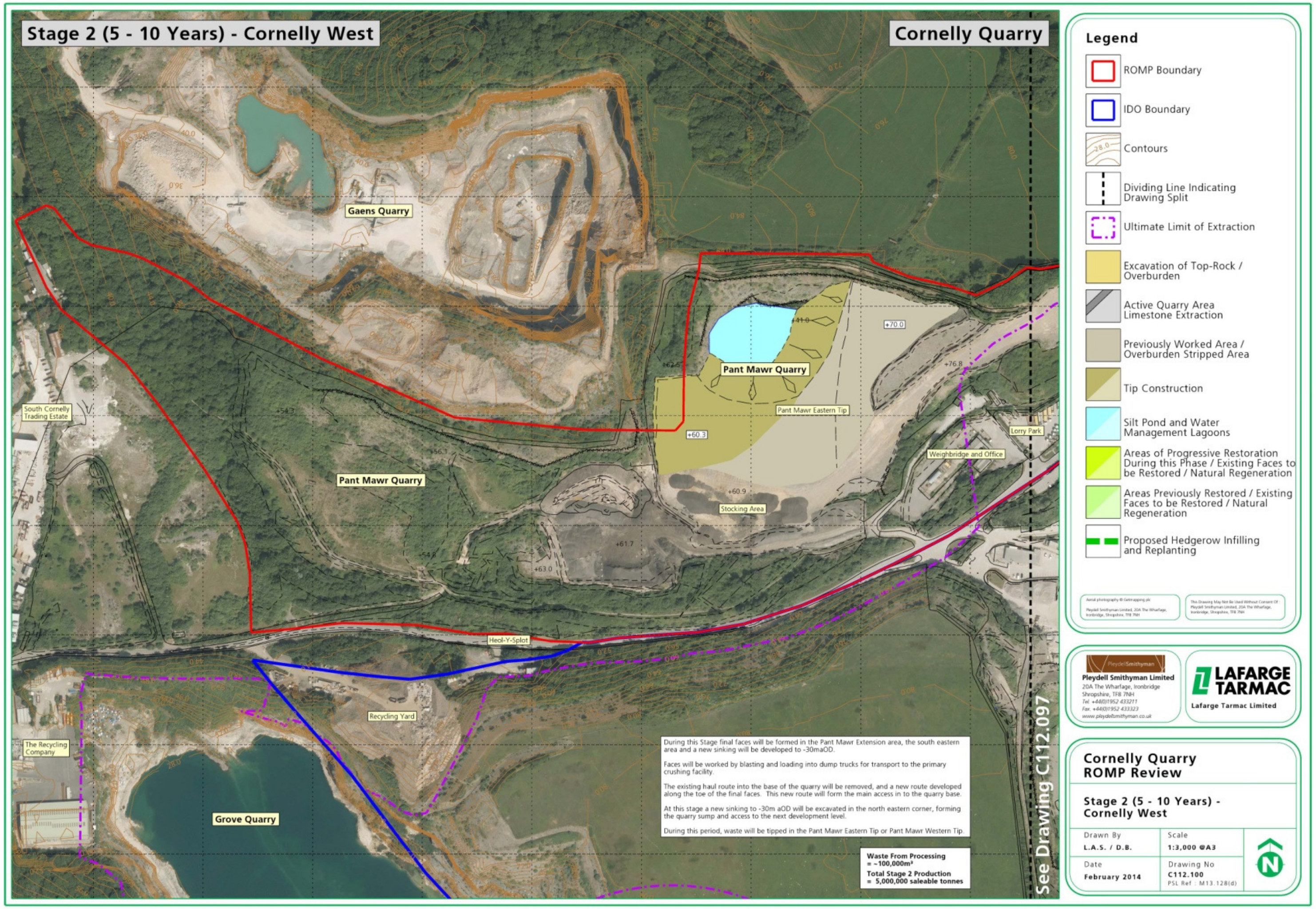


Figure 3-6 Stage 3: 10– 15 years Cornelly East

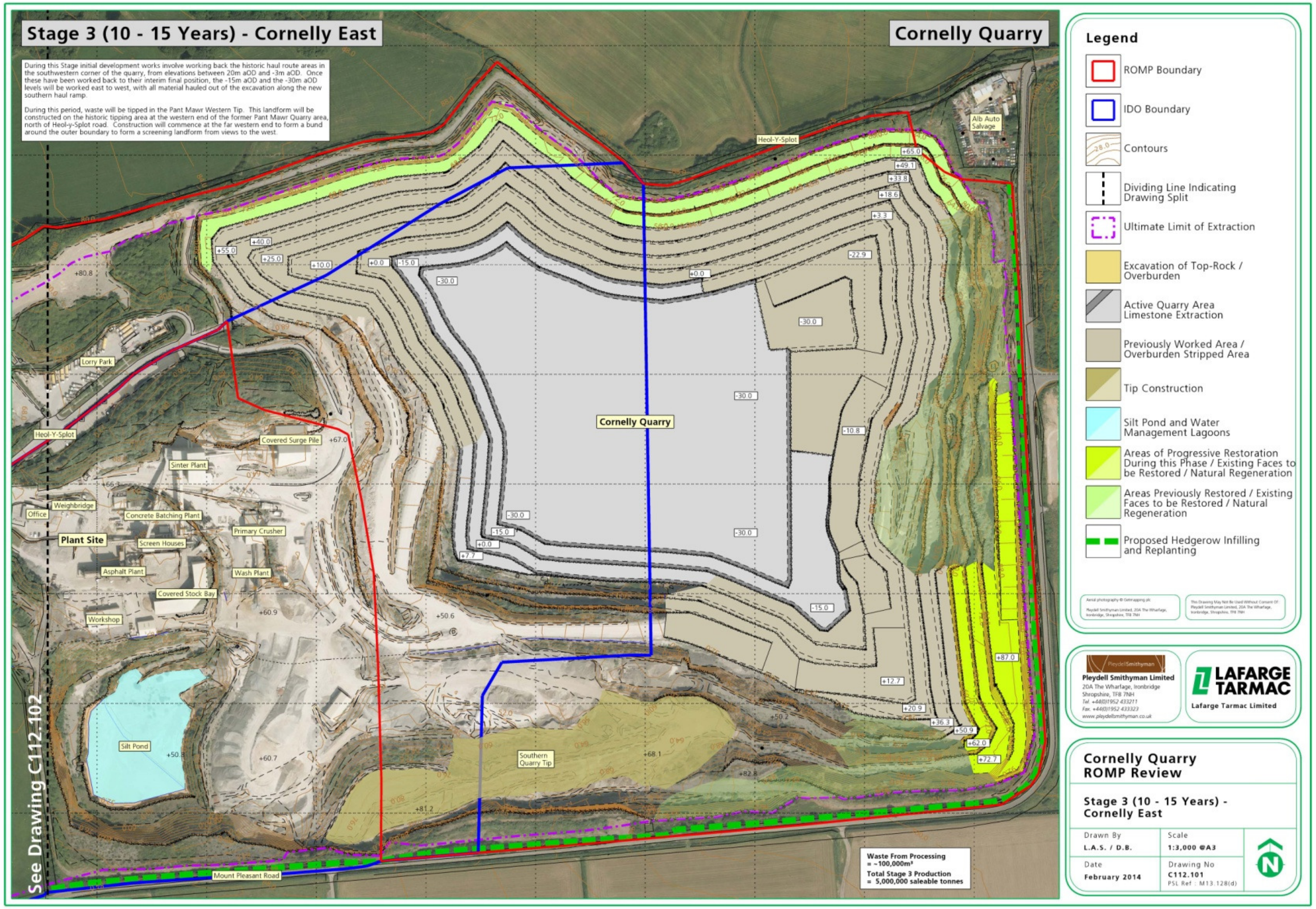


Figure 3-7 Stage 3: 10-15 Years Cornelly West

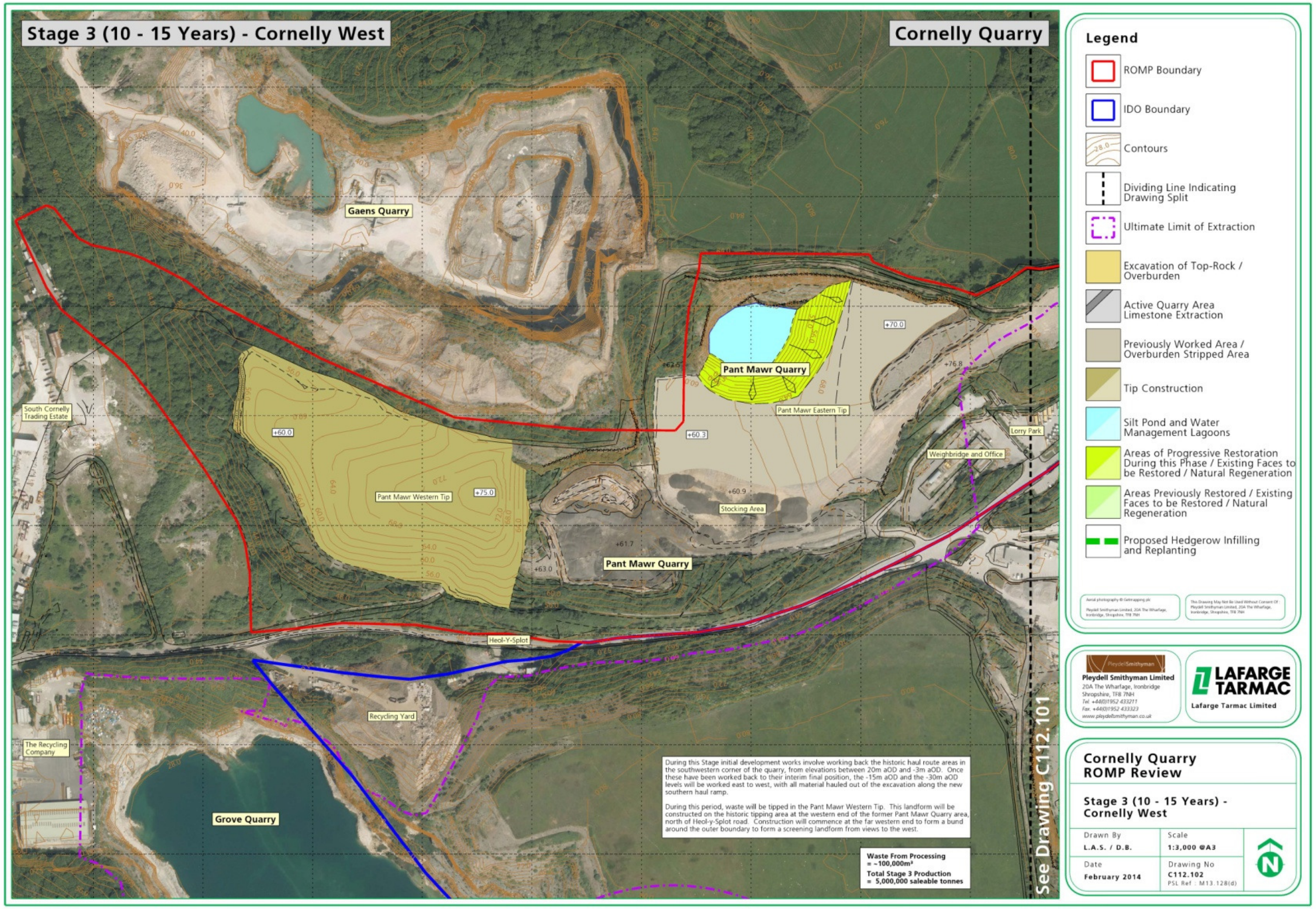


Figure 3-8 Stage 4: 15-30 Years Cornelly East

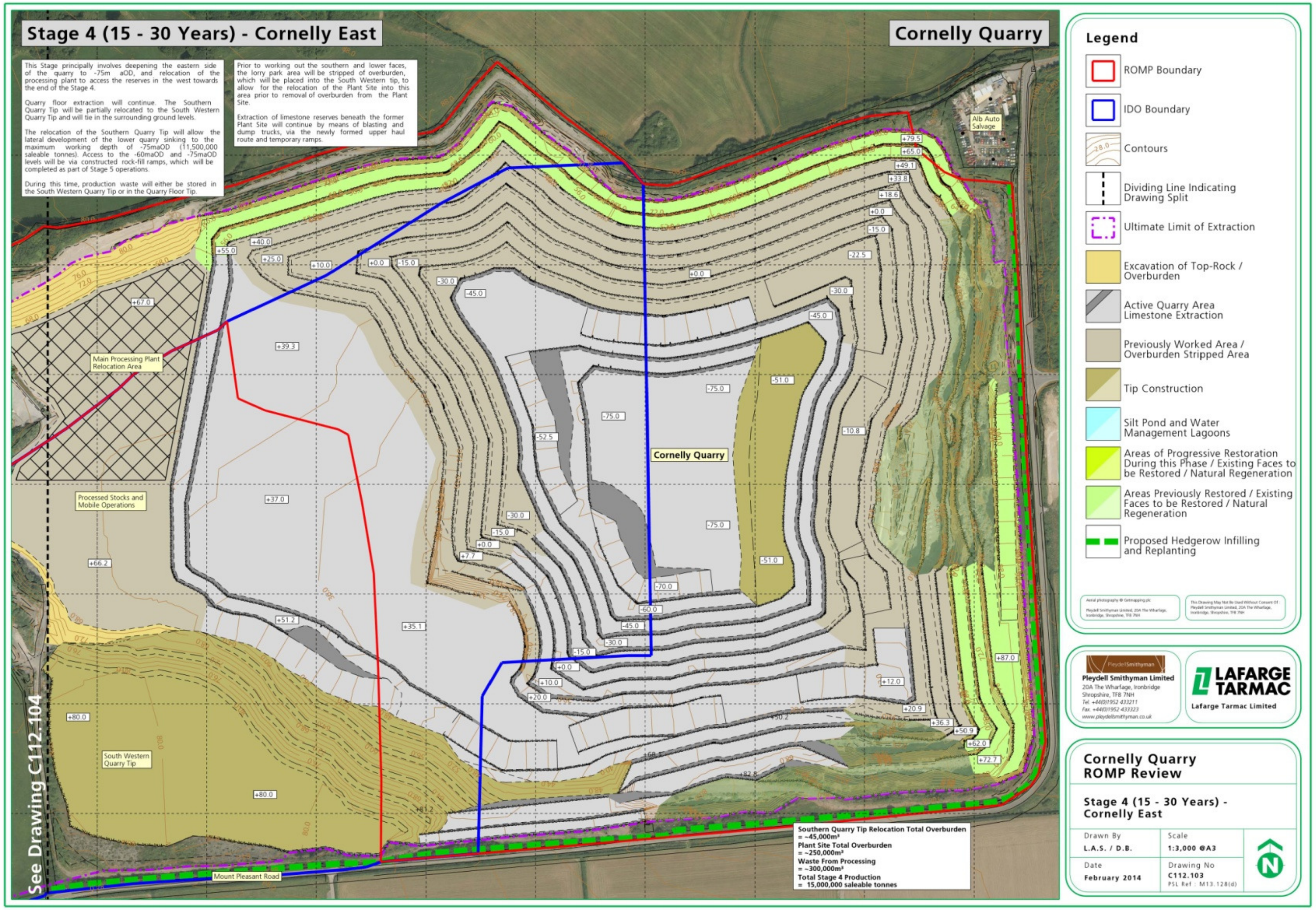


Figure 3-9 Stage 4: 15-30 Years Cornelly West

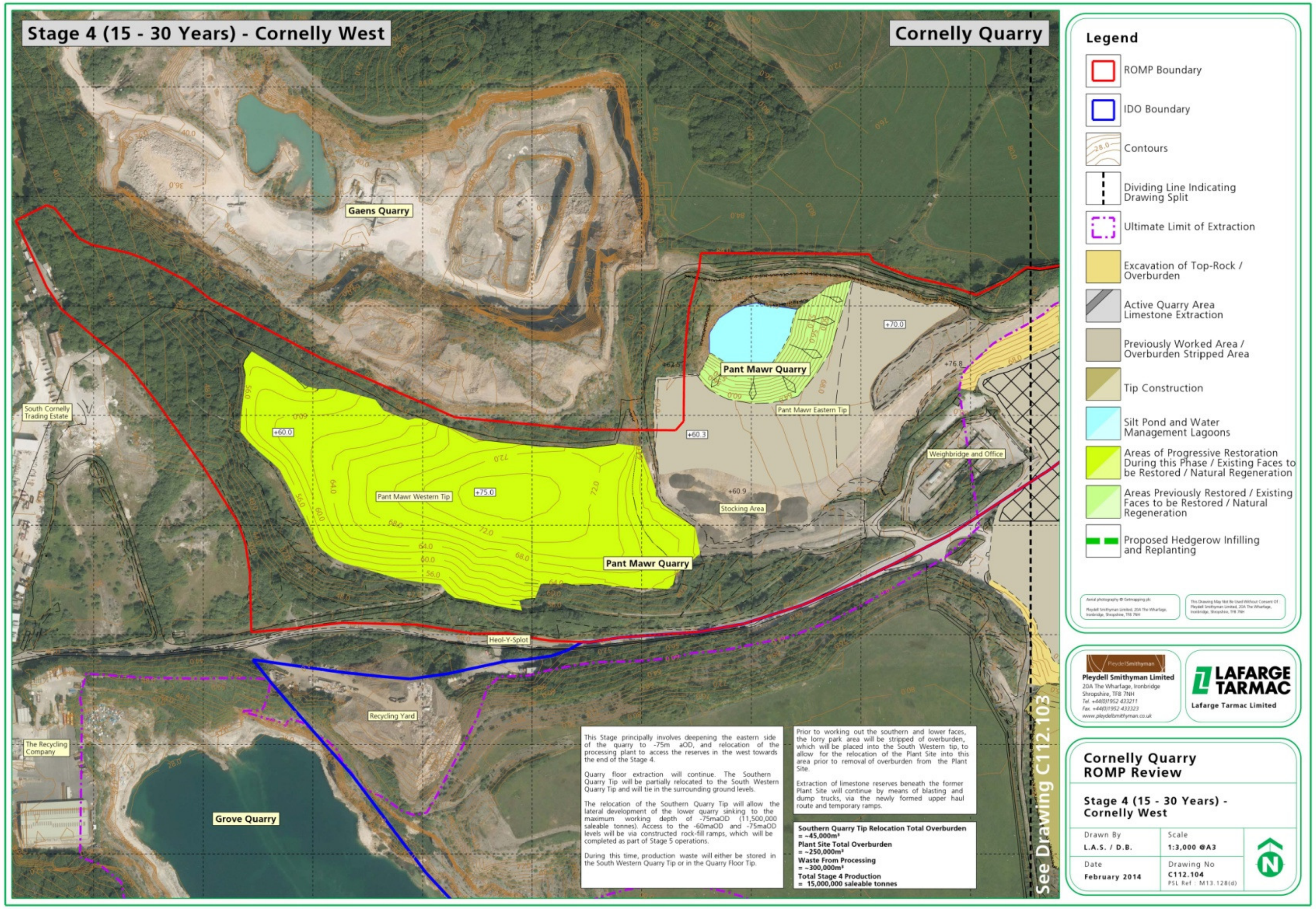
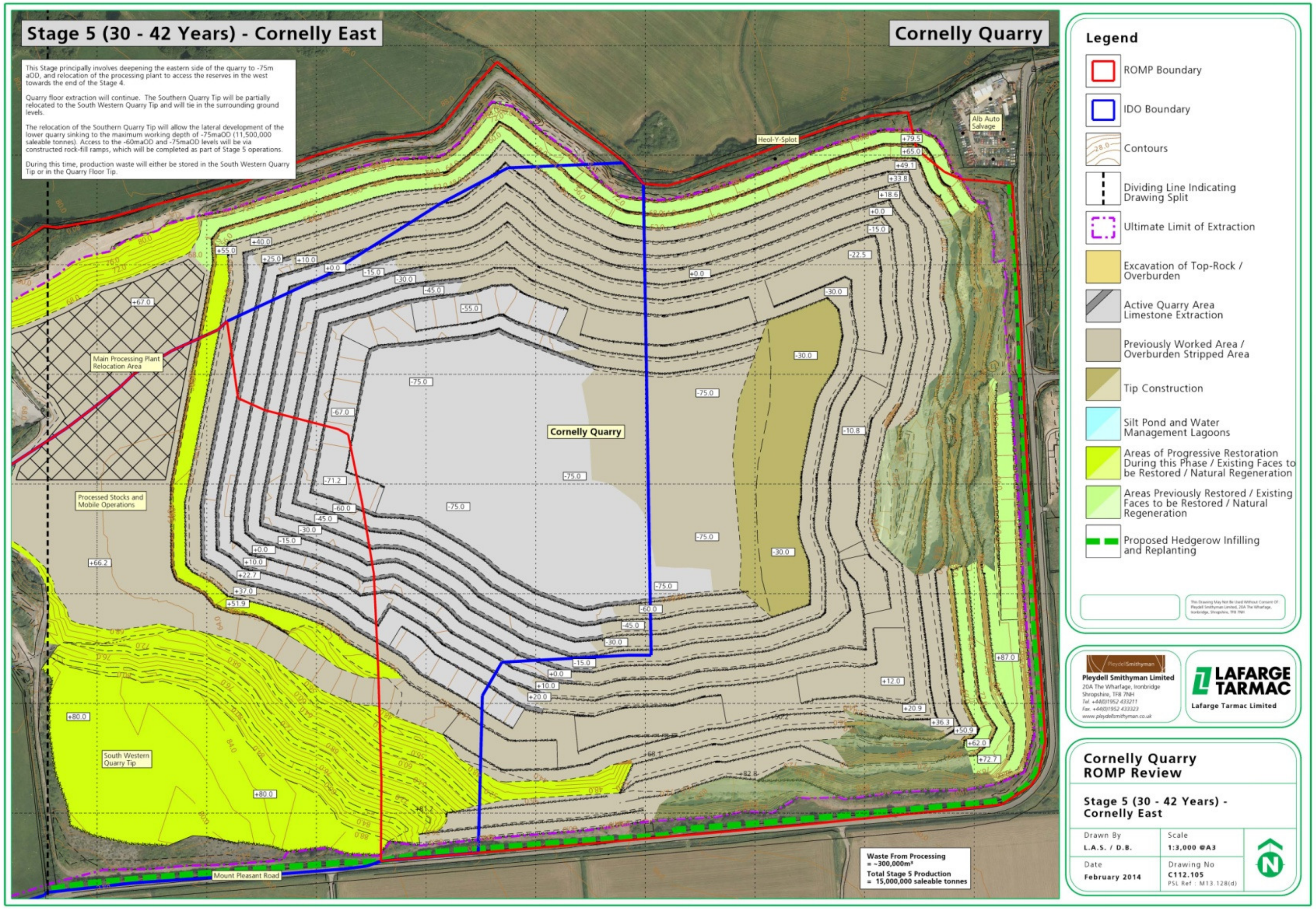


Figure 3-10 Stage 5: 30-42 Years Cornelly East



5.0 ENVIRONMENTAL IMPACT ASSESSMENT

5.1 Introduction

The potential environmental effects of continued quarrying and related activities at Cornelly Quarry (and indirectly Grove and Gaens Quarries) has been informed by (i) the original request from the National Assembly (now WG) for the Applicants to undertake an EIA in support of the ROMP application; (ii) the issuing of a formal Scoping Direction by the WG as part of the procedures introduced by the Stalled ROMP EIA Regulations 2009, which has set out specific requirements as to the issues which should be addressed by the EIA/ES; and (iii) by the Applicants' experience of environmental and amenity issues associated with the ongoing operation at Cornelly Quarry. The result has been a comprehensive study which has addressed each of the individual topics, and, where relevant, the inter-relationship between topics and the potential for indirect remote effects.

As noted in section 1.3.4 of the ES, the need to undertake an EIA in relation to the ROMP applications was prompted by concern raised by the Assembly in relation to the following:

(a) *the potential impact of quarrying on Kenfig Pool and Dunes SSSI a site of European importance being a candidate Special Area of Conservation;*

(b) *the potential impact of quarrying on the hydrology and hydrogeology of the area;*

(c) *the likely impact from further quarrying of the migration of leachate and landfill gas;*

(d) *the likely effect on the visual amenities of the area;*

(e) *the likely impact on flora and fauna in the locality;*

(f) *the scale of traffic likely to be generated and the likely effect on the environment;*

(g) *the likely impact of noise from sources associated with the development and its likely effects on the local population;*

(h) *the likely impact on ground and air vibration on nearby properties and utilities including the reservoir at Ty Coch,and local residents;*

(i) *the likely effects of dust levels on the local population, flora and fauna;*

(j) *the likely environmental effects of the closure of Heol y Splot;*

(k) *the likely effects of quarrying on the archaeological value of the site;*

(l) *the likely implications of quarrying on the stability of surrounding land."*

Of these topics, the key concern was that the development of the quarry, and associated dewatering, might give rise to adverse hydrogeological effects, and indirectly affect the integrity of important nature conservation features, most notably Kenfig SAC.

5.2 Methodology

Each technical chapter sets out the methodology adopted in the assessment, to include, where appropriate:

5.2.1 The approach to the Assessment:

- Desk based data collection, site survey, etc
- Guidance to be adopted [*GLVIA, BS4142 etc*];
- Sources of information
- Scoping and a cross reference to the Scoping Direction

- Relevant Planning Policy or Strategy referred to;
- How "*significance*" is defined ;
- The 'characteristics' of the impacts (see further below).
- The 'sensitivity' of receptors (see further below).
- The 'nature' of the effects (e.g. direct/indirect, temporary (reversible) / permanent (irreversible) (see further below). Further definitions are provided in the ES Glossary.
- How timescales (short, medium, long term) are defined in the assessment;
- Any interaction with other topics [in this case the particular importance of the inter relationship between hydrogeology and potential indirect ecological effects; and
- Any technical difficulties associated with the assessments.

5.3 Assessment Structure

There are be differences of approach in undertaking the respective assessments, which are for certain topics prescribed in detail by external guidance, but where others follow less prescriptive approaches.

The Chapters do however follow a generally common approach with, where appropriate, sections which deal with:

- **Baseline conditions**;
- **Key Receptors**;
- **Summary of development,** highlighting those issues of relevance to the technical topic;
- **Design Mitigation,** highlighting the 'built – in' or 'designed '

- In' mitigation measures;

- **Assessment,** relevant to the technical chapter and following specific technical guidance, but with a description of the sensitivity of receptors, character of impact, significance, and of particular importance in this case, dealing with 'uncertainty' as part of the assessment process, particularly in relation to hydro / ecology issues;
- **Mitigation measures,** which are identified as a means of addressing identified impacts;
- **Residual impacts,** after taking into account in built and additional mitigation measures;
- **Cumulative effects,** particularly relevant to hydro / ecology/ water management, but also a more general requirement of the Scoping Direction;
- **Summary of effects;**
- **Recommendations,** which can be translated into planning conditions;
- **Planning Conditions,** which draws upon the recommendations as a basis for planning conditions; and
- **Conclusions.**
- **Glossary**: the ES includes a central glossary covering all topics.

.

5.4 EIA and ES

A key focus of the EIA has accordingly been to very carefully assess the potential hydrogeological, and indirect hydro- ecological effects. The studies have sought to provide a sound level of understanding of the hydrological and hydrogeological regime, upon which reasoned assessments can be made regarding potential direct and indirect effects, and the mitigation measures which might be available to address any residual uncertainties regarding effects.

The hydrogeological impact study is produced as Chapter 7.0 of the ES, supported by a suite of technical appendices produced within Appendix 7 of ES Volumes 2A – 2C. The potential for indirect effects on Kenfig SAC (and other potentially sensitive ecological receptors) is considered within Chapter 8.0, again supported by technical appendices produced within Appendix 8 of ES Volume 2D.

Subsequent chapters 9.0 -13.0 address other environmental topics in turn, namely:

- Noise (Chapter 9.0)
- Blast Vibration (Chapter 10.0)
- Air Quality (Chapter 11.0)
- Transportation (Chapter 12.0)
- Cultural Heritage (Chapter 13.0)

The underlying objectives of the technical chapters have been to identify impacts and mitigation measures, but, importantly in the context of the purpose of the ROMP Review, to use the assessment to inform the nature of planning conditions which should be imposed to regulate on-going quarrying activities.

An overall summary of the environmental effects is set out in Chapter 14.0 which draws upon the main environmental issues set out in preceding chapters, and the recommendations for mitigation measures. This provides a link between the conclusions and recommendation of the topic studies, and the overall conclusions of the ES.

The planning conditions are further informed by a brief review of planning policy (Chapter 15.0), which, inter alia, highlights WG guidance and requirements for planning conditions (notably the advice set out in MTAN1), and the main issues set out in the adopted Bridgend LDP.

7.0 HYDROLOGY AND HYDROGEOLOGY

7.1 Introduction

The potential for the limestone quarries in the Cornelly area to affect the Kenfig/Cynffig SAC/SSSIs has been recognised since at least 1998 and was a significant driver for the 'calling in' of the initial ROMP applications at Cornelly, Grove and Gaens Quarries. A range of other potential impacts on the local water environment was also recognised at that time.

In 1998 there was significant uncertainty about the risk of these impacts occurring. However, over the last 12 years the quarry operators at Cornelly, Grove, and Gaens have invested in a major programme of investigation, monitoring and analysis aimed at reducing this uncertainty. The assessment presented in this chapter is based on the data collected over this period.

7.2 Scope

7.2.1 Scoping Direction

The WG issued a Scoping Direction for the EIA / Environmental Statement to support the ROMP Review application for new planning conditions at Cornelly Quarry on 3 March 2013 (ref A-PAA-25-08-004 – Appendix 1.2 to the ES (within ES Volume 2D). In summary, with respect to hydrology and hydrogeology this stated that:

The ES should include an updated and refined conceptual model, using all the data collected to date, which will underpin the assessment of potential impact from the dewatering operations on end receptors such as the Kenfig SAC and Cefn Cribwr Grasslands SAC and the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body, which is classified as being of poor status as a result of risks from saline intrusion, water abstraction and flow regulation, diffuse source pollution and terrestrial ecosystems.

The issues which should be addressed include:

- *the potential impact of quarrying on Kenfig/Cynffig SAC/SSSIs and Cefn Cribwr Grasslands SAC/SSSIs;*
- *the potential impact of quarrying on hydrology and hydrogeology of the area, including the possibility of interception during quarrying of a 'highly permeable feature' within the limestone, and although there is a low probability of this occurring the prospect should be recognised as a continuing risk during further development of the quarry and appropriate action identified (for example a risk management/monitoring strategy which recognises the critical stage at which potential adverse impact may occur);*
- *the potential impacts on the Kenfig/Cynffig SAC and the hydrology of the dune system and Kenfig Pool, including the nature of the hydraulic connection between the dune sands and the underlying sand and gravel aquifer at Cynffig/Kenfig SSSI and the related sensitivity of groundwater levels in the dune sands to drawdown in the sand and gravel aquifer;*
- *the potential impacts on other groundwater users and water features in the area;*
- *the potential for quarry dewatering to induce saline intrusion into the aquifer;*
- *the likely impact from further quarrying on the migration of leachate and landfill gas;*
- *the likely impact of quarrying on the stability of surrounding land;*
- *an evaluation of potential surface lowering and sinkhole collapse.*

The ES should include a refinement of the water management plan, which should include a description of water management measures at the quarries, linked to the proposed works, quarry development, quarry restoration and reinstatement and set out the monitoring programme, a description of any necessary remedial strategy and any actions the operator would take to prevent and/or reverse any impacts. This should *facilitate the improved understanding of the regional and local water regime and the nature of any uncertainty which might remain.*

In relation to predicted effects of future quarry development, potential effects that need to be considered and explained include:

- *general effects on groundwater levels and flows and loss of groundwater resources.*
- *derogation of existing or planned groundwater abstraction wells and boreholes*
- *impact on surface watercourses and wetlands*
- *impact on flora and fauna*
- *implications of subsequent water table rebound*
- *saline intrusion caused by changes in groundwater flow paths*
- *subsidence and settlement caused by falling groundwater levels*
- *water flows from proposed discharge points*
- *timing and duration of any impacts*

7.2.2 Background

Cornelly, Grove, and Gaens Quarries

Production in Cornelly Quarry began circa 1875 with extraction of Carboniferous Limestone for lime and aggregates. Cornelly quarry has since developed into the largest quarry in Wales, providing over 1 million tonnes of limestone per year, principally for the steel mill at Port Talbot. The total area covered by existing consents for mineral extraction is approximately 76 ha (both the consented areas and current extent of Cornelly quarry are shown on Figure 2.2 of Appendix 7.1 - ES Volume 2A).

The main quarry floor at Cornelly is currently at around -2 mAOD with a sump at -5 mAOD. Cornelly Quarry is dewatered by pumping from a sump in the quarry floor. This lifts water to a settlement lagoon which is also used to re circulate water used in processing stone on site. Water is also pumped directly to Grove Quarry and re-infiltrates into the Carboniferous Limestone aquifer by seepage through the floor and sides of this flooded quarry. Water has also been pumped to Pant Mawr Quarry and Stormy Down Quarry in the past.

Grove Quarry lies about 1 km to the west of Cornelly. The total area covered by existing consents for mineral extraction at Grove is approximately 30 ha. When worked, Grove quarry requires only occasional dewatering; water is discharged to a disused railway cutting to the west as required. Grove quarry floor is currently at around 30 mAOD. Grove quarry is currently not operational.

Gaens Quarry lies immediately to the north west of Cornelly Quarry and covers a total consented area of approximately 13 ha. Gaens quarry floor is currently at around 11 mAOD with a sump at 9 mAOD.

Planning Context

In 1997, applications were made to Bridgend CBC under the Terms of the Environment Act, 1995 (Review of old mineral permissions, ROMP), for determination of a scheme of conditions for:

- Cornelly Quarry (operated by Cambrian Stone Limited);
- Grove Quarry (then operated by Pioneer Aggregates (UK) Limited, now owned by Lafarge Tarmac Limited);
- Gaens Quarry (operated by T S Rees Limited).

The Gaens Quarry application was called in by the Secretary of State for Wales in May 1998 and the Cornelly and Grove Quarry applications were called in in June 1998. The reasons for these decisions were largely related to concerns about the potential effects of dewatering Gaens, Grove, and Cornelly quarries on the local environment. The National Assembly for Wales (now the WG) subsequently took on the role of determining authority for the applications.

In December 1999, the National Assembly for Wales instructed the British Geological Survey (BGS) to produce a report covering the hydrological issues related to the continued operation of the Cornelly Group of Quarries

(Cornelly, Grove, and Gaens). In August 2000, the National Assembly for Wales requested the preparation of voluntary Environmental Statements (ESs) to assist in the determination of the Environment Act submissions.

In May 2001 ESI Ltd was appointed by the operators of the Cornelly, Grove, and Gaens quarries (the Applicants) to carry out appropriate investigations and to prepare environmental statements presenting hydrogeological impact assessments for the three quarries. Note that in this section the term 'hydrogeological impact assessment' is taken to include the assessment of hydrological impacts associated with the operation of the quarries. Hydrological effects are considered to be entirely related to the dewatering operations as the footprint of the quarries will not significantly change with respect to off site runoff etc. The hydrogeological impact assessment is a technical component of the overall EIA.

A hydrogeological impact assessment for Cornelly Quarry was completed in 2004, and the results were incorporated within an ES accompanying the ROMP application which was submitted to the National Assembly for Wales in October 2004. Following submission of the ES, further discussions were held with the Regulatory bodies, notably Environment Agency for Wales and the Countryside Council for Wales (CCW) (now both incorporated into Natural Resources Wales (NRW)) aimed at clarifying and verifying the conclusions of the ES, and refining the Water Management Plan (WMP) which had been submitted in draft with the ES. This culminated in the submission in September 2007 of an updated WMP for Cornelly Quarry.

Environmental Statements were submitted in January 2008 in respect of the Grove Quarry ROMP Review application, and in September 2009 in support of a First Periodic Review application relating to Cornelly-Grove IDO permitted area. These ESs included updated hydrogeological impact assessments for Cornelly and Grove Quarries.

For reasons explained in Chapter 1.0 of this ES, the respective applications have not been determined, and there is a requirement to undertake further updated EIAs and to present the results in updated formal ESs. This chapter of the ES comprises an update of the previous hydrogeological impact assessments, informed by ongoing discussions with the EA and CCW, and more recently NRW (hereafter referred to as the Regulators).

7.2.3 Study area

The study area for the hydrogeological impact assessment is shown on Figure 7.1. Due to the potential for indirect effects caused by quarry dewatering, this area is larger than the study area for many of the other disciplines within the EIA.

The study area has been defined on the basis of the conceptual understanding of the local hydrogeology that has been developed over the last 12 years of investigation. It includes all the areas that are potentially affected by dewatering at Cornelly, Grove, and Gaens quarries plus some additional areas that allow a holistic (catchment based) approach to the assessment to be completed.

Cornelly, Grove and Gaens quarries are situated on an elevated area of land (up to 100 m AOD) south of Junction 37 of the M4 (Pyle) and immediately to the south and east of the village of South Cornelly. To the west and south west of the quarries, the ground falls steeply to an area where low, rolling ground slopes gently to the sea. There are two large areas of sand dunes close to the coast to the north west (Kenfig) and south (Merthyr Mawr) of this upstanding block of limestone.

The northern edge of the upstanding block of limestone is cut by the M4. To the north of this the ground falls steeply to the valley of the Afon Fach, which runs through the town of Pyle and joins the Afon Cynffig to the west. The high ground extends eastward through Laleston towards Bridgend where it is cut by the valley of the Ogmore River.

A disused quarry and lime works is situated just over 2 km to the north east of Cornelly Quarry and to the north of the M4. A further disused quarry (Stormy Down) is located immediately to the east of Cornelly Quarry; this is now flooded to a considerable depth.

Two former municipal landfills are located in old quarries to the east and south of Cornelly Quarry (Stormy West and Tythegston Landfills respectively). The locations of these landfills are shown on Figure 7.1. Both landfills were closed in the late 1990s and subsequently capped. Neither landfill is lined, both having been designed as dilute and disperse sites.

The dune fields at Kenfig and Merthyr Mawr are classified as SSSIs on account of their rare dune habitats and species. The combined dune field system has been defined as a Special Area of Conservation (SAC) under Council Directive 93/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora referred to as the "Habitats Directive". The extent of the SAC is shown on Figure 2.1 of Appendix 7.1.

7.2.4 Approach to the Hydrology/Hydrogeology Assessment

As discussed above, when the Cornelly ROMP application was first called in, there was a significant degree of uncertainty as to the risk of impacts from quarrying activities, particularly with respect to the Kenfig/Cynffig (then candidate) SAC/SSSIs. Due to the wording of the Council directive 92/43/ECC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora ('Habitats Directive') and subsequent case law which protects these sites, the level of certainty required for the assessment is very high: the Waddenzee Ruling (European Court of Justice Case C-127/02, 7 September 2004) clarifies the requirements of the Habitats Directive, specifically the need for certainty that the project will not adversely affect the integrity of the SAC site to the point that "no reasonable scientific doubt remains".

As a result, the key challenge for the hydrological / hydrogeological impact assessment was to reduce the pre-existing uncertainty about how the local groundwater system behaves and for the associated ecological impact assessment to draw upon this information in reaching informed scientifically robust conclusions regarding possible indirect impact on the SAC.

The objective to reduce uncertainty is acknowledged to be constrained by the nature of groundwater flows in limestone systems where some element of uncertainty will always remain. The task is thus to reduce that uncertainty as far as is practicably possible, and to then consider the extent to which any remaining limited uncertainty influences the impact conclusions or whether residual uncertainties can be addressed by other means. The approach adopted was as follows:

1) Reduce uncertainty in conceptual model and water balance by field investigation and monitoring. This was carried out in a phased manner (see Section 7.2.4) so that the results of each phase could be used to refine and focus subsequent phases.

2) Reduce uncertainty further by construction of a detailed flow network model which allows consistent treatment of groundwater flows within the system and is calibrated to observed flow and heads (Section 7.5.2).

3) Further reduction of uncertainty by extensive sensitivity analysis. Where parameter values could not be fully constrained, these were taken forward to the predictive scenarios (Section 7.5.2).

4) The Scoping Direction (3 March 2013 ref A-PAA-25-08-004 see Section 7.2.1) requires the assessment to address *the possibility of interception during quarrying of a 'highly permeable feature'*. Although not consistent with the conceptual model and calibrated flow network model presented in this report, this issue must therefore be addressed in the assessment. The issue is therefore discussed at several points in the text below but ultimately this risk is addressed by means of a revised Water Management Plan which specifies the monitoring required and the Contingency Measures that should be taken if such a feature were to be encountered.

Each of these phases was carried out in close consultation with the regulators. This phased process has provided the opportunity to reduce the level of uncertainty in the assessment to a level that allows the related ecological impact assessment to draw conclusions which meet the exacting requirements of the Habitats Directive.

7.2.5 Programme of Work

Submission of first set of ESs (up to September 2009)

The report prepared by The British Geological Survey (BGS) on behalf of the National Assembly for Wales (BGS, 2000) made a number of recommendations for further investigations that could be carried out in order to clarify the local hydrogeology at the level of detail required. The approach recommended by BGS was reviewed by ESI Ltd and was considered to be too prescriptive: instead a phased approach was proposed. This revised approach was discussed with the regulators and submitted to the WG in July 2001 as an informal 'Scoping Request' (ref ESI, 2001).

The phased approach that was adopted for the investigations was designed to allow the key uncertainties in the conceptual understanding of the study area to be identified at the start of each phase (in discussion with technical experts from the relevant regulatory bodies). The investigations in each phase were then designed in order to maximise the opportunities to reduce these uncertainties. Close liaison with the regulators on these issues has guided the design of each phase of work.

The work was carried out in three main phases:

> **Phase 1** (water features survey, spot gauging, geophysics and construction of additional monitoring boreholes) was completed in late 2001. An interim factual report was prepared to integrate the findings of Phase 1 into the existing conceptual understanding of the area (ESI, 2002a). The aim was to highlight aspects of the conceptual model for which uncertainty still existed. This provided a target for investigations during Phase 2 (ESI, 2002b).
>
> **Phase 2** (additional drilling, tracer test and continued monitoring) took place during the summer and autumn of 2002. A factual report summarising all the work carried out under Phase 2 and the results of monitoring to date was issued at the beginning of March 2003 (ESI, 2003a).
>
> **Phase 3** Building on the data gathering and collation work undertaken during both Phases 1 and 2 of the study, a conceptual hydrogeological model of the area was developed (ESI, 2003b). The purpose of this report was to set out the conceptual model of the local hydrogeology. This conceptual model was used for quantifying the likely impact of quarrying dewatering and the technical basis for the first hydrogeological impact assessment of Grove, Cornelly and Gaens quarries. The conceptual model report also provided the baseline data for the first hydrogeological impact assessment.

Following submission of the conceptual model report, several meetings were held with the technical experts from the relevant regulators (principally Environment Agency Wales (EA Wales) and CCW) in order to clarify all aspects of the conceptual model. Further details of the approach adopted to some of the calculations were also submitted at that time (ESI, 2003c). Confirmation was received that all information to support the conceptual model was adequately described (Environment Agency, 2003a and b).

During the process of reviewing the voluntary Cornelly Quarry ROMP ES (which was submitted in October 2004, see Table 7-1 below), EA Wales made further comments on the conceptual model and provided a draft report on the nitrogen budget for Merthyr Mawr which contained some information relevant to the hydrogeology of the area (Jones et al 2005). EA Wales commissioned some further work on the Merthyr Mawr Blown Sand dune system and draft outputs were provided. Key elements relevant to these reports are discussed in Section 7.4.1.

In total, three hydrogeological impact assessment reports were produced, each covering the potential impacts relating to one of Cornelly, Grove, and Gaens quarries in isolation as well as the combined effects of working all three of them in conjunction. These are detailed in Table 7-1.

Table 7-1 Impact Assessment Reports

Report title	Report content
Cornelly Group of Quarries: Impact Assessment for Cornelly Quarry and Combined Quarries (ESI, 2004)	Quantified assessment of the likely impacts on a targeted list of water features, resulting from proposed quarry development activities at Cornelly Quarry alone and also in response to combined quarry development activities at Cornelly, Grove and Gaens quarries.
Cornelly Group of Quarries: Impact Assessment for Grove Quarry (ESI, 2008)	Quantified assessment of the likely impacts on a targeted list of water features, resulting from proposed quarry development activities at Grove Quarry.
Cornelly Group of Quarries: Impact Assessment for Gaens Quarry (ESI, 2010) – Unsubmitted draft.	Quantified assessment of the likely impacts on a targeted list of water features, resulting from proposed quarry development activities at Gaens Quarry.

In addition a combined EIA was produced for the Periodic Review of the IDO permission covering parts of Cornelly and Grove quarries (WYG, ES January 2009).

Discussion on the scope and content of the Water Management Plan for Cornelly Quarry continued up until June 2009 with several iterations being submitted for review by the regulators with comments being addressed in subsequent iterations.

A summary of reports and studies prior to the March 2013 Scoping Directions is provided in Section 7.4.1.

Submission of second set of ESs (up to present)

The ROMP process stalled following the submission of the first set of ESs until March 2013, when new Scoping Directions (dated 4th March 2013) were issued for each of Cornelly , Grove, and Gaens quarries by the WG under the Town and Country Planning Act (Environmental Impact Assessment) (Undetermined Reviews Of Old Minerals Permissions) (Wales) Regulations 2009, referred to elsewhere in this ES as the Stalled ROMP EIA Regulations 2009.

These are summarised in Section 7.2.1 and provided in full in Appendix A of Appendix 7.1. These form the context for the work presented in this ES including the Revised Conceptual Model Report presented in Appendix 7.1.

A key requirement of the Scoping Direction for Cornelly Quarry is for the conceptual model to be updated to take account of new data and for all the work to be brought together into a single coherent structure. The additional work incorporated into and carried out for the revised conceptual model was:

- Review of recent monitoring data (groundwater levels, surface water flows, quarry pumping, chemistry and climate data);
- Incorporation of additional borehole data;
- An updated palaeokarst survey;
- A review of rainfall and recharge calculations;
- A revised approach to modelling of the system which included explicit simulation of groundwater within the Kenfig and Merthyr Mawr Blown Sand aquifer systems in transient (rather than steady-state) mode.

7.2.6 Consultation

As noted above, the programme of investigation has been designed, implemented and reviewed in close consultation with technical experts from the regulatory authorities, particularly NRW (and its antecedents). The following meetings were held during the course of the Phase 1, 2 and 3 investigations:

Table 7-2 Summary of Meetings for Phase 1, 2, and 3 Investigations

DATE	MEETING / CORRESPONDANCE
29-May-01	Meeting to discuss Phase 1 report and proposals for Phase 2.
08-Jun-01	Meeting with CCW to discuss citation details of SAC and monitoring data
21-Jun-01	Meeting with Agency to discuss approach to investigations and EIA
03-Jul-02	Technical meeting to review Phase 1 report and proposals for Phase 2.
23-Oct-02	Technical meeting to discuss results from Phase 2 and need for any more work.
31-Oct-02	Full meeting to discuss results from Phase 2 and need for any more work.
19-Aug-03	Full meeting to discuss conceptual model report.
16-Oct-03	Full meeting to discuss conceptual model report.
07-Nov-03	Technical meeting to discuss conceptual model report.

Following the issue of the first voluntary ES in support of the Cornelly Quarry ROMP application (October, 2004), there was a period of correspondence between the various parties to clarify various parts of the hydro assessment. This included a meeting on 4 May 2005 between staff from ESI and WMC (Water Management Consultants Ltd - the consultants appointed by EA Wales to review the technical aspects of the hydrogeological impact assessment) to discuss the water balance model that forms the technical core of the hydrogeological impact assessment. EA Wales issued its formal response to the first ES in support of the Cornelly Quarry ROMP application in July 2005 and ESI subsequently provided the results of further detailed calculations and clarifications, as summarised in Table 7-3 below.

Following submission of the first voluntary ES and draft WMP, a series of discussions and exchanges of correspondance took place between representatives of the Applicants (ESI) and the regulatory bodies, notably EA Wales, CCW and the National Assembly for Wales. A summary of those exchanges is set out in Table 7-3 below.

Table 7-3 Consultation on WMP

DATE	MEETING / CORRESPONDANCE
28.10.04	Meeting between the National Assembly for Wales, EA, CCW, BCBC and Applicants to review content of ES and first draft WMP.
28.01.05	Meeting between National Assembly for Wales, EA, CCW, BCBC and Applicants to progress discussions on ES.
23.02.05	Letter from EA to Applicants requesting clarification of technical data and submission of water balance spreadsheets.
11.03.05	Response from ESI with further data supplied by email on 04.04.05.
11.03.05	Letter from CCW to Applicants relating to, *inter alia*, significance of changes in water levels in the Blown Sand aquifer system, and the content of the WMP and mitigation strategy.
25.05.05	Letter from EA requesting additional data in support of the hydro study.
09.05.05	Letter from ESI to EA with the requested data.
04.07.05	Letter from EA raising further queries and providing report on Merthyr Mawr.
11.07.05	Preliminary response from ESI to EA.
23.11.05	Letter from ESI to EA with requested further hydrological calculations.
03.10.05	Reply from EA with particular reference to timescale of water level recovery following cessation of dewatering.
14.11.05	Letter from WYG to the National Assembly for Wales with comments on the letter from the EA of 03.10.05.
01.12.05	Letter from WYG to the National Assembly for Wales, with comments on the CCW letter of 11.03.05.

DATE	MEETING / CORRESPONDANCE
24.04.06	Letter from CCW to the National Assembly for Wales, cross-referencing letter dated 05.10.05 from CCW to the National Assembly for Wales.
26.05.06	Letter from WYG to the National Assembly for Wales.
18.07.06	Letter from EA to the National Assembly for Wales, requesting further details/ clarification of groundwater model and assumptions, and suggested alterations to the WMP.
19.07.06	Meeting to discuss current position and outstanding issues attended by CCW, EA, National Assembly for Wales and Applicants, where the key focus was on the need for an updated WMP.
14.08.06	Technical meeting to discuss content of WMP attended by ESI, EA and CCW.
25.09.06	Further technical meeting to review draft WMP (V1.1) attended by ESI, EA and CCW.
23.10.06	Circulation of revised draft WMP (V1.2) to the National Assembly for Wales, CCW, EA and BCBC.
16.01.07	Technical meeting attended by ESI, EA and CCW to discuss draft WMP.
19.09.07	Formal submission of revised and updated WMP (ref August 2007) to the National Assembly for Wales, CCW, EA and other interested parties.
Oct-08	v3.1b Cornelly WMP submitted in response to WAG Jun 08 comments
Sep-09	v3.1c Cornelly WMP submitted with combined Cornelly Grove IDO EIA

Following revival of the ROMP process in March 2013, a series of communication and meetings were held with NRW to allow involvement with the process of revision of the conceptual model and numerical model development and to keep relevant technical experts up to date with the proposed approach and results of modelling of Cornelly, Grove, and Gaens Quarry development scenarios. These interactions are summarised in the table below:

Table 7-4 Post March 2013 Consultation with NRW

DATE	MEETING / CORRESPONDANCE
19.06.13	Initial meeting to allow acquaintance of new ES and NRW team; confirm issues outstanding; discuss levels of assessment and the requirements of the habitats directive; dealing with uncertainty
13.08.13	Cornelly site visit. Discussion with focus on outstanding hydrogeological issues.
11.10.13	Issue conceptual model report for review.
25.10.13	Presentation and discussion of conceptual model.
08.11.13	Further technical discussion on the conceptual model and focusing in on the numerical model.
02.12.13	Presentation and discussion of quarry development model prediction runs.
14.02.14	Presentation of hydrogeological impact assessment results and conclusions.

7.3 Proposed Development

7.3.1 Cornelly, Grove, and Gaens Quarry Development

Summary details of the proposed future phasing of Cornelly, Grove, and Gaens Quarries are shown in Table 7-5 to Table 7-7. In addition, the proposed phasing plans for these quarries are shown in Appendix B of Appendix 7.1.

The proposed phasing of Cornelly Quarry is summarised in Table 7-5 Excavation details are based on Lafarge Tarmac drawings C112.087 to C112.092 dated February 2014.

Table 7-5 Proposed Quarry Phasing - Cornelly Quarry

Timescale*	Drawing No.	Planned Excavation	Comments
Stage 0 (Present day)	C112.095	Main quarry floor at -2 mAOD	Current situation
Stage 1 (0-5 years)	C112.097	Main quarry floor at 0 to -3 mAOD. Expansion of lowest level northwards and working of northern benches.	Quarry sump at -15m AOD
Stage 2 (5-10 years)	C112.099	Lowest floor level at –15 mAOD. Working of north western, eastern, and south eastern parts of the quarry.	Quarry sump at -30m AOD
Stage 3 (10-15 years)	C112.101	Lowest floor level at –30 mAOD. Working of central area of quarry.	End current ROMP cycle position
Stage 4 (15-30 years)	C112.103	Lowest floor level at –75 mAOD. Working of central, southern and western areas of quarry.	
Stage 5 (30-42 years)	C112.105	Lowest floor level at –75 mAOD. Working of central, southern and western areas of quarry.	42 years represents the end of the planning permission.

* Timescales measured from August 2013

The proposed phasing of Grove Quarry is summarised in Table 7-6. Final excavation levels are shown on Lafarge Tarmac's drawing 03/175/D03 dated 25 September 2003. No information exists on specific dates at which various levels will be reached within Grove Quarry; however, for the purposes of the hydrogeological impact assessment it is conservatively assumed that the full depth of excavation will be achieved within 15 years and maintained for 42 years.

Table 7-6 Proposed Quarry Phasing – Grove Quarry

Timescale	Planned Excavation	Comments
Present day	Deepest excavation around 12 mAOD.	Current situation
15 years	Excavation to -15 mAOD	
42 years	Excavation to -15 mAOD	

The proposed phasing of Gaens Quarry is summarised in Table 7-7. Final excavation levels are based on SLR drawing 3782/05 dated January 2014. It is understood that final development represents approximately 50 years of working, although no information exists on specific dates at which various levels will be reached within Gaens quarry. A most likely phasing is presented in the table and assumed for the purposes of the hydrogeological impact assessment.

Table 7-7 Proposed Quarry Phasing – Gaens Quarry

Timescale	Planned Excavation	Comments
Present day	Deepest level at around 9 mAOD.	Current situation
15 years	Excavation to 0 mAOD	
42 years	Excavation to -20 mAOD	

7.3.2 Cornelly, Grove, and Gaens Quarry Restoration

Cornelly, Grove, and Gaens quarries will ultimately be restored to open bodies of water. The likely position to which water levels will ultimately recover has been assessed as part of this hydrogeological impact assessment.

Substantial volumes of water are required to fill the Cornelly, Grove, and Gaens Quarry voids (particularly Cornelly Quarry) and the period during which this recovery is occurring has been flagged by this assessment as a potentially critical period for impacts to occur. It is important that monitoring of the environment continues after the end of normal operation at Cornelly, Grove, and Gaens quarries until it can be demonstrated that no significant impacts are likely to occur. Some form of residual pumping for several years after the end of extraction may be required to mitigate any such impacts.

7.4 Baseline Conditions

The baseline hydrogeology of the study area has been described in a series of reports issued by ESI (see Table 7-8). Key reports are the original conceptual model report (ESI, 2003b) and the updated conceptual model presented in support of this assessment (Appendix 7.1). These present baseline conditions, including local surface water features, geology, hydrogeology (groundwater levels and flows), hydrochemistry, land use, water users and other relevant human activities.

Current conditions (which are equivalent to the baseline conditions discussed above) do not represent an undisturbed baseline in that Cornelly, Grove, and Gaens quarries have already been substantially developed, and Cornelly Quarry is being dewatered to a substantial depth. However, the effect of current dewatering is limited to a relatively small area around Cornelly, Grove, and Gaens quarries and, for most of the rest of the area, current conditions are a good approximation to baseline conditions. The long time series of data collected at most monitoring sites supports this conclusion (e.g. Appendix K of Appendix 7.1).

Very small ‘theoretical’ effects (i.e. below the resolution of available monitoring techniques) are simulated over a broad area by the flow network model developed for this assessment (Appendix 7.3 - ES Volume 2B). These effects are discussed in detail in Appendix 7.4 - ES Volume 2B.

7.4.1 Previous reports

A summary of relevant reports and studies to date is presented in Table 7-8 below.

Table 7-8 Reporting History prior to submission of first set of hydrogeological Impact Assessment Reports

Report title	Report content
Scoping Request - Hydrology and Hydrogeology (ESI, 2001)	The response to an informal scoping request by the National Assembly of Wales in respect of proposed Environmental Impact Assessments (EIAs) being undertaken for Cornelly, Grove, and Gaens quarries. This scoping report relates only to environmental issues linked to the water environment (hydrology and hydrogeology). A preliminary conceptual model of the hydrogeology of the study area is included.
Cornelly Group of Quarries: Proposed Programme of Work for Phase 2 Hydrogeological Investigations (ESI, May 2002a) Report Reference 6227R2D2	Outlines a proposed programme of borehole and water feature monitoring across the study area, designed to address a range of hydrogeological uncertainties relating to the conceptual groundwater system.

Report title	Report content
The Hydrogeology of the Area Around the Cornelly Group of Quarries (ESI, May 2002b) Phase 1 Report Reference 6227R3D2	A factual summary of the data collected during Phase 1, including information concerning local geology, hydrology, formation properties, key water features, and general groundwater conditions. The data are drawn together to illustrate the preliminary conceptual model of the hydrogeology of the study area. Key uncertainties in the conceptual model are highlighted.
Hydrogeological Investigations at the Cornelly Group of Quarries: Factual Report on Phase 2 (ESI, March 2003a) Report Reference 6227R4	Sets out the results of the Phase 2 work including a report on the tracer tests by Prof P Smart. No attempt is made to refine the conceptual model of the area although some interpretation of the geology in the vicinity of Kenfig Pool is undertaken.
Cornelly Group of Quarries: Conceptual Model of the Local Hydrogeology (ESI, July 2003b) Phase 3 Report Reference 6227R5D1	Presents the conceptual model of the hydrogeology of the area based on all of the work to date. A key part of the report is the identification of any significant uncertainties in the conceptual model and discussion of how these will affect the approach to the hydrogeological impact assessment.

In addition, annual reports in the format consistent with the requirements of the Water Management Plan for Cornelly (Appendix 7.6 - ES Volume 2C) have been prepared since 2007. These present the baseline data in detail and discuss trends on a year by year basis.

Since the issue of the draft ES in March 2014, an annual report reviewing the data collected in the Cornelly area between April 2013 and March 2014 has been prepared and is produced as a new Appendix 7.5. This most recent data has been reviewed in the context of the ES and it is concluded that the data is consistent with the conceptual model reported in the ES and the overall conclusions of the ES.

7.4.2 Geology

A detailed description of the geology can be found in Appendix G of Appendix 7.1. A summary is provided below.

Regional Geology

<u>*Solid Geology*</u>

The key solid geology formations are:

- Triassic Mercia Mudstone: Coarse grained, conglomeratic marginal facies (aquifer) and distal mudstone facies (non aquifer);
- Carboniferous Limestone: A variable sequence of limestones, shales and sandstones. The most layered, shaley units are concentrated at the top and bottom of the sequence. The main limestones worked at the quarries comprise the Cornelly Oolite and Stormy Limestone (Cornelly and Grove) and the overlying Oxwich Head Limestone (Gaens Quarry).

The mapped extent of these strata and associated cross sections from the BGS (2000) are shown on Figure 3.1 and 3.2 respectively in Appendix 7.1.

The Carboniferous Limestone which is worked by Cornelly, Grove, and Gaens quarries forms the main aquifer in the area, and is classified as a Major Aquifer by NRW for the purposes of groundwater protection. The Carboniferous Limestone forms the higher plateau around Cornelly, Grove, and Gaens quarries.

Other formations form minor aquifers (e.g. the blown sand deposits at Kenfig and the Triassic Mercia Mudstone Marginal Facies) or non-aquifers (e.g. the Mercia Mudstone (undifferentiated) and the estuarine clays and silts at Kenfig).

The major unconformity between the Carboniferous strata and the overlying Triassic deposits is a significant feature of the local geology. The exposure of the limestone to erosion and karstification during this period is discussed below and in Appendices G and H of Appendix 7.1.

The Carboniferous strata dip to the north at 0 to 40^{o} exposing progressively younger strata to the north. The sequence is also disrupted by the north west - south east Newton Fault and associated splays. To the north, the sequence is truncated by the east-west Triassic Boundary Fault which downthrows Triassic Mudstones and Upper Carboniferous Coal Measures strata.

Superficial Geology

The superficial deposits in the study area are shown on Figure 3.3 of Appendix 7.1. The main units of significance at outcrop are:

- Blown sands: The dune fields at Kenfig and Merthyr Mawr comprise loose, fine-grained sand with shell debris.
- Estuarine clays and alluvium (organic rich clays and silts with beds of peat) underlies the blown sands at Kenfig. At Merthyr Mawr a thin 1-3 m thick clay layer underlies the Blown Sands.
- Till: Much of the area around Pyle is underlain by relatively impermeable Diamicton and gravelly, clayey sand.
- Glaciofluvial deposits. Predominantly sand and gravel forming a minor aquifer. This underlies the estuarine clays at Kenfig. In places this lies directly on the Triassic marginal facies or Carboniferous Limestone thus providing a potential pathway between the main aquifer system and groundwater in the superficial deposits.

Local Geology

Kenfig

A schematic diagram of the evolution of Kenfig Pool is shown in Figure 3.4 of Appendix 7.1 (BGS, 2000).

The nature of the superficial deposits in this area is of critical importance to the understanding of the degree of connection between the Blown Sand hydrological system and that of the underlying Triassic and Carboniferous strata. This in turn has implications for the potential for dewatering Cornelly, Grove, and Gaens quarries to affect groundwater levels at Kenfig. The superficial geology around Kenfig was the focus of much of the geological and geophysical investigations commissioned by Lafarge-Tarmac and has been the subject of detailed discussions between ESI and the regulators. Wherever possible uncertainties have been resolved by investigation, but the remaining residual uncertainties have been taken through to sensitivity analysis on the predictive model runs.

A detailed review of the local geology presented in Appendix G of Appendix 7.1 concludes that the low permeability estuarine clays and alluvium is present throughout the main area in which the overlying Blown Sands are saturated. The estimated thickness of this layer and the lateral extent of saturated Blown Sands are shown on Figure 3.5 of Appendix 7.1.

Merthyr Mawr

The system at Merthyr Mawr had not been studied by external sources in as much detail as Kenfig at the start of the investigations commissioned by Lafarge Tarmac. The SAC has subsequently been investigated in detail by the regulators (as reported in CEH, 2005 and SWS, 2010). Within the SAC, Blown Sand overlies Friar's Point Limestone over most of the area. In the west there is a small area of subcrop of Mercia Mudstone Marginal Facies and in the east, around Candlestone Stream, there is a small outcrop of Brofiscin Oolite Formation and Barry Harbour Limestone Formation. Beneath the Mean High Water line the outcrop is predominantly marine beach deposits of sand with some outcrop of limestone in the west. A strip of Tidal Flat Deposits follows the line of the River Ogmore.

The main area of humid dune slacks within the Blown Sand is in the southern and eastern part of the SSSI. In the north, the dunes overlie a step in the underlying limestone, roughly parallel with the coastline. To the north of the step, the dunes are considered to be 'dry' with no active dune slacks. Limestone has also been observed cropping out in a number of places along this step (BGS, 1:10,000 geology maps).

Borehole logs and augering have demonstrated the occurrence of a 1-3 m thick clay layer separating the sands from the underlying limestone in the central part of the dune system (south of the step in topography). Beneath the sand in the west, gravels are present, rather than clay: gravel workings west of Burrows Well confirm this. Gravel was also encountered close to the Candlestone Stream channel and to the River Ogmore in the east.

The low elevation of the top of the limestone in the east indicates the presence of a possible buried channel associated with the River Ogmore.

Structure

The locations of key faults in the area are shown on the solid geology map (Figure 3.1 of Appendix 7.1) and on cross sections through the area (Figure 3.2 of Appendix 7.1). The study area lies on the southern edge of the South Wales syncline. Cornelly, Grove, and Gaens quarries themselves lie on the northern limb of the Candleston Anticline, a subsidiary fold in this system.

The most prominent structural feature in the area is the north west - south east trending Newton Fault which down throws Triassic strata to the south west. A series of north-northwest to south-southeast- trending cross faults, which include the Morfa Fault, link into the Newton Fault to the west of Cornelly, Grove, and Gaens quarries. South of the same quarries, the Newton Down Fault Zone comprises a complex set of east-west reverse faults. The east-west Kenfig and Triassic Boundary Faults act as opposing normal faults which downthrow Triassic and Jurassic strata in a trough to the north of Cornelly, Grove, and Gaens quarries.

7.4.3 Hydrology

Rainfall

The NRW has provided data for the rainfall stations at:

- Margam (SS808856, about 4 km to the north of the Cornelly, Grove, and Gaens quarries) for the period February 1991 to June 2013,
- Cefn Cribwr (SS856838, about 3 km to the north east of the Cornelly, Grove, and Gaens quarries) for the period January 1981 to January 2009; and
- Schwyll from December 1991 to June 2013.

Long term average rainfall at Margam is 1149 mm/a with 1996 being the driest year in the 22 year sequence (845 mm) and 2012 being the wettest (1655 mm). The very wet sequence of months from April 2012 onwards affects most of the recent water level records.

Evapotranspiration and Recharge

From the Met Office Rainfall and Evaporation Calculation System (MORECS) potential evapotranspiration (PE) data, the long term average PE is 644 mm/a (2002-2012). PE is less variable from year to year than rainfall. However, the wet weather in 2012 coincided with a low PE (614 mm) which will enhance recharge in this period.

Recharge to the groundwater system has been calculated using a Penman two store soil moisture balance model implemented in an Excel spreadsheet. The approach was adapted for the calculation of climate based assessment criteria (CBAC) as required for the draft Water Management Plan. This yielded a range of recharge values for different borehole locations as follows:

Table 7-9 Recharge values at various borehole locations

Site	Rain gauge	Long term average recharge (mm)	Comment
B-a	Cefn Cribwr (95%)	761	Temporal pattern of Cefn Cribwr worked better than Margam
CC_5	Margam	587	Drying constant reduced to 40 mm to reflect the thin soils
G	Cefn Cribwr (110%)	973	
South Cornelly	Cefn Cribwr	830	
Porthcawl (using S Cornelly)	Average of Margam and Schwyll	533	
Merthyr Mawr	Schwyll	557	drying constant reduced to 40 mm to reflect the thin soils

Further details are described in Appendix I of Appendix 7.1.

Stream Flows

Available stream flow data for the area are described in Appendix J of Appendix 7.1.

The main surface water flows of interest relate to the two large springs in the area:

- The large, perennial springs at New Mill Farm have been identified as an important feature of the local hydrology and flow measurements have been made on numerous occasions over the last ten years (Appendix J of Appendix 7.1). The spring complex comprises a main spring (20 to 70 l/s, 1,700 to 6,000 m3/d) sourced from underlying Triassic strata and numerous other smaller seeps and springs in this general area. The total gain in the reach around the springs is around 190 l/s (16,400 m3/d) although some of this is derived from the surface water catchment of the reach.
- A flume and data logger have been installed by Lafarge-Tarmac on Burrows Well, the Carboniferous Limestone spring that rises in the middle of Merthyr Mawr dunes (Appendix J of Appendix 7.1). The data show that the spring is ephemeral with flows up to 350 l/s (30,000 m^3/d) but more typically around 50 l/s (4,300 m^3/d).

In addition to these flows, there is some surface water flow in the dune slacks at Kenfig during high groundwater level conditions (Jones, 1993). However, this all recharges to the Blown Sands to the west rather than flowing to the coast.

The majority of the effective rainfall in the area discharges via groundwater to the sea in a way such that it cannot be measured. As a result, the water balance of the aquifer cannot be constrained by measured data, hence the need for a transient flow network model. Uncertainties in the water balance have been dealt with by sensitivity analysis on the flow network model, varying recharge within a range that is considered to be physically realistic (+/- 15%).

7.4.4 Hydrogeology

Relevant Formations and their Properties

Two types of aquifer are present in the study area: porous medium aquifers, in which flow is distributed relatively evenly throughout the whole formation (e.g. the Blown Sands of the sand dune systems) and karstic aquifers in which flow occurs almost entirely through solution enhanced fissures or conduits (e.g. the Carboniferous Limestone and Triassic Marginal Facies). The type of flow associated with the aquifer dictates the most appropriate approach to the assessment of baseline conditions and potential impacts in the aquifer:

- In porous aquifers, flows are well defined by existing groundwater flow equations. Definition of the physical extent of the aquifer and a few key properties (e.g. hydraulic conductivity) allows predictions of impact to be made with a high degree of confidence;
- In contrast, in karstic aquifers the flows and potential for impact are almost entirely controlled by the nature and distribution of the conduits which cannot be physically constrained with any degree of certainty by field measurements. Furthermore, the equations governing flows in such a system are much more complex than for a porous medium and are highly sensitive to the detailed nature of the conduit system.

As a consequence, whilst porous medium equations are commonly applied to karstic aquifers for the purposes of scoping calculations, the degree of confidence in the resultant predictions is generally low. It is therefore generally accepted (e.g. Environment Agency, 2007) that the most appropriate approach to the investigation of karstic systems is not to attempt full parameterisation but rather to try and understand the nature and distribution of the conduit system at a larger scale (through tracing experiments (Appendix M of Appendix 7.1), measuring spring flows (Appendix J of Appendix 7.1) and carrying out lumped water balances (Appendix 7.3). This understanding can then be used to make a qualitative (or semi-quantitative) assessment of potential impacts and to identify appropriate monitoring measures to check for their occurrence. Due to the associated uncertainties, sensitivity analysis is required for any calculations presented.

The available groundwater level data have been interpreted to derive estimates of aquifer properties (Appendix G of Appendix 7.1). These give a broad indication of the contrast in properties between the different formations:

- Jones, 1993 carried out tests on the blown sands which suggested that the mean hydraulic conductivity was around 9 m/d. Calculations based on observed hydraulic gradients and estimated recharge suggest that the value could be higher than this (up to 25 m/d)
- A wide range of values of bulk transmissivity have been estimated for the Carboniferous Limestone. In general it is probably around 100 m^2/d but it may be ten times as high between Porthcawl and Grove and only around 25 m^2/d at Cornelly itself.

Post Depositional Influences on Formation Properties

The Carboniferous Limestone is a karstic aquifer in which flow is concentrated in fissures rather than being distributed within the matrix of the formation. Understanding the implications of the general nature and distribution of these fissures is important to the current assessment. The Scoping Direction has also specifically required that *'the possibility of interception during quarrying of a 'highly permeable feature' within the limestone'* is included in the assessment. The risk of encountering such a feature is very dependent on the post depositional history of the limestones as discussed in the following sub sections.

Structure

As well as disrupting and offsetting strata, faults and joints may act as zones of enhanced permeability within the limestone. However, where they are infilled with clayey material, they may also act as zones of low permeability (e.g. in the north-south joints observed in Cornelly Quarry).

There is no direct evidence of the role of faults on groundwater flows in the area. However, from consideration of groundwater levels (Appendix K of Appendix 7.1) some indications can be inferred:

- Groundwater levels are generally fairly low to the south west of the Newton Fault and rise steeply to the north east. In addition, Borehole H (located close to the junction of a dry valley and the Newton Fault) shows small tidal fluctuations in water levels despite its distance from the sea (2.5 km). Together, this evidence suggest that the Newton Fault (and possibly the north-south faults running down to Porthcawl) acts as a zone of enhanced permeability.

- As discussed above and in detail in Appendix H of Appendix 7.1, clay filled north-south fissures in Cornelly Quarry appear to significantly reduce the transmissivity of the aquifer in this direction such that the water level in Stormy Down Quarry is approximately 75 m higher than the sump level in Cornelly Quarry (only a few hundred metres away).

The New Mill Farm springs appear to be close to a north-south running splay from the Newton Fault and thus their position (and associated focussed zone of high permeability) may be linked to this. However, there are no mapped faults near the similarly sized Burrows Well in Merthyr Mawr and so general rules about mapped fault locations and enhanced flows cannot be made.

Palaeokarst

The Carboniferous Limestone was sub-aerially exposed prior to the deposition of the overlying Triassic strata and during this period extensive karst networks developed in the formation. These karstic voids were subsequently infilled by later, predominantly fine grained deposits. During intervening and more recent exposure of the Carboniferous strata, some of the shallowest of these palaeokarst features have become reactivated, although at depth they remain full of low permeability deposits. The main area showing surface expression of active karst features locally is the outcrop of Oxwich Head Limestone to the north of Cornelly Quarry (e.g. along the line of the M4).

BGS, 2000 suggested that reactivation of pre-existing karst features may enhance groundwater circulation, giving rise to sudden changes in the hydrological regime, and the potential for collapse, and sediment-filled features might impede groundwater flow. The report also advances a particular assumption that the sub-vertical palaeokarst features observed in the area connect to laterally sub-horizontal karst features at depth.

A detailed review of the palaeokarst features in the vicinity of Cornelly, Grove, and Gaens quarries has been carried out by Prof. Peter Smart of Bristol University and is presented in Appendix H of Appendix 7.1. This was based on survey data from Cornelly, Grove, and Gaens quarries collected in 2003 and then again in 2013. This concluded that:

- There is a well-developed active vadose karst in the Cornelly area (i.e. in the unsaturated zone above the natural water table), comprising 8-10 m of epikarst (shallow weathered zone) with frequently spaced vadose drains.
- The present phase of vadose karstification extends down about 40 m from the surface. There is little evidence for integration of the dispersed recharge from the unsaturated zone within a substantive karst conduit network within the segment of the saturated zone made accessible by dewatering in Cornelly Quarry. Rather, due to the very high frequency of dilated joints, the dewatered saturated zone appears to be characterised by diffuse fracture flow.
- The current Cornelly Quarry inflow is via diffuse flow from fractures and fissures, and focussed flow from blast-induced fractures, rare small capacity bedding tubes and local washout of sediment in palaeocaves.
- It is unlikely that a general increase in the risk of karst collapse will occur as a result of further dewatering. There is small possibility that some local subsidence could occur in the vicinity of any discharge point to groundwater. However, this has not occurred in the vicinity of any groundwater discharges in the area over the past 20 years.

In summary, it is considered to be unlikely that there are any active karst features at depth below the Cornelly Quarry and it is unlikely that the palaeokarst features that do exist at depth will be re-activated by Cornelly Quarry dewatering. Thus the risk of *'interception during quarrying of a 'highly permeable feature' within the limestone'* below Cornelly Quarry is judged to be extremely low. This conclusion is taken forward into the Water Management Plan as the most appropriate mechanism for managing this low level, residual risk.

The 2013 survey was extended into Grove, Gaens and Stormy Down Quarries. In general, similar features were noted in these quarries, although there were some local variations. It is considered that the risk of encountering enhanced permeability at depth may be somewhat higher in these Grove and Gaens quarries than in Cornelly because:

- Grove Quarry is crossed by several major faults. Previous work (Robert West and Partners, 1998) reported that water strikes were encountered in several boreholes drilled in this area. Water levels in boreholes fell from east to west across the general area although, in the vicinity of Grove Quarry, there was some evidence of a stepped pattern in the levels, possibly related to the position of faults. A series of water strikes are also reported in the nearby South Cornelly borehole at +20 to -7 mAOD and at a final depth of 47 mAOD (72 mbgl). Strikes are also reported at +5 to -16 mAOD (21 to 42 mbgl) in the nearby Grove borehole (Appendix K of Appendix 7.1).

- Gaens Quarry lies predominantly within the Oxwich head Limestone which has been shown to be highly karstified in the M4 nearby. There is also a north-south fault mapped in this area. However, the main karst feature noted in the recent survey of the Gaens Quarry (Appendix H of Appendix 7.1) was the presence of palaeosols (fossil soil horizons) which appeared to inhibit the vertical flow of water except where they are breached by vertical features.

The depth to which Grove and Gaens quarries will be dewatered and the amount by which the water table will need to be lowered is much smaller in Gaens and Grove Quarries than in Cornelly. Pumping rates would therefore be expected to be relatively low. However, as no permanent dewatering has been carried out and pumping rates monitored at these sites there is some uncertainty about this.

The risk of *'interception during quarrying of a 'highly permeable feature' within the limestone'* below Grove and Gaens Quarries is taken forward into the Water Management Plan for each quarry as the most appropriate mechanism for managing this risk.

In terms of the wider groundwater system around Cornelly, Grove, and Gaens quarries, it is considered, on the basis of the palaeokarst review, that a general model of enhanced permeability in a zone immediately above and below the position of the current water table is applicable. This is supported by a review of the groundwater level hydrographs which shows that groundwater levels in the Carboniferous Limestone fall rapidly after winter recharge but generally most boreholes show a 'base' level to which groundwater levels fall. This 'base' level is controlled by the elevation of this zone of enhanced permeability rather than a physical discharge point from the aquifer.

Groundwater Levels

Baseline monitoring

Groundwater levels have been monitored by Lafarge-Tarmac, the NRW and staff at the Nature Reserves at nearly 60 sites in the area (Figure 5.1 of Appendix 7.1) over the last decade with some sites having up to 16 years of data. This forms an exceptional baseline for the assessment of the impacts of Cornelly, Grove, and Gaens quarries.

The longer term data series are shown on Figure 5.2 of Appendix 7.1 (all the hydrographs are presented in Appendix K of Appendix 7.1). From this it can be seen that, whilst there has been some local lowering of the water table in the immediate vicinity of Cornelly quarry in response to the Cornelly Quarry deepening over this period by around 20 m, no long term declines can be observed in the more distant sites. Indeed, a common feature of all the hydrographs is the particularly high recent groundwater levels in response to the wet weather in 2012.

Using hydrographs to understand groundwater conditions

The hydrogeology of the area is complex and, because of the karstic nature of some of the aquifers, groundwater levels provide the best evidence of groundwater conditions and the behaviour of the aquifers.

In order to facilitate the description of the conceptual model and assessment of the potential impacts of Cornelly, Grove, and Gaens quarries, the area has been divided into a number of groundwater units (i.e. parts of the aquifer that share common conditions or properties). Within the groundwater units there is generally a very good correlation in groundwater levels between sites. The aim of the review has been to identify areas in which either the processes occurring appear to be relatively uniform or in which a variety of processes are so linked that it is essential to describe them together. The groundwater levels in each unit are reviewed in detail in Appendix K of Appendix 7.1. The implications of the groundwater level review for various parts of the study area are discussed below.

Kenfig Dunes

The Blown Sands appear to act as a fairly homogeneous system, with groundwater flow radially from a high located to the north west of the pool (see contours on Figure 3.3 of Appendix 7.1).

Annual fluctuations in water level are relatively small (~0.7 m) and maximum levels are, to some extent, controlled by the level of the dune slacks that allow 'surplus' recharge to overtop the aquifer during wet periods and flow down the slacks: this can be seen in the 'flat' top of some of the hydrographs, particularly near to Kenfig Pool.

However, there is also a significant amount of inter-annual variation in groundwater levels in the dunes: groundwater levels build up slowly over wetter periods and then fall gradually over subsequent years. The summer minimums in the dip tubes monitored at Kenfig have typically varied by around 0.8 m over the last decade (i.e. more variation between years than within years). It is understood that the ecology of the dune slacks may respond to the water levels experienced over several years (say three): the three year rolling average summer minimum values at the dip tubes have varied by an average of 0.4 m over the last decade.

Underlying this Blown Sand system is a series of glaciofluvial sands and gravels. Water levels in these gravels are generally lower than in the overlying Blown Sands and show distinctly different behaviour (Figure 5.3 of Appendix 7.1). This indicates that Kenfig Pool and the Blown Sands are not well connected to this underlying sand and gravel system. This is believed to be because an intervening layer of estuarine clay separates the Blown Sand system from the glaciofluvial deposits.

The glaciofluvial system is not well connected to the underlying 'solid geology' groundwater flow system around the south of the pool but appears to be in closer connection to the north east (borehole N). The glaciofluvial sand and gravels appear to act as a 'sink' for both the overlying Blown Sands and the underlying solid geology at this point.

The direction of groundwater flow within the glaciofluvial deposits is both to the west (towards K1) and to the north (O and River Kenfig). As the area around borehole N is likely to be the main recharge area for the deposits (the only mapped area of outcrop), it is likely that flow is radial from this point with flow both towards the coast to the west and to the River Kenfig to the north.

The glaciofluvial deposits/till around Borehole A acts as a minor, perched aquifer to feed the ephemeral springs that flow to Kenfig Pool.

Merthyr Mawr

In most of the sand dune system at Merthyr Mawr the groundwater levels fluctuate in a similar manner to those at Kenfig. However, in the area to the south of Burrows Well, water levels are affected by the discharge of limestone groundwater into the dune sands which causes large areas of surface water ponding in winter, possibly on a shallow clay layer in this area (SWS, 2010). When the spring stops flowing, these water levels drop rapidly by three or more metres (e.g. piezometer D7) i.e. the groundwater system in this area is not typical of dune slacks more generally.

Groundwater gradients are locally occasionally upwards from the limestone to the dune sands (e.g. at Burrows Well) but predominantly downwards.

Elsewhere in the study area:

There is a broad contrast between the coastal areas, in which groundwater heads and seasonal fluctuations are fairly subdued, and the main block of Carboniferous Limestone in which heads rise rapidly away from the edges together with the observed range in fluctuation.

Changes in head in the Carboniferous Limestone appear to coincide with the locations of some of the main fault zones potentially indicating a low permeability across these zones. However, steep gradients are observed elsewhere within the aquifer (e.g. from Pant Mawr to Gaens, Cornelly and Stormy Down) which indicates the presence of zones of low transmissivity.

Hydrochemistry

A detailed review of all the hydrochemical data in the area has been carried out (Appendix L of Appendix 7.1). This has provided a number of insights into the groundwater flow processes occurring.

- Groundwaters in the study area are all relatively fresh, calcium-bicarbonate type waters with no evidence of deep circulation or long residence times. Seasonal fluctuations in concentration are observed reflecting the flushing of the system with fresh winter recharge water.
- Kenfig Pool is predominantly fed by direct rainfall and Blown Sand groundwater from the north west, although there is a small contribution from shallow seeps to the east which provides water with slightly elevated concentrations of sulphate.
- Water in Cornelly and Grove Quarry sumps has slightly elevated concentrations of sulphate which is believed to be related to oxidation of pyrite in the freshly exposed quarry faces. There have been no long term trends in water quality in the sump at Cornelly Quarry over the last 20 years.
- Groundwater in the immediate vicinity of Stormy West and Tythegston landfills shows the influence of landfill leachate although this does not appear to have migrated any significant distance beyond the landfill sites (Appendix L of Appendix 7.1).
- There appears to be some localised effect on groundwater quality to the north of Gaens Quarry which may be linked to the farm soakaway in this area.
- Samples from the area around New Mill Farm Springs show a mixture of groundwaters with a strong influence from the Triassic strata.

Groundwater Flow

In a non-karstic system, analysis of groundwater heads gives a good indication of the direction of flow. Around the Cornelly, Grove, and Gaens quarries (where the main Carboniferous Limestone aquifer is karstic) it is not possible to get a definitive answer from just groundwater levels. Two tracer tests were conducted in 2002 in an attempt to:

- assess the potential for sustained recharge of the Carboniferous Limestone and associated Triassic Marginal Facies aquifers in the vicinity of the Cornelly, Grove, and Gaens quarries;
- determine the regional direction of flow in the Carboniferous Limestone and associated Triassic Marginal Facies aquifers in the Cornelly area; and
- determine the nature of transmission within the Carboniferous Limestone and associated Triassic Marginal Facies aquifers.

Water injected with fluorescent dye was pumped into Stormy Down Swallet north east of Cornelly Quarry, and the abandoned Railway Cutting west of

Grove Quarry. The sites were chosen because they both accommodated extended discharge of water at high rates, and would therefore be suitable for the long-term discharge of water pumped from the Cornelly, Grove, and Gaens for dewatering purposes. The full results (including borehole and other sampling locations), discussion and conclusions are available in Appendix M of Appendix 7.1. In summary:

- Tracer injected at the Grove Railway Cutting was only detected at two sampling sites, the Grove Golf Club Borehole 0.25 km from the injection site, and Pyle and Kenfig Golf Club Borehole 1.0 km away to the west. Straight-line groundwater velocities were low, indicating movement via diffuse circulation in fissures and fractures. However, the majority of the tracer injected was not recovered at any of the sampling sites, despite comprehensive on-land coverage.

- Neither of the tracers were recovered in Cornelly Quarry or in adjacent sumps in Stormy Down Quarry, Gaens Quarry or Grove Quarry, indicating that recirculation via diffuse flow in the Carboniferous Limestone was limited. The tracers were also not detected at any other sampling sites, despite a second injection. This confirmed the earlier results of Aldous (1988) at this site. The failure to detect the major part of the tracer injected in both test may be due to technical limitations, including adsorption of the tracer, excessive dilution or photodecomposition (Fluorescein in the case of Stormy Down Swallet). However, it could also be due to long travel times and/or discharge of the conduit systems at other unknown springs, possibly along the coast.

7.4.5 Conceptual model

The conceptual model submitted in support of the first voluntary ES for the Cornelly Quarry ROMP (ESI, 2003b) was developed in an iterative manner in close consultation with the regulators. This conceptual model has now been updated in the light of subsequent further consultations and the large amount of data collected since that time. A draft of the enhanced, comprehensive conceptual model was submitted to NRW for review in October 2013 and was the subject of subsequent meetings in autumn 2013. A comprehensive, updated conceptual model is presented in Appendix 7.1 and summarised below.

Aquifer System

Cornelly, Grove, and Gaens work Carboniferous Limestone that forms part of a wider, inter-connected aquifer system extending over an area of around 25 km^2 (see Figure 6.1 of Appendix 7.1). This is bounded by the River Kenfig to the north, the River Ogmore to the south, by various faults to the north east and by the coast to the south and west.

The Carboniferous Limestone forms the main, karstic aquifer in this area but is overlain by permeable, layered and possibly karstic, Triassic strata to the west and south. The Blown Sands at Kenfig and Merthyr Mawr form minor aquifers that have a degree of connection with the underlying Carboniferous/Triassic aquifers (described in more detail below).

The main directions of groundwater flow within these aquifers are illustrated on Figure 6.1 of Appendix 7.1. These are derived from a range of evidence described in the preceding sections of this report.

The main discharge point for groundwater in this area (~70%) is to the ~10 km of coastline that forms the western and southern boundaries of the area. As these discharges are effectively immeasurable, this introduces an element of uncertainty in the overall water balance for the catchment. Apart from these coastal discharges, groundwater also emerges:

- At the large springs at New Mill Farm. This groundwater has a strong hydrochemical signature from the Triassic strata.

- Within the Blown Sand dunes at Kenfig and in Kenfig Pool. The hydrochemistry of Kenfig Pool suggests that this water is almost entirely sourced from the Blown Sands, with small amounts of flow from ephemeral springs to the east. Surface water overflow from Kenfig Pool largely re-circulates into the Blown Sands to the west.

- At the large spring at Burrows Well which emerges from the Carboniferous Limestone in the middle of Merthyr Mawr and flows through some dune slacks, eventually soaking back into the sands before reaching the sea.

- Pumping from Cornelly Quarry (and occasionally from Grove and Gaens Quarries). This water is all re-circulated back into the limestone and is therefore not lost to the system.

The following sections describe the conceptual model of some of the key parts of this system in more detail.

Cornelly, Grove, and Gaens Quarries

Cornelly is the largest quarry in the group and, as it has been extensively worked and dewatered, it is the one about which the most information is available. The most striking aspect of the groundwater system at Cornelly Quarry is how little abstraction and drawdown effect there is and how stable it has been since detailed monitoring started in approximately 2001: over a period of approximately 30 years groundwater levels have been reduced by a total of around 60 m over an area of around 0.5 km^2 and yet the average inflows to Cornelly Quarry sump are only approximately 3,500 m^3/d and the off-site pumping rate is only around 2,000 m^3/d - equivalent to a catchment area of less than 1 km^2. Monitoring of groundwater levels in the area confirms that drawdown has extended over a limited area.

The low transmissivity of the aquifer in this area is due to a combination of stratigraphical, structural and erosion/dissolution processes:

- The Cornelly Oolite worked at the Cornelly Quarry is a thickly bedded, oolitic limestone which is likely to be less prone to karstification than units with numerous mudstone horizons;

- The strata within Cornelly Quarry are generally horizontal with little faulting. The extensive north-south jointing is largely infilled with clayey material;

- This area forms a high plateau with little opportunity for chemically aggressive runoff from adjacent strata which might enhance/reactivate karst;

- The karst re-activation that has occurred is limited to the zone near the natural position of the water table. The current sump elevation is well below this.

The conclusion of the palaeokarst review carried out for this study (Appendix H of Appendix 7.1) was that the present phase of karst development/re-activation extends down about 40 m from the surface. There is little evidence for integration of the dispersed recharge from the unsaturated zone within a substantive karst conduit network. Rather, due to the very high frequency of dilated joints, the dewatered saturated zone appears to be characterised by diffuse fracture flow. Taken together, this suggests that there is a low probability of the further deepening of Cornelly Quarry encountering significant zones of enhanced permeability at depth.

Although the karst survey was extended to the Grove and Gaens quarries in 2013, the extent of active karst in these quarries is less clear as these quarries are smaller and have not been worked to such depths. Discussion in Section 7.4.5 implies that there may be a higher risk of encountering permeable features at depth in Grove and Gaens quarries although, because the quarries are smaller and will not be worked to as great a depth as at Cornelly, the significance of these is expected to be somewhat reduced.

A schematic cross section east-west through Cornelly and Grove Quarries and then north westward to Kenfig illustrates some of the points made above and also links this to the groundwater flow systems between Cornelly, Grove, and Gaens Quarries and Kenfig (Figure 6.2 of Appendix 7.1). It can be seen that the groundwater gradients to the west of the Newton Fault are generally flatter than to the east, implying a much lower transmissivity in the latter area.

New Mill Springs

New Mill Springs form an important discharge point for the northern part of the Carboniferous Limestone/Triassic aquifer system. The springs have a strong hydrochemical signal indicating that the groundwater has flowed through the Triassic strata (Appendix L of Appendix 7.1). The total gain in the River Kenfig in this area is consistent with a catchment area of 8.8 km^2 (Appendix J of Appendix 7.1).

Kenfig Pool and Dunes

The groundwater system at Kenfig comprises three aquifers: the Blown Sand dunes, and the underlying glaciofluvial gravels and Carboniferous/Triassic aquifers. Figure 6.3 of Appendix 7.1 shows a schematic east-west cross section of the conceptual model of the area.

The eastern boundary of the saturated Blown Sand has been estimated by Jones, 1993 (see Figure 3.3 of Appendix 7.1). It follows the eastern boundary of Kenfig Pool northwards to the remains of Kenfig castle and south west out to Sker point. Directly beneath the sands a sequence of low permeability estuarine clay deposits extends across the majority of the site from beneath Kenfig Pool to the coast (as confirmed by borehole logs and geophysical surveys). This horizon limits the hydraulic connection between the sands and the underlying aquifers.

Contours by Jones, 1993 based on a very extensive monitoring network of dip tubes, show the presence of a groundwater high north west of Kenfig Pool (Figure 3.3 of Appendix 7.1). The majority of groundwater within the sand aquifer flows westwards, down gradient from this high towards the coast, with a smaller amount of flow north to the River Kenfig and south east to Kenfig Pool. Groundwater level and hydrochemical data imply that recharge from rainfall over the site provides the great majority of flow in the system.

Beneath the estuarine clay, the underlying gravels form a minor, confined aquifer. Groundwater level fluctuations are much larger in the gravels than within the Blown Sands and the hydraulic gradient is downwards except in very wet periods (Figure 5.3 of Appendix 7.1). The latter fact implies that the gravel aquifer discharges towards the coast rather than upwards through the sands. There will be some downwards leakage from the sands to the gravels, however, the contrast in the behaviour of groundwater levels in the Blown Sands and gravels in the immediate vicinity of Kenfig Pool provides a clear indication that these two aquifers are not well connected.

Groundwater levels in the gravels show similar, if subdued, trends compared to boreholes completed in the underlying/adjacent Triassic strata. This may imply a degree of connection between these groundwater systems.

Borehole N is the nearest borehole completed in the Triassic strata to the dunes. It has groundwater levels which are almost always below those in the nearby Kenfig Pool. Groundwater levels in Borehole A (also completed in the Triassic about 300 m to the south west) are also lower than the pool in summer. This implies that this aquifer system discharges towards the coast rather than upwards through the sands. There is a mapped area of Triassic strata on the beach to the west of Kenfig pool and this may be the main discharge point.

Merthyr Mawr

There are two distinct hydrogeological units at Merthyr Mawr – the Blown Sand superficial deposits at surface (within which the dune slacks form) and the underlying Carboniferous Limestone. A degree of hydraulic separation between the two units is provided by a clay layer which appears to be present across the majority of the site and is typically more than 0.5 m thick. Clay may be absent in the west toward the SAC boundary and in what may be a buried channel next to the Ogmore River. A schematic of the conceptual model is shown in Figure 6.4 of Appendix 7.1.

The Blown Sand aquifer is split into two topographic levels with an area at lower elevation, within which the dune slacks form, adjacent to the sea and an area at higher elevation further inland. The elevation step between the two is coincident with a step in the underlying limestone which can be seen cropping out where the Blown Sand thins along this line. North of this, the

Blown Sands are considered to be largely dry and the text below focusses on the southern half of the site where the slacks occur.

Although there are no co-located monitoring locations in the limestone and sand, comparison of the closest monitoring locations suggests that limestone water levels are generally below those in the sand. Due to the low storage of the limestone, groundwater levels are significantly more variable than the sands aquifer and therefore there are times when the limestone aquifer water levels are higher than the sand levels and the gradients are reversed (i.e. when Burrows Well discharges).

In the area to the south of Burrows Well, water levels are affected by the discharge of limestone groundwater levels into the Blown sands which causes large areas to pond, possibly on a shallow clay layer in this area (SWS, 2010). When the spring stops flowing, these water levels drop rapidly by three or more metres (e.g. piezometer D7) i.e. the groundwater system in this area is not typical of dune slacks more generally.

There are three main inputs to the groundwater system in the sands: direct recharge, runoff from less permeable catchments to the north east and intermittent flow from the underlying Carboniferous Limestone that discharges at Burrows Well. Flow from this large, ephemeral spring floods several dune slacks to the south before soaking back into the sands. Groundwater in both the sands and limestone is likely to flow southwards towards the sea.

Water Balance

Water balance calculations were originally carried out for and presented in ESI's previous conceptual model report (ESI, 2003b). These have been updated using the results of the flow network model developed for this assessment (Appendix 7.3) and the following conclusions have been drawn:

- The water balance for the Kenfig Blown Sand system shows that almost all of the flow in the Blown Sands is sourced from direct rainfall (2% from surface water inflow). This flow leaves the system by a mixture of groundwater flow and overland flow via the slacks with a very small component of downwards leakage into the underlying sands and gravels.
- All of the water recharging to the Carboniferous Limestone and Triassic marginal facies aquifers in the northern part of the study area can be accounted for, principally via outflows at the New Mill Farm Springs. The good flow balance in this area provides strong support for the conceptual model and is consistent with the observed water levels and hydrochemistry.
- In the coastal lowlands around Porthcawl the water balance is not as good. This is because the main outflows from the aquifer are spread out along 10 km of coast. In places these outflows can be directly observed, but a high proportion appears to be relatively diffuse.
- The water balance for the Merthyr Mawr area implied that Burrows Well provides 45% of the total inflow to the Blown Sand system with the remainder being sourced by direct recharge. The principal outflow is outflow to the sea but around 14% leaks downwards to the underlying limestone.

Discussions with NRW for this phase of work have identified a need to assess transient aspects of dewatering at Cornelly, Grove, and Gaens quarries (the rate at which the effects of a sudden increase in abstraction would transmit away from the quarries, the effects and duration of recovery at the end of pumping), and also an incorporation of the variation in hydrogeological conditions at Kenfig and Merthyr Mawr.

In order to do this, it was decided to adapt the groundwater flow network model used for the previous Cornelly ROMP ES to work in transient mode and also to directly simulate conditions at Kenfig and Merthyr Mawr through the incorporation of additional cells (rather than using the supplementary calculations developed previously). The updated model construction and results are described in Appendix 7.3.

7.4.6 Uncertainties

At the start of the current investigation in 2001 a number of key uncertainties were identified which could constrain the ability to predict the potential impacts of deepening Cornelly, Grove, and Gaens quarries accurately. As discussed in Section 7.2.4, these uncertainties have been reduced as far as possible by a phased approach of investigation (including over 12 years of baseline monitoring) followed by very detailed modelling (Appendix 7.3) and associated sensitivity analysis. This has reduced the level of uncertainty in the assessment to a point at which any residual uncertainties can be appropriately addressed by means of an adaptive management strategy (See Section 7.10 Water Management Plan).

In this section these uncertainties are discussed together with the implications for the hydrogeological impact assessment (i.e. how they have been addressed).

Outflows from the Aquifer

Uncertainty

The most significant uncertainty in the conceptual model is the nature and distribution of conduits in the limestone aquifer. At the start of the present investigation this uncertainty was exacerbated by the fact that the main discharges from the aquifer had not been identified during previous studies.

The current investigation has confirmed that the New Mill Farm Springs are the major discharge point for most of the northern part of the study area. A good water balance has now been constructed for this area (Appendix I of Appendix 7.1) consistent with the substantial volume of monitoring data and with a consequent improvement in confidence in the conceptual model. The tracer tests were not successful in demonstrating the catchment area for these springs, but the combined analysis presented in this study provides some constraints on the possible boundaries of the catchment.

In the coastal lowlands the water balance is still poorly constrained. However an assessment of the total recharge to these areas indicates that the total outflow is consistent with aquifer properties derived by other methods (Appendix G of Appendix 7.1).

Implications for Hydrogeological Impact Assessment

The improved water balance for the area has significantly increased confidence in the conceptual model. This provides increased confidence in the impact assessments. However, sensitivity analysis has been carried out on the effect of changing recharge by the largest range considered credible: +/-15% (with associated variation in aquifer transmissivity) on the predictive simulations.

Conditions at Depth below Cornelly, Grove, and Gaens Quarries

Uncertainty

At present Grove and Gaens quarries are not being dewatered and Cornelly Quarry requires relatively little pumping to control water levels considering the size of the excavation. The available borehole information and the review of palaeokarst features has clearly indicated that there are unlikely to be active karst features at depth underneath Cornelly Quarry and that quarry dewatering is unlikely to reactivate any of the palaeokarst features present at depth.

The situation at Gaens and Grove Quarries is less clear and there are some grounds for believing that the risk of encountering fissures at depth are greater at these two quarries However, the fact that these quarries are substantially smaller than Cornelly and the depth to which they are proposed to be worked is less, will also reduce this risk.

Implications for Hydrogeological Impact Assessment

As discussed in Section 7.2.4, this risk/uncertainty is best managed by means of close scrutiny of pumping rates at each of the sites as envisaged by the revised Water Management Plan (Appendix 7.6).

Connection Between the Limestone Aquifer System and the Dune System at Kenfig

Uncertainty

At the start of this study it had been suggested that up to 30% of the water in Kenfig Pool could be sourced from the limestone aquifer (BGS, 2000).

The evidence presented in this study (e.g. hydrochemistry in Appendix L of Appendix 7.1 and modelling (Appendix 7.3)) clearly demonstrates that the hydrological system in the Blown Sands at Kenfig is almost entirely sourced from direct rainfall rather than the limestone aquifer (there is some minor inflow to Kenfig Pool from the till to the east).

In addition, the main area of humid dune slacks to the west of the pool is underlain by a relatively impermeable layer of estuarine clay which separates the Blown Sands aquifer from the underlying glaciofluvial sand and gravel aquifer.

To the north east of the pool the glaciofluvial sand and gravel appears to act as a 'drain', both for a small part of the overlying Blown Sands and the underlying 'solid geology' (Carboniferous and Triassic). At this point there is therefore a link, if rather tenuous and indirect between the Blown Sands and limestone aquifer. However, the flow network model (Appendix 7.3) indicates that the Blown Sands aquifer is not a significant discharge point for the Carboniferous Limestone aquifer system.

Implications for Hydrogeological Impact Assessment

The lack of a direct link between the Carboniferous Limestone aquifer and the Blown Sands system significantly reduces the risk that dewatering of Cornelly, Grove, and Gaens quarries could affect the habitat in the dune slacks. However, the hydrogeological impact assessment still considers the potential impact of dewatering on water levels in this area via indirect routes (i.e. the gravels).

Previously the effects of predicted changes of water level in the underlying strata were translated into effects on water levels in the Blown Sands by means of simple, supplementary calculations. There were a number of comments on this approach by the regulators in previous rounds of consultation (ref section 7.2.6) and the approach adopted (Section 7.2.4) has been to develop a fully integrated approach using a transient flow network model. The exact details of the connection between the limestone and the Blown sands at Kenfig has been the focus of detailed consultation between ESI and NRW during autumn 2013.

The need for sensitivity analysis to address the aspects of the model that are not fully constrained by the calibration of the flow network model has been discussed in detail with NRW during autumn 2013 and, where appropriate, these sensitivity runs have also been taken through to the predictive stages.

Connection between the Limestone Aquifer System and the Dune System at Merthyr Mawr

Uncertainty

At the start of the study the hydrogeology of the Blown Sands system at Merthyr Mawr was much less well understood than that at Kenfig.

The data subsequently collected by Lafarge-Tarmac and the regulators indicate that there is a thin clay layer between the limestone and sand over most of the site, potentially limiting the connections between these formations. Groundwater levels in the Blown Sand are otherwise mostly above those in the underlying limestone. The discharge from Burrows Well spring therefore provides the main inflow from the limestone to the Blown Sands and this has now been monitored for approximately six years.

Implications for Hydrogeological Impact Assessment

The improved understanding of the hydrological system at Merthyr Mawr has focussed attention on the area of Carboniferous Limestone to the south of Cornelly, Grove, and Gaens quarries. The potential for dewatering of Cornelly, Grove, and Gaens quarries to cause drawdowns in this area and the effect of this on the hydrology of the Blown Sands is addressed in this hydrogeological impact assessment.

Local baseline monitoring also demonstrates that the groundwater levels in the vicinity of the flooded slacks in Merthyr Mawr are not typical of other areas of dune slacks in Martyr Mawr and Kenfig: groundwater levels appear to be perched on a shallow clay layer and drop rapidly by several metres once the spring stops flowing.

Again, as at Kenfig, an integrated approach has been adopted rather than the supplementary calculations previously used. The exact nature of the connection between limestone and Blown sands at Merthyr Mawr has also been subject of detailed discussion between ESI and NRW during autumn 2013. The discharge from Burrows Well is very variable and so a transient approach is required.

The need for sensitivity analysis to address the aspects of the model that are not fully constrained by the calibration of the flow network model has been discussed in detail with NRW and, where appropriate, these sensitivity runs have also been taken through to the predictive stages.

Migration of Leachate from Landfills

Uncertainty

The migration of landfill leachate from the two landfills in the area is potentially indicative of groundwater flow directions (although density effects on the flow of the leachate may mean that this is less indicative of broader groundwater flow patterns). The interception of contaminated groundwater Cornelly, Grove, and Gaens quarry dewatering would be potentially problematical. A detailed review of hydrochemical data from the study area (Appendix L of Appendix 7.1) has identified that some groundwater in the immediate vicinity of the landfills has been contaminated by leachate but that this effect was very local to the landfills. In the case of Stormy West this is in part due to the frequent, north-south orientated, clay filled joints that cross the aquifer in this area.

An area of slightly contaminated groundwater was identified to the north of Gaens Quarry. This is believed to be related to the presence of a farm soakaway in this area.

Implications for Hydrogeological Impact Assessment

The potential for migration of landfill leachate towards Cornelly, Grove, and Gaens quarries will be assessed by means of assessing simulated changes in groundwater flow in the model cells that represent the landfills. The contamination of groundwater to the north of Gaens Quarry has some implications for the potential impacts of dewatering at this site.

Requirements for monitoring the water quality in Cornelly, Grove, and Gaens quarry sumps are included in the Water Management Plan.

Feasibility of Water Management Options at Cornelly, Grove, and Gaens Quarries

Uncertainty

An important consideration for the hydrogeological impact assessment will be the feasibility of future water management options for Cornelly, Grove, and Gaens quarries. Deepening Cornelly, Grove, and Gaens quarries will involve additional dewatering and the location of the discharge for this pumped water will have an effect on the predicted impacts of the operation of the Cornelly, Grove, and Gaens quarries.

The present preference is for continuation of current practice of the discharge of water into adjacent sumps as this does not involve the loss of water from the aquifer system. The tracer tests carried out as part of this study involved the pumping of large quantities of water to two sinkholes. The tracer tests did not fully demonstrate the direction of groundwater flow from these sinkholes although this has now been constrained by the results of the flow network model.

Implications for Impact Assessment

The hydrogeological impact assessment will address the remaining uncertainty in the various options for disposal of dewatering water. This is best managed by means of the Water Management Plan (Appendix 7.6) and discussed further in Section 7.10 below.

7.5 Methodology: Approach to Hydrogeological Impact Assessment

On the basis of the conceptual model developed for the area, an approach to the impact assessment has been adopted which incorporates a quantitative simulation of groundwater flows within the recommended risk assessment framework.

7.5.1 Hydrogeological Impact Assessment Methodology

The standard approach recommended for environmental risk assessment is set out in “Guidelines for Environmental Risk Assessment and Management”, DEFRA, 2011. This recommends a source-pathway-receptor methodology. In the context of the impact assessment for Cornelly Quarry these elements may be defined as:

Source: Dewatering associated with further working of Cornelly Quarry.

Pathways: The groundwater flow pathways or hydrogeological linkages identified in the conceptual model.

Receptors: Key water features.

The risk assessment process can be sub-divided into a number of steps as described below.

Step 1: Identification of Receptors. The identification of a risk requires the presence of all three elements in the source-pathway-receptor chain. The source is by definition the quarries at which active dewatering is occurring (specifically, the reduced groundwater levels in Cornelly, Grove, and Gaens quarries). The first task in the risk assessment process is therefore to identify any relevant receptors. Potential impact receptors include all water features identified during the water features survey (Appendix D of Appendix 7.1). In addition, the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body, which is classified as being of poor status as a result of risks from saline intrusion, water abstraction and flow regulation, diffuse source pollution and terrestrial ecosystems, has been identified as a potential receptor in the Scoping Direction.

Step 2: Identification of Pathways. Having established all potential impact sources and receptors, it is then necessary to identify pathways between the quarry (the source) and each water feature (the potential receptors) (i.e. determine all source-pathway-receptor linkages). In simple terms, the assessment process must establish whether the groundwater level effects of Cornelly, Grove, and Gaens Quarry dewatering could potentially affect any of the identified water features. This has been achieved by considering each potential source-pathway-receptor chain in the context of the conceptual model. Hence, where there is believed to be no significant groundwater pathway between the quarry and a given receptor, this receptor can be removed from the hydrogeological impact assessment process (note: where a pathway linkage is unclear, for example due to uncertainty in the conceptual model, the pathway is assumed to exist). In effect, this risk assessment approach serves to filter the list of potential receptors.

The complete list of potential receptors is shown in Appendix 7.2. This list is divided into potentially vulnerable receptors (i.e. those receptors which are hydrogeologically connected to Cornelly Quarry) and insignificant receptors (i.e. those receptors for which there is no pathway to Cornelly, Grove, and Gaens quarry). A brief justification for all receptors considered to be insignificant is also given in Appendix 7.2, along with a figure showing the location of all potentially significant and insignificant receptors.

In summary, in addition to the Kenfig SAC (Kenfig Pool and Dunes and Merthyr Mawr SSSIs and associated water features), a total of 24 potentially vulnerable receptors (or groups of receptors) have been identified.

Note that, in this process the Cefn Cribwr SAC referred to in the Scoping Direction was not considered to be dependent on the groundwater systems affected by dewatering at Cornelly, Grove, and Gaens quarries (See Section 2.4.2 of Appendix 7.1 for details) and has therefore not been taken forward as a potentially vulnerable receptor.

Step 3: Quantification of Effects. The presence of a hydrogeological pathway between the quarry and a receptor does not on its own indicate that an effect will occur at the receptor. The next step in the hydrogeological impact assessment process must therefore be to address whether or not there is likely to be a hydrological/hydrogeological effect at each potentially vulnerable receptor resulting from Cornelly, Grove, and Gaens Quarry development (and restoration) works. This requires a degree of quantification. Since the majority of impacts relate to water level changes, it is therefore necessary to quantify the degree of groundwater level change at each potentially vulnerable receptor, or alternatively the change in water balance components (i.e. groundwater inflows and outflows) surrounding that receptor. This was achieved by means of using the calibrated flow network model in predictive mode (Appendix 7.3).

Step 4: Assessment of Significance. The demonstration and quantification of a potential effect does not in itself represent a significant potential impact as this requires an assessment of the significance of the effect. There are two aspects to the assessment of significance:

1. it is necessary to compare the size of the potential effect with a relevant criterion. If the size of effect is smaller than the criterion then the effect does not represent a significant impact.

2. if the size of effect is potentially greater than the relevant criterion, it is necessary to assess the significance that the potential impact represents. The significance of an impact is dependent on the magnitude of the effect and the importance of the receptor.

1. Relevant Criteria

Step 4 (Section 7.5.1) requires a measure of impact significance (i.e. when does a predicted effect become a potentially significant impact?).

The simulated effects on flows and water levels in the SAC have been carried forward to Chapter 8.0 where their potential significance is discussed in the context of their ecological status. The text in this section therefore simply presents the timing and magnitude of these effects in hydrogeological terms, without comment on indirect ecological effects.

However, the detailed time series statistics discussed in Appendix D of the Water Management Plan (Appendix 7.6) shows that, within the Blown Sand aquifers at Kenfig and Merthyr Mawr, sustained changes in water level of 0.1 m or less would be very difficult to detect even after several years i.e. changes smaller than 0.1 m would effectively be below the resolution of current technology (by which we mean the combination of monitoring data and the simulation of expected levels).

In this section, the impact significance at each receptor site has been evaluated separately on the basis of the conceptual understanding of the local groundwater system. To assist in this evaluation, the following interim, conservative guidelines (based on those agreed with NRW in the WMP (Appendix 7.6) have been adopted for screening purposes:

- For the Blown Sand aquifers at the Kenfig and Merthyr Mawr SACs a predicted groundwater level reduction of 0.1 m has been adopted. This is at the lower limit of what would be detectable through statistical analysis of long-term (three years minimum) groundwater levels. There are no receptors at this location other than ecological ones and therefore this limit is used as an initial screening threshold for the purposes of this section.

- For licensed groundwater abstraction boreholes a predicted groundwater level reduction in excess of 0.5 m is taken to indicate a potentially significant impact which has required further assessment.

- For shallow wells, a predicted groundwater level reduction in excess of 0.25 m is taken to indicate a potentially significant impact which has required further assessment.

- For ponds (excluding Kenfig Pool and any dune slacks in Kenfig Pool and Dunes and Merthyr Mawr SAC), a predicted groundwater level reduction in excess of 0.1 m is taken to indicate a potentially significant impact which has required further assessment.

- For spring flows, a derogation of flow in excess of 10% of mean long term flows is taken to indicate a potentially significant impact which has required further assessment.

With regard to water quality, the effects of Cornelly, Grove, and Gaens Quarry development should not induce additional landfill leachate or saline intrusion to the extent that key drinking water quality standards (i.e. ammonia and EC) are likely to be compromised. In practise a semi-quantitative, expert judgement-based approach has been taken to determine the degree of effect and the consequent impact significance rather than comparison against specific guideline values for individual contaminants or groups of contaminants.

Where an effect falls below the threshold criteria described above, it is taken to be negligible (apart from simulated changes at the SACs where all changes are taken through for consideration in Section 8). Where it exceeds the critical threshold, a site specific assessment of the degree of effect (low, medium, or high) is applied based on the particular conditions at that receptor (e.g. large natural variation in groundwater levels compared to the predicted change).

<u>2. Importance of Receptors</u>

The second factor in the consideration of degree of impact is the importance of the receptor. Receptors have been assigned to one of three status categories – low, medium or high. The methodology for assigning to a particular category is based on the following general criteria although it is subjective to a large degree:

- Low Status – Unlikely to be of significant ecological or societal value (e.g. small ephemeral pond); surface water and groundwater abstractions that supply or impact on an individual or small number of people (e.g. farm or home supply);

- Medium Status – Of local ecological or societal value or supporting medium or high status ecological features (e.g. springs); surface water or groundwater abstractions that supply or impact on a local community (e.g. local water supply or water supply to a local amenity);

- High Status – Nationally and internationally designated ecological sites (e.g. SACs) or features supporting these (e.g. springs); surface or groundwater abstractions that feed into public water supply. However, the significance of any simulated effects on Kenfig / Cynffig SAC is not discussed in this Chapter (See Chapter 8.0).

Degree of impact is determined by applying the degree of effect with the receptor status according to the matrix in Table 7.10 below:

Table 7-10 Hydrogeological Impact Assessment Matrix

		Receptor Value		
		Low	**Medium**	**High**
Degree of effect	**Negligible**	Negligible	Negligible	Negligible
	Low	Minor	Minor	Moderate
	Medium	Minor	Moderate	Major
	High	Moderate	Major	Major

Whilst the table above provides impact magnitude, impacts are further defined in terms of whether they are adverse (i.e. negative) or beneficial (i.e. positive).

Only adverse impacts that are Moderate or higher (highlighted with red text in the table above) are considered to be potentially significant and in need of mitigation.

Note that the hydrological / hydrogeological impacts at Kenfig / Merthyr Mawr relate to changes in water levels, and the terminology used to characterise the impacts are not to be equated with other indirect impacts. The nature of any indirect ecological effects are considered separately in Chapter 8.0 of the ES.

Categories for Reporting Effect / Impact

A short list of potential impacts associated with quarrying activities at Cornelly, Grove, and Gaens quarries is presented in Table 7-11. In order to present the results of the assessment in a clear and concise manner, these have been combined with the list of potential hydrological/hydrogeological impacts identified in the Scoping Direction (Section 7.2.1) to produce the following four categories:

A. General effects on groundwater levels and flows – this is taken to include the assessment of the potential impacts on the water resources of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body;

Relevant Scoping Direction impact categories:

- *The potential impact of quarrying on hydrology and hydrogeology of the area, including the possibility of interception during quarrying of a 'highly permeable feature' within the limestone, and although there is a low probability of this occurring the prospect should be recognised as a continuing risk during further development of the quarry and appropriate action identified (for example a risk management/monitoring strategy which recognises the critical stage at which potential adverse impact may occur).*

B. Potential effects on water levels at Kenfig/Cynffig SAC/SSSIs;

Relevant Scoping Direction impact categories:

- *The potential impact of quarrying on Kenfig/Cynffig SAC/SSSIs and Cefn Cribwr Grasslands SAC/SSSIs.*
- *The potential impacts on the Kenfig/Cynffig SAC and the hydrology of the dune system and Kenfig Pool, including the nature of the hydraulic connection between the dune sands and the underlying sand and gravel aquifer at Cynffig/Kenfig SSSI and the related sensitivity of groundwater levels in the dune sands to drawdown in the sand and gravel aquifer.*

C. Potential effects on water levels and flows at other potentially vulnerable receptors; and

Relevant Scoping Direction impact categories:

- *The potential impacts on other groundwater users and water features in the area.*

D. Other potential effects (water quality and settlement) – this is taken to include the assessment of the potential impacts on the water quality of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body.

Relevant Scoping Direction impact categories:

- *The potential for quarry dewatering to induce saline intrusion into the aquifer.*
- *The likely impact from further quarrying on the migration of leachate and landfill gas.*
- *The likely impact of quarrying on the stability of surrounding land.*
- *An evaluation of potential surface lowering and sinkhole collapse.*

Table 7-11 Short List of Potential Impacts

Phase of Development	Activity	Potential Impact	Impact Category	Impact Duration[1]
Quarrying Phase	Dewatering	Change of current groundwater flow regime	A	T
		Reduction in stream baseflow contribution	C	T
		Disturbance of contaminated groundwater (aggravation of leachate migration)	D	T
		Ground instability associated with dewatering extent	D	P
		Reduction in spring flows	C	T
		Reduction in pond or pool levels	C	T
		Drying of dune slacks	B	T
		Reduction in borehole performance / yield	C	T
		Induced saline intrusion	D	(P)
	Quarry working	Groundwater pollution from accidental fuel spills, leaks etc.	D	T
		Surface water pollution from contaminated run off	D	T
	Disposal of dewatering water	Change of current groundwater flow regime (change in infiltration / recharge)	A	T
		Change of stream baseflow contribution	C	T
		Change of spring flows	C	T
		Change of pond or pool levels	C	T
		Change to groundwater quality	D	T
		Increased surface water turbidity	D	T
Restoration Phase	Creation of permanent quarry lake (cessation of dewatering)	Change of current groundwater flow regime	A	P
		Change of stream baseflow contribution	C	P
		Change of spring flows	C	P
		Change of borehole performance / yield	C	P
		Change of pond or pool levels	C	P

1 Temporary (T) or Permanent (P)

7.5.2 Groundwater Flow Simulation

Groundwater Flow Network Model

A groundwater flow network model (constructed in MS Excel) has been developed to assist in the prediction of groundwater level impacts. This tool predicts the spatial distribution of groundwater level changes resulting Cornelly, Grove, and Gaens quarry dewatering by dividing the area up into a number of cells and performing linked water balance and groundwater flow calculations between each cell.

The model used in this assessment is based on the steady state model used in the previous assessment (ESI, 2004) which was subject to detailed review by the EA for Wales at that time. In response to the increased amount of baseline data collected since that time and the improved understanding of the conceptual model, the steady state model has been refined and converted into a transient model. This allows a better understanding of the potential impacts on sensitive receptors to be achieved. The way in which this refinement and conversion has been carried out has been discussed in detail with NRW at several meetings in the second half of 2013 (Section 7.2.6).

The flow linkages within the model were set up to include all potentially significant source-pathway-receptor chains as identified by the risk assessment work described above. Full details of the flow network model are presented in Appendix 7.3.

The model has been calibrated to current conditions (observed flows and groundwater levels) and then used to predict the effects of changing the way in which each of Cornelly, Grove, and Gaens quarries is dewatered (including restoration). The success of the model in predicting current conditions provides a measure of confidence in its accuracy.

Sensitivity analysis has been used to assess the level of uncertainty associated with each aspect of the model calibration. Where this uncertainty is potentially significant, sensitivity runs have been carried forward into the predictive phase.

Assessment of Current Effects of Cornelly Quarry

Monitoring of groundwater levels in the vicinity of Cornelly Quarry over the last 20 years has shown that, whilst there has clearly been some local effects of lowering Cornelly quarry floor to ~60 m below rest water levels (and associated off site pumping), this has been confined to the immediate vicinity of Cornelly quarry. No effects have been detected at a greater distance (e.g. at South Cornelly Borehole, ~1 km west of Cornelly, Grove, and Gaens quarries) and clearly not at the Blown Sands (see discussion on water levels in Appendix K of Appendix 7.1 and Climate Based Assessment Criteria in Appendix C of the Water Management Plan (Appendix 7.6).

The flow network model provides a tool that allows the theoretical effects of the current Cornelly, Grove, and Gaens quarrying activities to be assessed as described in Appendices 7.3 and 7.4. This confirms that any theoretical effects on water levels and flows at the SAC are very small and are below the likely level of physical detection.

Model Scenarios

The flow network model has been used to predict the effects on groundwater flows and cell water balance components at a number of key phases of development of Cornelly, Grove, and Gaens quarries (i.e. 15 year (end of current ROMP cycle) and 42 year/full development). Descriptions of all model prediction runs, including those relating to the development of Cornelly Quarry in isolation and the simultaneous development of Cornelly, Grove and Gaens quarries, are outlined in Table A7.4a (Appendix 7.4). These can be summarised as follows:

- *Baseline run – Baseline conditions (see Section 7.4) carried forward over the prediction periods for comparison;*
- *Individual development runs – 15 and 42 year scenario for Cornelly only (run codes CN15 and CN42 respectively – pumping to Grove);*
- *Combined development runs - 15 and 42 year scenario for Cornelly, Grove, and Gaens quarries combined (run codes ALL15*

and ALL42 respectively, Cornelly pumping to Pant Mawr, Grove to railway cutting, Gaens to sump in north of Gaens Quarry);

- *Sensitivity runs – nine runs based on run ALL15 with key parameters altered within uncertainty limits (run codes SENS1 to SENS9 respectively)*
- *Recovery runs – Cessation of pumping at the end of the ALL42 scenario with various combinations of Cornelly, Grove, and Gaens quarries ceasing and r*esidual pumping rates. Reference name and summary of scenarios as follows:

  - RECOVERY for all quarries recovering;
  - RECOVERYGAENS for only Gaens recovering;
  - RECOVERYPUMPING5 for all quarries recovering and mitigation pumping disposal to the railway cutting; and
  - RECOVERYPUMPING6 for all quarries recovering and mitigation pumping to Stormy Down).

The model is a transient model and, therefore allows prediction of the time that water levels will take to reach the equilibrium position at each of these development stages. In general water level changes are expressed as differences with respect to the current conditions (i.e. the baseline run); however, it should be noted that current conditions may not reflect pre-quarrying conditions as some quarry development and dewatering has already taken place at Cornelly, Grove, and Gaens, although monitoring to date has been unable to discern any effects of the quarrying at Cornelly, Grove, and Gaens outside the immediate vicinity of each respective quarry.

Changes in groundwater levels and flows are generally presented in this assessment in one or both of the following forms:

- Five year means taken from the last five years of the model run. These are taken to represent equilibrated conditions (i.e. there is no ongoing falling or rising trend) and are representative of long-term changes; or
- Maximum changes (positive or negative) over the entire model run period. These are taken to represent short-term abolute worst case changes but will include periods during which the model is reaching equilibration and could be more extreme than the equilibrated condition.

The climate sequence for the predictive scenarios has been constructed by repeating the climate sequence for the historic, calibration, model run (1992 to 2013) twice. This gives a long sequence with several extreme wet/dry events which allows the sensitivity of the conclusions to variations in rainfall to be assessed.

Note that the results presented are for changes at the cell node (as shown on Figure A7.2a in Appendix 7.2): no interpolation has been applied to assess the variation in changes within an individual cell. The cell sizes are generally such that this should not significantly affect the conclusions at individual receptors. However, some of the cells (e.g. that at Porthcawl) are quite large and impacts at some of the more distant receptors in this area may be slightly overstated by this approach.

Consideration of Uncertainties (Sensitivity Analysis)

Although the previous phases of investigation have succeeded in clarifying many aspects of the conceptual understanding of the ‘Cornelly’ system (i.e. the aquifers which are connected to and have potential to be affected by dewatering at Cornelly, Grove, and Gaens quarries), there remains a level of uncertainty regarding certain aquifer properties and groundwater flow processes. In order to account for this inherent uncertainty in the prediction of groundwater behaviour within a fissured limestone system, all predictions of groundwater level change must be considered in the context of a potential margin of error.

The extent of these potential error margins has been defined using model sensitivity analysis and also by testing the effect of modifications to the conceptual model on the model predictions - see Appendix 7.3). These modifications were designed in consultation with technical staff from the regulators starting during 2003 including detailed discussions with NRW in 2013, particularly consideration of the connection between the Blown Sands at Kenfig and Merthyr Mawr and consideration of ‘highly permeable features’ as discussed in the following section..

Consideration of the possible effects of interception during Cornelly, Grove, and Gaens quarrying of a 'highly permeable feature'

As discussed in Section 7.4.4, a detailed review of the local palaeokarst by an appropriate expert has found that there is a very low possibility of encountering a highly permeable feature at depth in Cornelly Quarry. At Gaens and Grove Quarries the risk of encountering such a feature is less well constrained due to the fact that the Grove and Gaens quarries are not currently dewatering.

It is proposed to manage this very low possibility risk by means of the revised Water Management Plan (Appendix 7.6). However, some of the approach and results of the modelling assessment are of relevance to the management of this risk:

1. The predictive development scenarios apply the full change in water level in Cornelly, Grove, and Gaens quarries instantaneously. This is a conservative assessment as, in reality, Cornelly, Grove, and Gaens quarries would be deepened over a number of years. However, the resultant simulated change in water levels at the more distant receptors (e.g. Kenfig and Merthyr Mawr) provides a useful indication of the timescales over which the effect of intercepting a highly permeable feature in Cornelly, Grove, and Gaens quarries would develop. This is discussed in the relevant sections below.

2. A predictive sensitivity run has been run with recharge increased throughout the model by 15% (this is the largest change in recharge relative to the best estimate that is considered to be credible). To ensure that groundwater heads are maintained at their approximate calibration position, the transmissivity was also increased by 15% throughout the model. This therefore provides a predictive run with the highest transmissivity that is consistent with the current conceptual model.

7.5.3 Assessing Other Impacts

It is recognised that not all impacts of quarrying relate solely to changes in groundwater level. It is also necessary to consider potential impacts on surface and groundwater water quality, ground stability and the freshwater-saline interface (i.e. saline intrusion impacts).

The assessment of these additional impact categories has been performed either by qualitatively (or, if appropriate, quantitatively) considering their impact in the light of the groundwater level or flow predictions, or through the application of previous experience and expert knowledge (e.g. saline intrusion impacts may be assessed by predicting groundwater level changes along the coastal margin in the context of both specific coastal hydrogeological conditions and expert knowledge of freshwater-saline interface processes).

7.6 Predicted Impacts of Future Quarry Development at Cornelly

In this section, the effects predicted by the model runs involving further development of Cornelly Quarry on its own are discussed (CN15 and CN42). In Section 7.7, the predicted effects of the combined operation of all Cornelly, Grove, and Gaens quarries are discussed, whilst in Section 7.8 the predicted effects of Cornelly, Grove, and Gaens Quarry restoration are discussed. The potential significance of these predicted effects on the SAC receptors is discussed in Section 8 and for other receptors is discussed in each section below.

The predicted effects of both the development of Cornelly alone (i.e. model runs CN15 and CN42) and the combined development of Cornelly, Grove and Gaens (ALL15 and ALL42) are summarised in Tables A7.4a to A7.4e in Appendix 7.4:

- Table A7.4b presents the simulated change in groundwater levels relative to baseline for each prediction run at the model cell nodal points.

- Table A7.4c shows the simulated change along certain critical flow paths relative to baseline conditions, such as the groundwater inflow to the model cell representing the sand and gravel aquifer at Kenfig.

The assessment of the potential impacts relating to the development and restoration of Cornelly Quarry is presented in Tables 7.12 and 7.13 respectively. Where appropriate, comments relating to the combined development of Cornelly, Grove, and Gaens quarries are incorporated into the two tables (note: the restoration condition for the combined Cornelly, Grove, and Gaens quarries scenario is assumed to represent a worse case compared to restoration of Cornelly alone).

Both tables combine the list of potentially sensitive receptors (see Appendix 7.2) with the listing of potential impacts as shown in Table 7-10. The result is a list of all potential impacts (from either quarry development or restoration) which may arise at each of the identified receptor sites.

Each of the identified potential impacts is assessed in the context of:

- predicted water level changes.
- predicted changes to groundwater flows.
- expert knowledge of the local groundwater system (i.e. the conceptual understanding of the system) and the nature of specific receptors (as derived from the detailed water features survey).

Details of the criteria used to assess each impact are indicated on Tables 7.12 and 7.13 under the ‘Assessment Criteria’ column. Comments regarding the hydrogeological impact assessment itself are presented in the ‘Impact Assessment’ column. The remaining columns provide an indication of whether or not the impacts are considered to be potentially significant in hydrological / hydrogeological terms (based on the comparison of predicted water level or ground water flow changes and appropriate impact thresholds).

Note that the hydrological / hydrogeological effects at Kenfig / Merthyr Mawr relate to changes in flows and water levels, and the terminology used to characterise these effects are not to be equated with indirect ecological impact to habitats within these areas (the SAC). The nature of any indirect effects is considered separately in Chapter 8.0 of the ES.

All potentially significant impacts on Table 7.12 and Table 7.13 are highlighted in one of two colours, indicating the stage of development at which the impact becomes significant (i.e. after 15 years or at 42 years/full development). A separate colour scheme is used to highlight potential impacts which are different for the combined Cornelly, Grove, and Gaens Quarry scenarios.

Further discussion of the potentially significant impacts which are highlighted on Table 7.12 and Table 7.13 are provided in the relevant effects sections.

7.6.1 A: General effects on groundwater levels and flows (Cornelly only)

Groundwater Levels

In general, the effects of the planned development of Cornelly Quarry on groundwater levels in the surrounding area are small. For consistency, the effect on mean water levels over the last five years of the future simulation is discussed below (i.e. after full equilibration). However, the full simulated hydrographs are presented in Appendix 7.4 and any potentially significant short term effects are raised in the text below.

At full scale development of Cornelly, the largest predicted drawdowns in five year mean levels are in the immediate vicinity of Cornelly quarry and in the area to the south and east. Beyond this immediate area, predicted five year mean drawdowns are less than 0.5 m at all potentially vulnerable receptors. To the north and west of Cornelly, groundwater levels are predicted to rise due to the discharge of dewatering water to Grove, with five year mean levels increasing by not more than 0.5 m at all potentially vulnerable receptors.

Groundwater level changes are not established instantaneously. In areas close to Cornelly quarry they can occur rapidly but in more distant locations they can take 10 years or more to be felt fully.

When the difference between each sensitivity run (SENS1 to SENS9) and its equivalent baseline is compared with the difference between the relevant best estimate end of ROMP cycle run (ALL15) and its baseline run the differences are similar which indicates that the modification of key model parameters within a plausible range does not significantly change the conclusions of this assessment. The range in differences observed in individual sensitivity provides a confidence range on the drawdown predictions for all model runs.

Cornelly Quarry Dewatering

The model simulates that average off-site pumping rates at Cornelly Quarry will be around:

2670 m^3/d at 15 years (-30 mAOD).

2740 m^3/d at 42 years/full development (-75 mAOD).

These rates are not significantly higher than recent rates for two reasons:

1. These rates are off-site rates and do not take into account recirculation that occurs where the disposal is close to Cornelly Quarry sump (as it currently is when pumped to the lagoon). The occurrence of recirculation has minimal impact on the flows within the aquifer outside the sump and lagoon area but does result in a higher pumping rate from the sump itself. This is the main reason that flows are less than recorded rates from the sump. The model implies that, during the period of pumping to date, around 1,500 to 2,000 m^3/d of water has recirculated from Cornelly Quarry lagoon back to the sump. The simulated rate of pumping from Cornelly Quarry sump would therefore be correspondingly higher.
2. The fact that Cornelly Quarry will be deepened into a zone in which the permeability is predicted to be very low. This is the main reason why there is relatively little change in rate simulated between the 15 year and 42 year runs.

These are long term average values; the actual rate in any one month will depend strongly on the amount of rainfall and the way in which Cornelly Quarry is being worked at that time. Dewatering records at Cornelly Quarry indicate that weekly average pumping rates may vary by +/-50% from the average.

Groundwater Flows

In general, groundwater flows in the limestone tend to increase in Cornelly Quarry development scenarios: more water is being pumped round the system, creating steeper hydraulic gradients and hence more groundwater flow. These effects are largest in the immediate vicinity of Cornelly Quarry and are strongly affected by the pattern of dewatering disposals in each scenario.

Away from Cornelly quarry the changes in groundwater flow between cells are predicted to be much smaller (generally in the order of a few per cent even for the full scale development scenario).

The sensitivity runs show that there is some difference in the change in mean flows when the sensitivity run and its baseline are compared with the best estimate run (ALL15) and its baseline. Some flowpaths appear to be relatively sensitive (show greater than 10% difference) including:

- Kenfig glaciofluvial deposits
- Kenfig seep
- Kenfig Pool
- Cornelly, Grove, and Gaens inflows
- Flow to Afon Fach/Railway Springs
- Flow from Stormy West to Stormy Down
- Flow toward Tythegston Landfill
- New Mill Farm Springs (and nearby groundwater abstractions)

- Porthcawl coastal discharge

Consideration of the effects of these changes of flow on simulated water levels at key receptors is discussed in the relevant sections (Kenfig and Merthyr Mawr in Section 7.6.2 and other receptors in Section 7.6.3).

Review of the sensitivity runs suggests that these effects on flow are not significantly affected by any uncertainties in model parameterisation. The wider implications of the model sensitivity results are discussed further below.

<u>Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body</u>

The simulated changes in groundwater level and flow are considered to have a **Negligible** impact on the quantitative status of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body.

7.6.2 B: Potential effects on water levels in the dune sands at Kenfig SAC and the Merthyr Mawr SSSI (Cornelly only)

As noted above, the predicted effect of the future development of Cornelly Quarry with the associated disposal of the water to the west, is to raise water levels to the north west and to lower them to the south and east of Cornelly Quarry. The results of the CN42 run are generally discussed below although the CN15 results are similar (slightly smaller).

Kenfig

When compared with the baseline run, the net result in the Blown Sand aquifer at the Kenfig SAC is a rise in simulated five year mean water levels of not more than 5 mm and maximum change in water levels during the entire run period of 6 mm. These very small theoretical effects are far below the level of resolution of current detection methodologies (typically 0.1 m).

This can be clearly seen on Figure 7.2 which shows the simulated water levels in the Blown Sand to the west of Kenfig Pool the Baseline and CN42 runs which are effectively indistinguishable although the difference line shows a small theoretical rise in level. This is the area with the largest simulated change in level: simulated changes in the Blown Sand to the north and north west of Kenfig pool are much smaller and take around ten years to manifest themselves.

The changes in flow along various flow paths between Cornelly Quarry and Kenfig dunes discussed in Section 7.6.1 therefore do not appear to have a significant effect on water levels in the Blown Sand aquifer. This is because, whilst these changes in flow are proportionally large, flow (and thus water levels) in the Blown Sand aquifer are dominated by local recharge.

Careful review of the difference line implies that a sudden change in water level e.g. a theoretical encountering of a highly permeable feature (or by implication pumping rate) at Cornelly Quarry would take 5 to 10 years to fully manifest itself as a change in water level in the Blown Sand aquifer at Kenfig.

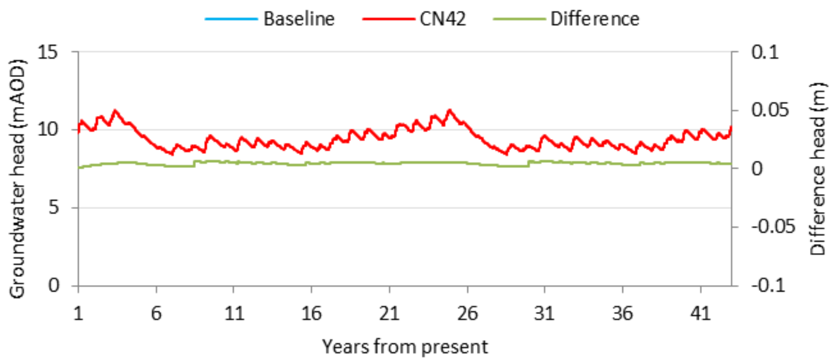


Figure 7-1 Groundwater levels and difference at Kenfig – Run CN42 (Model Cell 55 – West of Kenfig Pool)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

Merthyr Mawr

The effects of future Cornelly Quarry development on Merthyr Mawr are assessed by two measures:

1. For the dune slacks to the east and west of the SAC (model cells 44 and 45), the direct model simulation of water levels is used.
2. For the cells representing the Burrows Well and overflow slacks system, the simulated flow at Burrows Well is used. This is because the water levels in this area are not typical of other dune slacks and are entirely maintained by spring flow: when the spring stops flowing each year, water levels rapidly drop by at least 3 m.

In the Blown Sand Merthyr Mawr SAC there is a simulated decline in five year mean water levels of not more than 7 mm and a maximum decline during the full run period of 8 mm. This compares with inter-annual variations which are of the order of metres (see Table 7.2 below).

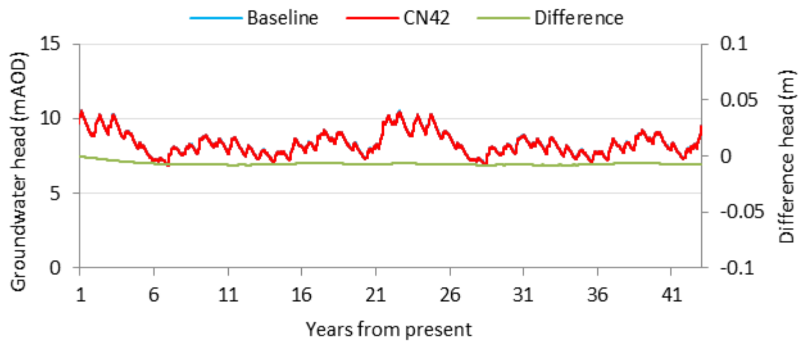


Figure 7-2 Groundwater levels and difference at Merthyr Mawr – Run CN42 (Model Cell 45)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

Likewise, mean and maximum changes in mean five year flow at Burrows Well in the case of Merthyr Mawr are small. The maximum difference is not more than 35 m^3/d decrease (positive difference indicates decrease in flow with respect to baseline). Differences throughout the run are always less than 4% and typically less than 2%

Careful review of the difference line implies that a sudden change in water level (or by implication pumping rate) at Cornelly Quarry would take around five years to fully manifest itself as a change in flow at Burrows Well.

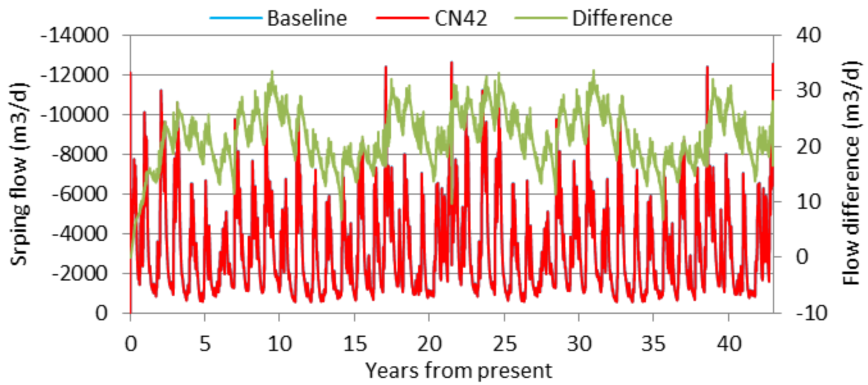


Figure 7-3 Flows at Burrows Well – Run CN42

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a decrease in flow). NB Baseline not visible as it is so similar to development run.

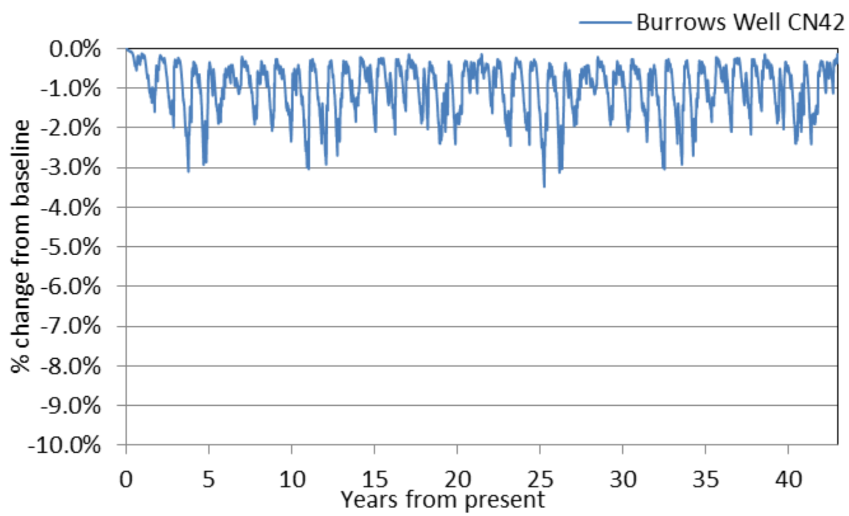


Figure 7-4 Changes in Burrows Well flow (as % change from baseline) – Run CN42

Summary

The impact of development of Cornelly Quarry alone on the Blown Sand aquifers at Kenfig and Merthyr Mawr is therefore judged to be **Negligible in hydrogeological terms**.

As noted above, the potential indirect effects on habitats within the Kenfig SAC are considered in Chapter 8.0 of the ES.

7.6.3 C: Potential effects and impacts on water levels and flows at other receptors (Cornelly only)

In general, the predicted effects on water levels at most of the other potentially vulnerable receptors are less than the adopted criterion for change in water level. Receptors at which slightly larger, potentially significant changes in water level occur are listed below (see Figure A7.2a for locations):

Home Wood (Loc. 33): This shallow well (NB. there is also a spring box and pond (Loc. 34) in the field to the north west) is predicted to show a drawdown of five year mean water levels of up to 0.45 m and thereby exceed the critical change of 0.25 m (Section 7.5.1, Appendix 7.6) in 15 and 42 year scenarios.

However, the previous phases of investigation during this study have shown groundwater levels to fluctuate significantly in this area (by up to 30 m at the nearby borehole G and over 40 m simulated for the model cell).

- If the Home Wood supplies are sourced from the main limestone system, such small predicted changes will have an insignificant effect on their functionality (the degree to which they are ephemeral will change very slightly).
- If they are not connected to the main limestone aquifer (i.e. perched) then they will not be vulnerable to the predicted drawdown.

In conclusion, whilst these sites have been identified as being potentially vulnerable, site specific considerations indicate a low potential for impact.

The pond at location 34 (Loc. 34): The situation here is the same as at Home Wood which is located nearby although in this case the critical threshold is 0.1 m reduction (Section 7.5.1, Appendix 7.6).

In general, the predicted effects on groundwater flows in cells which represent selected receptors are also small:

- Five year mean flows at New Mill Farm Springs (which should be taken to also include the potential effects on groundwater abstractions in this area) are predicted to show less than 1% reduction for both the 15 year scenario and at full development.
- Five year mean net groundwater flows into Afon Fach/Railway Springs/Stormy Down Spring are predicted to decrease by a maximum of around 6% for the 42 year scenario.

The effect of development of Cornelly Quarry alone on water levels or flow at Home Wood (Loc. 33) and the pond at Location 34 is judged to be **Minor adverse** and at other receptors it is judged to be **Negligible**.

7.6.4 D: Other potential impacts (Cornelly only)

Leachate Migration

The detailed review of the available hydrochemical data (Appendix L of Appendix 7.1) concluded that, whilst the two landfills at Stormy West and Tythegston had contaminated groundwater in their immediate vicinity, this had not extended any significant distance. This is despite the fact that, at present, the hydraulic gradient is already from the landfills towards Cornelly Quarry (by which we mean that groundwater levels in the quarry are lower than those at the landfills). In addition, the strength of the leachate at the sites is likely to attenuate through time.

It would thus appear unlikely that further Cornelly Quarry dewatering will create a significant risk of inducing contaminated groundwater into the Cornelly Quarry sump. The implications of the predicted groundwater flow changes in the immediate vicinity of the landfills, resulting from the development of Cornelly Quarry, is discussed in more detail below.

Stormy West: Simulated five year mean groundwater outflows from Stormy West to Stormy Down increase by around 25% at full development of Cornelly Quarry whilst five year mean flows from Stormy Down to Cornelly increase by around 15%. This reflects the increase in hydraulic gradient between the landfills and Cornelly.

These changes are potentially significant and, as a result, there is an increased risk of creating enhanced leachate migration. However, this should be seen in the context of the understanding that overall flows are small (even when increased) and groundwater quality monitoring to date which suggests that there is no significant migration of the leachate toward Cornelly Quarry. Furthermore there is a large body of open water in Stormy Down Quarry between Stormy West and Cornelly Quarry which will attenuate any leachate diverted in this direction.

Tythegston Landfill: Flows at Tythegston are predicted to be away from the Cornelly Quarry although, with increased development, the magnitude of these flows decreases. At full scale Cornelly development the five year mean flow decrease is around 21% (compared to the current calibration conditions). This theoretically increases the risk of creating enhanced leachate migration but practically would make no difference as flow is still away from Cornelly Quarry.

Gaens Quarry: An area of contaminated groundwater was identified to the north west of Gaens Quarry. The origin of this contaminated groundwater is not clear but it may be related to a local farm soakaway. Given the limited effect of the much larger sources of contamination (i.e. Stormy West and Tythegston Landfills) on the groundwater quality across the aquifer, it seems unlikely that there will be any significant, widespread impact from such a localised source of contamination.

Mitigation measures to deal with scenarios such as Cornelly Quarry intercepting a significant amount of landfill leachate are discussed in the Water Management Plan (Appendix 7.6).

Cornelly Quarry Operations

There is a potential risk to groundwater quality from routine quarrying activities at Cornelly Quarry. This risk essentially relates to the accidental release of pollutants which may enter the local groundwater system either through the quarry base or via water discharged off site. The likelihood of any pollution occurring can be reduced through sound operational practices including suitable pollution control measures. Such measures have been proposed in the draft planning conditions submitted with the ROMP application and, based on their wide-spread and effective use in quarries in Wales, they are not considered further in this hydrogeological impact assessment.

Ground Stability

In this hydrogeological impact assessment of Cornelly Quarry only it has been assumed that it is feasible to continue to discharge any water required to dewater Cornelly Quarry into Grove Quarry. This is a relatively large void and it is not anticipated that this discharge will cause any localised concentration of groundwater flow that could cause washout and hence localised effects on ground stability.

Saline Intrusion

Discharges of groundwater to the coast are only affected in scenarios in which the amount of discharge at New Mill Farm Springs (the other discharge from the system) is simulated to change. In general the simulated changes in coastal discharge are very small (less than 1% change in five year mean flow along any of the critical flowpaths) in all scenarios (see Table A7.4c). This compares with seasonal variation in coastal outflows under baseline conditions which is between approximately 60% higher and 40% lower than the mean.

As a result, it is considered that there is no significant risk that the proposed developments will cause saline intrusion. This is consistent with the fact that the proposed Cornelly Quarry developments only involve moving water from one part of the groundwater system to another rather than removing it to a different system.

Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body

The simulated changes in groundwater level and flow are considered to have a **Negligible** impact on the groundwater quality status of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body.

7.6.5 Uncertainty and Risk

Model Sensitivity Analysis

As discussed previously (Section 7.5.2), there is a degree of uncertainty in the model predictions and therefore the hydrogeological impact assessment results. This derives from inherent uncertainties in the underlying conceptual model of the hydrogeological system (as discussed in Section 7.4.4) and also from the effect of model equivalence (different combinations of model parameter can generate similar model calibrations but potentially different model predictions).

In order to address these uncertainties, sensitivity analysis has been used to define the likely error margin for all model predictions (see Section 7.5.2 for approach). The results from the sensitivity analysis (presented in Tables A7.4a and A7.4e in Appendix 7.4) indicate that the error margins for both groundwater level and groundwater flow predictions are relatively modest, especially at the most critical receptors. Hence, for Kenfig, the sensitivity results show a maximum variation of 1 cm from the difference seen in the equivalent prediction run (15 year combined development). At Merthyr Mawr, the sensitivity results show an equivalent maximum difference of 1.5 cm. These are small absolute differences and do not change the conclusions of this assessment. This provides strong support for the robustness of all model predictions.

A further sensitivity analysis was undertaken to investigate the adequacy of the model representation at Burrows Well (see Sections 3.7.2 and 4.6.3 of Appendix 7.3). This used a mathematical function to transform the simulated flows at Burrows Well to a closer representation of reality. The average post development difference in water levels between the calibrated model and the sensitivity run with the Burrows Well function showed that using the Burrows Well flow function increases the simulated effect of the proposed development (i.e. All15 v. Baseline) on water levels by between 13 and 17%. This is considered to be small relative to the uncertainties in the whole assessment process and suggests that, whilst the calibration of flows at Burrows Well is not ideal, this is unlikely to affect the overall conclusions of the assessment.

Possibility of interception during Cornelly, Grove, and Gaens quarrying of a 'highly permeable feature'

As discussed in Section 7.5.2, the model predictive simulations provide useful context for assessing this risk:

1. Timescale for sudden changes at Cornelly Quarry to manifest themselves at the key receptors. The instantaneous application of large drawdowns at Cornelly Quarry takes of the order of 5-10 years to fully manifest itself at Kenfig and around 10 years to manifest itself in the Blown Sand at Merthyr Mawr Note the exaggerated scale on the secondary y-axis. This slow response time to a sudden change in the quarries provides confidence that there would be time to implement the measures described in the revised Water Management Plan (Appendix 7.6) should such a feature be encountered.

2. Sensitivity analysis. In sensitivity run SENS8 the transmissivity is increased across the whole aquifer system by 15%, the highest amount consistent with the conceptual model, and yet comparison of the results of this predictive scenario with the base case shows that the simulated effects at Kenfig and Merthyr Mawr are not significantly different (variation of 1 cm from the difference seen in the equivalent prediction run at Kenfig and 1 mm at Merthyr Mawr).

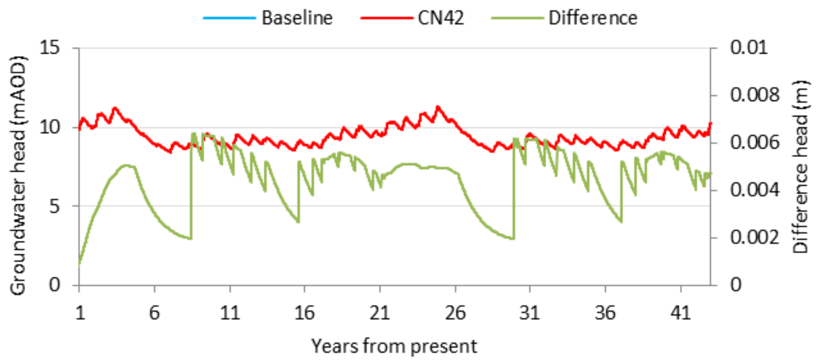


Figure 7-5 Groundwater levels and difference at Kenfig – Run CN42 (Model Cell 55)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

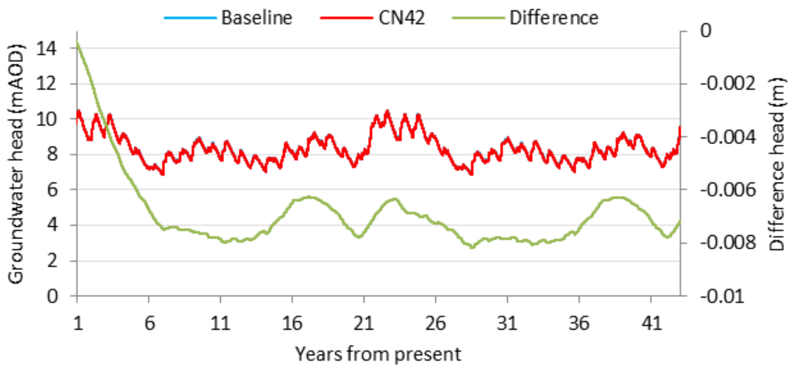


Figure 7-6 Groundwater levels and difference at Merthyr Mawr – Run CN42 (Model Cell 45)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

Summary of uncertainties

In summary, it is concluded that the predictions made by the model are robust and unaffected by the small amount of residual uncertainty in the conceptual model.

However, whilst, the quality of the model calibration and the results of the sensitivity analysis provide a strong measure of confidence in the predictions, in any project involving large scale excavation, there is always the possibility that ground conditions may differ from those anticipated. The water management measures described in Appendix 7.6 include contingency measures for dealing with conditions outside the range predicted. Section 7.8 includes discussion of the results of model scenarios to demonstrate the potential effectiveness of different pumping strategies in controlling water levels at a distance from Cornelly Quarry.

7.7 Potential Impacts of Combined Quarry Developments: Cornelly, Grove and Gaens

These effects and impacts are assessed by comparing the results of the baseline run with the combined Cornelly, Grove, and Gaens quarries runs (ALL15 and ALL42).

7.7.1 A: General effects on groundwater levels and flows (combined development)

Groundwater Levels

At full scale development of Cornelly, Grove, and Gaens quarries there are greater predicted drawdowns relative to the baseline in the immediate vicinity of each quarry. Groundwater level rises are also generated in response to patterns of water disposal. Thus, rises are seen in the area around Pant Mawr and immediately to the north of Gaens. In all other areas there is a decline in water levels. However, the larger changes in groundwater level continue to be localised around Cornelly, Grove, and Gaens quarries. Effects on individual receptors are discussed below.

Groundwater Flows

There are further increases in groundwater flows as a result of combined Cornelly, Grove, and Gaens Quarry development. These effects are largest in the immediate vicinity of Cornelly, Grove, and Gaens quarries and are once again strongly affected by the pattern of dewatering disposals in each scenario. These effects are not expected to have significant regional effects.

Cornelly, Grove, and Gaens Quarry Dewatering

The model predicts that average pumping rates required to dewater Cornelly, Grove, and Gaens quarries at full combined development will be around:

Cornelly: 2990 m^3/d (-75 mAOD) - to Pant Mawr;

Grove: 1640 m^3/d (-15 mAOD) – to railway cutting;

Gaens: 4080 m^3/d (-20 mAOD) - to northern quarry sump.

These are long term average values; the actual rate in any one month will depend strongly on the amount of rainfall and the way in which the quarry is being worked at that time. Dewatering records at Cornelly Quarry indicate that weekly average pumping rates may vary by +/-50% from the average.

The accuracy of pumping rate predictions at Grove and Gaens are more uncertain than those derived for Cornelly due to the lack of historical data and less certainty about hydrogeological conditions at depth.

Increases in flow at Cornelly reflect the influence of changed patterns of disposal (i.e. Pant Mawr rather than Grove). The relatively high rate at Gaens reflects the effect of groundwater flow from the nearby discharge from Cornelly to Pant Mawr.

Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body

The simulated changes in groundwater level and flow are considered to have a **Negligible** impact on the quantitative status of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body.

7.7.2 B: Potential effects on water levels in the dune sands at Kenfig SAC and the Merthyr Mawr SSSI (combined development)

The combined effects of Cornelly, Grove, and Gaens quarries is to produce reductions in water levels at both Kenfig and Merthyr Mawr (in contrast to the Cornelly only runs where a slight rise is simulated in Kenfig due to the location of water disposal). However, the changes are small, with a maximum reduction in simulated five year mean water levels of not more than 1 cm and maximum change in water levels during the entire run period of around 1 cm at Kenfig (Figure 7.8).

At Merthyr Mawr SAC there is a reduction in five year mean levels relative to baseline of not more than 1.5 cm and a maximum reduction during the full run period of the same amount (Figure 7.9). This compares with inter-annual variations at the two sites which are of the order of metres. Flows from Burrows Well, which discharges into the Merthyr Mawr Blown Sand aquifer are also little affected with five year mean flows decreased by less than 1% relative to baseline (Figure 7.10).

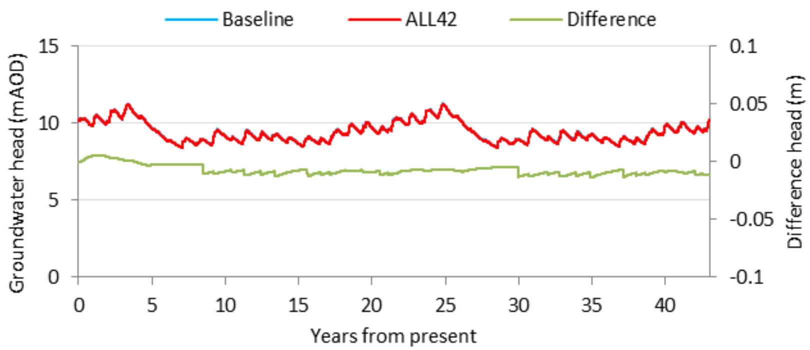


Figure 7-7 Groundwater levels and difference at Kenfig – Run ALL42 (Model Cell 55)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

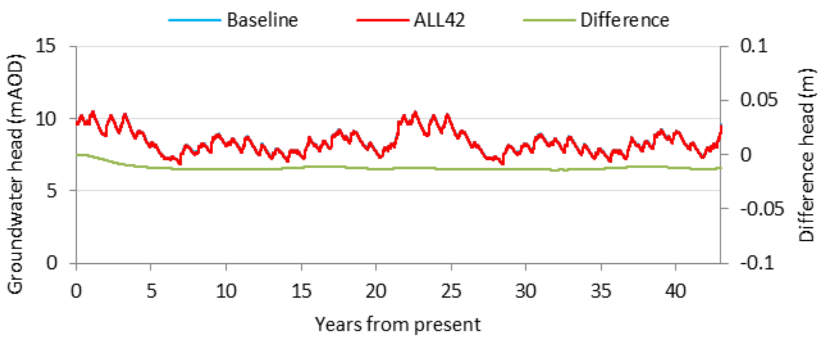


Figure 7-8 Groundwater levels and difference at Merthyr Mawr – Run ALL42 (Model Cell 45)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

The illustrations above show the baseline and development run heads at representative model cells at Kenfig and Merthyr Mawr for the full development run. Against the background variation the differences between the two hydrographs are imperceptible on the graphs. Only when the difference is plotted on a separate y-axis (green) is it observable. The difference is extremely small and shows no obvious long term trend downward or upward. In practice the differences simulated would be immeasurable in the field.

Figure 7-9 shows the simulated flows at Burrows Well. The maximum difference is not more than 50 m^3/d decrease and the minimum simulated flow is not less than 550 m^3/d. Differences throughout the run are always less than 5% (the critical change threshold being 10% – see Section 7.5.1) and average just under 1.5%.

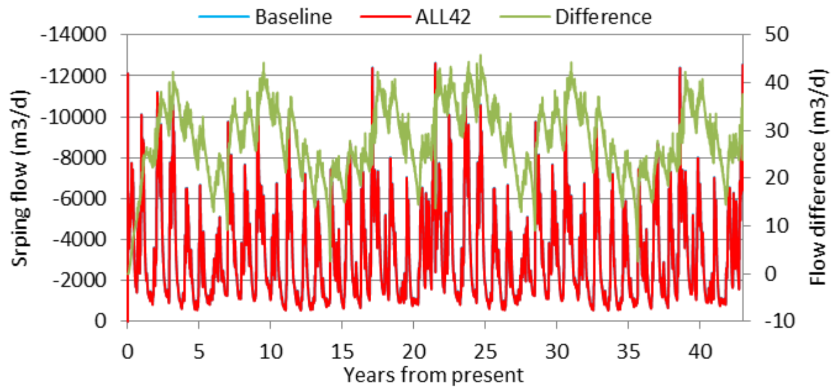


Figure 7-9 Flows at Burrows Well – Run ALL42

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means decrease in flow). NB Baseline not visible as it is so similar to development run.

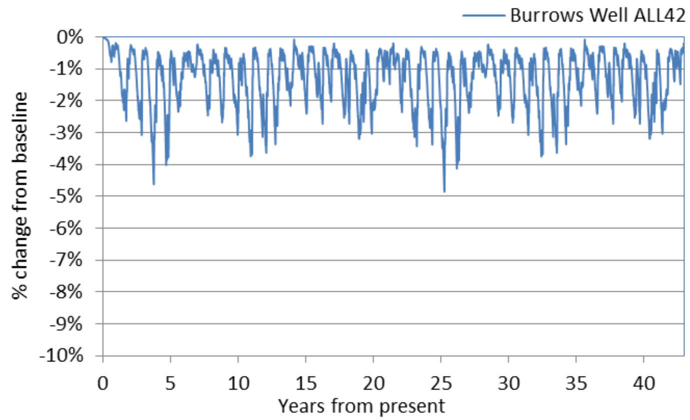


Figure 7-10 Changes in Burrows Well flow (as % change from baseline) – Run ALL42

The hydrological impact of development of Cornelly, Grove, and Gaens quarries combined on the Blown Sand aquifers at Kenfig and Merthyr Mawr is therefore judged to be **Negligible in hydrogeological terms**.

As noted above, the potential indirect effects on habitats within the Kenfig SAC are considered in Chapter 8.0 of the ES.

7.7.3 C: Potential effects on water levels and flows at other receptors (combined development)

The flow network model simulates that the future development of the Cornelly, Grove, and Gaens quarries will not have a significant impact at the majority of the potentially vulnerable receptors/groups of receptors identified in the study area. For seven of the receptors, potentially significant effects have been identified as discussed below.

Ty Talbot Farm, Nottage (Loc. 18b): This well is predicted to experience a drawdown of five year mean levels by around 0.6 m (for the full development scenario) relative to baseline. This exceeds the critical change of 0.5 m (Section 7.5.1) for both the 15 year and full development scenarios. The model suggests a natural variation in groundwater levels of around 11 m and therefore, for the same reasons as discussed for Home Wood (Loc. 33) in Section 7.6, whilst these sites have been flagged up as being potentially vulnerable, site specific considerations indicate a low potential for impact.

Wilderness Pond (Loc. 20): This pond is predicted to experience a drawdown of five year mean levels by just over 0.6 m (for the full development scenario) relative to baseline. The critical change in levels here is 0.1 m (Section 7.5.1 , Appendix 7.6), otherwise the situation here is the same as at Ty Talbot Farm which is located nearby. Furthermore, the simulated natural variation of 11 m simulated here is clearly not experienced by the pond. This receptor is located close to the coast in a large model cell and so the variation and effect seen here is likely to be less.

The well at White Wheat (Loc. 21): The situation here is the same as at Ty Talbot Farm which is located nearby.

Pwll y Waun pond (Loc. 23): The situation here is the same as at Wilderness Pond which is located nearby.

Home Wood (33): This shallow well (NB. there is also a spring box and pond (Loc. 34) in the field to the north west) is predicted to experience a drawdown of five year mean levels of up to 0.5 m relative to baseline. This exceeds the critical change of 0.25 m (Section 7.5.1, Appendix 7.6 in the 15 and 42 year scenarios. However, for the reasons discussed in Section 7.6, whilst these sites have been flagged up as being potentially vulnerable, site specific considerations indicate a negligible impact.

The pond at location 34 (Loc. 34): The simulated change in water level at this location is the same as at Home Wood which is located nearby. However, in this case the critical threshold is set at 0.1 m reduction (Section 7.5.1, Appendix 7.6).

Grove Golf Club (Loc. 40): The reduction in five year mean water levels relative to baseline at this location is predicted to be just under 3.8 m for the full development scenario. For both 15 year and full development scenarios the drawdown exceeds the critical threshold of 0.5 m (Section 7.5.1). Simulated natural variation in levels at this location is just under 20 m so this does represent a potentially significant change.

In general, the simulated effects on groundwater flows in cells which represent selected receptors are not more than minor:

- Five year mean flows at New Mill Farm Springs (which should be taken to also include the potential effects on groundwater abstractions in this area) are predicted to show a potentially significant increase (around 11%) for the both 15 and 42 year scenarios.
- Five year mean net groundwater flows into Afon Fach/Railway Springs/Stormy Down Spring are predicted to decrease by a maximum of around 11% for the 15 year scenario (less than this

for the 42 year scenario due to the locations of discharges from Cornelly, Grove, and Gaens quarries). This is slightly larger than the selected criterion for changes in stream flow (Section 7.5.1 , Appendix 7.6). However, given the inaccessible and developed location of these springs (and therefore low amenity/ environmental value), this impact is concluded to be Negligible.

- At Parc Newydd Spring there is a temporary significant drop in five year mean groundwater levels (0.5 m) which may impact on spring flows.

The impact of development of Cornelly, Grove, and Gaens quarries combined as a result of change in water level or flow on Grove Golf Club (Loc. 40) is judged to be **Moderate adverse**; at all springs except New Mill Farm Springs (**Negligible**) it is judged to be **Minor adverse**; at other receptors it is judged to be **Negligible**.

7.7.4 D: Other potential effects (combined development)

Leachate Migration

The changes in simulated flow under the combined scenario are very similar to the equivalent Cornelly only runs (See Section 7.6.4). This is because the regional flow field is dominated by the dewatering at Cornelly which is the same in both cases.

Mitigation measures to deal with scenarios such as Cornelly, Grove, and Gaens quarries intercepting a significant amount of landfill leachate are discussed in the WMP (Appendix 7.6).

Cornelly, Grove, and Gaens Quarry Operations

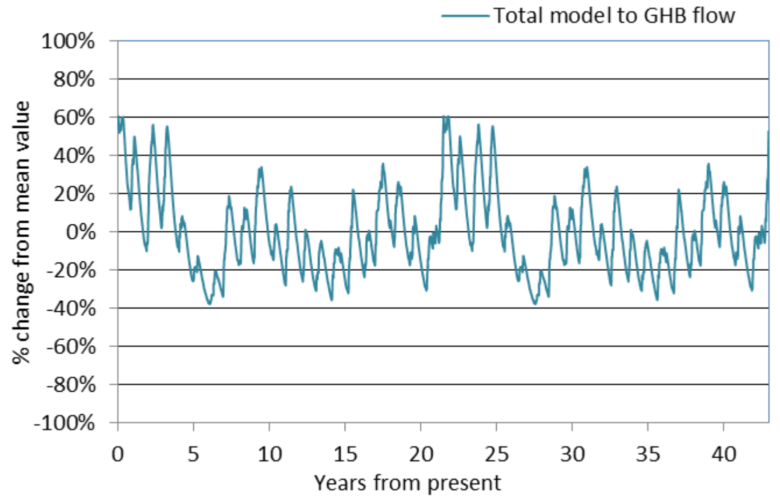
See comments in Section 7.6.4.

Ground Stability

In this combined scenario, as Grove is being actively dewatered, the Cornelly discharge location has been simulated as reverting from Grove to Pant Mawr. Alternative locations such as Stormy Down or direct to the railway cutting could also be considered if necessary as set out in the WMP (Appendix 7.6). However, as these are existing locations of quarry discharge for many years and the risk of any adverse effect on ground stability is considered to be very low.

Saline Intrusion

The flow network model indicates that there is very little or no change to the amount of water flowing towards the coast – mean five year flows along critical flowpaths reduce by no more than 7% and the net change in total flow is around 4% over the full run period. This compares with a variation in flows under baseline conditions which is between approximately 60% higher and 40% lower than the mean (ref Figure 7-11).



.

Figure 7-11 Variation in simulated outflow to the coast – Run BASELINE

As a result, it is considered that there is no significant risk that the proposed developments will cause saline intrusion. This is consistent with the fact that the proposed Cornelly, Grove, and Gaens Quarry developments only involve moving water from one part of the groundwater system to another rather than removing it to a different system.

Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body

The simulated changes in groundwater level and flow are considered to have a **Negligible** impact on the groundwater quality status of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body.

7.7.5 Uncertainty and Risk

See Section 7.6.5 for general comments (model sensitivity analysis and possibility of intercepting a highly permeable feature).

The combined Cornelly, Grove, and Gaens Quarry scenario considered here makes some assumptions about how Cornelly, Grove, and Gaens quarries could operate together. Clearly there is some uncertainty as to how this will develop in future. This issue is considered in the Water Management Plan (Appendix 7.6).

7.8 Effects of Cornelly, Grove, and Gaens Quarry Restoration

Once dewatering ceases, it will take a number of years for Cornelly, Grove, and Gaens quarry voids to fill up (discussed below). This creates the potential to cause some temporarily increased impacts at a number of receptors. It may therefore be necessary to maintain some residual pumping during dry periods to maintain outflows until natural groundwater levels are adequately restored. It should be noted that the natural groundwater levels reached after equilibrium has been established at some receptors may differ from those of the current baseline. This is discussed in more detail in Appendix 7.4 but is not discussed further here as the differences are not considered to be significant.

Note that the RECOVERY run does not include the effect of working the Grove IDO (base of working 15 mAOD). As final recovery levels in this area are above 15 mAOD, this would have the effect of enhancing the effective transmissivity of the aquifer in this area (flat water surface). This is considered in the Grove IDO environmental statement.

Once stabilised, the additional storage represented by the re-filled Cornelly, Grove, and Gaens Quarry voids will have the positive effect of giving the local groundwater system additional tolerance to droughts.

The flow network model has also been used to predict the effects on groundwater flows and cell water balance components following the cessation of quarrying at Cornelly, Grove, and Gaens. The model run RECOVERY has been used to represent the effects of post quarrying conditions following the cessation of quarrying at Cornelly, Grove, and Gaens quarries.

A pair of residual pumping runs RECOVERY PUMPING 5 and RESIDUAL PUMPING 6 have also been undertaken to demonstrate the feasibility of reducing the degree of effects of recovery by maintaining a lower rate of dewatering from Cornelly, Grove, and Gaens quarries for a number of years after the cessation of normal operations. In RESIDUAL PUMPING 5 (used to demonstrate mitigation of effects at Kenfig) residual pumping was set to 50% of the full development run pumping rate at Cornelly and Grove Quarries (Gaens Quarry was switched off) with disposal to the railway cutting to the west of Grove Quarry. For RESIDUAL PUMPING 6 (used to demonstrate mitigation of effects at Merthyr Mawr) residual pumping was set to 50% of the full development run pumping rate at Cornelly only and this was directed to Stormy Down. Comparison of the results from these runs with the no mitigation scenario (RECOVERY) implies that this would be a feasible form of post development mitigation. Further runs to optimise the mitigation have not been carried out at this stage as this scenario is so far into the future.

A description of recovery model runs is presented in Table A7.4a in Appendix 7.4 and analysis of the results is presented in the text of the appendix.

7.8.1 A: General effects on groundwater levels and flows (Restoration)

Groundwater Levels

The effects of cessation of pumping are variable both spatially and in time. Full recovery of water levels in Cornelly Quarry may take around 30 years (much faster responses occur in Grove and Gaens due to the smaller volumes).

At Cornelly and Grove, the water levels show a straightforward recovery (seefigure 7.12 for recovery at Cornelly); conversely in the remainder of the model there is generally an initial period of decreasing heads (during the period when recharge is being diverted to fill Cornelly, Grove, and Gaens quarry voids) followed by gradual recovery to Cornelly, Grove, and Gaens pre-quarrying levels as hydraulic gradients re-establish themselves.

In the absence of mitigation / residual pumping, these effects are greatest closest to Cornelly, Grove, and Gaens quarry, but small effects are simulated across a wide area.

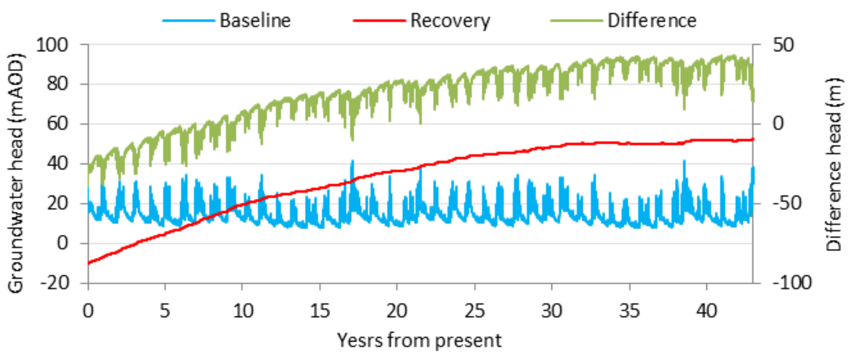


Figure 7-12 Groundwater levels at Cornelly – Run RECOVERY

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level).

In terms of final levels the model simulates the average recovered levels to be as follows for each of the quarries:

- Cornelly: 53 m AOD
- Grove: 21 m AOD
- Gaens: 28 m AOD

One effect of the restoration of Cornelly, Grove, and Gaens quarries to open water is that groundwater level fluctuations in and around Cornelly, Grove, and Gaens quarries will become more subdued due to the influence of the large storage capacity of the flooded Cornelly, Grove, and Gaens Quarry void. This effect is considered to be positive with respect to the water resources of the system by making it more tolerant to drought conditions.

Groundwater Flows

Some large changes in groundwater flow relative to baseline occur in the immediate vicinity of Cornelly, Grove, and Gaens quarries as a consequence of the cessation of dewatering. However, these changes are rapidly dampened with distance; away from Cornelly, Grove, and Gaens quarries changes in groundwater flows relative to current conditions are limited to a few per cent.

It is noted that the flow network model does not make any allowances for the effect of changes to the rate of evaporation from the system following restoration as open water. Calculations presented by ESI to EA Wales (letter dated 23 August 2005, reference 6227SN006.doc – see Section 2.3 of Appendix 7.3 for further discussion) suggest that for the proposed restoration of Cornelly Quarry (open water area 25 ha) the additional evaporative loss is could be around 70 m^3/d. This effective abstraction rate is very small in relation to current and predicted dewatering rates from the system.

Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body

The simulated changes in groundwater level and flow are considered to have a **Negligible** impact on the quantitative status of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body.

7.8.2 B: Potential effects on water levels in the dune sands at Kenfig SAC and the Merthyr Mawr SSSI (Restoration)

Kenfig

At Kenfig the general effect of the unmitigated recovery (RECOVERY) is for simulated levels to fall slightly initially (due to the cessation of pumping westwards) and then to recover gradually over subsequent years (Ref Table 7.13)). The maximum simulated short term (a few years) reduction in levels relative to baseline is 10 cm at Kenfig Pool (Cell 53) and around 12 cm in the dunes to the west of the pool (Cell 55). These peaks occur in drought periods when the baseline run shows elevated heads relative to naturalised (i.e. the apparent 'drawdown' here is because the baseline is higher than naturalised). Generally the differences from baseline are much smaller than this (a few centimetres). In the dunes to the north and north west the maximum change over the period is just under 3.5 cm.

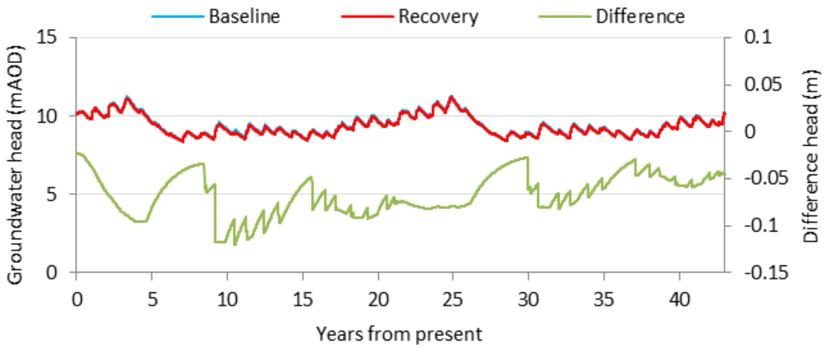


Figure 7-13 Groundwater levels at Kenfig – Run RECOVERY (Model Cell 55)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

Whilst the critical threshold of 0.1 m is temporarily exceeded in the Kenfig Blown Sand aquifer immediately west of Kenfig Pool under unmitigated recovery conditions, residual pumping effectively prevents exceedance of the threshold. The residual pumping scenario markedly reduces simulated effects on water levels at Kenfig; resulting in smaller changes over the period of pumping but a longer recovery and slightly larger changes than unmitigated recovery beyond the period of pumping (i.e. some deferral of effects). The simulated short term maximum reduction at Kenfig Pool is just under 8 cm relative to baseline; in the dunes to the west it is just under 10 cm; and in the other parts of the dunes it is just under 3.5 cm.

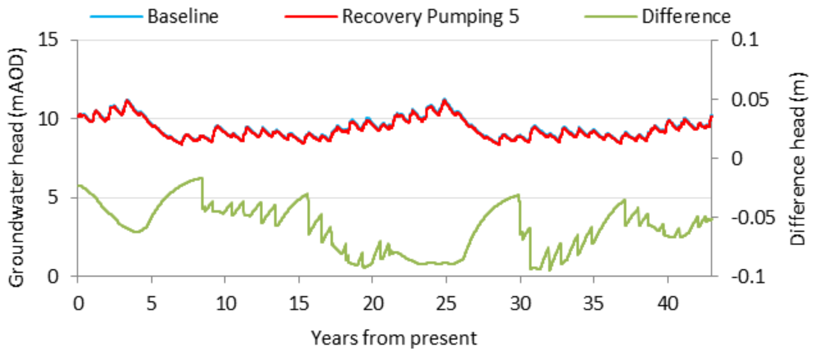


Figure 7-14 Groundwater levels at Kenfig – Run RECOVERY PUMPING 5 (Model Cell 55)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

Merthyr Mawr

At Merthyr Mawr a similar trend is simulated although the change here is from an initial decrease relative to baseline to just under a 5 cm increase by the end of the run. However, unlike at Kenfig, the maximum change is maintained at the end of the simulation period. This represents a return towards the theoretical naturalised conditions which would be higher than baseline due to the current diversion of disposal water from Cornelly westwards, away from Merthyr Mawr. Cells 42 and 43, whilst not being used as an indicator of groundwater level changes in the Blown Sand aquifer do show decreases which are greater than the 0.1 m critical threshold; however, this is due to starting head issues and is discussed in detail in Appendix 7.4.

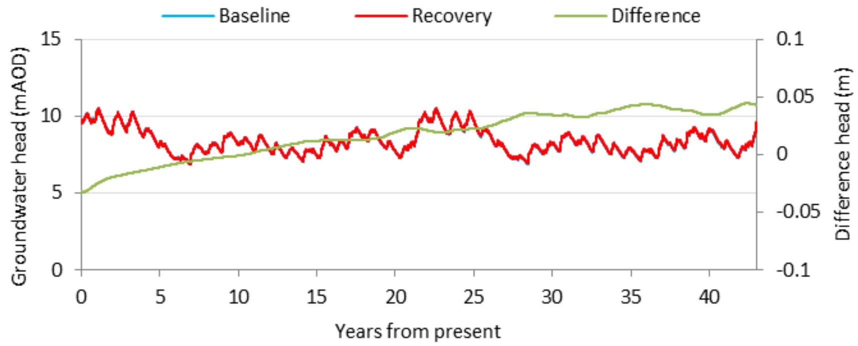


Figure 7-15 Groundwater levels at Merthyr Mawr – Run RECOVERY (Model Cell 45)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

Figure 7.16 shows the simulated flows at Burrows Well under unmitigated conditions. There is an initial decrease of just under 50 m^3/d relative to baseline which then progresses to an increase of around 150 m^3/d by the end of the run. The initial reduction is less than 4% on average and, whilst the magnitude of the final change is just under 6% on average over the last 5 years it is positive and therefore does not exceed the critical threshold of 10% reduction in long term flows (Section 7.5.1).

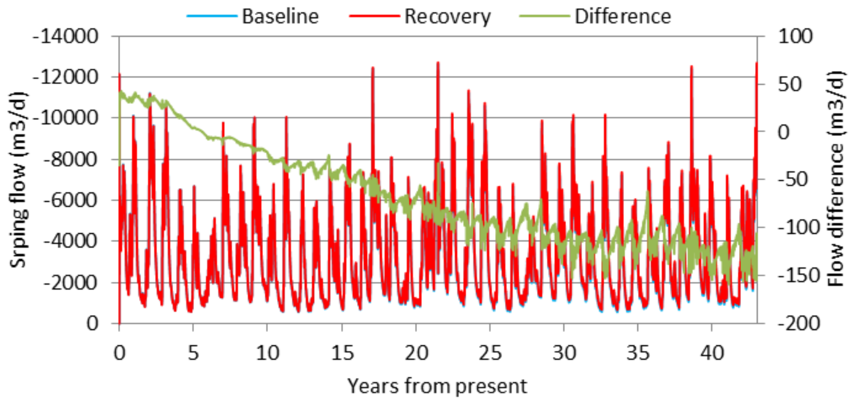


Figure 7-16 Flows at Burrows Well – Run RECOVERY

Baseline (blue) and development run (red), difference (green) is development run minus
milar to

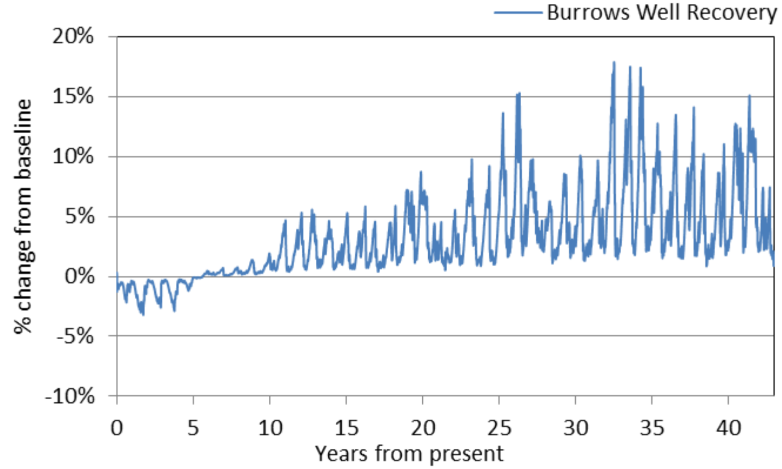


Figure 7-17 Changes in Burrows Well flow (as % change from baseline) – Run RECOVERY

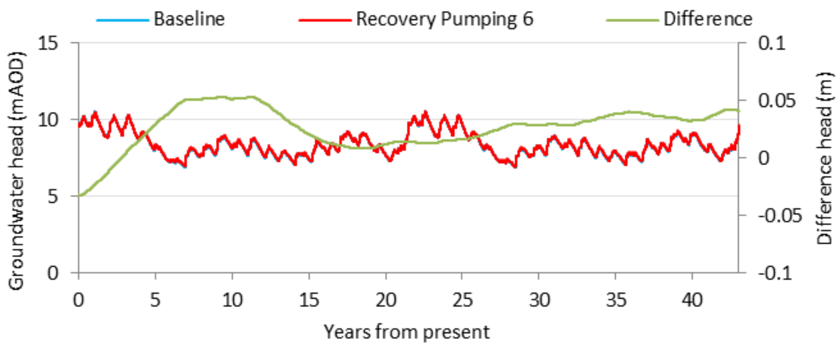


Figure 7-18 Groundwater levels at Merthyr Mawr – Run RECOVERY PUMPING 6 (Model Cell 45)

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

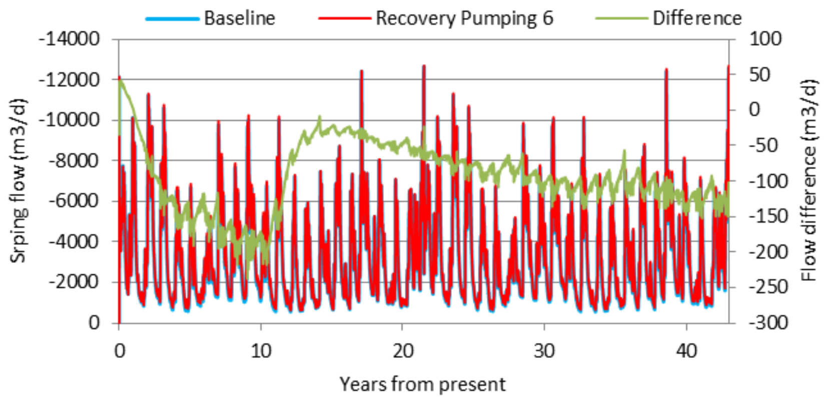


Figure 7-19 Flows at Burrows Well – Run RECOVERY PUMPING 6

Baseline (blue) and development run (red), difference (green) is development run minus baseline (positive means a rise in water level). NB Baseline not visible as it is so similar to development run.

Summary

It should be noted that the results presented for Kenfig and Merthyr Mawr above represent the cells in the model that are most affected in the recovery run. Cell 55 at Kenfig is particularly sensitive to flows coming out of Kenfig Pool compared to the other dune cells and the equivalent changes in adjoining cells are far more attenuated and less than 3 cm in all cases.

Without mitigation the impact of development of Cornelly, Grove, and Gaens quarries combined on the Blown Sand aquifers at Kenfig is judged to be **Negligible** in hydrogeological terms (there is no long-term decline greater than 0.1 m) but requires further ecological assessment due to short term exceedence of the screening threshold of 10 cm as the lower limit of delectability to a modelled 12 cm over a short period (a few years). With mitigation it does not exceed the screening threshold and the impact is judged to be **Negligible**.

At Merthyr Mawr it is judged to be **Negligible both without and with mitigation.**

Consistent with the comments above, the potential indirect effects on habitats within the Kenfig SAC are considered in Chapter 8.0 of the ES. .

7.8.3 C: Potential effects on water levels and flows at other receptors (Restoration)

The restoration scenario without mitigation measures shows temporary potentially significant effects on a number of the identified receptors during the period of Cornelly, Grove, and Gaens Quarry filling. These are:

- Royal Porthcawl Golf Club well (Loc. 14)
- Ty Tanglwyst Farm pond (Loc. 17)
- Ty Tanglwyst Farm well (Loc. 17a)
- Ty Talbot Farm, Nottage (Loc. 18b)
- Wilderness Pond (Loc. 20)
- The well at White Wheat (Loc. 21)
- Pwll y Waun pond (Loc. 23)
- The well at Home Wood (Loc. 33)
- The pond at location 34 (Loc. 34)
- Royal Porthcawl Golf Club well (Loc. 36)
- Grove Golf Club well (Loc. 40)
- Tynycaeau (Loc. 61)
- Pyle & Kenfig Golf Course (Loc. 65)

For all but Grove Golf club (Loc. 40) whilst the effects of groundwater level changes are greater than the critical threshold (0.5 m – see Section 7.5.1 , Appendix 7.6), they are generally small when compared with the natural variation in the aquifer.

In general, the predicted effects on groundwater flows in cells which represent selected receptors are small:

- Flows over the simulation period at New Mill Farm Springs (which should be taken to also include the potential effects on groundwater abstractions in this area) are predicted to show an initial decrease relative to baseline, with short term decreases of more than 10% during the first four years (but with annual average decrease less than this). The reduction in flows decreases over time until, after about 25 years, the difference in flows becomes positive (peaking at around 15% increase). The use of recovery pumping reduces the effect to less than a 10% decrease initially up to a maximum of around 10% increase at the end of the simulation.
- Mean net groundwater flows into Afon Fach/Railway Springs/Stormy Down Spring show just over 20% increase over the simulation period.
- At Parc Newydd Spring there is a temporary potentially significant drop in groundwater levels (1.6 m) which may impact on spring flows.

In the absence of mitigation / residual pumping, the impact of recovery of Cornelly, Grove, and Gaens quarries as a result of change in water level or flow on Grove Golf Club (Loc. 40) is judged to be **Moderate adverse**; at Parc Newydd Spring the impact is **Minor adverse**; all other springs it is judged to be **Negligible**; at the remaining receptors listed above the impact is judged to be **Minor adverse**; and at other receptors it is judged to be **Negligible**.

With mitigation / residual pumping the effects are generally reduced although not enough to change the impact categorisation from the unmitigated case.

7.8.4 D: Other potential effects (Restoration)

Leachate Migration

Flows toward Cornelly, Grove, and Gaens quarries are initially higher than baseline due to the way it has been modelled. However, after 5 years and, apart from short-lived spikes, flow toward Cornelly, Grove, and Gaens quarries is less than baseline. There the risk of increased leachate migration toward Cornelly, Grove, and Gaens quarries is reduced as a result of the recovery.

Flow through Tythegston remain positive (i.e. coastward away from Cornelly) throughout the recovery (ref Figure 7-19). There is therefore no increased risk of leachate migration.

There appears to be some contaminated groundwater in the immediate vicinity of Gaens Quarry and any dewatering and disposal of groundwater in this area may act to dilute and disperse these contaminants.

Ground Stability

This is not an issue in the restoration scenario as, apart from residual pumping for mitigation purposes, there will be no off-site discharge that could lead to stability issues. It is anticipated that any residual pumping would be at lower rates than previously and so, again, stability should not be an issue.

Saline Intrusion

Comparison with the baseline run indicates that flows initially decrease by just under 9% (ref Table 7-20). As recovery progresses the reduction in flow lessens. Based on this, and seen in the context of natural variation of levels (as discussed in Section 0), no significant change to coastal outflows relative to pre-quarrying conditions is predicted as a consequence of ceasing Cornelly, Grove, and Gaens Quarry activity.

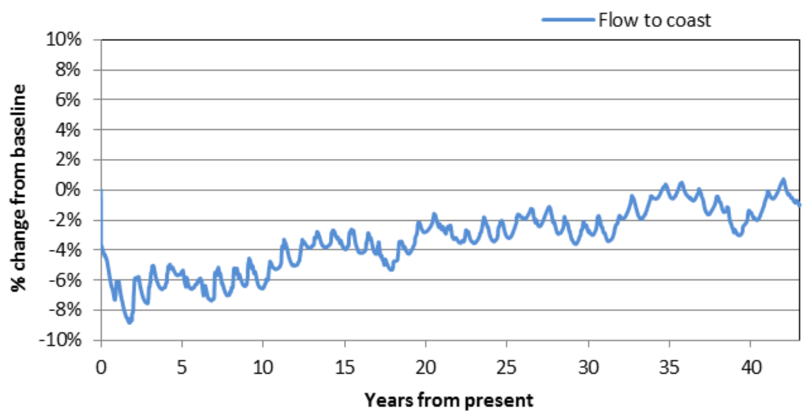


Figure 7-20 Changes in coastal outflow (as % change from baseline) – Run RECOVERY

Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body

The simulated changes in groundwater level and flow are considered to have a **Negligible** impact on the groundwater quality status of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body.

7.8.5 Uncertainty and Risk

See Section 7.6.5 for general comments (model sensitivity analysis and possibility of intercepting a highly permeable feature).

As with the combined Cornelly, Grove, and Gaens Quarry operation scenario, there are uncertainties about when the Cornelly, Grove, and Gaens quarries will be restored, although timescales are provided in the hydrogeological impact assessments based upon reasoned assumptions regarding reserves and projected future output, and, in the case of Grove, an assumed resumption of operations. The assumption used in this section is that Cornelly, Grove, and Gaens quarrying operations will be completed simultaneously and that they will be restored concurrently from the maximum Cornelly, Grove, and Gaens Quarry development limits, which is a conservative assumption.

7.9 Summary of Pre-Mitigation Effects

A summary of the pre-mitigation effects is provided in the following tables:

Table 7-12 Summary of Pre-Mitigation Potential Impacts: Cornelly Quarry Development (Including Combined Effects)

ESI map ref.	Location Name	Type of Receptor	Potential Impact	Assessment Criteria	Effect Assessment	Degree of Effect	Receptor Status	Significance of Impact	Mitigation Requirement
Site Specific Impacts									
-	Kenfig dune slacks	Dune slacks	Long-term decline in groundwater levels greater than 0.1 m. Ecological impacts dealt with under separate ecological assessment)	Predicted GWLs at dunes & Predicted water balance effects	Predicted reduction in groundwater level significantly less than critical threshold (10 cm) reaching 1 cm (full model period).	Negligible	High	Negligible (see also ecological assessment).	
-	Merthyr Mawr dune slacks	Dune slacks	Long-term decline in groundwater levels greater than 0.1 m. Ecological impacts dealt with under separate ecological assessment)	Predicted GWLs at dunes & Predicted water balance effects	Predicted reduction in groundwater level in main dune area (cells 44 and 45) significantly less than critical threshold (10 cm) reaching around 1 cm (full model period).	Negligible	High	Negligible (see also ecological assessment).	
1	Alpha Floc Well/borehole	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted water balance effects	Water level decreases well below critical threshold under all model scenarios therefore impacts judged to be insignificant. Result expected owing to the close continuity of the drift deposits (from which the borehole is thought to abstract) with the Afon Kenfig. Abstraction also	Negligible	Low	Negligible	

					north of both Afon Kenfig and New Mill Fm springs which are likely to fix local groundwater levels.				
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks etc. within quarry)	Conceptual understanding	No impact anticipated due to the distance of the well from Cornelly quarry and the intervening effects of both the Afon Kenfig and New Mill Fm springs	Negligible	Low	Negligible	
2	Kenfig Industrial Estate	SW abstraction	Reduced abstraction potential due to reduction in stream baseflow contribution	Predicted water balance effects	Surface water abstraction from Afon Kenfig will not be impacted upon by quarry dewatering - simulated flow balances for shows very minor or positive changes to groundwater flows toward the river (and therefore by inference river baseflow) as a result of full-scale quarry development.	Negligible	Low	Negligible	
3	Borg Warner well, Industrial Estate	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted water balance effects	As site 1.	Negligible	Low	Negligible	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks etc. within quarry)	Conceptual understanding	No impact anticipated due to the distance of the well from Cornelly quarry and the intervening effects of both the Afon Kenfig and New Mill Fm springs	Negligible	Low	Negligible	
4	Chapel Spring	Spring	Reduction in spring flows due to dewatering abstraction	Predicted water balance effects	Only very minor reduction in groundwater inflows predicted as a consequence of full scale Cornelly dewatering; thus no significant change in average spring flows	Low	Medium	Minor	

					anticipated. Result expected owing due to a limited hydrogeological connection with Cornelly quarry.				
5a/b, 60	New Mill Farm Springs	Spring	Reduction in spring flows due to dewatering abstraction	Predicted water balance effects	Reductions in spring flow negligible or positive so no significant negative impact.	Negligible	High	Negligible	
14	Royal Porthcawl Golf Club	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted GWLs at the well site	Water level decreases below critical threshold under all model scenarios therefore impacts judged to be insignificant.	Negligible	Low	Negligible	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks etc. within quarry)	Conceptual understanding	Risk of well contamination very low due to the distance between the source and receptor and the absence of an established pathway.	Negligible	Low	Negligible	General requirement to control of pollution hazards on site
			Induced saline intrusion due to effects of dewatering abstraction	Predicted GWLs at the well site	Slight increase in likelihood of saline intrusion due to reduced heads and slightly reduced coastal outflows; however, no reversal of gradient and flows are still seaward. Not judged to be significant.	Negligible	Low	Negligible	
17	Ty Tanglwyst Farm	Pond	Reduction in pond levels due to the effects of quarry dewatering	Predicted GWLs at pond	Groundwater level rises predicted so no negative impacts. Practical impacts limited since pond not used.	Negligible	Low	Negligible	
			Reduction in water quality due to groundwater pollution (accidental fuel	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry	Negligible	Low	Negligible	General requirement to control of pollution hazards on site

			spills, leaks etc. within quarry)						
17a	Ty Tanglwyst Farm	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted GWLs at the well site	Groundwater level rises predicted so no negative impacts.	Negligible	Low	Negligible	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks, increased turbidity etc.)	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry	Negligible	Low	Negligible	General requirement to control of pollution hazards on site
18b	Ty Talbot Farm, Nottage	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted GWLs at the well site	Groundwater level changes exceed critical threshold in combined development scenarios; however natural groundwater variation considerably greater than predicted effect. Impact not considered significant.	Medium	Low	Minor	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks etc. within quarry)	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry	Negligible	Low	Negligible	General requirement to control of pollution hazards on site
20	Wilderness	Pond	Reduction in pond levels due to the effects of quarry dewatering	Predicted GWLs at pond	As site 18b.	Low	Medium	Minor	
21	White Wheat	Borehole	Reduction in borehole	Predicted GWLs at the well site	As site 18b.	Medium	Low	Minor	

			performance / yield due to dewatering abstraction						
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks etc. within quarry)	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry	Negligible	Low	Negligible	General requirement to control of pollution hazards on site
23	Pwll y Waun	Pond	Reduction in pond levels due to the effects of quarry dewatering	Predicted GWLs at pond	As site 18b.	Low	Medium	Minor	
28, 30, 45	Collection of springs at Merthyr Mawr	Springs	Reduction in spring flows due to dewatering abstraction	Predicted water balance effects	Predicted reduction in net groundwater inflows to the area and Borrows Well flows are small (less than 5% at worst). No significant impacts therefore anticipated.	Low	Medium	Minor	
33	Home Wood	Shallow Well	Reduction in borehole performance / yield due to dewatering abstraction	Predicted GWLs at well site	As site 18b except that water level decreases below critical threshold in all scenarios.	Medium	Low	Minor	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks, increased turbidity etc.) resulting from quarry activities	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry	Negligible	Low	Negligible	General requirement to control of pollution hazards on site

34	Pond	Pond	Reduction in pond levels due to the effects of quarry dewatering	Predicted GWLs at pond	As site 33.	Medium	Low	Minor	
36	Royal Porthcawl Golf Club	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted GWLs at the well site	Groundwater levels do not exceed critical threshold so no significant impacts.	Negligible	Low	Negligible	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks etc.) resulting from quarry activities	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry	Negligible	Low	Negligible	General requirement to control of pollution hazards on site
39a-e	Railway Springs	Spring	Reduction in spring flows due to dewatering abstraction	Predicted GWLs at spring & Predicted water balance effects	Limited impacts - greatest in combined 15 year scenario (up to 11% inflow reduction).	Medium	Low	Minor	Water level monitoring
40	Grove Golf Club	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted GWLs at well site	As site 33.	Medium	Medium	Moderate	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks,	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry	Negligible	Low	Negligible	General requirement to control of pollution hazards on site

			increased turbidity etc.) resulting from quarry activities						
54, 55	Kenfig Pond seep	Seep	Reduction in seeps due to dewatering abstraction	Predicted GWLs at seeps & Predicted water balance effects	Predicted change in water level less than 2 cm drop and less than 6% change in flow (mean over last 5 years). No significant impact.	Low	Medium	Minor	
			Reduction in water quality of seeps due to groundwater pollution (accidental fuel spills, leaks etc.) resulting from quarry activities	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry due to distance	Negligible	Medium	Negligible	
56/56N	Stormy Down Spring	Spring	Reduction in spring flows due to dewatering abstraction	Predicted GWLs at spring & Predicted water balance effects	As site 39a-e.	Medium	Low	Minor	
59	Parc Newydd Spring	Spring	Reduction in spring flows due to dewatering abstraction	Predicted GWLs at spring & Predicted water balance effects	Potentially significant impact due to a drop in levels under combined development runs (just under 0.5 m).	Medium	Low	Minor	
65	Golf club borehole	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted GWLs at well site	As site 36.	Negligible	Low	Negligible	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks etc.)	Conceptual understanding	No risk of water contamination from activities at Cornelly Quarry	Negligible	Low	Negligible	General requirement to control of pollution hazards on site

			resulting from quarry activities						
KP	Kenfig Pool	Pond	Reduction in pond levels due to the effects of quarry dewatering	Predicted GWLs at pond & Predicted water balance effects	Predicted change in water level less than 2 cm drop (mean over last 5 years). No significant impact.	Negligible	High	Negligible	
61	Tynycaeau	Borehole	Reduction in borehole performance / yield due to dewatering abstraction	Predicted GWLs at well site	As site 36.	Negligible	Low	Negligible	
			Reduction in water quality due to groundwater pollution (accidental fuel spills, leaks, increased turbidity etc.) resulting from quarry activities	Conceptual understanding	There is a limited risk of water contamination from quarrying activities at this location.	Negligible	Low	Negligible	General requirement to control of pollution hazards on site
General Impacts									
-	Groundwater along coastal fringe	Groundwater	Induced saline intrusion	Predicted GWLs along coast	Very small changes in coastal outflow predicted. No reversal of gradient predicted.	Negligible	N/A	N/A	
-	Land directly surrounding quarry	Ground	Ground instability associated with dewatering extent	Conceptual understanding	Disposal of water from Cornelly Quarry is only to existing quarries and therefore there is no localised high flows which could induce washouts in fissures. No ground stability issues are anticipated	Negligible	N/A	N/A	

-	General groundwater quality	Groundwater	Disturbance of contaminated groundwater (aggravation of landfill leachate migration - Stormy West and Tythegston landfills)	Conceptual understanding Predicted water balance effects	Predicted groundwater flows suggest that the dewatering effects associated with Cornelly do induce some additional inflows to the quarry area from the former landfill sites (particularly from Stormy West). However, accounting for the absence of any significant migration of leachate to date, and the inferred anisotropy of the local aquifer system, there is considered to be no significant additional risk from landfill leachate migration.	Low	N/A	N/A	Precautionary water quality monitoring

*The base colour is for the scenarios with Cornelly Quarry operating on its own. Where the assessment is different for the scenarios with all three quarries operating together, then this is overprinted as coloured stripes (using the same legend) in the 'Potentially Significant Impact' column only.

Key* : Potentially significant impact 15 year scenario — Potentially significant impact 42 year scenario

Key continued:

Magnitude of effect	Status of receptor	For lookup	Degree of impact
Negligible	Low	NegligibleLow	Negligible
Low	Low	LowLow	Minor
Medium	Low	MediumLow	Minor
High	Low	HighLow	Moderate
Negligible	Medium	NegligibleMedium	Negligible
Low	Medium	LowMedium	Minor
Medium	Medium	MediumMedium	Moderate
High	Medium	HighMedium	Major
Negligible	High	NegligibleHigh	Negligible
Low	High	LowHigh	Moderate
Medium	High	MediumHigh	Major
High	High	HighHigh	Major

Table 7-13 Summary of Pre Mitigation Potential Impacts: Cornelly Quarry Decommissioning (Including combined effects)

ESI map ref.	Location Name	Type of Receptor	Potential Impact	Assessment Criteria	Effect Assessment	Degree of effect	Receptor Status	Significance of Impact
Site Specifics								
-	Kenfig dune slacks	Dune slacks	Long-term decline in groundwater levels greater than 0.1 m. Ecological impacts dealt with under separate ecological assessment)	Predicted GWLs at dunes & Predicted water balance effects	Predicted reduction in groundwater level temporarily less than critical threshold (10 cm) reaching around 12 cm at worst case. Effect is hydrogeologically negligible but requires further ecological assessment.	Negligible	High	Negligible (see also ecological assessment).
-	Merthyr Mawr dune slacks	Dune slacks	Long-term decline in groundwater levels greater than 0.1 m. Ecological impacts dealt with under separate ecological assessment)	Predicted GWLs at spring & Predicted water balance effects	Predicted temporary change in groundwater level of just under 15 cm exceeds critical threshold of 10 cm for 2 months initially - result of starting head selection. Remainder of run does not exceed critical threshold.	Negligible	High	Negligible (see also ecological assessment).
1	Alpha Floc Well/borehole	Borehole	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted water balance effects	Water level decreases well below critical threshold under all model scenarios therefore impacts judged to be insignificant. Result expected owing to the close continuity of the drift deposits (from which the borehole is thought to abstract) with the Afon Kenfig. Abstraction also north of both Afon Kenfig and New Mill Fm springs which are likely to fix local groundwater levels.	Negligible	Low	Negligible
2	Kenfig Industrial Estate	SW abstraction	Reduced abstraction potential due to modification of stream baseflows	Predicted water balance effects	Surface water abstraction from Afon Kenfig will not be impacted upon by quarry dewatering - simulated flow balances for shows very minor changes (<1%) to groundwater flows toward the river (and therefore by inference river baseflow).	Negligible	Low	Negligible
3	Borg Warner well, Kenfig Indus	Borehole	Change in borehole performance / yield due to alteration of	Predicted water balance effects	As site 1.	Negligible	Low	Negligible

			groundwater flow regime					
4	Chapel Spring	Spring	Alteration of spring flows due to changes in the groundwater flow regime	Predicted water balance effects	Only very minor reduction in groundwater inflows predicted; thus no significant change in average spring flows anticipated. Result expected owing due to a limited hydrogeological connection with Cornelly quarry.	Negligible	Medium	Negligible
5a/b, 60	New Mill Farm Springs	Spring	Alteration of spring flows due to changes in the groundwater flow regime	Predicted water balance effects	Long term flows do not exceed 6% reduction and are positive once stabilised so no significant negative impact.	Negligible	High	Negligible
14	Royal Porthcawl Golf Club	Borehole site	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at the well site	Groundwater level changes exceed critical threshold; however natural groundwater variation considerably greater than predicted effect. Impact not considered significant.	Low	Low	Minor
17	Ty Tanglwyst Farm	Pond	Change in pond levels due to alteration of groundwater flow regime	Predicted GWLs at pond	Groundwater level changes exceed critical threshold; however natural groundwater variation considerably greater than predicted effect. Impact not considered significant. Practical impacts limited since pond not used.	Low	Low	Minor
17a	Ty Tanglwyst Farm	Borehole	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at the well site	As site 14.	Low	Low	Minor
18b	Ty Talbot Farm, Nottage	Borehole	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at the well site	As site 14.	Low	Low	Minor
20	Wilderness	Pond	Change in pond levels due to alteration of groundwater flow	Predicted GWLs at pond	As site 14.	Low	Medium	Minor

			regime					
21	White Wheat	Borehole	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at the well site	As site 14.	Low	Low	Minor
23	Pwll y Waun	Pond	Change in pond levels due to alteration of groundwater flow regime	Predicted GWLs at pond	As site 14.	Low	Medium	Minor
27, 28, 29 30, 31, 45	Collection of springs at Merthyr Mawr	Springs	Alteration of spring flows due to changes in the groundwater flow regime	Predicted GWLs at spring & Predicted water balance effects	Predicted reduction in net groundwater inflows to the area are small and changes in flows at Burrows Well are also small (less than 3% peak reduction followed by long term increase of around 6%). No significant impacts therefore anticipated.	Negligible	Medium	Negligible
33	Home Wood	Shallow Well	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at well site	As site 14.	Low	Low	Minor
34	Pond	Pond	Change in pond levels due to alteration of groundwater flow regime	Predicted GWLs at pond	As site 14.	Low	Low	Minor
36	Royal Porthcawl Golf Club	Borehole	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at the well site	As site 14.	Low	Low	Minor
39a-e	Railway Springs	Spring	Alteration of spring flows due to changes in the groundwater flow regime	Predicted GWLs at spring & Predicted water balance effects	Initial small drop in spring flows but averaging around 20% increase over model period.	Negligible	Low	Negligible

40	Grove Golf Club	Borehole	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at well site	Potential temporary drop of around 9 m predicted. This is a significant proportion of the natural variation (around 19 m) and therefore is considered significant.	Medium	Medium	Moderate
54, 55	Kenfig Pond seep	Seep	Change in seep flows due to alteration of groundwater flow regime	Predicted GWLs at seeps & Predicted water balance effects	Maximum reduction in flows less than 10% of total flow variation.	Negligible	Medium	Negligible
56/56N	Stormy Down Spring	Spring	Alteration of spring flows due to changes in the groundwater flow regime	Predicted GWLs at spring & Predicted water balance effects	As 39a-e.	Negligible	Low	Negligible
59	Parc Newydd Spring	Spring	Alteration of spring flows due to changes in the groundwater flow regime	Predicted GWLs at spring & Predicted water balance effects	Potentially significant impact due to a drop in levels under combined development runs (around 1.6 m).	Medium	Low	Minor
65	Golf club borehole	Borehole	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at well site	As site 14.	Low	Low	Minor
KP	Kenfig Pool	Pond	Change in pond levels due to alteration of groundwater flow regime	Predicted GWLs at pond & Predicted water balance effects	Predicted change in water level equals 10 cm. No significant impact.	Negligible	High	Negligible
61	Tynycaeau	Borehole	Change in borehole performance / yield due to alteration of groundwater flow regime	Predicted GWLs at well site	As site 14.	Low	Low	Minor
General Impacts								

-	Groundwater along coastal fringe	Groundwater	Induced saline intrusion	Predicted GWLs along coast	Groundwater level changes along the coastal fringe do not permit the reversal of hydraulic gradients necessary to induce saline intrusion.	Negligible	N/A	N/A
-	Land directly surrounding quarry	Ground	Ground instability associated with water level changes	Conceptual understanding	No ground stability issues are anticipated	Negligible	N/A	N/A
-	General groundwater quality	Groundwater	Disturbance of contaminated groundwater (aggravation of landfill leachate migration - Stormy West and Tythegston landfills)	Conceptual understanding Predicted water balance effects	There are no significant increases in flow from the landfill locations toward the quarries. Because of this, the absence of any significant migration of leachate to date, and the inferred anisotropy of the local aquifer system, there is considered to be no significant additional risk from landfill leachate migration.		N/A	N/A

Key : [green box] Potentially significant impact

7.10 Mitigation Measures: Water Management Plan (WMP)

The impacts identified on the water environment from the proposed development of Cornelly Quarry are, in general, minor. The Scoping Direction requires that risks from residual uncertainties such as the chances of encountering a highly permeable feature at depth are considered. This potential has been considered and modelled, but the risk of intercepting a highly permeable feature is considered to be extremely low (ref Section 7.4.4). Notwithstanding this, the simulated effects are minor and would take between 5 and 10 years to manifest themselves.

The potential and residual risks have been addressed by means of a monitor and mitigate strategy embedded in the revised Water Management Plan (WMP) for the site (Appendix 7.6). This sets out how the Cornelly Quarry abstraction and discharges will be managed and includes recommendations for associated monitoring, triggers levels and responses to triggers being breached. Figure 7.21 provides a flow chart illustrating the various processes involved in the WMP.

The WMP has previously been subject to extensive consultation with the regulators (Table 7-3 in Section 7.2.6). The version in Appendix 7.6 has now been updated for this Environmental Statement in response to comments made on previous versions and in light of the results of the current assessment as presented above.

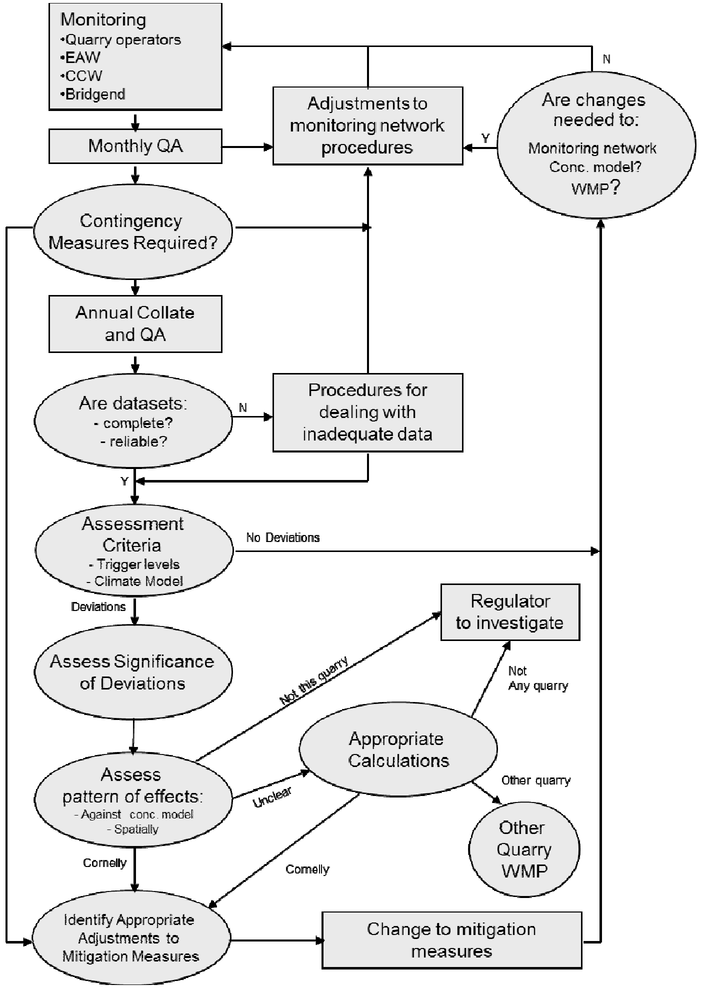


Figure 7-21 Processes in Water Management Plan

7.10.1 Disposal Options

There are a number of different potential disposal options for the discharge of water pumped from Cornelly Quarry sump. Retaining all of these options is an effective way to minimise the risk of any adverse effects of dewatering on water levels in any particular direction. The scenarios used for this hydrogeological impact assessment (Table A7.4a) have been selected to represent a range of options that reflects current practice. The scenarios can be subdivided on the basis of the way in which the dewatering operations in Cornelly, Grove, and Gaens quarries interact in future:

- No operations in Grove Quarry: It is assumed that most water from Cornelly Quarry will be discharged to Grove Quarry.
- Grove Quarry Active: Dewatering water from Cornelly Quarry will be primarily to Pant Mawr and (if required) Stormy Down Quarries. Grove Quarry will discharge to the railway cutting. It may also be feasible to pump direct from Cornelly to the railway cutting.
- Gaens Quarry will discharge to a sump to the north west of the current operational area (within the existing Gaens Quarry boundaries) as and when required.

In future, the most appropriate distribution of dewatering discharge between these sites will be based upon operational practice, but refined, as required by the WMP (the Annual Reports will determine the most appropriate discharge options and requirements to mitigate any effects identified via the ongoing monitoring (as set out in Section 7 of the WMP, Appendix 7.6).

Note that, whilst there are some small simulated environmental benefits from discharging to Stormy Down Quarry, these scenarios are associated with higher pumping rates in Cornelly Quarry. Unnecessary pumping to Stormy Down Quarry is therefore undesirable.

7.10.2 Contingency Measures

The revised WMP includes a process for triggering Contingency Measures for eventualities which are outside the range of conditions that are considered to be realistic in this study.

The predictions of average dewatering rates are made on the basis of the revised and updated conceptual model described in Appendix 7.1. This conceptual model was based on a comprehensive review of all the data available, including a detailed review of the palaeokarst features in Cornelly Quarry and in deep boreholes in the limestone. This indicated that there are unlikely to be any significant active fissures at depth below Cornelly quarry.

If this conceptual model is inaccurate and a ‘highly permeable feature’ were to be encountered, then the rates of inflow would potentially be greater than predicted above. Whilst this is considered to be very unlikely, the revised WMP includes a proposed procedure whereby the observed pumping rate at Cornelly Quarry could be compared to the anticipated pumping rates (given antecedent rainfall) and any potentially significant change detected. Detection of such a change in pumping rate would trigger appropriate Contingency Measures, as set out in the WMP Section 6.3.3.

A potential threat to groundwater quality relates to increased rates of landfill leachate migration as a result of modified patterns of groundwater flow. The risk from this is judged to be very small. However, the Water Management Plan contains an outline groundwater quality monitoring programme to identify any such pollution should it occur.

Note that it is expected that water quality standards for the water discharged off site from dewatering activities at Cornelly, Grove, and Gaens quarries will be addressed by means of Discharge Consents which will be agreed separately with Natural Resources Wales.

7.11 Residual Effects

A summary of the mitigation of significant effects (i.e. those where the impact is more than minor, or in the case of the SACs, where the screening threshold is passed) and the resulting residual effects are presented in the table below. Following application of the mitigation measures residual effects are expected to be not more than **Minor in hydrogeological terms**.

Table 7-14 Potentially Significant Residual Effects and Proposed Mitigation[1]

Receptor	Description of effect	Degree of impact	Description of Mitigation	Resultant impact
Grove Golf Club	Reduction in groundwater levels at abstraction location during development and recovery.	Moderate	Application of WMP – Mitigation measures may include: • Modification of the structure of the abstraction • Provision of alternative supply • Financial compensation	Negligible
Kenfig SAC	Temporary reduction of groundwater levels past screening threshold during recovery relative to baseline conditions during drought periods.	Hydrogeological impacts are Negligible. See ecological assessment for potential indirect impacts. Under baseline conditions the existing Cornelly Quarry pumping is effectively ameliorating drought conditions to some extent.	Application of WMP – Maintain residual pumping during recovery period.	Critical screening threshold is not exceeded. Hydrogeological impacts are Negligible. See ecological assessment for potential indirect impacts.

[1]Signifcant = more than **Minor** or beyond critical threshold for SACs

7.12 Conclusions

Four categories of potential impact from the proposed Cornelly quarrying activities (referred to in the assessment as A – D as described in Section 7.5.1) were identified by discussion with the relevant regulators. The likely extent of the various impacts has been addressed through a detailed programme of hydrogeological investigation (culminating in a robust conceptual model of the local hydrogeology) and subsequent groundwater flow simulation.

The volume of data collected for the site (including groundwater level, flow, and quality) and duration of monitoring records (greater than 10 years) represents a highly robust basis for this assessment.

The simulation of both groundwater flows and levels by a calibrated transient flow network model has facilitated a robust quantitative assessment to be made of the impacts associated Cornelly Quarry development and restoration.

The conclusions to be taken from the hydrogeological impact assessment work are presented below in Table 7.15, in the context of the impact areas or categories

7.13 Recommendations

A draft Water Management Plan (WMP) has been drawn up to formalise future monitoring and management of abstraction/disposal at Cornelly, Grove, and Gaens quarries (Appendix 7.6).

7.14 Planning Conditions

The key planning condition requires the implementation of the Water Managament Plan and the obligations which it sets out for continual monitoring, assessment and mitigation measures if required.

A number of additional and conventional planning conditions would be appropriate to enshrine the fuel handling protocol to minimise the risk of ground and surface water contamination.

These issues are reflected in the updated schedule of proposed planning conditions.

Table 7-15 Impact/Risk Assessment Conclusions (Including Cumulative Impacts)

	Impact Category (as per Scoping Direction – see Section 7.2.1)	Effect/Impact Category (as per Section 7.5.1)	Impact/Risk assessment conclusions
1	The potential impact of quarrying at Cornelly on Kenfig/Cynffig SAC/SSSIs and Cefn Cribwr Grasslands SAC/SSSIs.	B	Small predicted hydrogeological effects but no significant hydrogeological impact on Kenfig Pool and Dunes or Merthyr Mawr SSSIs. (The potential indirect effects on habitats within the Kenfig SAC are considered in Chapter 8.0 of the ES). Cefn Cribwr discounted as no effective hydrological pathway (Section 7.5.1).
2	The potential impact of quarrying at Cornelly on hydrology and hydrogeology of the area, including the possibility of interception during quarrying of a 'highly permeable feature' within the limestone, and although there is a low probability of this occurring the prospect should be recognised as a continuing risk during further development of Cornelly Quarry and appropriate action identified (for example a risk management/monitoring strategy which recognises the critical stage at which potential adverse impact may occur).	A	Predicted impacts on the local hydrology are minor. Some effects but no significant impacts predicted for the 24 potentially vulnerable receptors. The likelihood of encountering a significant interconnected fissure at depth has been considered in detail and is concluded to be very low. The implications of encountering such a feature (if one did exist) have been considered by means of modelling which has informed the development of a Water management Plan for the site to tackle this residual uncertainty. The modelling work shows that the timescales for the effects of encountering such a feature to manifest themselves at key receptors are such that the proposed monitoring would provide sufficient warning to allow effective mitigation to be put in place.
3	The potential impacts on the Kenfig/Cynffig SAC and the hydrology of the dune system and Kenfig Pool, including the nature of the hydraulic connection between the dune sands and the underlying sand and gravel aquifer at Cynffig/Kenfig SSSI and the related sensitivity of groundwater levels in the dune sands to drawdown in the sand and gravel aquifer.	B	See 1. The nature of the connections and sensitivity of the groundwater levels have been well-constrained through further investigation and integrated numerical modelling.

	Impact Category (as per Scoping Direction – see Section 7.2.1)	Effect/Impact Category (as per Section 7.5.1)	Impact/Risk assessment conclusions
4	The potential impacts on other groundwater users and water features in the area.	C	See 2.
5	The potential for Cornelly Quarry dewatering to induce saline intrusion into the aquifer.	D	No significant risk of saline intrusion predicted (see Section 7.6.5).
6	The likely impact from further Cornelly quarrying on the migration of leachate and landfill gas.	D	Further deepening of Cornelly Quarry will steepen the hydraulic gradient between the landfills and Cornelly quarry. However, careful consideration of this issue implies that this does not represent a significant risk (See Section 7.6.5). The Water Management Plan (Appendix 7.6) includes measures to monitor the quality of water pumped from Cornelly quarry sump.
7	The likely impact of Cornelly quarrying on the stability of surrounding land.	D	It is not anticipated that the proposed discharge will cause any localised concentration of groundwater flow that could cause washout and hence there are no localised effects on ground stability (See Section 7.6.5).
8	An evaluation of potential surface lowering and sinkhole collapse.	D	It is not anticipated that the proposed discharge will cause any localised concentration of groundwater flow that could cause sinkhole development (See Section 7.6.5)

7.15 References

BGS, 2000, An assessment of the possible effects of dewatering proposed extensions to quarries in the South Cornelly area, South Wales

CEH, 2005. Determining a nitrogen budget for Merthyr Mawr sand dune system

Environment Agency, 2003a. email from B Cordier regarding clarification of conceptual model (11 November 2003)

Environment Agency, 2003b. email from S Neale regarding clarification of conceptual model (28 November 2003)

Environment Agency, 2007 Science Report – SC040020/SR1 Hydrogeological impact appraisal for dewatering abstractions

ESI, 2001. Scoping Request

ESI, 2002a. Cornelly Group of Quarries: Proposed Programme of Work for Phase 2 Hydrogeological Investigations

ESI, 2002b. The Hydrogeology of the area around the Cornelly Group of Quarries.

ESI, 2003a. Hydrogeological Investigations at the Cornelly Group of Quarries: Factual Report on Phase 2

ESI, 2003b. Conceptual Model of the Local Hydrogeology

ESI, 2003c. Letter addressed to EA Wales and CCW offering clarification of the conceptual model. Dated 12 November 2003. Reference 6227SN004.doc

ESI, 2004. Cornelly Group of Quarries: Impact Assessment for Cornelly Quarry and Combined Quarries

ESI, 2008. Cornelly Group of Quarries: Impact Assessment for Grove Quarry

ESI, 2010 Cornelly Group of Quarries: Impact Assessment for Gaens Quarry

ESI, 2009. Water Management Plan for Cornelly Quarry

Jones M L M, Pilkington M G, Healey M, Norris D A, Brittain S A, Tang Y S and Reynolds (CEH) 2005 Determining a nitrogen budget for Merthyr Mawr sand dune system. CCW R&D Report No. 14, Contract FC 72-02-59

Jones, P.S., 1993. Ecological and hydrological studies of dune slack vegetation at Kenfig NNR. Unpubl. PhD thesis. University College, Cardiff.

SWS, 2010. Refining river basin planning through targeted investigations on selected welsh groundwater dependent terrestrial ecosystems (GWDTEs)

quarry, as well as in the wider context of Cornelly/Grove and Stormy Down Quarries.

- Progressive working and restoration of the upper faces/benches as they reach final position by overtipping/restoration blasting techniques to create a more naturalistic landform and allow these areas to mature as early within the development as possible prior to the removal of the naturally regenerating vegetation

These issues are reflected in the schedule of proposed updated planning conditions.

14.3 Hydrology and Hydrogeology

14.3.1 Hydrology and Hydrogeology Study

The study reflects the detailed requirements with respect to hydrology and hydrogeology which are asset out in the March 2013 Scoping Direction.

It reflects the results of a major programme of investigation, monitoring and analysis unedertaken over the last 12 years, and updates and refines studies undertaken as part of previous voluntary ES's for the Cornelly, Grove and IDO areas.

The study is based upon a phased programme of work and extensive consultations and discussions with the EA, CCW and latterly NRW. A key element of the study is the conceptual model which was originally developed in support of the first voluntary ES for the Cornelly Quarry but which has now been updated in the light of subsequent further consultations and the large amount of data collected since that time.

At the start of the current investigation in 2001 a number of key uncertainties were identified which could constrain the ability to predict the potential impacts of deepening the quarries accurately. These uncertainties have been reduced as far as possible by a phased approach of investigation (including over 12 years of baseline monitoring) followed by very detailed modelling (Appendix 7.3) and associated sensitivity analysis. This has reduced the level of uncertainty in the assessment to a point at which any residual uncertainties can be appropriately addressed by means of an adaptive management strategy (ref Water Management Plan).

The assessment approach has considered the source of the potential impact (dewatering assocated with further working of Cornelly Quarry); the pathways (the groundwater flow pathways or hydrogeological linkages identified in the conceptual model); and the receptors (the key water features identified in the water features survey). The investigations, conceptualisation, and groundwater flow model which have been undertaken and developed to assist in the prediction of groundwater level impact, have, as required by the Scoping Direction, specifically considered the possible effects of interception during quarrying of a ‘highly permeable feature’.

In presenting the results of the assessment, the study has grouped potential effects into four, as follows:

(i) Groundwater levels and flows in the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body (A);
(ii) Water levels in the dune sands at Kenfig SAC / Kenfig Pool and Dunes SSSI and the Merthyr Mawr SSSI (B);
(iii) Water levels and flows at other receptors (C); and
(iv) Other potential impacts, including leachate migration, ground stability and saline intrusion (D).

The effects have been considered for both the operational and restoration stages, based upon Cornelly Quarry working in isolation (at the 5 year ROMP period and at the end of the circa 42 year life of the development), and in combination with quarrying and restoration at Grove and Gaens Quarries based upon the same time periods. The modelling has included a series of sensitivity runs to define the likely error margin for the respective predictions.

In relation to the Cornelly only model runs, in the absence of mitigation, the impacts are assessed as:

(i) **Negligible** impact on groundwater levels and flows (A);
(ii) **Negligible** impact on water levels in the SAC / SSSI dune systems (C); (but see also the indirect ecological impact assessment);
(iii) **Minor adverse** / **negligible** effects on water levels and flows at other receptors (C); and
(iv) No significant risk of other impacts is predicted **(D).**

In the cumulative assessment development runs, again in the absence of mitigation, the impcts are assessed as:

(i) **Negligible** impact on groundwater levels and flows (A);
(ii) **Negligible** impact on water levels in the SAC / SSSI dune systems (C); (but see also the indirect ecological impact assessment);
(iii) The impact of development of Cornelly quarry alone as a result of change in water level or flow on Grove Golf Club (Loc. 40) is judged to be **Moderate adverse**; at all springs except New Mill Farm Springs (**Negligible**) it is judged to be **Minor adverse**; at other receptors it is judged to be **Negligible (C)**.
(iv) No significant risk of other impacts is predicted **(D).**

The effects of quarry restoration have been assessed for the same groups of receptors, again without mitigation, with the conclusions of:

(i) **Negligable** impact on groundwater levels and flows (A);

(ii) Without mitigation the impact of development of all quarries combined on the Blown Sand aquifers at Kenfig is judged to be **Negligible** in hydrogeological terms but requires further ecological assessment due to short term exceedence of the screening threshold of 10 cm as the lower limit of detectability to a modelled 12 cm over a short period (a few years). With mitigation it does not exceed the screening threshold and the impact is judged to be **Negligible**. At Merthyr Mawr it is judged to be **Negligible both without and with mitigation (D).**

(iii) In the absence of mitigation / residual pumping, the impact of recovery of the quarries as a result of change in water level or flow on Grove Golf Club (Loc. 40) is judged to be **Moderate adverse**; at Parc Newydd Spring the impact is **Minor adverse**; all other springs it is judged to be **Negligible**; at

- Royal Porthcawl Golf Club well (Loc. 14)
- Ty Tanglwyst Farm pond (Loc. 17)
- Ty Tanglwyst Farm well (Loc. 17a)
- Ty Talbot Farm, Nottage (Loc. 18b)
- Wilderness Pond (Loc. 20)
- The well at White Wheat (Loc. 21)
- Pwll y Waun pond (Loc. 23)
- The well at Home Wood (Loc. 33)
- The pond at location 34 (Loc. 34)
- Royal Porthcawl Golf Club well (Loc. 36)
- Tynycaeau (Loc. 61)

the impact is judged to be **Minor adverse**; and at other receptors it is judged to be **Negligible**. With mitigation / residual pumping the effects are generally reduced although not enough to change the impact categorisation from the unmitigated case (C).

(iv) No significant risk of other impacts is predicted **(D).**

Following application of the mitigation measures residual effects are expected to be not more than **Minor in hydrogeological terms**.

14.3.2 Hydrology and Hydrogeology Mitigation Measures: Water Management Plan (WMP)

The impacts identified on the water environment from the proposed development of Cornelly Quarry are, in general, minor. The Scoping Direction requires that risks from residual uncertainties such as the chances of encountering a highly permeable feature at depth are considered. This potential has been considered and modelled, but the risk of intercepting a highly permeable feature is considered to be extremely low (ref Section 7.4.4 and 7.5.2). Notwithstanding this, the simulated effects are minor and would take between 5 and 10 years to fully manifest themselves.

The potential and residual risks have been addressed by means of a monitor and mitigate strategy embedded in the revised Water Management Plan (WMP) for the site (Appendix 7.6). This sets out how the quarry abstraction and discharges will be managed and includes recommendations for associated monitoring, triggers levels and responses to triggers being breached.

The WMP has previously been subject to extensive consultation with the regulators (Table 7-3 in Section 7.2.6). The version in Appendix 7.6 has now been updated for this Environmental Statement in response to comments made by the regulators on previous versions and in light of the results of the current assessment.

There are a number of different potential disposal options for the discharge of water pumped from Cornelly quarry sump. Retaining all of these options is an effective way to minimise the risk of any adverse effects of dewatering on water levels in any particular direction.

In future, the most appropriate distribution of dewatering discharge between these sites will be based upon operational practice, but refined, as required by the WMP / Annual Reports which will determine the most appropriate discharge options and requirements to mitigate any effects identified via the ongoing monitoring (ref Section 7 of the WMP).

The revised WMP includes a process for triggering Contingency Measures for eventualities which are outside the range of conditions that are considered to be realistic in this study.

The predictions of average dewatering rates are made on the basis of the most recent revision of the conceptual model described in Appendix 7.1. The conceptual model was based on a comprehensive review of all the data available, including a detailed review of the palaeokarst features in the quarry and in deep boreholes in the limestone. This indicated that there are unlikely to be any significant active fissures at depth below the quarry.

If this conceptual model is inaccurate and a ‘highly permeable feature’ was encountered, then the rates of inflow would be greater than predicted above. Whilst this is considered to be unlikely, the revised WMP includes a proposed procedure whereby the observed pumping rate at the quarry could be compared to the anticipated pumping rates (given antecedent rainfall) and any potentially significant change detected. Detection of such a change in pumping rate would trigger appropriate contingency measures, as set out in the WMP Section 6.3.3.

A potential threat to groundwater quality relates to increased rates of landfill leachate migration as a result of modified patterns of groundwater flow. The risk from this is judged to be small. However, the Water Management Plan contains an outline groundwater quality monitoring programme to identify any such pollution should it occur. It is anticipated that in future any discharges from the quarries will need to comply with appropriate water quality standards

14.3.3 Planning Conditions

The key planning condition requires the implementation of the Water Managament Plan and the obligations which it sets out for continual monitoring, assessment and mitigation measures if required.

A number of additional and conventional planning conditions would be appropriate to enshrine the fuel handling protocol to minimise the risk of ground and surface water contamination.

14.4 Ecology

14.4.1 Ecology Study

A wide range of specialist ecological surveys have been carried out of the Cornelly Quarry ROMP area and wider survey areas, both recently in 2013/14 and historically in 2003 and 2008/09. These are as follows:

- Extended Phase I habitat
- Bat roost assessment and activity survey
- Protected mammal survey including badger and dormouse
- Great crested newt habitat assessment and survey
- Reptile habitat assessment and survey
- Breeding bird survey

The area referred to as the 'site' relates to the Cornelly Quarry ROMP area as shown in Figure 8.3. This is set within a wider area over which the surveys were carried out, which is referred to as the 'survey area' and shown also in Figure 8.3.

In addition to surveys, existing ecological data was obtained from South East Wales Biological Records Centre (SEWBReC). Reference was also made to existing studies and published documents for further context, including plants and animals listed in the Bridgend Local Biodiversity Action Plan (LBAP), as Species of Principal Importance in Wales (as listed in Section 42 of the Natural Environment and Rural Communities (NERC) Act, 2006) and consideration of the criteria provided in the Guidelines for the Selection of Wildlife Sites in South East Wales.

Nine Phase I habitat types were recorded within the site as follows:

- Broadleaved semi-natural woodland – pockets in Pant Mawr Quarry on site and Grove Quarry in the wider survey area;
- Mixed plantation woodland - along Heol y Splot on site in Pant Mawr Quarry;
- Dense continuous and scattered scrub – extensive on site and in wider survey area, dominated by non-native buddleja;
- Ephemeral (seasonal)/short perennial – developing mosses and plant species on areas of less disturbed bare ground on site in the west of Pant Mawr Quarry and in Grove Quarry in the wider survey area;
- Species-poor defunct hedgerows – located along the southern and western boundaries on artificial bunds and contained hawthorn, sycamore, hazel and gorse;
- Standing water and swamp – six waterbodies were recorded within the survey area; three on-site within the Cornelly Quarry ROMP area and three within the wider survey area. These included man-made standing water in quarry voids, silted lagoons, washing ponds and a seasonal pond;
- Quarry - excavated rock faces were present throughout the survey area, with less disturbed faces in Pant Mawr and Grove quarries, and an active quarry face within Cornelly Quarry;
- Bare rock and scree – common in site and survey area; and
- Buildings and bare ground – plant buildings and associated areas of disturbed bare ground.

In addition, two further habitat types were recorded off-site in the wider survey area:

- Semi-improved calcareous grassland – located north of Pant Mawr Quarry, species-rich pockets of limestone grassland affected by scrub encroachment; and
- Semi-improved neutral grassland – large sheep-grazed agricultural fields between Cornelly and Grove quarries.

A range of plant species were recorded within the habitats listed above, particularly in the ephemeral (seasonal) areas and calcareous grasslands that were considered to be of comparatively greater nature conservation interest in the context of the site and survey area.

The habitats present within the site and survey area were assessed for their potential to support roosting and foraging bats. Opportunities for roosts were limited, with potential for small cracks and crevices within the less disturbed quarry faces of Grove and Pant Mawr quarries, and mature broadleaved trees. The mosaic of habitats within the site and survey area were likely to provide suitable foraging habitat for bats, with common and soprano pipistrelle recorded along the quarry margins as well as Daubenton's over Pant Mawr Quarry waterbody.

Otter and water vole are not considered to be present, based upon the lack of suitable habitats and connecting watercourses. Dormouse are similarly not considered to be present as no signs of evidence were recorded during surveys and the woodland pockets are relatively isolated with somewhat limited food sources.There were no badger setts within the site or survey area, but peripheral areas were found to be used for foraging.

There was no evidence of the presence of great crested newts in the waterbodies on site, which were found to be generally unsuitable for this species. However, palmate newt and common toad were present.

Two species of reptile have been confirmed present within the site and survey area – slow worm and common lizard.

A range of invertebrates have been recorded on site and in the wider survey area including the butterflies dingy skipper, grayling (both Bridgend LBAP and SPI), wall brown (SPI) and small blue (SPI) as well as common species including meadow brown, red admiral and peacock. Bee and hoverfly species were also frequently observed. The extensive scrub, rough ground and bund habitats were considered to provide ideal habitat for a range of terrestrial invertebrates, with the buddleja scrub providing nectar sources for butterflies and bees.

The freshwater fish common rudd appears to have been introduced to some of the waterbodies on site and in the survey area. No existing records of fish species of conservation interest at a national (such as eel or Atlantic salmon) or regional (South Wales) level were provided,

The habitats within the non-operational areas of Cornelly Quarry supported a wide range of birds during the breeding season, some of which were widespread and others concentrated in specific habitat types such as Pant Mawr Quarry. The species diversity present was considered to be of interest, and is likely associated with the range of habitats present. This included Welsh SPI and one protected species (protected under Schedule 1 of the Wildlife and Countryside Act, 1981 as amended). Further details are provided in the Confidential Annex.

14.4.2 Direct Ecological Effects

No statutory nature conservation sites are located within the Cornelly Quarry ROMP boundary or wider survey area. Eight are located within a 2km radius – two internationally designated sites Kenfig Dunes SAC and Cefn Cribwr Grasslands SAC – and six nationally designated sites – Cefn Cribwr Grasslands Site of Special SSSI (x4), Kenfig SSSI (and NNR) and Merthyr Mawr SSSI (and NNR). No impacts of significance are predicted on any statutory designated sites directly through habitat loss, fragmentation or disturbance.

One non-statutory nature conservation site is located within the Cornelly Quarry ROMP boundary – Cornelly Quarry SINC - with a further 19 within a 2km radius. Potential effects on the SINC were identified as resulting from temporary and permanent habitat loss and disturbance due to the quarry expansion and creation of two tips – Pant Mawr Eastern Tip and Pant Mawr Western Tip. These would be accumulated progressively and allowed to re-vegetate naturally during the lifetime of the works and thereafter, and an overall impact of minor (i.e. not significant in EIA terms), reduced to minor to no significance with mitigation was predicted.

As a result of the continued quarry operation during the ROMP period, no impacts greater than minor were predicted on the habitats present as a result. However, mitigation and enhancement measures have been recommended to maximise the biodiversity value of the quarry site and wider survey area.

With reference to the fauna species recorded on site or in the wider survey area (common reptiles and amphibians, foraging bats, badger, invertebrates and breeding birds), the effects of the continued quarry expansion were concluded to be of no greater than minor significance on all species in the absence of mitigation. Mitigation, together with enhancement measures have been set out to reduce these impacts further and to maximise the biodiversity value of the site and wider area during the operational period. Following the cessation of operation, a Restoration Strategy will be implemented, as detailed in Chapter 4.0.

14.4.3 Indirect Ecological Effects: Kenfig SAC

The potential for indirect impacts arising from changes to groundwater regimes on the qualifying features of Kenfig SAC (listed below) have been considered as part of the assessment.

The degree of connection between the Kenfig SAC and the limestone aquifers in which the quarries are located has been the focus of major investigations by the Quarry Operators over the last 12 years. These phased investigation and associated extensive monitoring, which have been carried out in close consultation with the relevant regulators, have shed important insights into the behaviour of these systems. This conceptual understanding has allowed the development of a calibrated groundwater model which has been used as a tool for determining the likely degree of effect of the proposed developments on the hydrology of the SAC.

The hydro-geological conditions at the Kenfig Dunes part of the SAC differ from those at the Merthyr Mawr part. As a result, each is discussed separately in relation to effects during the quarry operation (during the 15-year ROMP period and beyond until cessation of operations circa 2055) and thereafter during recovery.

Kenfig Dunes

The groundwater system that supports the humid dune slacks is almost entirely driven by direct rainfall over the site with a very small amount of runoff/overflow from minor aquifers to the east. There is also some downwards leakage from the sand to the underlying glaciofluvial sand and gravel. Section 7.4.5 ES describes the hydro-geological relationship between the Kenfig dune system and the underlying glaciofluvial sands and gravels. It demonstrates that water levels in the underlying glaciofluvial deposits show a distinctly different behaviour to those in the dunes, indicating that the dunes are not well connected to the underlying groundwater system due to the presence of an intervening layer of estuarine clay which separates the dune sand system from the glaciofluvial deposits.

In turn, the glaciofluvial deposits are not well connected to the limestone aquifers worked by the quarries.

However, the clay layer that largely separates the dune system from the underlying groundwater system is not completely impermeable, and some linkage therefore exists between the two. It therefore follows that any change in the groundwater system in the underlying geology could have an effect on the almost “perched” aquifer that supports the vegetation communities within the dune system. However, it has been established that the groundwater regime of the underlying solid geology plays only a very minor role in the functioning of the dune slack vegetation communities within the dune system.

The document Ecohydrological guidelines for wet dune habitats: Wet dunes Phase 2 (full reference in Section 8.2.3 above) sets out, in Table 3.1, the water table conditions for defining humid dune slack habitats, derived from a wide ranging literature review and data gathered from a range of UK dune systems, including Kenfig and Merthyr Mawr. This can be interpreted as giving the range of water table conditions required to sustain the various types of dune slack habitats. These confirm a range of water table depths below ground level of between 50cm and 200cm.

Appendix 7.4 (section 3.5.1) of the ES describes the predicted changes in water levels within the Kenfig dunes over both the 15 year ROMP period and the position where the quarry will be at its full extent (42 years):

“*Due to the disposal of water westward into Grove Quarry, water levels at Kenfig show a small rise under both 15 year and 42 year conditions (in contrast to the fall seen under the combined scenario runs). A maximum change of 6 mm rise over the full period is simulated at Kenfig Pool.*

Elsewhere in the dunes the maximum change is also 6 mm over the full run period"

An increase in groundwater levels of this predicted magnitude would be insufficient to shift any of the dune slack habitats within the Kenfig dunes system from one of the sub-categories described in the Ecohydrological guidelines to another, or to adversely affect the benthic vegetation of *Chara* species that exists within Kenfig Pool. On this basis, is concluded that there would be **no effect** on the dune slack habitats at Kenfig Dunes, or the hard oligo-mesotrophic waters in Kenfig Pool during the quarry operation, resulting in an impact of **no significance**.

On decommissioning of the quarry, dewatering will cease. This will result in temporary effects on the surrounding groundwater as natural levels are re-instated. Once stabilised, the additional storage represented by the re-filled quarry voids will have the positive effect of giving the local groundwater system additional tolerance to droughts (Section 7.8 of the ES).

The effects of this temporary recovery period have been carefully modelled and the results are set out in Chapter 7 of the ES. A very conservative scenario has been adopted in which dewatering of all three quarries at their maximum extent ceases instantaneously and simultaneously and no residual pumping is retained.

Without mitigation, it is predicted that there would be a short term lowering of groundwater levels in the dunes to the west of Kenfig Pool of up to 12 cm relative to baseline, although only during drought conditions. Elsewhere, in the dunes to the north and north west of Kenfig Pool, the maximum change over the modelled period is 3.5 cm (again in the absence of mitigation). As is the case with the operational stage, these changes are unlikely to result in the summer maximum water table conditions that support the various dune slack habitats falling outside the ranges set out in the Ecohydrological guidelines. In the light of this, and their temporary nature (the largest changes are only simulated to occur for a few years), changes to the vegetation communities within the slack habitats and within Kenfig Pool are not predicted to arise as a result of the quarrying recovery period, and thus there is **no effect** on the habitats resulting in an impact of **no significance**.

Notwithstanding this conclusion, it would be possible to impose a condition to the ROMP Schedule of Conditions that required residual pumping to take place after decommissioning. This option is described in section 7.8.2 of the ES, and would reduce the simulated short-term effects on the water tables at Kenfig Dunes to a maximum of 8cm, while increasing the recovery period.

Merthyr Mawr

Conditions at Merthyr Mawr differ from those at Kenfig, as parts of the the humid dune habitats are entirely dependent upon flows from Burrows Well. Section 7.6.2 of Chapter 7 of this ES highlights this, and notes that, when Burrows Well stops flowing each year, water levels fall by at least 3m. Therefore, for the area of the SAC that is affected by overflow from Burrows Well, hydrological effects are assessed by consideration of the simulated change in flows at the spring.

Elsewhere, to the east and west, the dunes (Blown Sands) are primarily fed by rain, with a lesser contribution from diffuse seepage. In these areas, hydrological effects are assessed by direct simulation of changes in groundwater levels.

In the Blown Sand Merthyr Mawr SAC there is a simulated decline in five year mean water levels of not more than 7 mm and a maximum decline during the full run period of 8 mm.

Modelled changes in flow rates at Burrows Well show that flows would reduce by up to 3.5%, but on average would change by just over 1% over the 42 year period.

Compared with an inter-annual variation in the order of metres (Figure 7.3 of the ES), this amount of variation is negligible and would have **no effect** on the dune slack habitats at Merthyr Mawr resulting in an impact of **no significance**.

During the restoration phase and groundwater recovery the quarry, in the absence of mitigation, groundwater levels within the Blown Dunes at Merthyr Mawr are predicted to decline initially by up to 10 cm, but to increase above baseline by just over 5cm by the end of the recovery period. This is as a result of the "natural" baseline condition of the water table at Merthyr Mawr being slightly higher than at present.

Similarly, in the absence of mitigation, there is predicted to be an initial decline in flow rates from Burows Well of 5%, while the during the final five years of the simulated recovery period, flows are predicted to be 6% above current baseline.

Change of this magnitude would be insufficient to lead to summer maximum water table conditions altering to a point where the dune slack habitats they support would be affected. Consequently, **no effect is predicted** on the habitats resulting in an impact of **no significance**.

14.4.4 Indirect Ecological Effects: Cefn Cribwr Grasslands SAC

Due to the distance of this internationally designated site from the quarrying operations (1.4km north at its closest point), only indirect hydrological effects due to changes in the groundwater from dewatering and subsequent recovery could be possible, with resultant effects on the wetland habitats – feature 1 *Molinia meadows* – and the species supported – feature 2 marsh fritillary butterfly.

In this context, detailed hydro-geological studies, reported in Chapter 7.0 of the present ES and in Section 2.4.2 of Appendix 7.1 of this ES, have concluded that no parts of the Cefn Cribwr Grasslands SAC are dependent upon groundwater systems that could be affected by the dewatering of Cornelly Quarry. In light of this, it is assessed that there would be **no effect** on this site of **international nature conservation value,** such that the quarry proposals are likely to have **no significant effect** upon this SAC.

14.4.5 Cumulative and Residual Effects

In the absence of mitigation, there are no significant ecological impacts (i.e. greater than minor significance) as a result of the ongoing extraction of Cornelly Quarry during the ROMP period. The nature and significance of residual impacts i.e. impacts following mitigation are likewise of no significance, with many minor impacts reduced to no impact with mitigation.

The combined operation and recovery of the three quarries has been assumed as a worst case for the potential indirect effects on the SAC, and thus the combined operations are considered to have no effect on the dune slack habitats.

No significant cumulative effects are predicted from the combined operation of Cornelly, Grove and Gaens quarries in terms of habitats or fauna.

14.4.6 Planning Conditions

A series of mitigation and enhancement measures have been recommended relating to:

(i) Generic mitigation measures aimed at applying best practice to protect habitats and species; and

(ii) A specific Ecological Mitigation Strategy which would include all work to prevent or reduce potentially adverse effects on ecological receptors, to include measures relating to breeding birds, bats, reptiles, amphibians, invertebrates and other species (ref ES Section 8.7).

These issues are reflected in the updated schedule of proposed planning conditions.

14.5 Noise

14.5.1 Noise Study

Noise surveys were conducted in November 2013 to provide up to date measurements of the noise environment around Cornelly Quarry. The noise surveys indicate that distant and local road traffic is the dominant noise source throughout the area with individual locations also being affected by other sources.

The study updates noise surveys and assessments of site noise undertaken by WBM in 2003, 2004 and 2008 as part of the Cornelly and Grove ROMP Review EIA's and the Cornelly / Grove IDO Periodic Review EIA.

A review of previously suggested noise criteria based on current Welsh Assembly Government advice, namely MTAN1: 2004, has been conducted, with regard daytime and night-time periods, with consideration also given to the morning (06:00-07:00) and evening (19:00-22:00) periods.

The extraction and processing plant, and associated operations, have been described and set out in terms of the equipment proposed to be used and typical Sound Power Levels of the plant.

14.5.2 Noise Mitigation Measures

Comparison of the calculated site noise levels for daytime, early morning, evening and night-time periods with the corresponding noise criteria indicates that operations on site should comply with the noise criteria suggested without the need for further mitigation.

The reasonable worst case overall $L_{Aeq,T}$ noise levels for extraction site noise and the fixed plant area, calculated at each property are set out, along with the noise criterion levels recommended in MTAN 1 and the National Planning Practice Guidance to the NPPF (applicable in England but used for comparison purposes).

In order to ensure complainece with the criteria, the use of the rock drill and pecker is not recommended outside the normal daytime working hours (07:00 to 19:00) unless operating one bench down, and therefore the calculated noise levels for the morning and evening periods (06:00 to 07:00 and 19:00 to 22:00) are lower than during the day.

The comparison of calculated worst case noise levels arising from the operation with the noise criteria indicate that it is possible to work the extraction area fully whilst complying with the suggested noise limits and without the need for further mitigation

14.5.3 Planning Conditions

Planning conditions wold be appropriate to enshrine the suggested noise limits for temporary and normal operations, with a requirement to monitor adherence to the noise limits which have been set.

14.6 Blast Vibration

14.6.1 Blast Vibration Study

Ground vibration is calculated in terms of 'peak particle velocity' (PPV), and is measured in millimetres per second (mms). Detailed research has determined that vibration levels well in excess of 50 mms are necessary to produce structural damage to residential type properties. For human perception, government advice is that levels should be set in the range of 6-12 mms as discussed further below.

Vibration is also generated within the atmosphere where the term 'air over pressure' is used to encompass both its audible and sub audible frequency components.

It is important to realise that for any given blast it is very much in the operators interest to always reduce vibration, both ground and air borne to the minimum possible in that this substantially increases the efficiency and hence the economy of blasting operations.

Minerals Technical Advice Note 1: Aggregates (MTAN1) published by the Welsh Assembly Government in March 2004, sets out detailed advice on suitable planning conditions to control the environmental impact of blasting operations at quarries. This includes controls on the days and times of blasts and restrictions on ground vibration where MTAN1 suggests that ground vibration as a result of blasting operations should not exceed a peak particle velocity of 6 mms^{-1} PPV in 95% of all blasts measured over any 6 month period, and no individual blast should exceed a peak particle velocity of 10 mms^{-1} PPV.

All blasts are monitored at Cornelly, and detailed records are maintained of the location and design of the blast, the maximum instantaneous charge (MIC) – i.e. maximum weight of explosive per delay interval in kilograms, and the recorded ground vibration and air over pressure.

The most recent blast vibration records for 2012 and 2013 confirm that blasting took place in a range of locations within the quarry, and at a range of elevations from the top bench in the Pant Mawr area to the quarry floor in the main Cornelly void. All blasts are monitored at Ballas Farm, deemed by Lafarge Tarmac to be representative of the nearest blast vibration sensitive residential property. For the majority of the blast events, the vibration levels at Ballas Farm were so low that the vibrograph did not trigger. The recorded ground vibration from blasts in 2012 ranged from 0.6 to 4.7mms PPV. There were similar results in 2013 with the majority of blasts not triggering the vibrograph, but with a recorded range of ground vibration of between 1.49 and 4.57 mms PPV. All blasts were below the 6mms PPV threshold, which confirms that with attention to blast design it is feasible to ensure that ground vibration from blasting can continue to accord with limits suggested in MTAN1. This provides a positive context for the drafting of updated planning conditions.

14.6.2 Blast Vibration Mitigation Measures

In terms of mitigation and planning conditions, the key requirement is to impose updated conditions which reflect the up to date advice set out in MTAN 1.

In this context, it is an established principle that specific aspects of blast design such as the number of boreholes or the amount of explosives used should not be included in the blasting conditions. Blasting design criteria must always be the direct responsibility of the site operator as defined by the Quarries Regulations 1999. Thus, conditions should state the desired objectives rather than the methods by which the objectives are to be achieved. In this case therefore the key issue is to set a limit on ground vibration, which will then require the Operators to design blasts to ensure adherence to the limits.

It follows that no specific prescriptive additional mitigation measures are considered to be necessary, since planning conditions are capable of regulating blasting in terms of timing, ground vibration limits etc. It is also important to recognise that blasting at Cornelly Quarry is undertaken by qualified and experienced personnel where, in addition to planning controls, the operations are regulated by the Mines and Quarries Inspectorate.

Similar advice is set out in the DETR publication on the Environmental Effects of Production Blasting from Surface Mineral Workings, to the effect that planning conditions should focus on days and times for blasting operations; allowable ground vibration limits; a scheme for air over pressure control in preference to limit values, and a scheme of monitoring.

The opportunity is thus available via the ROMP Review application to impose updated conditions regulating blast vibration, which accord with modern standards and the advice set out in MTAN1.

14.6.3 Planning Conditions.

It is recommended that a ground vibration limit is chosen that not only is perfectly safe for the integrity of structures, but also takes into account the physiological effects on adjacent neighbours. As such a vibration limit of 6 mms^{-1} peak particle velocity at 95% confidence level is recommended. The limit of 6 mms^{-1} at 95% should ensure that no individual blast exceeds an absolute maximum of 10 mms^{-1} at inhabited property, is in line with the current practice at Cornelly Quarry, is successful current practice at numerous similar quarries within the United Kingdom, and is consistent with the advice set out in MTAN (Wales) 1: 2004 and the relevant British Standard 6472-2: 2008.

It is impracticable to set a maximum air overpressure limit, with or without an appropriate percentile of exceedances being allowed, simply because of the significant and unpredictable effect of variable weather conditions.

This point is clearly recognised by the Government guidelines issued by the Department of the Environment in MPG 9, MPG 14 and MTAN (Wales)

15.0 PLANNING POLICY

15.1 Introduction

When undertaking EIAs and preparing an ES, it is conventional practice to carry out a review of relevant planning policy. This is not an express requirement of the Town and County Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 Schedule 4 (as amended), but the exercise acts as a useful checklist in terms of the environmental topics considered in the EIA, and allows the conclusions reached by the EIA / ES to be assessed against planning policy objectives and requirements. This in turn assists in identifying and isolating the key environmental issues associated with a particular development, and in arriving at a judgement of the overall merits of the development balanced against its environmental effects. In the case of a ROMP application, the exercise can also assist in identifying issues which should appropriately be included as updated planning conditions.

Planning applications which are accompanied by an EIA must be considered in the context of ‘Regulation 3’ of the EIA Regulations 1999, which prohibits the grant of planning permission without considering the environmental information set out in an ES (and any supporting details). More generally, the application must be determined in accordance with the content of the development plan, unless material considerations indicate otherwise (reference section 38(6) of the Planning and Compulsory Purchase Act 2004).

In practice, the two requirements are complimentary in that policies in the development plan will conventionally seek to safeguard environmental interests, and will aim to resist developments which are likely to give rise to significant adverse environmental and amenity effects.

Section 38(6) of the Act introduces a presumption in favour of granting planning permissions for proposals which are in accordance with policies in the development plan. This has been further interpreted in the Courts, which have established the principle that it is not necessary for a proposal to accord with each and every policy in the development plan, since there will be instances where policies pull in different directions. The key requirement is therefore for a proposal to accord with the ‘overall thrust’ of the development plan, taken as a whole, and not in accordance with each policy of the plan (reference R (Cummins) v. Camden LBC 2001).

Distinctions can however be drawn between the circumstances of a planning application, where the principle of a development needs to be assessed against policies in the development plan, and those associated with a ROMP application, where the principle of the mineral development is already established by virtue of the extant planning permissions for quarrying which exist. The relevance of the development plan in these circumstances is more geared towards providing guidance and advice regarding environmental controls and operational practices which should be enshrined within up to date planning conditions: it is not the function of a ROMP application to re visit the appropriateness of the development consent, unless the EIA identifies issues of such magnitude that the MPA consider that the planning consent should be modified (as discussed earlier in section 1.5 of this ES).

In the context of Section 38 (6) of the Planning and Compulsory Purchase Act 2004, the development plan in relation to the site comprises the Bridgend Local Development Plan which was adopted in September 2013. The LDP formally replaces the Bridgend Unitary Development Plan which was adopted in May 2005. Whilst the UDP has now been replaced it is briefly considered in this Chapter since it contained a policy relating the Environment Act Reviews and issues to be considered in planning conditions, where there is no such policy in the replacement LDP. The UDP policy is thus reviewed as useful background context, albeit recognising that the policy is no longer part of the development plan. The content of the adopted and previous development plan is discussed in section 15.3 below.

15.2 National Planning Policy: MPPW and MTAN1

15.2.1 Minerals Planning Policy Wales: December 2000

The Welsh Government's primary land use policy guidance in relation to mineral extraction and related development is set out within Minerals Planning Policy Wales (MPPW), (December, 2000).

The key objectives of MPPW are defined as seeking to provide mineral resources to meet society's needs; to protect areas of important natural and built heritage resources; to limit the environmental impact of extraction; and to achieve a high standard of restoration and beneficial after use. To this end, paragraph 67 states '*It is essential to the economic health of the country that the construction industry is provided with an adequate supply of the minerals it needs.*' In addition to the above, paragraph 34 sets out the following issues which must be considered when assessing the impact of mineral development on the environment and amenity of residents:

- Access and traffic generation,
- Noise,
- Control of dust, smoke and fumes,
- Blasting controls, land drainage and impact on groundwater resources
- Visual intrusion,
- Impact on sites of nature conservation, historic and cultural importance,
- Restoration, aftercare and after-use.

Policies set out within MPPW recognises that mineral extraction can only take place where the mineral is found to occur, and that operations are 'transitional', and cannot be regarded as a permanent land use, despite operations potentially occurring over a long period of time (para 5). MPPW therefore sets out a series of sustainable aims for minerals development, which include the provision of an adequate supply of minerals, but in a way which provides adequate protection to landscape features and the environment (para 7).

15.2.2 Minerals Technical Advice Note 1: Aggregates March 2004 (MTAN1)

MTAN1 sets out detailed advice on the mechanisms for delivering the policies of MPPW. Of particular relevance is 'Section C', which defines the objective 'to reduce the impact of aggregates production', and which outlines a number of measures of control to fulfil that objective, including control of dust, blast vibration, noise, visual impact, environmental audits, and community liaison.

MTAN1 includes specific advice on the means by which the impact of aggregate extraction might be reduced, the issues which should be considered in quarry restoration designs, and the nature of planning conditions which might control quarrying and restoration operations. The following are of particular relevance to Cornelly Quarry:

(a) Vibration limits and controls

MTAN1 reviews the effects of vibration from blasting operations, and confirms that planning conditions should provide for acceptable days for blasting operations; acceptable times of blasting operations; maximum levels of ground vitiation at vibration sensitive properties; and approval of a scheme of vibration monitoring.

These issues have been considered as part of the blast vibration study set out in chapter 10.0 of the ES, and are reflected in the updated planning conditions prepared by the Applicant (ref Chapter 15.0 and Annex 1 to the ES).

(b) Noise

MTAN1 confirms that the effects of noise should be fully considered in formulating proposals for mineral extraction (para 85), and advises that the aggregate industry should aim to keep noise emissions at a level that reflect the highest possible environmental standards, taking all reasonable steps to achieve quieter working (para 87). In that context, MTAN1 advises that:

"Noise limits should relate to the background noise levels, subject to a maximum daytime noise limit of 55dB(A) where the background noise levels exceed 45dB(A). 55dB(A) is the lower limit of the daytime noise levels where series annoyance is caused. Where background noise is less than 45dB(A), noise limits should be defined as background noise levels plus 10dB(A). Night time noise working limits should not exceed 42dB(A) at noise sensitive properties …… During temporary and short term operations higher levels may be reasonable but should not exceed 67dB(A) for periods of up to eight weeks in a year at specified noise sensitive properties" (ref para 88).

This advice has been considered as a context for the noise assessment set out in chapter 9.0, and is reflected in the proposed updated planning conditions relating to noise (ref chapter 15.0 and Annex 1).

(c) Dust

MTAN1 notes that experience has shown that dust emissions can result from haulage, particularly on internal un-surfaces routes, on nearby roads which are not adequately wetted and if vehicles are un-sheeted; crushing and grading operations; blasting, including drilling operations prior to blasting; surface stripping, including soils and overburden storage; and restoration operations." (para 72)

It further notes that planning conditions can control certain activities to protect against dust emissions, although many of these are controlled under the Environmental Protection Act 1990, and care should therefore be taken to avoid duplication of controls (para 76). However, it highlights a number of issues which might be controlled by planning conditions, including *the imposition of speed restrictions; sheeting of vehicles; the design of working programmes to locate dust emission sources away from sensitive developments; and the timing of soil handling and overburden stripping to suit weather conditions (para 77).*

This advice has similarly formed the context for the dust / air quality assessment and proposed updated planning conditions relating to dust controls prepared by the Applicant (ref Chapters 10.0, 15.0 and Annex 1). However, as discussed in Chapter 11.0, reliance is placed upon existing controls set out in the crushing and screening Permit which are not proposed to be duplicated.

(d) Landscape and Visual Impact

MTAN1 highlights the fact that hard rock quarries physically alter the ground surface through the development of faces and benches, and these landscape changes are often irreversible. It therefore advises that proposals for new aggregates extraction or extensions to existing sites should be assessed carefully to determine the potential impact on the character of the landscape. The assessment should also facilitate a comprehensive understanding of the visual impact of a development from various locations which will assist in devising an appropriate layout and phasing, and the most appropriate restoration strategy (ref para 90).

This ES has been prepared in support of a review of planning conditions, but the principle of a careful of assessment of the landscape and visual effects of the ongoing development has been a central feature of the EIA, as reflected in the updated design of the quarry development scheme (ES chapter 3.0) and the landscape mitigation measures (ES chapter 6.0); all of which have been enshrined within the proposed updated planning conditions (ref chapters 15.0 and Annex 1).

(e) Site Management

MTAN1 advocates the undertaking of environmental audits of quarries to assess the performance of the operation against set environmental objectives (para 95).

Lafarge Tarmac has implemented an accredited Environmental Management System (EMS) across all of the company's UK sites ISO140001, compliance which is externally audited. The control of potentially negative amenity and environmental impacts forms an integral part of the EMS and a number of controls and mitigation measures are currently operated at the site.

The site management controls are re-enforced by the planning conditions (which will be updated as part of this Review) and also by the Pollution

Prevention and Control Permit (PPCP) which will include conditions which limit emissions and control techniques to protect air quality. The site will also subject to regular inspection by Bridgend County Borough Council and the NRW to ensure compliance with permit conditions.

(f) Restoration

MTAN1 places considerable emphasis on the need to achieve high standards of restoration and aftercare, and to provide for a beneficial after use. This is to be secured by careful attention to restoration design, and specific advice is provided on the key topics to be considered when drawing up reclamation conditions (ref para 111, Box 2).

MTAN1 also emphasises the need for aftercare conditions to be imposed to ensure the successful implementation of the restoration scheme, where such conditions can either specify the steps to be taken via the planning condition, or require an aftercare scheme to be submitted to the minerals planning authority for approval.

These issues have been addressed in this submission via chaoter 4.0 of the ES albeit noting that the implementation of the final restoration strategy will extend into the long term. However, interim restoration works are identified where possible.

MTAN1 thus provides a useful checklist of issues to be considered as part of the objective to reduce the impact of aggregate extraction. Each environmental issue has been addressed in this ES, and the recommended criterion levels set out in MTAN1, together with the wider advice relating to planning conditions, is fully reflected in the schedule of conditions now proposed by the Applicant.

15.3 Bridgend Development Plan

15.3.1 Bridgend Unitary Development Plan (UDP) 2005

A noted in section 15.1, the UPD has been replaced by the Bridgend LDP (September 2013) but the former UDP contains policies which provide a helpful context to the issues which should be included as planning conditions. Policies M2 of the UDP provided general criteria and advise regarding measures which should be taken to reduce damage or disturbance to the environment to acceptable levels. It listed a series of topics relating to ground and surface water, landscape, nature conservation, agricultural interests, sites of archaeological importance and stability of adjoining land which should be addressed as part of mineral development schemes. Specific attention is afforded to the need for measures to reduce damage or disturbance to neighbouring land uses to acceptable levels in terms of the effects of noise, dust and vibration and the impact of traffic generated by the site. Each of these issues has been considered in detail in the ES and mitigation measures capable of being translated into planning conditions have been proposed where appropriate.

Similar themes are set out in policy M10 which directly refers to 'reviewing' mineral permissions, and the planning conditions which it may be appropriate to impose. The suggested conditions and response are set out in table 15.1 below.

Policy M10 Topic	Response
1. Vary the duration of the permission.	Included within the proposed updated schedule of conditions where the duration reflects the reserves and anticipated timescale of extraction.
2. Regulate hours of working	Detailed hours of working controls are proposed for the respective operations undertaken.
3. Measures to regulate traffic	No specific additional traffic measures are deemed to be required.
4. Mitigate noise levels to acceptable limits	The scheme has been assessed against the noise criteria set out in

	MTAN1, and conditions are proposed to ensure that the development continues in accordance with the MTAN1 criteria
5. Monitor blasting operations, control to specified times, and limit the effects of vibration.	Planning conditions proposed consistent with the advice in MTAN1. A
6. Minimise the impact of dust.	Dust control protocol proposed as a condition, with further reliance placed on controls via the PPC Permit
7. Monitor impact on groundwater and make provision for the protection of groundwater and surface water features.	Extensive monitoring undertaken over a period of 12 tears. Ongoing monitoring and protection of water features proposed via Water Management Plan condition.
8. Undertake archaeological assessment and record and / or protect identified features.	Assessment undertaken. No archaeological features present, and no conditions required..
9. Include landscape works or other screening operations to reduce visual effects.	Measures proposed and enshrined in updated planning conditions.
10. Provide for restoration and aftercare.	Restoration strategy prepared and referred to in schedule of planning conditions.
11. Evaluate nature conservation value and include measures for the protection of habitats or species, and mitigation measures as appropriate.	Detailed study undertaken and recommendations enshrined in updated planning conditions.

Each of the items listed in Policy M10 have thus, where relevant, been fully addressed via the EIA and updated schedule of conditions,

15.3.2 Bridgend Local Development Plan (LDP) 2013

The LDP was formally adopted in September 2013. It does not refer specifically to Environment Act 1995 Reviews, but it contains a general environmental protection policy which requires developments to satisfy a list of criteria relating to the need to avoid pollution to ground and surface water bodies; reduce damage to the environment associated with impact on the landscape, nature conservation, agricultural interest, sites of archaeological importance, and stability of adjoining land (ref Policy ENV11). The policy continues by making reference to the need to take measures to reduce disturbance associated with noise, dust, vibration and traffic, and the need for proposals to include measures for restoration and aftercare.

Each of these issues has been considered in response to similar planning policy themes referred to above, and a similar conclusion arises that each issues has been considered and is reflected in the schedule of proposed updated planning conditions.

15.4 Planning Policy Conclusions

The summary review of national and local planning policies has assisted in highlighting the advice and policy issues which should be reflected in planning conditions controlling ongoing activities at Cornelly Quarry. The advice and policies represent up to date criteria and best environmental management practice relating to, inter alia, noise, blast vibration, and dust control, and more general advice relating to landscape.

The policies have provided a further checklist of environmental issues relevant to the assessment, and the topics and issues which are likely to require control via planning conditions.

The Applicants have thus sought to fully reflect this advice in the updated schedule of conditions they have prepared, which is produced as Annex 1 to the ES.

16.0 CONCLUSIONS

This Environmental Statement (ES) sets out the results of an Environmental Impact Assessment (EIA) of the effects of quarrying and related activities at Cornelly Quarry.

The Environment Act 1995 introduced a process of Periodic Reviews of mineral permissions at 15 year intervals. This is designed to ensure that planning conditions imposed as part of an Initial Review do not become outdated with the passage of time, and to more generally ensure that conditions reflect up to date standards and requirements. This process of a 'Review of Old Mining Permissions' is commonly referred to by the acronym 'ROMP Review'.

A ROMP application for Cornelly Quarry was duly submitted to Bridgend County Borough Council (BCBC) in June 1997, accompanied by a statement in support of the application, and a schedules of proposed updated planning conditions.

By letter dated 29th July 1998, the Cornelly ROMP application was formally 'called-in' by the Welsh Office (now WG) for their determination.

A voluntary ES in support of the Cornelly Quarry ROMP application was submitted to the Welsh Assembly (now WG) on 13th August 2004 accompanied by a detailed hydrogeological assessment and a Water Management Plan (WMP). The ES was accompanied by a schedule of further updated planning conditions which had been informed by the results of the EIA/ES.

Discussions on the content of the Cornelly ES continued, and a substantial measure of agreement emerged regarding the technical issues. However, prior to the final resolution of the outstanding issues, the WG introduced new regulations relating to ROMP applications which, for varying reasons, had become "stalled".

The ES has been prepared pursuant to the requirements of those regulations, the Stalled ROMP EIA Regulations, which came into force on 8th January 2010.

The Regulations introduce an express requirement for EIAs to be undertaken in relation to 'stalled reviews', where such EIAs and ES's would update and replace any voluntary ES's which had been submitted. The Regulations also introduce a formal timetable for the completion and submission of the formal ES's which is designed to bring closure to the 'stalled' process.

The Stalled ROMP EIA Regulations 2009 require the WG, in cases which have been called in by the Welsh Ministers, to issue a "Scoping Direction" setting out the issues which should be addressed as part of an EIA, and confirming the timescale in which the EIA should be undertaking and a draft ES submitted.

A formal Scoping Direction was issued on 4th March 2013. The Scoping Direction sets out specific requirements under a series of environmental and amenity headings. The Regulations require the Welsh Ministers to "*check whether the content and extent of the information included in the draft Environment Statement appears to be consistent with the relevant Scoping Direction"* (reference Regulation 18 (5)). The Applicants have ensured that each issue is fully addressed as part of the EIA and this ES and, for ease of reference, a detailed table has been prepared which identifies the issues raised in the Scoping Direction, the way in which the issues have been addressed as part of the EIA, and the reference within the ES (reference table 1.2).

The Scoping Direction required a draft ES to be submitted to the Welsh Ministers by 31st March 2014. Following a review of the draft, the Welsh Government confirmed that the final ES and supporting dovcuments should be submitted to the Wesh Ministers by 26th June 2014. The ES has been prepared and submitted in accordance with that requirement.

The approach to undertaking the EIA and preparing the ES has recognised the inter-relationships between Cornelly and Grove Quarries in terms of historical planning permission boundaries, and the potential cumulative/in-combination environmental effects arising from the concurrent operation of the quarries. In particular, the scope of the assessment has recognised that it would be inappropriate and artificial to attempt to isolate individual IDO and ROMP permitted areas from the overall quarries, particularly in the context of the need for EIA's to consider the totality of a project.

The Cornelly Quarry ROMP ES thus considers the environmental effects of the full extent of the Cornelly Quarry development area, comprising the ROMP permitted areas in the eastern part of the quarry; the operations in the northern Pant Mawr area; and the associated quarrying, processing and ancillary operations in the Cornelly part of the IDO permitted area. It also considers the cumulative/in-combination effects of operating Cornelly Quarry in conjunction with Gaens Quarry (as at present), and in conjunction with a resumption of operations at the currently mothballed Grove Quarry.

The primary purpose of the ES is to assist in identifying environmental effects, and to use that information to (i) devise measures to minimise the environmental effects through an updated design of the quarry development scheme and / or via specific mitigation/ attenuation measures; and (ii) provide for the measures to be enshrined in up to date planning conditions which regulate ongoing quarrying in a way which is reflective of the EIA.

The purpose of the Review is to formulate a schedule of updated planning conditions which reflect modern standards and controls, and which provide (i) detailed controls over on-going operations for the 15 year Review period; and (ii) a context for subsequent Periodic Reviews by confirming the longer term intentions for the development of the Quarry, and the final restoration strategy.

The ROMP Review procedure place the initial onus on the Applicants to propose an updated schedule of planning conditions. A schedule of proposed planning conditions was duly submitted in 1997 with the original Cornelly Quarry ROMP application. The schedule was updated in 2004 at the time of submission of the voluntary ES, where the updated conditions were informed by the recommendations and conclusions of the 2004 ES. The schedule of conditions has been further updated, partly to reflect the passage of time, but also, consistent with the principles of the 2004 schedule, to reflect the recommendation of the updated 2014 ES regarding mitigation measures, and the way in which those mitigation measures can be translated into planning conditions.

The ES also includes a review of planning policy, noting that there have been substantial changes since the original application in 1997, and the analysis of planning policy set out in the voluntary 2004 ES. Particular reference has been paid to the way in which planning policy and advice can inform the drafting of up to date planning conditions.

The Welsh Ministers in relation to called in applications, are not obliged to accept the planning conditions proposed by the Applicant, and they are entitled to impose different conditions or additional conditions. However, where the Welsh Ministers determine conditions different from those submitted by the Applicant and the effect of the new conditions, other than restoration or aftercare, as compared with the effect of the exisitng conditions is to impose a restriction on working rights, then Applicants whose interests have been adversly effected by the restrictions will be entitled to claim compensation (reference Schedule 13, Paragraph 15 of the Environment Act 1995).

The updated conditions proposed by the Applicant accompany the ES, and the rationale behind the conditions is summarised in Chapter 14.0 of the ES. The updated conditions are considered to represent a positive and constructive approach to devising an environmental sensitive operation and to regulating the devleopment by modern, up to date planning controls. In those terms, as was the case with the 2004 ES, the exercise associated with the EIA has been of positive value in preparing specific conditions which reflect the conclusions and recommendations of the EIA.

TERM	DEFINITION
GLOSSARY	
ROMP	Review of Old Mining Permissions
ROMP area	Area which is the subject of the ROMP application
Applicants	The Applicants are Cambrian Stone Ltd, which is a joint venture compamy between Tata Steel (formerly Corus / British Steel plc) and Lafarge Tarmac Ltd, (formerly Tarmac Quarry Products Ltd)
Cornelly Group of Quarries	This comprises Cornelly Quarry, Grove Quarry and Gaens Quarry
IDO	Interim Development Order, which granted planning permissions for developments prior to the introduction of the1947 Town and Country Planning Act.
Regulators	Natural Resources Wales, formerly Environemnt Agency Wales (EAW) and Countryside Council for Wales (CCW)
Aftercare management	Management designed to ensure the success of restoration works.
Mineral Planning Authority	The Authority responsible for planning control of mineral working sites, currently Bridgend County Borough Council
MPPW	Minerals Planning Policy Wales December 2000
MTAN1	Minerals Technical Advice Note 1 : Aggregates March 2004
Bridgend LDP	Bridgend County Borough Council Local Develepment Plan, adopted September 2013
Operational Stage	Works during the quarrying and processing operations
Restoration Stage	Works followng the completion of quarrying
Decommissioning stage	Works associated with final restoration including removal of residual plant and groundwater recovery
Cornelly quarry development	This comprises the extraction of limestone from the quarry and related oparations of quarry waste tipping.
Plant Site	Cornelly Quarry processing pant site which includes the crushing and screening plant, storage bins, asphalt plant and ready mixed concrete plant.
Asphalt plant	Plant used for the coating of limestone and other aggregate with bitumen for use as in road surfacing.
LANDSCAPE AND VISUAL IMPACT ASSESSMENT	
Analysis	The process of breaking the landscape down into its component parts to understand how it is made up.
Assessment	An umbrella term for description, analysis and evaluation.
Baseline	A term to describe environmental conditions prior to development.
Character	A distinct pattern or combination of elements that occurs consistently in particular landscape.
Character Area	A geographic area with a consistent character.
Criteria	Factors that determine levels of sensitivity and magnitude.
Designated Landscape	Areas of landscape identified as being of importance at international, national or local levels, either defined by statute or identified in development plans or other documents.

GLOSSARY

Direct effect	An effect that is directly attributable to the proposed development.
Enhancement	Landscape improvement through restoration, reconstruction or creation.
Feature	A prominent, eye-catching landscape element (eg wooded hilltop, church spire).
Indirect Impact	Impacts which occur as a secondary or tertiary effect of a development, as a result of changes in a chain of environmental parameters.
Landform	Combination of slope and elevation producing the shape and form of the land surface.
Landscape	An area, as perceived by people, the character of which is the result of the action and interaction of natural and/or human factors.
Landscape Character	A distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another, rather than better or worse.
Landscape Character Assessment	The process of identifying and describing variation in the character of the landscape, and using this information to assist in managing change in the landscape. It seeks to identify and explain the unique combination of elements and features that make landscapes distinctive.
Landscape Effects	Change in the fabric, character and quality of the landscape as a result of development.
Landscape Quality (Condition)	A measure of the physical state of the landscape. It may include the extent to which typical character is represented in individual areas, the intactness of the landscape and the condition of individual elements.
Landscape Receptors	Defined aspects of the landscape resource that have the potential to be affected by a proposal.
Landscape Value	The relative value that is attached to different landscapes by society. A landscape may be valued by different stakeholders for a whole variety of reasons.
Magnitude (of effect)	A term that combines judgements about the size and scale of the effect, the extent of the area over which it occurs, whether it is reversible or irreversible and whether it is short or long term in duration.
Quality	Term used to indicate the value of a landscape, based on its character, condition and aesthetic appeal.
Sensitive Receptor	Physical or natural landscape resource, special interest or viewer group that will experience impact.
Sensitivity	Vulnerability of sensitive receptor to impact.
Severe(ity)	Term used to define a general level of impact significance.
Significance	A function of sensitivity and magnitude.
Significant	Term used to define a specific level of impact significance.
SLA	Special Landsacpe Area defined in the Bridgend Local Development Plan
Slight	Term used to define a specific level of impact significance.
Source	Project characteristic giving rise to impact.
Study Zone	Map showing the location of sensitive receptors within defined limits of the development.
Study Area	In this case a study area extending 20km from the Cornelly Quarry site has been defined for the purposes of identifying landscape designations.
Susceptibility	The ability of a defined landscape or visual receptor to accommodate the specific proposed development without undue negative consequences.
Technique	Specific tool for assessment eg. visibility mapping.
Tranquillity	A state of calm and quietude associated with peace, considered to be a significant asset of landscape.

Visual Amenity	Term indicating popularity of a particular area or view.
Visual Receptors	Individuals and/or defined groups of people who have the potential to be affected by a proposal.
Visual Impact	Change in the appearance of the landscape as a result of development.
Visual Intrusion	Degree to which a development intrudes upon the human field of view.
Visualisation	Computer simulation, photomontage or other tool to illustrate the appearance of new development.
Zone of Visual Influence/ Visual Envelope	Extent of potential visibility to or from the development.
ECOLOGY	
Ancient Woodland	A woodland which has existed since at least 1600 AD, and possibly much longer. Two broad types of ancient woodland can be identified; as below.
Ancient Semi-Natural Woodland (ASNW)	Woodland that is composed of native tree and shrub species which have not obviously been planted.
Plantation on Ancient Woodland Sites (PAWS)	Woodland that which has been continuously wooded since 1600 AD but where the former tree cover has been replaced with planted trees (often conifers).
Annex I habitat type(s)	A natural habitat listed in Annex I of the EC Habitats Directive.
Biodiversity	"The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (UN Convention on Biological Diversity 1992).
Birds of Conservation Concern	Assessment of the conservation status of UK birds. A total of 247 species have been assessed, and each placed onto one of three lists – red, amber or green. Red list species are those that are Globally Threatened and whose populations or range have declined rapidly in recent years. Amber list species are those with an unfavourable conservation status in Europe; those whose population or range has declined moderately in recent years; are rare breeders and those with internationally important or localised populations.
Calcareous	Habitats derived from limestone or chalk substrates.
CCW	Countryside Council for Wales – the statutory advisor to the Welsh Assembly Government on wildlife, landscape and access.
Ecosystem	An ecosystem is a natural unit consisting of all plants, animals and micro-organisms (biotic factors) in an area functioning together with all of the nonliving physical (abiotic) factors of the environment.
EA	Environment Agency
Flora and Fauna	The animal or plant life of a particular area or time.
Flushes and Seepages	Wetland features often of a localised occurrence where the ground is marshy due to inputs from groundwater.
Habitats Directive	In 1992 the European Community adopted Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (EC Habitats Directive). The Directive requires Member States to introduce a range of measures including the protection of habitats and species listed in the Annexes.
Invasive species	Plants, animals and microbes not native to a region which, when introduced either accidentally or intentionally, are harmful to the environment by outcompeting native species for available resources, reproducing prolifically, or

	dominating regions and ecosystems.
Local Nature Reserves (LNRs)	Declared by local authorities, in consultation with Natural England, under Section 21 of the National Parks and Access to the Countryside Act 1949. They are sites with wildlife or geological features that are of special interest locally, which give people opportunities to study, enjoy and have contact with nature.
Natura 2000	Network of Special Areas of Conservation and Special Protection Areas.
National Nature Reserve (NNR)	Statutory designation under the National Parks and Access to the Countryside Act 1949 and the Wildlife and Countryside Act 1981. NNRs contain examples of some of the most important natural and semi-natural terrestrial and coastal ecosystems in Great Britain. They are managed to conserve their habitats or to provide special opportunities for scientific study of the habitats communities and species represented within them. This designation is for land areas; the equivalent marine designation is Marine Nature Reserve.
Phase 1 Habitat Survey	A basic audit of site habitats in accordance with a defined methodology and mapping convention.
Phase 2 Habitat Survey	A more detailed survey of habitats to determine their community type in accordance with the National Vegetation Classification (NVC).
SEWBREC	South East Wales Biodiversity Records Centre.
SINC	Site of Importance for Nature Conservation. A non-statutory designation usually made by Local Authorities of sites of up to county level value.
Site of Special Scientific Interest (SSSI)	Nationally important sites forming a network of the best and most representative examples of our wildlife and geodiversity features. Selected and designated by CCW and afforded protection under the Wildlife and Countryside Act 1981 (as amended).
Special Areas of Conservation (SACs)	Designated under European Communities Directive 92/43/EEC known as the 'Habitats Directive'. This requires the conservation of important, rare or threatened habitats and species across Europe.
UK Biodiversity Action Plan (UK BAP)	The UK Biodiversity Action Plan, published in 1994, was the UK government's response to signing the Convention on Biological Diversity (CBD) at the 1992 Rio Earth Summit. It sets out a programme for the conservation of the UK's biodiversity.
The Wildlife and Countryside Act 1981	The Wildlife and Countryside Act 1981 gives protection to gives protection to native species (especially those at threat), controls the release of non-native species, enhances the protection of SSSIs and builds upon the rights of way rules in the National Parks and Access to the Countryside Act 1949. The Act is split into 4 parts covering 74 sections, it also includes 17 schedules.
HYDROLOGY / HYDROGEOLOGY	
Above Ordnance Datum (AOD)	Above Ordnance Datum: ground levels are measured relative to the mean sea level at Newlyn in Cornwall, referred to as "Ordnance Datum". Heights are reported in metres above AOD hence m AOD.
Abstraction	Removal of water from a source of supply (surface or groundwater).
Abstraction licence	The authorisation granted by the Environment Agency to allow the removal of water.
Adsorption	The process of holding molecules of gas or liquid to the surface of particles in a thin film.
Anisotropy	Anisotropy is the property of being directionally dependent, as opposed to isotropy, which means homogeneity in all

	directions. It can be defined as a difference in a physical property (in this context usually hydraulic conductivity) for some material when measured along different axes.
Anisotropy	Anisotropy is the property of being directionally dependent, as opposed to isotropy, which means homogeneity in all directions. It can be defined as a difference in a physical property (in this context usually hydraulic conductivity) for some material when measured along different axes.
Anthropogenic	Originating as a result of man's activities.
Anticline	A arch-shaped geological structure formed by a fold in which geological strata dip outwards.
Aquifer	A geological formation that can store and transmit groundwater in significant quantities.
Baseflow	The component of river flow that is derived from groundwater sources rather than surface run-off.
Bedding plane	A distinct surface of contact between two sedimentary rock layers.
Borehole	A hole bored into the ground for geological investigation or for the exploitation of geological deposits. An abstraction borehole is a well sunk into an aquifer from which water will be pumped.
British Geological Survey (BGS)	British organisation for mapping geology, partly funded by the Natural Environment Research Council. See www.bgs.ac.uk
Calibration	Adjustment to a numerical model to ensure its accuracy or response is acceptable: the process whereby model simulations are compared with field observations from the system being modelled, and the model being adjusted if necessary
Catchment	The area from which surface water and/or groundwater will collect and contribute to the flow of a specific river, abstraction or other specific discharge boundary. Can be prefixed by 'surface water' or 'groundwater' to indicate the specific nature of the catchment.
Cell	Generally the smallest unit within a numerical model within which water flux calculations are carried out.
Cell node	The centre of a cell at which the parameters, calculations, and results apply.
Conceptual model	A simplified representation or working description of how the real hydrogeological system is believed to behave. A quantitative conceptual model includes preliminary calculations, for example, of vertical and horizontal flows and of water balances.
Confined aquifer	An aquifer where the groundwater level as measured in a piezometer would be above the top of the aquifer. These aquifers are typically overlain by low permeability deposits.
Dewatering	A system of wells or sumps which are continuously pumped to lower the water table, providing stable, dry conditions allowing excavation to take place.
Diffuse Source Pollution	Pollution which arises as a result of many sources, from no one clear discharge point. Caused by a range of dispersed urban and rural land use activities.
Dilute and disperse	A method of managing contaminants whereby the effects of dilution within the groundwater are sufficient to reduce concentrations to acceptable levels.
Dip tube	Pipe inserted into the ground from which groundwater levels can be measured.
Discharge	The release of substances (i.e. water, sewage, etc.) into surface waters.
Discontinuity	A surface separating rock layers of differing properties or compositions

Downthrown	A description of the block of a fault which has observable downwards movement relative to the other side. The downthrow is the vertical component of the displacement of the two blocks.
Drawdown	Reduction in groundwater level relative to a previous reference groundwater level.
Effective rainfall/precipitation	Rainfall which remains following evaporation and evapotranspiration. This will either flow direct to streams (runoff) or recharge the groundwater system.
Environment Agency	Environmental regulatory authority in England established by the Environment Act 1995.
Evapotranspiration	The total loss of water as a result of transpiration from plants and the evaporation of water from soil, rock and surface water.
Fault	A rupture of lithological strata due to strain, in which displacement is observable. Reverse faults are compressional with one block moving over the other to some degree and normal faults are extensional with the blocks sliding away from each other.
Flow network model	A mathematical representation of flows in a groundwater system.
Formation	A geological layer.
Fracture	A breakage in a rock mass. Can be applied at any scale from a single crystal upwards but is generally used for large scale discontinuities. It implies breakage along a direction that is not the cleavage/fissility direction.
Gauged flow records	Records of flow in a river as conventionally measured. They reflect natural runoff from the catchment and artificial influences (abstraction, discharge, etc) that occur upstream of the measurement point.
Gauging station	A site where the flow of a river is measured
Groundwater	Water that is contained in underground rocks.
Groundwater level	The elevation which groundwater attains in a borehole at a specific location. Note that, where vertical hydraulic gradients are present, boreholes at the same location but with differing screened thicknesses may have different groundwater levels. Groundwater levels are normally considered to be equivalent to hydraulic heads although factors such as borehole construction and water density may invalidate this assumption.
Groundwater rebound	The rise in groundwater level that occurs after cessation of abstraction.
Hydraulic conductivity (K)	A constant of proportionality in Darcy's law that allows the calculation of the rate of groundwater flow from the hydraulic gradient. For a unit hydraulic gradient, the higher the hydraulic conductivity the higher the rate of groundwater flow.
Hydraulic head	Hydraulic head is a measure of potential energy represented by the groundwater at any point in an aquifer relative to a datum point. It is a combination of the elevation head and pressure head. Hydraulic head can be measured by the elevation of the water level in a borehole screened
Hydraulic gradient	In an aquifer this is the rate of change of groundwater level per unit distance in a given direction. Groundwater flows in the direction of the decline in hydraulic gradient.
Hydrograph	A graph showing a plot of water flow or level versus time.
Impermeable	A characteristic of a rock, soil or sediment that resists the passage of water
Karstic Aquifer	A body of soluble rock that conducts water principally via enhanced (conduit or tertiary) porosity formed by the dissolution of the rock. Karst aquifers are characterised by a network of conduits and caves..
Leachate	Liquid which is produced within or percolates through potentially contaminating material and which may contain

	contaminants as a result.
Licence	Formal permit allowing the holder to engage in an activity (in the context of this report, usually abstraction), subject to conditions specified in the licence itself and the legislation under which it was issued.
Lithology	The general characteristics of a rock or sedimentary formation.
Mean flow	A long term average of the daily flow.
Megalitres per day	Equal to thousand cubic metres per day.
Met Office Rainfall and Evaporation Calculation System	A generic name for Met Office services involving the routine calculation of soil moisture and evaporation for Great Britain and uses a grid of 40 x 40 km squares.
Metres above ordnance datum	See 'Above Ordnance Datum'
Natural Resources Wales (NRW)	Environmental regulatory authority in Wales, incorporating the Welsh section of the Environment Agency, Forestry Commission Wales and the Countryside Council for Wales. Established in 2013.
Naturalisation	Process of converting gauged flows into natural flows by removing consumptive abstraction and discharge impacts.
Nitrogen budget	A quantification of the amount of nitrogen in various forms within a system (e.g. within soil and groundwater).
Outcrop	Where rock strata are exposed at the ground surface (often beneath soil or other superficial deposits).
Non-aquifer	An impermeable body of rock or stratum of sediment that acts as a barrier to the flow of groundwater.
Palaeokarst	An area of karstified rock which has been in filled by later sediments, preventing further karstification.
Perennial spring	A spring which flows throughout the year.
Perched aquifer	An unconfined aquifer containing groundwater which is separated from an underlying unconfined aquifer by an unsaturated zone and shallow impermeable horizon.
Permeability	The capacity of soil or porous rock to transmit water.
Photodecomposition	The process of breaking down under exposure to light.
Piezometer	A borehole designed specifically to allow the measurement of groundwater level. Other methods of measuring groundwater levels (e.g. in abstraction boreholes) are available.
Piezometric surface	The level to which groundwater would rise in a piezometer if it is free to seek equilibrium with the atmosphere.
Porosity	The ratio of the total volume of pores and interstices in a rock or soil to its total volume. Expressed either as a fraction or as a percentage.
Porous	Containing void spaces. Virtually all sedimentary rocks are porous to some extent, and the term is commonly restricted to rocks which have significant effective porosity.
Potential evapotranspiration (PE)	The maximum loss of water from the surface (leaf canopy plus soil) when there is no restriction due to lack of soil moisture.
Public water supply	Term used to describe the supply of water provided by a water company.
Pumping test	Abstraction from a borehole to determine local aquifer properties.
Q95	The flow of a river which is exceeded on average for 95% of the time.
Reach	Section of a river between two points
Recharge	Water which percolates downward from the surface into groundwater.
Recirculation	The movement of water from a discharge point back to the point that it was abstracted from.

Risk assessment	Assessment of the risks associated with normal operation and possible accidents involving a source or practice. This includes consequence assessment.
Saline intrusion	Entry of salt water into an aquifer, from the sea or estuary, due to groundwater depression normally caused by excessive groundwater abstraction.
Saturated zone	The zone in which the voids in a rock or soil are filled with water at a pressure greater than atmospheric.
Sensitivity analysis	The variation of parameter values in a numerical model to determine the sensitivity of the results to the parameter being varied.
Soakaway	An excavation in the ground into which water is directed and allowed to discharge to the surrounding soil.
Solid geology	Bedrock geology as distinct from superficial geology which is typically glacial or post-glacial.
Solution enhanced fissures (conduits)	Fissures in limestone that are enlarged by dissolution of calcium carbonate by acidic water passing through them.
Seepage	The movement of water into or out of a material. A relatively slow flow rate is often implied so that, for example, a seep from an aquifer would be a lower flow rate than a spring.
Scenario	Describing a possible sequence or outcome of future events.
Site of Special Scientific Interest (SSSI)	An area given a statutory designation by English Nature or the Countryside Council for Wales because of its nature conservation value.
Special Area of Conservation (SAC)	Protected sites designated under the EC Habitats Directive due to their conservation value, providing protection for a wide variety of animals, plants and habitats.
Specific yield	The ratio of the volume of water that will drain, by gravity, from rock or soil that was initially saturated.
Steady state	(of a numerical model) The use of parameter values that do not vary through time (e.g. long term averages) to produce a model result that also does not vary through time.
Storage coefficient	The volume of water that an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in groundwater level normal to that surface.
Strata	Layers of rock, including unconsolidated materials such as sands and gravels.
Stratigraphy	The study of stratified rocks, their nature, their occurrence, their relationship to each other and their classification.
Sump	A point of low elevation to which water is directed and at which it collects. It is often removed by pumping.
Superficial deposits	Loose deposit(s) of sand, gravel, clay, etc on top of bedrock. Synonymous with ‘drift’, but a more modern term.
Surface water	This is a general term used to describe all water features such as rivers, streams, springs, ponds and lakes.
Surface water catchment	The area from which runoff would naturally discharge to a defined point of a river, or over a defined boundary.
Swallow hole/sinkhole/swallet	A hole in the ground, often found in limestone areas, through which a surface stream disappears underground
Syncline	A trough-like geological structure formed either by a fold in which geological strata dip inwards or faulted strata where the vertical displacements on parallel faults form a trough-like structure. Many synclines in rocks have a combination of both genetic mechanisms.
Till	Glacial deposits, dominantly unsorted and unstratified, that are generally unconsolidated, consisting of a heterogeneous mixture of particle sizes from clay to boulders.
Tracer test	A method of determining water flow paths and velocities by introduction of a “tracer” which can be monitored for at various locations downstream of the point of introduction.

Transient	(of a model) The use of parameter values that vary through time to produce a model result that also varies through time.
Transmissivity (T)	A measure of the ease at which water moves through a porous medium.
Unconfined aquifer	An aquifer whose upper boundary is the water table and not contained by an upper low permeability layer.
Unconformity	A junction between two rock masses representing a significant break in time, deposition, or structure.
Unsaturated zone	An area below the immediate surface of the ground but above the saturated zone.
Vadose	Of or relating to the unsaturated zone above the groundwater table.
Washout	The removal of sediment from filled voids through erosion by water.
Water Framework Directive	First major review of European water policy. Seeks to improve water quality in rivers and groundwater in an integrated way.
Water balance	Identification and quantification of water entering and exiting a selected system (e.g. an aquifer). Lumped water balances are those which combine various inputs and outputs for a given system or group of systems.
Water strike	The elevation at which water or a rise in water level is encountered within a borehole.
Water table	Level below which the ground is saturated with water The water table elevation may vary with recharge and pumping of boreholes.
Water table rebound	A rise in the water table following a period where it has been depressed (usually as a result of dewatering or other abstraction).
NOISE	
Decibels dB	Noise levels are measured in decibels. The decibel is the logarithmic ratio of the sound pressure to a reference pressure ($2x10^{-5}$ Pascals). The decibel scale gives a reasonable approximation to the human perception of relative loudness. In terms of human hearing, audible sounds range from the threshold of hearing (0 dB) to the threshold of pain (140 dB).
A-weighted Decibels dB(A)	The ‘A’-weighting filter emulates human hearing response for low levels of sound. The filter network is incorporated electronically into sound level meters. Sound pressure levels measured using an ‘A’-weighting filter have units of dB(A) which is a single figure value to represent the overall noise level for the entire frequency range. A change of 3 dB(A) is the smallest change in noise level that is perceptible under normal listening conditions. A change of 10 dB(A) corresponds to a doubling or halving of loudness of the sound. The background noise level in a quiet bedroom may be around 20 –30 dB(A); normal speech conversation around 60 dB(A) at 1 m; noise from a very busy road around 70-80 dB(A) at 10m; the level near a pneumatic drill around 100 dB(A).
Façade Noise Level	Façade noise measurements are those undertaken near to reflective surfaces such as walls, usually at a distance of 1m from the surface. Façade noise levels at 1m from a reflective surface are normally around 3 dB greater than those obtained under freefield conditions.
Free field Noise Level	Freefield noise measurements are those undertaken away from any reflective surfaces other than the ground.
Frequency Hz	The frequency of a noise is the number of pressure variations per second, and relates to the “pitch” of the sound. Hertz (Hz) is the unit of frequency and is the same as cycles per second. Normal, healthy human hearing can detect sounds from around 20 Hz to 20 kHz.

Octave and Third-Octave Bands	Two frequencies are said to be an octave apart if the frequency of one is twice the frequency of the other. The octave bandwidth increases as the centre frequency increases. Each bandwidth is 70% of the band centre frequency. Two frequencies are said to be a third-octave apart if the frequency of one is 1.26 times the other. The third octave bandwidth is 23% of the band centre frequency. There are recognised octave band and third octave band centre frequencies. The octave or third-octave band sound pressure level is determined from the energy of the sound which falls within the boundaries of that particular octave of third octave band.
Equivalent Continuous Sound Pressure Level LAeq,T	The 'A'-weighted equivalent continuous sound pressure level $L_{Aeq,T}$, is a notional steady level which has the same acoustic energy as the actual fluctuating noise over the same time period T. The $L_{Aeq,T}$ unit is dominated by higher noise levels, for example, the $L_{Aeq,T}$ average of two equal time periods at , for example, 70 dB(A) and 50 dB(A) is not 60 dB(A) but 67 dB(A). The $L_{Aeq,T}$ unit was commended by the Noise Advisory Council and is the chosen unit of BS5228 for Construction and Open site noise and BS 7445 for the Description and Measurement of Environmental noise.
Maximum Sound Pressure Level LAMax	The L_{Amax} value describes the overall maximum 'A'-weighted sound pressure level over the measurement interval. Maximum levels are measured with either a fast or slow time weighted, denoted as $L_{Amax,f}$ or $L_{Amax,s}$ respectively.
Sound Exposure Level LAE or SEL	The sound exposure level is a notional level which contains the same acoustic energy in 1 second as a varying 'A'-weighted noise level over a given period of time. It is normally used to quantify short duration noise events such as aircraft flyover or train passes.
Statistical Parameters LN	In order to cover the time variability aspects, noise can be analysed into various statistical parameters, i.e. the sound level which is exceeded for N% of the time. The most commonly used are the $L_{A01,T}$, $L_{A10,T}$ and the $L_{A90,T}$. **$L_{A01,T}$** is the 'A'-weighted level exceeded for 1% of the time interval T and is often used to gives an indication of the upper maximum level of a fluctuating noise signal. **$L_{A10,T}$** is the 'A'-weighted level exceeded for 10% of the time interval T and is often used to describe road traffic noise. It gives an indication of the upper level of a fluctuating noise signal. For high volumes of continuous traffic, the $L_{A10,T}$ unit is typically 2–3 dB(A) above the $L_{Aeq,T}$ value over the same period. **$L_{A90,T}$** is the 'A'-weighted level exceeded for 90% of the time interval T, and is often used to describe the underlying background noise level. It is defined in British Standard 4142 as the background noise unit and is used for establishing the reference against which industrial noises are assessed.
BLAST VIBRATION	
Displacement	The distance that a particle moves before returning to its original position, measured in millimetres (mm).

Velocity	The rate at which particle displacement changes, measured in millimetres per second (mms-1).
Acceleration	The rate at which the particle velocity changes, measured in millimetres per second squared (mms-2) or in terms of the acceleration due to the earth's gravity (g)
Frequency	The number of oscillations per second that a particle undergoes measured in Hertz (Hz
PV	Particle Velocity in mms-1
π	pi, a mathematical constant that is the ratio of any circle's circumference to its diameter
F	frequency
A	amplitude
Cosmetic or threshold	the formation of hairline cracks or the growth of existing cracks in plaster, drywall surfaces or mortar joints
Minor	the formation of large cracks or loosening and falling of plaster on drywall surfaces, or cracks through bricks/concrete blocks.
Major or structural	damage to structural elements of a building
SD	scaled Distance in mkg-½
W	maximum Instantaneous Charge (MIC) in kg, i.e. maximum weight of explosive per delay interval in kg
a	a dimensionless site factor is the peak particle velocity intercept at unity scaled distance
b	a dimensionless site factor and is the slope of the regression line
D	separation Distance (Blast to Receiver) in metres
PPV	maximum Peak Particle in mms-
AIR QUALITY	
AQMA	Air Quality Management Area
AQS	Air Quality Strategy
HGV	Heavy Goods Vehicle
AADT	Annual Average Daily Traffic Flow
LAQM	Local Air Quality Management
PM_{10}	Airborne particulate matter with an aerodynamic diameter of 10µm or less
$\mu g/m^3$	Units of concentration, micograms in a cubic meter of air
NO^2	Nitrogen Dioxide
AURN	Automatic Urban and Rural Network
DMRB	Design Manual for Roads and Bridges, produced by the Highway Agency

Appendix D

Approved Water Management Plan

Water Management Plan for Cornelly Quarry

Report reference: 6227 WMP Cornelly Quarry v5.8, 9 November 15
Report status: Final

CONTENTS

FIGURES

APPENDICES

PREFACE

Cornelly Quarry is currently the subject of an Environment Act 'ROMP Review' which will update the planning conditions controlling future operations at the Quarry. The Applicant, Tarmac Ltd, has proposed a series of updated planning conditions as required by the Review, including a commitment to carry out the development in accordance with a 'Water Management Plan' (WMP).

Several versions of the WMP have previously been submitted; initially as part of a previous ROMP Environmental Statement for Cornelly Quarry (WynThomasGordonLewis, 2004), with several subsequent versions being prepared to take into account comments made by the Environment Agency, the Countryside Council for Wales (now combined into Natural Resources Wales) and other interested parties.

On 3 March 2013 the Welsh Government issued a Scoping Direction for a new Environmental Statement (ES) under the 'Stalled ROMP Regulations' (ref A-PAA-25-08-004t). As a result the quarry operator prepared a new ES which showed that, assuming some residual pumping was carried out at the end of active working, the proposed development would not cause a 0.1 m or greater difference between expected and actual mean summer groundwater levels in the dune slacks/blown sands at Kenfig SAC over three consecutive years (the agreed hydrological criterion for these potentially sensitive features for the purposes of assessing whether there would be an adverse effect on the integrity of the Kenfig SAC).

The Scoping Direction also included a requirement to prepare a revised WMP:

> *The ES should include a refinement of the water management plan, which should include a description of water management measures at the quarries, linked to the proposed works, quarry development, quarry decommissioning and reinstatement and set out the monitoring programme, a description of any necessary remedial strategy and any actions the operator would take to prevent and/or reverse any impacts. This should facilitate the improved understanding of the regional and local water regime and the nature of any uncertainty which might remain.*

As a result, in 2014 Tarmac Ltd prepared a substantially revised WMP (v5.0) to comply with the Scoping Direction and in light of the results of the new ES for Cornelly Quarry (SLR, 2014 ES). This final version of the WMP (v5.8) has been prepared in response to comments received on v5.0 from Natural Resources Wales in early 2015 (letter to Welsh Government dated 18 Sept 2014 - Cornelly, Grove and Gaens Quarry ROMP Geoscience comments on Environmental Statements (SLR, June 2014)) and comments on the subsequent v5.1 WMP (ESI, April 2015) issued on 14 May 2015, v5.3 (ESI, July 2015) received on 31 July 2015[1] and some final iterations as part of the process of agreeing a Statement of Common Ground prior to the Public Inquiry in November 2015, in order to ensure impacts on the Kenfig Dunes SAC are avoided.

It is anticipated that this refined WMP will be cross referenced in a final version of a schedule of planning conditions which will be imposed by the determining Authority (Welsh Government).

[1] An interim v5.2 version was discussed at a meeting between Natural Resources Wales and ESI on 13 July 2015.

1 DEFINITIONS

Appropriate Calculations are defined in Section 6.7.

Assessment Criteria are 'standards' against which data can be compared in order to assess whether there has been a Deviation from the behaviour at that site relative to the behaviour that would be anticipated under 'natural'[2] conditions. There are two types of Assessment Criteria:

- Trigger Levels are defined in Section 6.2.1.
- Climate Based Assessment Criterion is defined in Section 6.3.1 and Climate Based Assessment Criteria will be interpreted accordingly.

A **Deviation** is considered to have occurred when the data at a site 'exceeds' an Assessment Criterion by a particular amount:

- Deviation from a Trigger Level Assessment Criterion is defined in Section 6.2.1.
- Deviation from a Climate Based Assessment Criterion is defined in Section 6.3.1.

The definition of a **Significant Deviation** is set out in Section 6.4.

Sensitivity Criteria are defined in Section 6.4.

Critical monitoring sites shall include:

- At least one pathway site monitoring the bedrock aquifer between the quarries and each of the SACs (Kenfig and Merthyr Mawr);
- The monitoring sites required to define the water balance within each quarry (this may include sump levels as well as various pumping rates).

  Critical monitoring sites are identified in Appendix A. The list of Critical Monitoring sites can be amended as part of the annual review if trends are occurring in a particular area that require particular attention.

There are two types of **'mitigation measures'** applied under this WMP:

- **Planned Mitigation Measures** are those actions described in Section 7.1 that have been considered in the Environment Statement (SLR, 2014 ES) and which have been shown in that document to be effective at mitigating any small hydrological effects that might be caused by the operation of the quarry at potentially sensitive receptors.
- **Contingency Measures** are defined in Section 8. Contingency Measures are actions that should be taken if potentially significant events occur in and around the quarry for which Planned Mitigation Measures were not specifically considered as part of the Environmental Statement. Contingency Measures can also be required in the event of a major failing in part or all of the monitoring network.

Source is defined in Section 4.1.

Pathway is defined in Section 4.1.

Receptor is defined in Section 4.1.

The **Quarry Operator** means the Company or Companies that operate Cornelly Quarry.

The **Regulator** means the public body that is responsible for ensuring that the activities that the Quarry Operator is required to carry out under this Water Management Plan (WMP) are carried out. On formal adoption of the WMP this will be Bridgend County Borough Council.

[2] There is a wide range of possible mechanisms that can cause variation from 'natural' conditions. Where these cannot be easily distinguished using the available data, Appropriate Calculations (Section 6.7) may be needed to estimate the relative significance of different potential causes.

2 INTRODUCTION

2.1 Background

Cornelly Quarry (the "Quarry") is the largest quarry in Wales providing over 1 million tonnes of limestone per year, principally for the steel mill at Port Talbot. It is also an important supplier of aggregates into the local construction industry. The total area covered by existing consents for mineral extraction at the Quarry is approximately 76 ha.

The main quarry floor is currently (2015) at around -2 mAOD. The Quarry is dewatered by pumping water out of the quarry floor sump and either to a settlement lagoon or to the adjacent Grove and/or Pant Mawr quarries. Water may also be pumped to Stormy Down Quarry to the east from time to time. It is planned that the Quarry should be worked to -75 mAOD.

2.2 Planning Context

A large part of the Quarry is consented under a 1948 Interim Development Order (IDO). Under the Planning and Compensation Act 1991, the consent was registered in 1992 (IDO 53/92/0308) and revised conditions were agreed in 1994. Subsequent to the 1948 IDO permission there were nine separate planning permissions for the winning and working of limestone as extensions to the original quarry. There are no planning conditions imposed on the respective permissions which limit the depth of quarrying, and the scheme of working submitted as part of the ROMP Review confirms the intention to develop the quarry to a depth of -75m AOD. The hydrogeological impact assessment has been based upon this intended working scheme.

In 1997, applications were made to Bridgend County Borough Council under the Environment Act, 1995 (Review of old mineral permissions – ROMP), for determination of a scheme of conditions in respect of the area of the Quarry covered by those planning permissions (the "ROMP application"). Separate applications were made in respect of the nearby Grove and Gaens Quarries. The applications were referred to the Secretary of State for Wales in May 1998 (Gaens') and July 1998 (Cornelly and Grove). Due to the commonality of issues at these sites, it was decided that they should be determined as a group. The National Assembly for Wales (now the Welsh Assembly Government) subsequently took on the role of determining authority for the applications.

An Environmental Impact Assessment (EIA) in connection with the ROMP application for the Quarry was undertaken voluntarily, and an Environmental Statement (ES) setting out the results of the EIA was submitted in 2004 (WynThomasGordonLewis, 2004). This included an earlier version of this WMP that was subject to extensive consultation with the relevant regulators at that time.

For reasons explained in Chapter 1.0 of the main ES (SLR, 2014 ES), the respective applications had not been determined by 2014, and there was therefore a requirement to undertake further updated EIAs and to present the results in updated formal ESs. The hydrological and hydrogeological elements of the EIA were based on the continuation and extension of current water management practices at the Quarry. A summary of the Hydrogeological ES for Cornelly Quarry is contained at Appendix F.

The ES includes a set of proposed planning conditions, including a requirement to continue the quarrying operations in accordance with a Water Management Plan (WMP), (ref SLR, 2014 ES Annex 1).

2.3 The Water Management Plan

The objective of the WMP is to guide the Quarry Operator in its management of water at the Quarry such that any adverse environmental impacts resulting from these activities can be minimised. In particular the water management plan has been devised to ensure that there is no impact on the integrity of the Kenfig SAC as a result of quarry dewatering. In order to achieve this, the WMP will:

- Specify the monitoring activities required;
- Outline how the resultant data should be reviewed in order to determine whether the operation of the Quarry has affected any of the monitoring sites;
- Outline the options for management of water at the Quarry and how these could be adjusted in the light of any effects detected at any of the monitoring sites.

The Quarry Operator will operate the WMP until the ongoing monitoring and reporting under the WMP demonstrates that the need for Planned Mitigation Measures as a result of the activities at the Quarry has ceased[3].

The determining authority under the ROMP procedure, and hence this document, is the Welsh Government, with Bridgend County Borough Council and Natural Resources Wales as statutory consultees. Following determination of the ROMP and formal adoption of the WMP, the regulatory body will become Bridgend County Borough Council (the Regulator) with Natural Resources Wales as statutory consultee.

Due to the commonality of issues, conditions for the adjacent Gaens and Grove Quarries will be determined in parallel with those for Cornelly Quarry. As a result, a separate WMP will be required for each quarry. Whilst there is a significant degree of overlap between the WMPs for the three quarries, they each form separate and independent documents. However, the respective WMPs are being prepared by the same hydrogeological consultant, using common data, the collection, analysis and interpretation of which has been jointly funded by the respective Quarry Companies.

2.4 This Document

This final version of the WMP (v5.8) updates the draft WMP (v5.0) that was submitted as part of the 2014 ES for the Quarry (SLR, 2014 ES) and has been revised to take into account comments by Natural Resources Wales (18 Sept 2014 - Cornelly, Grove and Gaens Quarry ROMP Geoscience comments on Environmental Statements (SLR, June 2014)) and comments on the subsequent v5.1 WMP (ESI, April 2015) issued on 14 May 2015[4].

Figure 1 provides a flow diagram illustrating the main processes required in the WMP. Figure 2 illustrates some of the general timelines and also draws together some of the key response times. These are for illustrative purposes only. The main text of this report provides the definitive description of the requirements of the WMP.

2.5 Future Amendments

It is intended that the WMP will be a ‘living document’ and will be operated over many years during which there are likely to be staff changes at both the Regulator and the Quarry Operator. It is important therefore that the WMP should be unambiguous and comprehensive. However, it should also contain appropriate mechanisms to allow it to be adapted so that it can continue to be used successfully as conditions change in the future. The inclusion of measures to deal with certain eventualities does not necessarily indicate that such eventualities are viewed as being likely.

It is anticipated that the actions required under the WMP (e.g. monitoring locations, frequencies, mitigation and contingencies etc.) may need to be revised from time to time in the light of data sets obtained and / or other factors affecting either the regulatory or hydrogeological environment. No changes requested by the Regulator shall, however, have the purpose or effect of stopping or preventing quarry operations or otherwise restricting

[3] See comments in Section 3.2 about the need for Planned Mitigation Measures to continue after the end of dewatering.

[4] An interim v5.2 version was discussed at a meeting between Natural Resources Wales and ESI on 13 July 2015.

working rights within the meaning of the Environment Act 1995. It is expected that the need for any changes will become apparent as part of the annual reporting cycle (Section 5).

Note that it is expected that water quality standards for the water discharged off site from dewatering activities will be addressed by means of Environmental Permits which will be agreed separately with Natural Resources Wales.

3 WATER MANAGEMENT

3.1 Quarry Pumping (Operational Phase)

Throughout the remaining operational life of the Quarry, the dewatering system within the Quarry will continue to operate as it does now, with pumping from a basal sump to the processing water lagoon. During the process of deepening the base of the Quarry, it may be necessary to construct one or more temporary sumps before relocating the main sump down again.

The calculations carried out as part of the environmental impact assessment (Appendices 7.3 and 7.4 of SLR, 2014 ES) indicate that average pumping rates off site from the Quarry will be around:

- 2670 m^3/d at 15 years (-30 mAOD).
- 2740 m^3/d at 42 years/full development (-75 mAOD).

These are average rates: clearly the rates required at any one time will depend on antecedent rainfall and quarry operational factors. The monthly average rate of pumping previously has varied by +/- a factor of two.

It is anticipated that, in future, the amount of variability around the mean monthly average rate is likely to be similar to that experienced in the past. Where the pumping rate in the Quarry is significantly higher than that which would be expected given antecedent rainfall and quarry operations, this would trigger Contingency Measures (Section 8).

3.2 Quarry Pumping (Recovery Phase)

The period during which the quarry void fills with water after the end of quarry operations and dewatering has been identified in the ES as a period with potential for impact on surrounding water bodies, unless Planned Mitigation Measures continue during the period required to restore groundwater equilibrium. The need to consider continued pumping out of the Quarry (albeit at lower rates) during this period until conditions have broadly stabilised is noted in the ES. The WMP has been written in a manner that will allow it to continue to guide the management of water on site during this period.

3.3 Discharge of Dewatering Water

From the processing water lagoon, water is pumped off site as required. There are three routes currently available for disposal of this water from the Quarry:

1. Pumping to Pant Mawr Quarry;
2. Pumping to Grove Quarry (from where it may subsequently be pumped to the adjacent railway cutting); or
3. Pumping to Stormy Down Quarry.

In some circumstances, it may be appropriate to pump to more than one of these quarries. In the future it is possible that other options for the disposal of dewatering water may arise.

4 MONITORING REQUIREMENTS

4.1 Normal Monitoring Procedures

The Quarry Operator shall ensure that monitoring is carried out at the sites set out in Appendix A - Sections A.1, A.2, A.3 and A.4 of this WMP at the frequencies specified therein. The methods required to ensure the accuracy and representativeness of the data collected are set out in Appendix B.

Procedures for managing any problems that it is anticipated could prevent the Quarry Operator from carrying out the required monitoring are set out in Section 4.1.3. The Quarry Operator and Regulator will work together to ensure that the functional integrity of the monitoring network is maintained.

4.1.1 Classification of sites

In Appendix A, monitoring sites have been classified according to the purpose of monitoring at that site[5]:

- Source (monitoring of activities in and around the Quarry that could give rise to impacts on the surrounding groundwater systems – principally dewatering and disposal of water)
- Pathway (monitoring of sites between the Quarry and potential receptors to provide early warning of potential impacts)
- Receptor (monitoring of hydrogeological conditions at a potentially sensitive site)
- Background (monitoring that provides information that helps interpret trends observed at other sites – e.g. rainfall)

The purpose for which a site has been selected for monitoring is relevant in helping to decide a course of action if a site becomes unavailable for monitoring (Section 4.2.3) and is also relevant when considering what actions would be appropriate if a Deviation is deemed to have occurred at that site (Sections 6.2.1, 6.3.1 and 6.4).

Sites are also defined in terms of their criticality which reflects not only their purpose (as above) but also, for Pathway and Background sites, their uniqueness/replaceability. The criticality of the dataset will be judged by two considerations:

1. Whether there are any other datasets from nearby monitoring sites that have a good correlation with the dataset with missing data (see ‘back up’ sites identified in Table A.2). Where there are such alternative datasets that allow the behaviour of the system over the period of missing data to be reasonably estimated, the missing data will be viewed as being less critical.
2. The speed with which it is anticipated responses may occur at these sites, and in respect of Pathway sites between the quarries and the SAC, the speed at which changes in ground water levels at those sites will translate into changes at the Kenfig SAC, based on the modelling work presented in SLR, 2014 ES.

Critical monitoring sites are identified in Appendix A. The list of Critical Monitoring sites can be amended as part of the annual review if trends are occurring in a particular area that require particular attention.

4.1.2 Data storage

All data collected as part of the WMP will be stored digitally by the Quarry Operator in an appropriate database system with an associated digital backup system (including off site storage of backup material). Digital copies of the data will be made available to the

[5] Sites in Tables A.1 and A.4 are all Source monitoring sites, Sites in Table A.3 are all Receptor monitoring sites. In Tables A.2 sites are identified individually.

Regulator as part of the annual reporting process (Section 5.3). However, relevant digital data would also be made available to support discussion on Contingency Measures (Section 8) and/or upon reasonable written request by the Regulator.

4.1.3 Third party monitoring

Table A.5 in Appendix A summarises other hydrometric monitoring that is being carried out in the area by third parties. Much of the data collected by third parties is of use in understanding the hydrogeological processes that are occurring in the area but does not form part of the requirements of this WMP. However, some datasets currently collected by third parties are identified as being of critical value to the operation of the WMP. These are highlighted in Bold in Appendix A, Table A.5 (third party monitoring) and duplicated in Sections A.1 to A.5 (monitoring for which the Quarry Operator is responsible).

4.2 Procedures for Managing Problems with the Monitoring Network

Appendix A sets out the monitoring required under this WMP. As this monitoring will need to be carried out over many decades, it is anticipated that a range of practical problems may be encountered in the future. The section below sets out procedures that should apply when such problems are encountered. It also sets out what failings would be substantial enough to trigger Contingency Measures. The timescale for remedial actions is different for Contingency Measures (Section 8) than for the 'anticipated' problems set out in this section.

The overall objective of the procedures in this section is to ensure that the network be maintained by the Quarry Operator at an appropriate level of functionality to allow the WMP to operate effectively. This requires a balance to be struck such that the need to ensure that critical data are collected is achieved but that this does not introduce unreasonably onerous requirements on the Quarry Operator.

The monitoring requirements of the WMP may also need to be revised in future: a mechanism for identifying and agreeing the need for such changes is described in Section 5.3.

For each site in Table A.2 (which sets out the water level monitoring sites), potential 'back up sites' are listed. These are sites which have a good correlation with the listed sites and could be appropriate alternative sites if data are lost at a site or if a site becomes unavailable for monitoring.

4.2.1 Missing data

The Quarry Operator will endeavour to ensure that all the monitoring specified in Appendix A is carried out each year. However, it is accepted that, even in well operated monitoring networks, there will be occasions on which data are not collected. Possible reasons for this include:

- Temporary inaccessibility of particular sites;
- Other practical difficulties with recording data at a site; or
- Loss or corruption of data collected by data loggers.

Experience at other equivalent sites with well managed hydrometric monitoring networks at which similar numbers of data loggers are employed indicates that it should be possible to achieve 90 to 95% of the target data collection across the whole network over the course of a year. The collection rate at individual sites would typically be 100% but, at a few sites, the rate of collection may drop below this (e.g. loss of one month's data would lead to a data collection rate of 92% at that site).

Given that missing data is an expected condition, it is important to have procedures in place to deal with the situation. The following procedures will therefore apply for losses at individual sites:

- Where data are lost because of problems during a particular month (i.e. all data for one monitoring round at a particular site), this shall be recorded by the Quarry Operator and reported in the annual review of data. The Quarry Operator will make reasonable efforts to ensure that the data loss does not extend to the following month. The annual report will explain the reason for the loss and propose actions that will be taken to prevent future loss.
- If the level of monitoring coverage across the network drops below 80% in any month (e.g. no data collected at more than 20% of sites), the Quarry Operator will notify the Regulator of the situation within 10 working days of becoming aware of the data loss and will outline the measures that are being taken to rectify the situation.
- If it becomes apparent that the period of data loss at any Critical site will exceed 60 days (i.e. the problem will not be rectified by the end of the next monitoring round), the Quarry Operator will notify the Regulator of the situation within 10 working days of becoming aware of the potential data loss and will outline the measures that are being taken to rectify the situation.
- In general the Quarry Operator will aim to re start monitoring within 1 month of notifying the Regulator for Critical Sites and within 3 months for other sites.
- For the above situations, the Regulator will consider the Quarry Operator's proposals and may recommend alternative monitoring that should be carried out during the period when data continues not to be collected. Any such alternative monitoring that is recommended by the Regulator should be proportionate to the criticality of the potentially missing data for the purposes of implementing this WMP.

Where the data losses of over 60 days apply to more than three Critical sites during the same period, this will trigger Contingency Measures (see Section 8).

4.2.2 Incorrect data

The QA measures outlined in Appendix B are designed to minimise the risk that data will be incorrectly recorded. The review elements of these QA measures and the annual data review (Section 5.3) should also help to identify where data have been incorrectly recorded.

Where data are identified as being incorrect (or potentially incorrect) the Quarry Operator shall flag them as being as such in the database system. If information is available to allow the data to be corrected, this shall be carried out by the Quarry Operator. However, the Quarry Operator shall maintain a digital record of any corrections made so that any corrected data can be identified as such.

Where the QA measures indicate that incorrect data are still being collected this will be treated in the same way as for missing data (Section 4.2.1) with respect of notification of the Regulator and remedial actions/Contingency Measures.

4.2.3 Site unavailable

It is not anticipated that monitoring Receptor monitoring sites will become a problem due to lack of access (it is in the interest of the owners/controllers of Receptors for the monitoring to take place and it would not be possible to initiate Planned Mitigation Measures or Contingency Measures under this WMP unless data are available).

The majority of the Source and Pathway sites that the Quarry Operator is required to monitor (Appendix A, Sections A.1 to A.5) are either under the direct control of the Quarry Operator, within the land under the control of one of the adjacent quarries that will have related Water Management Plans (Gaens' and Grove), or on land controlled by a public body (e.g. Kenfig Pools and Dunes NNR). The remaining Pathway sites are relatively few in number. However, it is possible that, at some point in the future, one or more of the sites may become unavailable for monitoring.

If it becomes apparent that a site has become unavailable for monitoring (or permanently unsuitable for monitoring for any reason), the Quarry Operator will notify the Regulator of the situation within 21 days of becoming aware of the potential loss of the site and will outline any proposed alternatives.

The Regulator will consider the proposal being made by the Quarry Operator. The Regulator may either accept the Quarry Operator's recommendation or may recommend an alternative. Alternatives that could be considered in these circumstances are:

- Changing the monitoring frequency at an existing nearby, equivalent monitoring site (see 'back up' sites listed in Table A.2);
- Changing the monitoring requirement to an existing unmonitored site for which access would be available (Appendix D of Appendix 7.1 SLR, 2014 ES); or
- Changing the monitoring requirement to a new site at which access would be available and at which an appropriate monitoring structure is not at the time installed. For Pathway sites, it is anticipated that any replacement sites should be within 300 m of the original site and ideally within the same geological formation.

Any alternatives that are specified should be proportionate to the criticality of the potentially missing data (see Section 4.1.1 for definition of criticality of datasets).

If the Regulator reasonably specifies that a new monitoring site needs to be introduced to the monitoring network, the Quarry Operator will use its reasonable endeavours to achieve the installation of the monitoring point within 6 months of agreement to do so. New monitoring sites will only be specified for locations at which the Quarry Operator can reasonably obtain access.

4.2.4 Cessation of third party monitoring

Natural Resources Wales has duties under various legislation (e.g. Habitats Directive, Water Framework Directive etc.) to protect and manage water related features that are of relevance to this WMP. In order to achieve this, Natural Resources Wales carries out monitoring activities in the area as listed in Appendix A (Table A.5). Bridgend County Borough Council is also responsible for monitoring at the Kenfig Dunes National Nature Reserve and there is some monitoring carried out at nearby landfill sites. Monitoring will also be required at Gaens' and Grove Quarries under their respective WMPs.

Some of the sites currently monitored by third parties have been identified as being of critical value to the operation of the Quarry WMP. These sites have been highlighted in Table A.5 and the Critical water level monitoring sites are duplicated in Sections A.1 to A.5 (monitoring for which the Quarry Operator is responsible).

If the Quarry Operator becomes aware that a third party is no longer monitoring any of the Critical sites listed in Table A.5 or that the QA methods applied by the third party at these sites are not adequate by reference to Appendix B, the Quarry Operator will notify the Regulator within 21 days that this is the case and suggest any appropriate actions.

The Regulator will consider the Quarry Operator's proposals and may recommend alternative monitoring that should be carried out by the Quarry Operator. Alternative monitoring that can be recommended in these circumstances is:

- Taking over the monitoring at the Critical third party site (subject to access agreements being obtainable);
- Moving a data logger from another, less Critical site to ensure that regular monitoring is still achieved at the third party site; or
- Changing the monitoring frequency at an existing nearby, equivalent site.

Any alternative monitoring that is specified should be proportionate to the criticality of the potentially missing data (see Section 4.1.1 for definition of criticality of datasets). In addition, no monitoring shall be recommended at sites to which the Quarry Operator does not have or cannot reasonably obtain access.

Measures that require the introduction of a new site to the monitoring network shall be dealt with under the procedures outlined in Section 4.2.3.

5 REVIEW AND REPORTING

5.1 Monthly QA

The Quarry Operator will carry out monthly QA of the data collected as described in Section B.1 of Appendix B.

5.2 Interim Report

The Quarry Operator will carry out an interim review of the data collected by the Quarry Operator and third parties during the 6 month period from November to April each year. The Quarry Operator will submit a concise interim data review report to the Regulator within 60 days of the end of the period under review (i.e. end of June each year). Achievement of this timescale will be assisted by third parties providing the data promptly.

The Interim report will assess the level of compliance of the monitoring carried out during the 6 month period and will list any problems with the monitoring and associated remedial actions.

Any sudden changes in the record at any of the sites monitored will be noted together with any steps taken to investigate further.

Any other actions triggered under the WMP (e.g. Contingency Measures) will be noted.

5.3 Annual Report

The Quarry Operator will carry out a review of the data collected by the Quarry Operator and third parties during each 12 month period from November to October. An annual data review report will be submitted by the Quarry Operator to the Regulator within 90 days of the end of the period under review (i.e. end of January each year). Achievement of this timescale will be assisted by third parties providing the data promptly.

The annual data review report will contain:

1. A description of any activities in the Quarry during this period that are relevant to local hydrogeological conditions. This will include presentation of data showing the rate of pumping from the quarry sump and the rate of pumping to adjacent discharge points together with plans of the Quarry showing the location of any sumps and the benches that have been worked during the period.
2. Assessment of quarry pumping rates against an appropriate Climate Based Assessment Criterion (Section 6.4.2).
3. Graphical presentation of all of the monitoring data collected at appropriate scales (e.g. for both the 12 month period and the full period of data availability).
4. Summary tables showing percentage completeness of data collection relative to target (as set out in Appendix A) together with a description of any difficulties encountered in collecting the data.
5. A concise summary of any incorrect or missing data that have been identified and how they have been treated.
6. Summary tables showing the range of values measured at each site during the 12 month period and how this compares to previous periods.
7. A summary of the condition of each monitoring point including comment on any possible change in datum levels and the recent plumbed depth of each borehole/dip well.
8. A concise summary of climatic conditions during the 12 month period and how this compares to previous periods.
9. A summary of any indications in the data that the conceptual model of the local hydrogeology as set out in SLR, 2014 ES (or as subsequently modified in previous

annual reports) needs to be adjusted and the significance of any such adjustments for the conclusions of the ES and hence the requirements of the WMP.

10. A comparison of the data collected at each site against the relevant Assessment Criteria for the 12 month period under review (see Section 6.2.1 and 6.3.1). This should also include an assessment of any observed trends and Deviations and thus the likelihood of a Significant Deviation occurring in the following review period.
11. An assessment of the significance of any Deviation (see Section 6.4). Note that exceedance of an Assessment Criterion by Quarry pumping rates (Section 6.4.2) automatically triggers changes to Planned Mitigation and/or Contingency Measures (Section 8) i.e. the Deviation mechanism does not need to be applied to achieve changes in Planned Mitigation Measures.
12. An assessment of the effects of any changes that have been made to the way in which the quarry discharges water over the previous 12 month period.
13. A description of any Contingency Measures (Section 8) that have been required during the previous 12 month period.
14. Recommendations for changes required to the monitoring network in order to support achievement of the objective of the WMP.
15. Recommendations for any changes in the Trigger levels or CBACs to take into account the data collected in the period under review[6].
16. Recommendations for any adjustments to the Planned Mitigation Measures (Section 7) being carried out supported as necessary by Appropriate Calculations (Section 6.7) to demonstrate that this will achieve the desired objective (either to reverse a Significant Deviation that has occurred or to forestall a Significant Deviation that seems likely (on the basis of observed trends) to occur in the coming period).
17. Recommended changes to the monitoring system to allow the effectiveness of any such changes to be monitored. During the Recovery Phase (Section 3.2), it is anticipated that this will include an assessment of how much residual pumping will be required to minimise any adverse environmental impacts.
18. An outline of any proposed developments that are scheduled to take place in the Quarry over the coming 12 months that have a bearing on the local hydrogeology (e.g. construction of new sumps, working of new benches, changes to pumping regime etc.) together with an assessment of likely effect on dewatering rates (i.e. a guide to likely dewatering rates under different rainfall scenarios).
19. A digital copy of all data collected during the course of the previous 12 months.

Copies of any reports issued will be sent direct to the relevant offices/departments of the Regulator and the statutory consultee (Natural Resources Wales).

5.4 Overview by the Regulator

The Regulator will review the Interim and Annual Reports in detail and will write to the Quarry Operator within 90 days of receiving the report detailing:

- Confirmation (or not) that the monitoring has been carried out as required;
- Confirmation (or not) that the Assessment Criteria had been correctly applied;
- Acceptance or disagreement with the conclusions reached;
- Acceptance or disagreement with the recommendations made;

[6] For clarity, changes to CBAC threshold ranges will be considered during annual review but the Sensitivity Criteria used to determine that a Deviation is significant would only be reviewed as part of future ROMP cycles.

- Details of any recommendations that the Regulator requires for changes in the WMP, including a need for a change to the periodicity of review.

In the absence of any comment within the 90 day period, the Regulator will be deemed to have accepted the content, findings and recommendations of the Annual Report.

Note that, due to the subtle and gradual nature of some of the changes that may occur, it is possible that the start of a Deviation may only become apparent several years later. Therefore confirmation that no Deviations have been detected in one year does not mean that a future assessment (with the benefit of additional data) may not conclude that the Deviations started at that point. The timing of any actions required following a Significant Deviation will be measured from the date of the Annual Report reporting of the Significant Deviation. In the event that the Significant Deviation is found to have started in a previous interim or Annual Reports, the Quarry Operator and Regulator will use reasonable and proportionate endeavours to expedite actions required.

6 MECHANISM FOR DETERMINING WHETHER A DEVIATION HAS OCCURRED AND IDENTIFYING RESULTANT ACTIONS

6.1 Summary of Approach

The general approach to assessing the data collected under the WMP is that, as part of the Interim or Annual Report process, data at each monitoring site are assessed against an Assessment Criterion (either a Trigger Level (Section 6.2) or a Climate Based Assessment Criterion (Section 6.3) as set out for each site in Appendix D2).

Where the data are considered to have 'exceeded' an Assessment Criterion (details of how 'exceedance' is defined are discussed in relevant sections below), a Deviation is considered to have occurred. Deviations at Pathway and Receptor sites which exceed a pre-defined Sensitivity Criiterion are to be considered and if they are Significant Deviations as set out in Section 6.4 certain actions are required to be taken (Section 6.6)[7].

Figure 1 illustrates the sequence of events in the procedure for determining whether a Deviation from an Assessment Criterion has occurred and whether any changes to the Planned Mitigation Measures are required as a result. In summary, the following steps are required:

1. Compare the measured data at the monitoring site against the relevant Assessment Criterion (Appendix C);
2. If a Deviation is identified (Sections 6.2.1 or 6.3.1), assess whether that Deviation is a Significant Deviation (Section 6.4);
3. Review the spatial pattern of Deviations, the behaviour of the groundwater system during the period in question (Section 6.3.2) and carry out Appropriate Calculations (Section 6.7) to determine whether dewatering activities at the Quarry are a contributory cause to any Significant Deviations;
4. If dewatering activities at the Quarry are a contributory cause to any Significant Deviations identify any amendments required to the Planned Mitigation Measures (Sections 6.6 and 7) and monitoring under the WMP[8].

Two different types of Assessment Criteria are used in this WMP: Trigger Levels (Section 6.2.1) and Climate Based Assessment Criteria (Section 6.3.1). Different procedures apply to these different approaches as described below. Sites using each type of criterion are listed in Appendix C. In general, Climate Based Assessment Criteria are used for sites with good monitoring records which show predictable responses to antecedent rainfall, whereas Trigger Levels are used for sites with shorter data periods or irregular responses to rainfall. It is anticipated that as the data sets for the monitoring sites improve, there will be a gradual migration of some of the remaining sites with Trigger Levels to Climate Based Assessment Criteria. Steps required to achieve this migration are described in Section 6.7.

---

[7] NB The process for annual reporting (Section 5.3) also requires a review of trends and deviations to assess whether a Significant Deviation is likely to occur in the next reporting period.

[8] See paragraph 6.5 3.d as to what should happen in circumstances where dewatering operations cannot be ruled out as a potential contributory cause.

6.2 Trigger Levels

6.2.1 Definitions

Trigger Levels are absolute values against which data can be compared. If any of the data measured at a Pathway or Receptor site[9] 'exceed'[10] the relevant Trigger Level, a Deviation has occurred. The proportion of the data in the period under review that has to 'exceed' the Trigger Level before a Deviation is considered to have occurred is defined in Section 6.2.2.

Trigger Levels are a relatively simple approach to setting Assessment Criteria and suffer from a limited ability to take into account antecedent climatic conditions which usually dominate the data being recorded. However, there are some sites for which Climate Based Assessment Criteria are not appropriate: this principally applies to shallow ponds and wells (e.g. ID 17, 20, 23 etc. in Table A.2) or sites affected by tidal variations (e.g. ID 21 in Table A.2). Trigger Levels have been developed for these sites, as set out in Appendix C.

Some other sites (e.g. HL 6, 11, 13, 14 and 15) have no Trigger Levels because there is currently insufficient data to develop a Climate Based Assessment Criterion. Transitional arrangements for developing new Trigger Levels or moving from Trigger Levels to Climate Based Assessment Criteria at these sites are set out in Section 6.8 and Appendix C.

6.2.2 Proportion of data to 'exceed' a Trigger Level Assessment Criterion before a Deviation is considered to have occurred

Data derived from the monitoring of natural systems typically have a degree of 'noise' in them. The aim of this section is to define periods over which data have to 'exceed' a relevant Trigger Level Assessment Criterion before a Deviation is considered to have occurred, so that the effects of such 'noise' in the data do not unnecessarily affect the water management at the Quarry.

Where a pre-defined proportion of the data measured at a Pathway or Receptor Site 'exceed' a relevant Trigger Level Assessment Criterion by a defined amount during the period under review, it will be considered that a Deviation has occurred[11].

The relevant proportions of the data are defined as follows:

- For a water level monitoring site monitored by a data logger at daily intervals (or more frequently), the proportion is 10% of values measured during the 12 month period under review.
- For a water level monitoring site monitored manually at monthly intervals, the proportion is two consecutive values measured during the 12 month period under review.

Similar proportions will be derived for stream and spring flow data series once a representative period of time series data has been collected (See Section 6.7).

The amount by which the data measured at a Pathway or Receptor Site need to 'exceed' a relevant Trigger Level Assessment Criterion to contribute to a Significant Deviation is set out in Section 6.4.

If it appears, by reference to a Trigger Level, that a Significant Deviation has occurred, it may be appropriate to develop a Climate Based Assessment Criterion for that site to confirm this conclusion. However, this should not delay the issue of an Annual Report or the conclusion as to whether a Significant Deviation has occurred at that site.

---

[9] Deviation can only be defined for Pathway and Receptor monitoring sites. Source water level monitoring sites are by definition already significantly affected by Quarry dewatering. Exceedance of an Assessment Criterion by Quarry pumping rates triggers Contingency Measures (Section 8). The zone over which dewatering at the Quarry is considered to have already significantly affected groundwater levels (estimated at 1.2 to 1.4 km^2) is discussed in the ES for the Quarry (SLR, 2014 ES).

[10] Note, trigger levels may either be minimum values or maximum values. In the former case, 'exceed' in this context means to fall below, in the latter case, to fall above.

[11] Note that the loss of water supply from a private water supply that has been identified in the Quarry ES (SLR, 2014 ES) as being potentially vulnerable to changes in water management activity at the Quarry triggers Contingency Measures (Section 8).

6.3 Climate Based Assessment Criteria

6.3.1 Definitions

A Climate Based Assessment Criterion is a calculation that allows the 'natural' behaviour of a monitoring site under different climatic conditions to be estimated. The approach that is used to calculate these Climate Based Assessment Criteria is outlined in Appendix D. By making allowance for antecedent climatic conditions, the Climate Based Assessment Criteria allow a more sensitive assessment of other effects on the local groundwater system (e.g. quarry dewatering) to be carried out.

Deviation from a Climate Based Assessment Criterion is defined as the occurrence of a statistically significant difference between the behaviour measured at a Pathway or Receptor Site[12] and the behaviour predicted by the relevant Climate Based Assessment Criterion. The statistical approaches that will be used to determine the presence and size of any Deviation between the observed data and the Climate Based Assessment Criteria are described in Appendix D.

The Climate Based Assessment Criterion for a site needs to be calibrated against a 'baseline' - observed data from that site for a period over which it can be agreed that there are no significant effects of water management at the Quarry on the observed data (or if there are such effects, that correction can be made for them). The CBACs that have been developed for various flow and water level monitoring sites are presented in Appendix C.

6.3.2 Determination that a Deviation has occurred

As with all models of natural systems, there will be some variance between the simulated and observed values. The size of this variance will determine both the confidence that can be placed in the Climate Based Assessment Criterion for that site and also the minimum difference between the simulated and observed data that could be considered to be statistically significant.

For each of the Climate Based Assessment Criteria set out in Appendix C, threshold ranges have been set, based on the range of CuSum trends that have occurred in the baseline period. If these threshold ranges are exceeded, further statistical tests should be carried out as described in Appendix D, to check whether there is a statistically significant difference between modelled and observed data in the periods before and after the CuSum trend started. If there is such a statistical difference, it will be concluded that a Deviation has occurred at that site.

6.4 Assessment of the Significance of a Deviation

6.4.1 Receptor Sites

Where a Deviation has been determined at a Receptor Site, the Quarry Operator will assess the significance of the Deviation by reference to the sensitivity of that Receptor. The following Sensitivity Criteria will be used for determining whether a Deviation at a Receptor site is a Significant Deviation[13].

- For licensed groundwater abstraction boreholes, a groundwater level reduction in excess of 0.5 m relative to the relevant Assessment Criterion is taken to indicate a potentially significant impact unless further assessment (i.e. evaluation of borehole

[12] Deviation can only be defined for Pathway and Receptor monitoring sites. Source water level monitoring sites are by definition already significantly affected by Quarry dewatering. Exceedance of an Assessment Criterion by Quarry pumping rates triggers Contingency Measures (Section 8). The zone over which dewatering at the Quarry is considered to have already significantly affected groundwater levels (estimated at 1.2 to 1.4 km^2) is discussed in the ES for the Quarry (SLR, 2014 ES).

[13] Note that the loss of water supply from a private water supply that has been identified in the Quarry ES (SLR, 2014 ES) as being potentially vulnerable to changes in water management activity at the Quarry triggers Contingency Measures (Section 8). It is anticipated that this would be identified by the owner reporting the loss to the Operator.

construction details, pump intake level etc.) indicates that this has not materially affected the functioning of the supply.

- For shallow wells, a groundwater level reduction in excess of 0.25 m relative to the relevant Assessment Criterion is taken to indicate a potentially significant impact unless further assessment indicates that this has not materially affected the use or value of the well[8].
- For ponds (excluding Kenfig Pool and any dune slacks in Kenfig Pool and Dunes and Merthyr Mawr SAC) the criteria will be a change of 0.1 m relative to the relevant Assessment Criterion for each of the ponds monitored (sites 17, 20 and 23 in Appendix A, Table A.2) unless further assessment indicates that this has not materially affected the use or amenity/ecological value of the pond.
- For spring flows, a reduction of flow in excess of 10% of mean long term flows relative to the relevant Assessment Criterion is taken to indicate a potentially significant impact unless further assessment indicates that this has not materially affected the use or value of the spring.

The Environmental Statement showed that the proposed future development of the quarry would not have an adverse effect on the integrity of the Kenfig SAC provided that Planned Mitigation Measures (Section 7) are carried out as set out in this WMP. However, notwithstanding that conclusion, the possibility remains that conditions may differ from those assessed. The hydrological criterion, agreed with NRW, for the purposes of assessing a possible adverse impact on the integrity of the Kenfig SAC as a result of the quarrying operations is that a 0.1m or greater difference between expected and actual mean summer groundwater levels in the blown sands at Kenfig SAC over three consecutive years must not be allowed to occur. This is set out in the preface to this document. The WMP seeks to prevent such adverse effects on the integrity of the Kenfig SAC from occurring by reference to intermediate Pathway Sites, where potential impacts on groundwater levels can be detected early, before they translate into an impact at the Kenfig SAC receptors, with sufficient time for remedial action to be taken via changes to Planned Mitigation/Contingency Measures before a 0.1m or greater difference between expected and actual mean summer groundwater levels over 3 consecutive years is reached. The monitoring of the Kenfig SAC receptors still fulfils an important function in that the conceptual modelling carried out and the efficacy of mitigation strategies can be checked.

6.4.2 Pathway Sites

The modelling carried out for the ES for the Quarry (SLR, 2014 ES) indicates that some changes are anticipated at Pathway sites. The occurrence of a change in water levels at a Pathway site below the precautionary Sensitivity Criteria set out below may indicate the effect of natural variations in ground water levels or the application of different Planned Mitigation Measures but, on their own, should not be taken as a cause for concern.

The occurrence of changes in water level that are equal to or exceed those Sensitivity Criterion set out below will be taken to indicate a risk that an adverse effect on the integrityof the Kenfig SAC could occur after a period of time at the Kenfig SAC and will suggest that some elements of the conceptual model and Planned Mitigation Measures need to be revised and/or that Contingency Measures may need to be implemented The minmum and maximum time delay between the breach of a Sensitivity Criteria and the impact on the integrity of the Kenfig SAC is set out below for reference purposes.

The Sensitivity Criteria for the various Pathway Sites are as follows:

Site	Receptor	Estimated water level change at Pathway site for 0.1m at Kenfig/Merthyr Mawr (m)*	Sensitivity. Criterion (m)	Min delay from pathway response to response in SAC (years)	Max delay from pathway response to response in SAC (years)
21	Merthyr Mawr	1.2	1	3.1	4.8
40	Kenfig	33.6	7.5	8.0	10.3
A-a	Kenfig	2.1	0.75	7.7	9.4
B-a	Kenfig	3.3	1	7.8	9.9
C (new)	Kenfig		1.5	7.9	10.4
D (new)	Kenfig		5	8.0	10.3
G	Merthyr Mawr	8.0	3	3.1	4.3
H	Merthyr Mawr	1.2	1	3.1	4.8
K1a	Kenfig	0.3	0.1	7.4	8.6
K2a	Kenfig	0.3	0.1	7.4	8.6
N (3)	Kenfig	0.7	0.25	7.6	8.7
O	Kenfig		0.5	4.4	9.6
P	Kenfig		5	6.2	10.0
Q	Kenfig		7.5	7.4	9.3
R	Kenfig		0.5	4.4	9.6
T	Merthyr Mawr	2.3	1	3.1	4.2
T_95/01	Merthyr Mawr	30.0	7.5	3.5	4.7

Cells shaded grey are not on direct pathway to stated receptor.

*These values were derived by interrogating the outputs from the scenario runs of the transient water balance (ES Appendix 7.4) to compare the change in water level at each model cell with the maximum response at the SAC on that pathway. These pathway responses were then scaled up to be equivalent to a 0.1 m change at the SAC assuming a direct proportionality between the two. The mean value for the different scenarios is presented here. Note that if the simulated change in water level at the SAC was in a different direction to that in the Pathway site, then this result will be negative (i.e. those sites are probably not appropriate for the purpose of detecting and preventing water level change at the SAC – these values have not been included in the table above and mostly occur at sites that are not on a direct pathway to the SAC).

6.4.3 Quarry pumping rate

The Scoping Direction requires assessment of:

> *the potential impact of quarrying on hydrology and hydrogeology of the area, including the possibility of interception during quarrying of a 'highly permeable feature' within the limestone, and although there is a low probability of this occurring the prospect should be recognised as a continuing risk during further development of the quarry and appropriate action identified (for example a risk management/ monitoring strategy which recognises the critical stage at which potential adverse impact may occur);*

Discussion with Natural Resources Wales has indicated that an appropriate way of managing this risk is to focus on regularly determining whether the pumping rate in the quarry is in the range anticipated.

A Climate Based Assessment Criterion for pumping rates at the quarry (ref Section 6.4.2) will be included in Appendix C in future to allow the regulator to check whether pumping rates are higher than anticipated. A preliminary Climate Based Assessment Criterion for the rate of pumping out of the sump was presented to Natural Resources Wales on 13 July 2015 (included in Appendix C for reference). However, in subsequent discussion, it was agreed that the water management system in the quarry is complex and not all the components are currently measured (e.g. on site storage, re-circulation from lagoon leakage, consumption in the plants on site etc.). As a result, it was agreed that Tarmac would implement an enhanced monitoring scheme within the quarry by 31 March 2016 and, once a sufficient amount of data from these additional components becomes available (12 months), the preliminary Climate Based Assessment Criterion will be finalised.

6.5 Identification of the Cause of Deviations and Significant Deviations

As part of the annual report (Section 5.3), the Quarry Operator will review the spatial distribution of any Deviations and/or Significant Deviations (collectively “deviations” in the text below) that have been identified in the 12 month period under review with the aim of identifying their cause. In addition, the Quarry Operator will also review the available monitoring data and assess whether it is likely that any deviations are likely to occur in the next 12 month period.

If any deviations have occurred or are considered likely to occur, three possible outcomes of this review are anticipated:

1. The pattern of deviations clearly indicates that water management at the Quarry is a contributory cause of the deviations. In this circumstance, the Quarry Operator will identify appropriate changes to the Planned Mitigation Measures as described in Sections 6.6 and 7.
2. The pattern of Deviations clearly indicates that water management at the Quarry is not a contributory cause of the Deviations. In this case, the Quarry Operator will report this finding to the Regulator for its attention and no further action is required under Section 6.6 below. The Regulator will review this conclusion as part of its review of the annual report (Section 5.4). If the Regulator does not agree with this conclusion, it will set out its reasons for disagreeing and/or make a reasonable request further information or Appropriate Calculations that, in its view, will help to determine the cause of the Deviations.
3. The pattern of Deviations does not clearly indicate whether water management at the Quarry is a contributory cause of the Deviations. In this case, the Quarry Operator will carry out Appropriate Calculations (Section 6.6) to determine the most probable degree to which dewatering at the Quarry is the cause of the Deviations.
    a. If the Appropriate Calculations indicate that water management at any of the Cornelly Group of Quarries is not a contributory cause of the Deviations, the Quarry Operator will report this finding to the Regulator for its attention.
    b. If the Appropriate Calculations indicate that water management at another of the Cornelly Group of Quarries is a contributory cause of the Deviations, the Quarry Operator will report this finding to the regulator and the relevant Quarry Operator for implementation via the relevant WMP.
    c. If the Appropriate Calculations indicate that water management at the Quarry is a contributory cause of the Deviations, the Quarry Operator will identify appropriate changes to the Planned Mitigation Measures as described in Section 6.6.

d. If the Appropriate Calculations cannot rule out that water management at the Quarry is a contributory cause of the Deviations, the Quarry Operator will need to identify and implement changes to the Planned Mitigation Measures described in Section 6.6 on a precautionary basis until such time that water management at the Quarry can be ruled out as a cause.

If the scale and extent of Deviations is significantly different from that anticipated in the ES (SLR, 2014 ES as summarised Appendix F), then this would trigger Contingency Measures (Section 8).

6.6 Identifying Actions Required in the Case of a Significant Deviation Occurring at a Receptor Monitoring Site

Where a Significant Deviation has been identified, as part of the annual report, the Quarry Operator will recommend adjustments to the Planned Mitigation Measures/Contingency Measures (Section 7 and 8)[14]. These adjustments should be proportionate to the degree to which the Quarry is a contributory cause of the Significant Deviation. The Quarry Operator will support its proposal for adjustments to the Planned Mitigation Measures/Contingency Measures by means of Appropriate Calculations (Section 6.7) as necessary.

6.7 Appropriate Calculations

Some parts of the WMP require Appropriate Calculations to be carried out. For instance:

- Calculations to develop Climate Based Assessment Criteria (Section 6.3).
- Calculations required to clarify the extent to which dewatering at the Quarry is the cause of a Deviation (Section 6.3);
- Calculations to assess whether a Deviation is likely to occur at a Receptor monitoring site in the next 12 months (Section 6.5); and
- Calculations to demonstrate the likely effectiveness of proposed adjustments to Planned Mitigation Measures (Section 6.6).

Appropriate calculations can include some or all of the following:

- Simple scoping calculations using appropriate analytical and mass balance equations
- Time series recharge calculations such as those presented in Appendix D;
- More complex calculations such as the Flow Network Model presented in Appendix 7.3 of SLR, 2014 ES (included as Appendix E of this document for completeness);
- Distributed numerical groundwater modelling of all or parts of the system.

The complexity of the calculations applied will be discussed and agreed with the Regulator (and the relevant statutory consultees) and will be proportionate to the significance of the impacts being considered and the actions required as a result of the calculations.

6.8 Current Status and Future Development of Assessment Criteria

Sites for which Assessment Criteria are required are the Pathway and Receptor sites listed in Table A.2 in Appendix A and all the sites in Table A.3 in Appendix A. These should be CBACs except where these are considered to be infeasible (Section 6.2.1).

The current status of the various Assessment Criteria is set out for all sites in Tables C.1 (Trigger Levels) and C.2 (CBACs) in Appendix C.

[14] Note that the loss of water supply from a private water supply that has been identified in the Quarry ES (SLR, 2014 ES) as being potentially vulnerable to changes in water management activity at the Quarry triggers Contingency Measures (Section 8).

Where no (or very limited) data are currently available for a site, Table C.3 sets out which alternative sites should be considered to represent conditions at the site until an adequate data set is available to define a Trigger Level or CBAC.

7 PLANNED MITIGATION MEASURES

7.1 Available Planned Mitigation Measures

The Planned Mitigation Measures for water management at the Quarry available under the terms of this WMP are:

1. Pumping to Pant Mawr Quarry. This would be with the aim of raising groundwater levels on the pathway to Kenfig Pool and Dunes SSSI;
2. Pumping to Grove Quarry. This would be with the aim of raising groundwater levels on the pathway to receptors to the south and west of the quarries; and/or
3. Pumping to Stormy Down Quarry. This would be with the aim of raising groundwater levels on the pathway to Merthyr Mawr SSSI.

No other sites for Planned Mitigation Measures for water management at the Quarry are currently available to the Quarry Operator. However, the ES (SLR, 2014 ES) showed that these measures would be adequate for mitigating any small effects on the local hydrological system. Where a Significant Deviation has been identified, as a part of the annual or interim report, changes to the Planned Mitigation Measures or implementation of Contingency Measures may be proposed by the Quarry Operator in the relevant report and or required by the Regulator. Changes or alternatives to the Planned Mitigation Measures referred to above may include alternative re-injection locations to those currently available, or other measures that are considered to be necessary to ensure there is no ongoing breach of the Sensitivity Criterion and no adverse effect on the integrity of the Kenfig Dunes SAC. Any such changes to the Planned Mitigation Measures will need to be incorporated into later versions of the WMP (see also Contingency Measures Section 8).

In the case of a Significant Deviation occurring at a private water supply (as listed in Appendix A, Table A.2) [15], Planned Mitigation Measures may also include:

4. Modification to the structure of the private water supply to minimise or remove the impact (e.g. deepening a well or borehole or lowering the pump);
5. Provision of an alternative mains water supply; or
6. Financial compensation for the loss of the water supply.

In the event of a quarry off-site discharge failing to meet the terms of the relevant Environmental Permit, Planned Mitigation Measures include dilution within the large volumes of water held in various quarries and simple options for treatment such as aeration etc.

7.2 Implementation of Planned Mitigation Measures

The Quarry Operator will make reasonable endeavours to implement any recommended adjustments to the Planned Mitigation Measures within 6 months of agreement of the measures.

If the Deviation is large enough to cause the interruption of water supply at a private water source that has been identified in the Quarry ES (SLR, 2014 ES) as being potentially vulnerable to changes in water management activity at the Quarry (this triggers Contingency Measures), then the Quarry Operator will respond within 5 working days (Section 8).

As part of the implementation of the Planned Mitigation Measures, the Quarry Operator will submit details of any adjustments to the monitoring programme in Appendix A that are required in order to determine the effectiveness of the revised Planned Mitigation Measures (See Point 15 in Section 5.3).

[15] Note that the loss of water supply from a private water supply that has been identified in the Quarry ES (SLR, 2014 ES) as being potentially vulnerable to changes in water management activity at the Quarry triggers Contingency Measures (Section 8).

8 CONTINGENCY MEASURES

Contingency Measures are actions that may be required under the WMP in circumstances where events occur that were not predicted in the ES or in the previous annual report and that require actions to be carried out before the next 12 month data review is complete (excluding the generally anticipated difficulties with any monitoring network defined in Section 4.2).

The following events will trigger Contingency Measures:

- An increase of the monthly quarry pumping rate so that it exceeds the maximum rates predicted in the relevant Climate Based Assessment Criterion by more than an agreed percentage (see Section 6.4.3);
- Occurrence of any signs of significant ground instability in and around the Quarry that could reasonably be attributed to activities in the Quarry;
- The loss of monitoring data at more than three Critical sites in a particular month due to the same cause;
- The loss of more than 60 days monitoring data at more than three Critical sites in a 12 month period;
- The loss of water supply from a private water supply that has been identified in the Quarry ES (SLR, 2014 ES) as being potentially vulnerable to changes in water management activity at the Quarry[16];
- The scale and extent of Deviations observed during a 12 month period is significantly different from that anticipated in the ES (SLR, 2014 ES as summarised Appendix F);
- A marked change in the behaviour of a Pathway or Receptor monitoring site relative to previous behaviour at that site such that it is reasonable to expect that a Significant Deviation has occurred.

Other events in the Quarry that can reasonably be considered by the Quarry Operator or Regulator to be likely to affect the local groundwater systems rapidly in ways that were not anticipated at the time of the issue of the previous annual report will also trigger Contingency Measures.

The Quarry Operator will notify the Regulator of the occurrence of such an event within five working days of becoming aware of its occurrence. Within 21 days of notifying the Regulator of the occurrence of such an event, the Quarry Operator will inform the Regulator of the steps which it intends to take in response to an event, with, where appropriate, a list of proposed Contingency Measures, and a timetable for implementing those measures.

In the case of loss of water supply from a private water supply, the Quarry Operator will investigate the reason for the loss of supply and, if it is attributable to water management activities in the Quarry, will make arrangements to provide an alternative or back up supply within five working days as a short term measure. After this, the normal Contingency Measures procedure will apply.

Contingency Measures may include:

- Additional monitoring of water levels, pumping rates or water quality;
- Changes to the way water is managed within the Quarry (see Sections 3 and 7.1);
- Other physical measures to minimise the problems encountered. This could include alternative re-injection locations to those currently available, as set out in Section 7

[16] It is anticipated that this loss of supply would be identified by the owner reporting it to the Operator.

above, or other measures that are considered to be necessary to ensure there is no ongoing breach of the Sensitivity Criterion and no impact on the Kenfig Dunes SAC. It could also include the type of measures envisaged in outline in Appendix G, albeit the circumstances pertaining at the time will need to be considered before the remedial action required is determined either by the Quarry Operator with the agreement of the Regulator or, in the absence of agreement, requested by the Regulator.

The Quarry Operator will also provide the Regulator with a digital copy of any data from the hydrometric network described in Appendix A that may be required by the Regulator in relation to the proposed Contingency Measures.

9 REFERENCES

SLR, 2014 ES. Environmental Statement Volume 1 Environment Act Romp Review: Cornelly Quarry

WynThomasGordonLewis, 2004. Environment Act 1995: Review of Mineral Planning Permissions Cornelly Quarry Environmental Impact Assessment

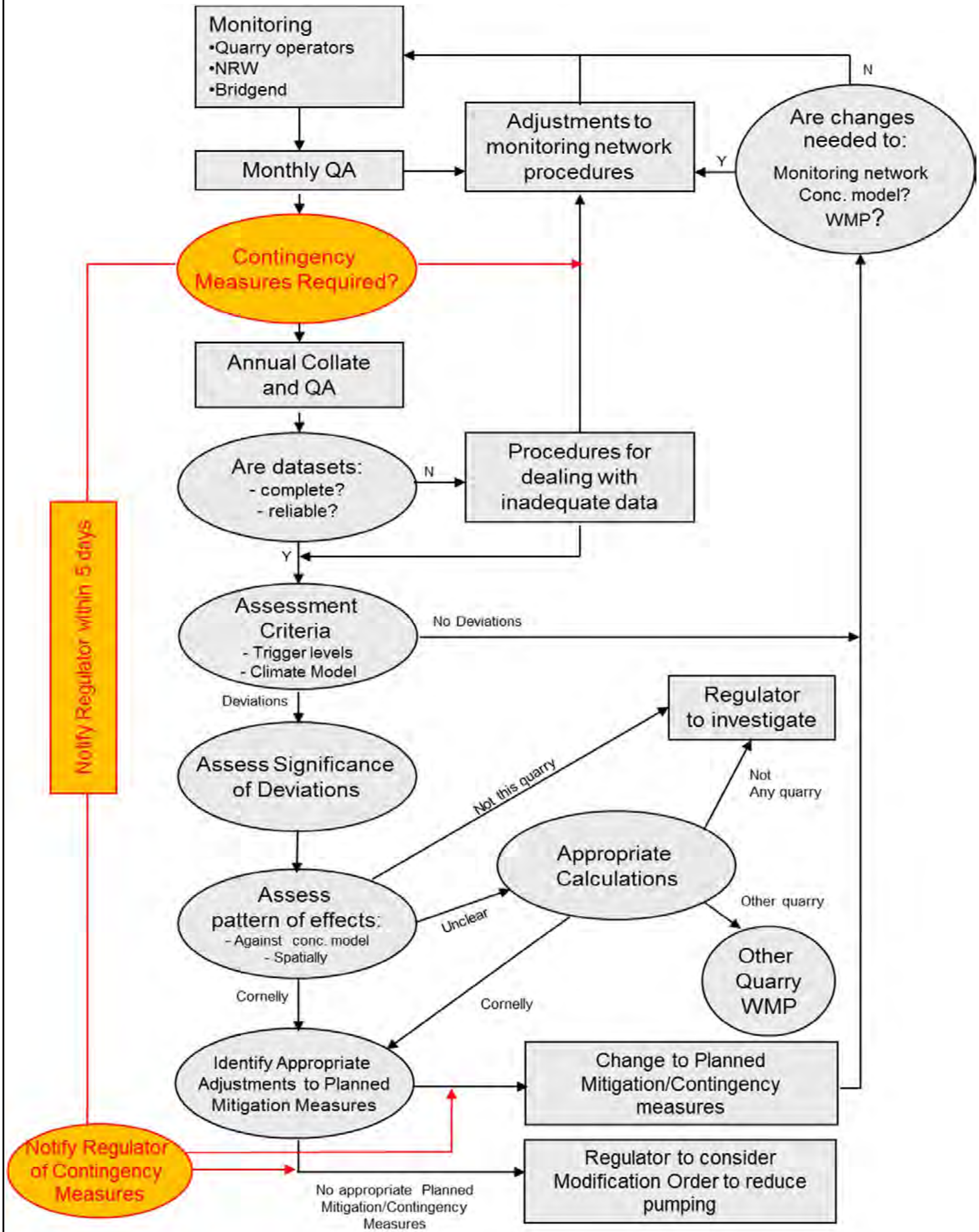
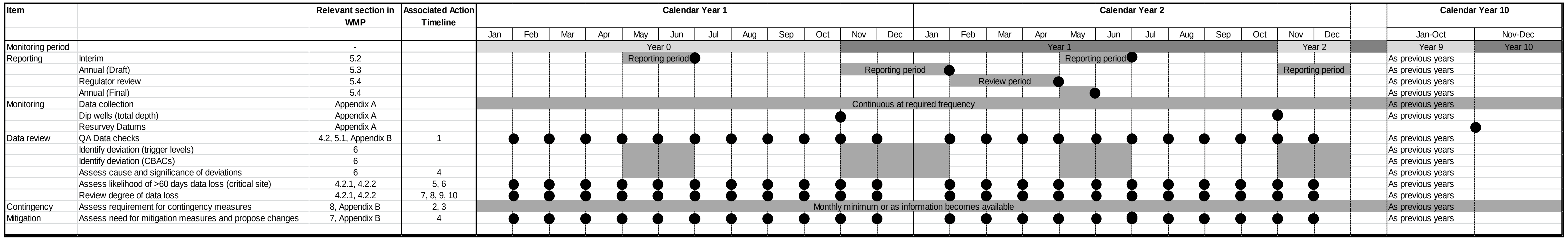


Figure 1
Illustrative flow chart showing processes required for Cornelly Quarry WMP

Date	Drawn
Jul 15	MJS
Scale	Checked
dns	MJS
Original	Revision
A4	5.3
File Reference	
O:\6227_Cornelly\reports\R17 EIA\Outline flow chart.xls	

esi soil & groundwater

General Timelines:



Specific Event Timelines:

Ref.	Event	Response time (initial)	Initial Action	Response Time (follow on action 1)	Follow on action 1	Response Time (follow on action 2)	Follow on action 2
1	Site unavailable/unsuitable for monitoring	+21 days	Notify regulator and propose appropriate actions	Unspecified duration	Receive regulator feedback	+6 months	Install new site (if required)
2	Interruption to water supply	+5 working days	Implementation of corrective measures				
3	Contingency measure trigger	+5 working days	Notify regulator	+21 days	Present plan to regulator	As agreed	provide digital data
4	Significant Deviation identified and changes to mitigation measures required	+6 months	Implementation of changes				
5	Likelihood of greater than 60 days data loss at a critical site	+10 working days	Notify regulator with plans for addressing				
6	Likelihood of greater than 60 days data loss at four or more critical sites	Immediate	Initiate contingency measures				
7	Monitoring coverage drops below 80% in any month	+10 working days	Notify regulator with plans for addressing				
8	Minor data loss (i.e. data loss not falling into other event categories listed here)	next annual report	Explain reason for loss and actions to prevent future loss				
9	Interruption to monitoring at any critical site	1 month	Resume monitoring				
10	Interruption to monitoring at any non-critical site	3 months	Resume monitoring				

Figure 2
Timelines

Date Nov 15	Drawn CMC
Scale A3	Checked XXX
Original A3	Revision 1
File Reference O:\6XXX\Reports\Drawing\DrawingX.X.doc	

esi Environment Specialists

APPENDICES

Appendix A Monitoring Requirements

A.1 Pumping Rates

The Quarry Operator will record the reading on the impellor flow meters installed on the various pumps in the Quarry on a weekly basis. The number of pumps being used will depend on the precise water management activities in the Quarry at the time. However, the Quarry Operator should measure the following flows if pumping has occurred to that site in the previous weekly period.

Table A.1 Abstraction Rate Monitoring (Source)

Site	Comment
Pumping from quarry sump to processing lagoon	Generally fairly continuous although may cease from time to time when levels in the deepest sinking are allowed to recover.
Pumping from processing lagoon to Pant Mawr Quarry	Over recent years the Quarry has predominantly disposed of water either to Pant Mawr or Grove Quarry
Pumping from processing lagoon to Grove Quarry	From Grove Quarry, water may also be pumped to the railway cutting. This is an operational matter pertinent to the Grove Quarry WMP.
Pumping from processing lagoon to Stormy Down Quarry	If Grove Quarry does become operational during this period then surplus water will be diverted to Stormy Down Quarry. It is anticipated that disposal to Stormy Down Quarry may become a significant part of the water management at the site in the long term.

A.2 Water Levels

The Quarry Operator will monitor water levels at the sites and frequencies set out in Table A.2. Locations of these sites are shown on Figure A.1. Decisions on monitoring frequency etc have been in part based on the speed of response indicated by the modelling carried out for the ES (SLR, 2015). Sites have been divided into Response Groups (1 is most rapid and 4 least rapid)

Two specific circumstances are noted here under which monitoring frequency would change:

1. Following 12 months of monitoring and if no response is seen in the corresponding pathway sites, monitoring at some distant receptor sites may be discontinued (subject to agreement by the Regulator). These sites are identified in the comments in Table A.2.
2. Where a Significant Deviation occurs in a Response Group 1 site, the frequency of monitoring in Response Group 2 sites on that pathway should be increased.

In either case, this would be agreed via the annual report process.

Table A.2 Water Level Monitoring (Source, Pathway & Receptor Sites)

ID	Desc. (Name)	Locality	Monitored Aquifer / Water Body	Source[1]	Receptor[1]	Pathway[1]	Receptor Group	Pathway for receptors	Alt receptor sites	Alt pathway sites	Response Group[2]	Mon frequency	Mon Method	Critical[1,3]	Land controlled by	Comment	WMP[5]
17a	Pond	Ty Tanglwyst Farm, South Cornelly	Surface water (Lst)				Ty Tanglwyst Group Lst	17b, K2b, KP, K1b, CC_5, CC_9, K4	17b	D (new)	1	Monthly	Manual		Private		GR, GA
17b	Borehole	Ty Tanglwyst Farm, South Cornelly	Limestone				Ty Tanglwyst Group Lst	17a, K2b, KP, K1b, CC_5, CC_9, K4	17a	D (new)	1	Monthly	Manual		Private		GR, GA
20	Pond	The Wildnerness , Porthcawl	Surface water (Lst)				Porthcawl Group Lst	None		n/a	2	Monthly	Manual		Bridgend CBC		GR, GA
21	Borehole	White Wheat, Porthcawl	Triassic				Porthcawl Group Lst	20, 23	23	H	2	Monthly	Manual		Private	Private water supply. Tidal fluctuations.	GR, GA
23	Pond	Pwll y Waun, Porthcawl	Surface Water (Triassic)				Porthcawl Group Lst	None	21	n/a	2	Monthly	Manual		Bridgend CBC		GR, GA
34	Pond	Tythegston	Surface water (Lst)				Tythegston Group Lst	61, D4, D7, D8	61	T, G, L	3	Monthly	Manual		Private		GA
61	Borehole	Tythegston	Limestone				Tythegston Group Lst	D4, D7, D8	34	T, 34, G, L	3	Monthly	Manual		Private	Licensed abstraction/Private water supply. Named as Tynycaeau although located at Tythegston.	
A-a	Borehole	Kenfig	Triassic				n/a	K2b, KP, K1b, CC_5, CC_9, K4		17a, 17b, D (new), C (new), B-a, N (piezo 3), A-b, K2a	2	Monthly	Manual		Golf course		GR, GA

ID	Desc. (Name)	Locality	Monitored Aquifer / Water Body	Source[1]	Receptor[1]	Pathway[1]	Receptor Group	Pathway for receptors	Alt receptor sites	Alt pathway sites	Response Group[2]	Mon frequency	Mon Method	Critical[1,3]	Land controlled by	Comment	WMP[5]
A-b	Borehole	Kenfig	Sand and Gravel				n/a	K2b, KP, K1b, CC_5, CC_9, K4		17a, 17b, D (new), C (new), B-a, A-a, N (piezo 3), K2a	3	Monthly	Manual		Golf course		GR, GA
B-a	Borehole	Kenfig	Triassic				n/a	K2b, KP, K1b, CC_5, CC_9, K4		17a, 17b, D (new), C (new), A-a, N (piezo 3), A-b, K2a	2	Monthly	Manual		Golf course		GR, GA
C (new)	Borehole	South Cornelly	Limestone				n/a	K2b, KP, K1b, CC_5, CC_9, K4, New Mill Farm Springs		D (new)	2	Daily	Auto		Golf course	Replacement bh	GR, GA
CC_5[4]	Borehole	Kenfig	Dune Sand				Kenfig	CC_9, K4	CC_9, K1b, K2b, KP	17a, 17b, D (new), C (new), B-a, A-a, K1a, N (piezo 3), KP, A-b, K1b, K2a, K2b	4	Monthly	Manual		Kenfig Corp	Apex of groundwater ‘dome’ in dune slacks	GR, GA
CC_9[4]	Borehole	Kenfig	Dune Sand				Kenfig	None	CC_5, K1b, K2b, KP	n/a	4	Monthly	Manual		Kenfig Corp	Western side of groundwater ‘dome’ in dune slacks.	GR, GA
CP	Settlement Pond	Cornelly	Limestone				n/a	n/a	n/a	n/a	1	Daily	Auto		Tarmac		
CS	Sump (Cornelly Sump)	Cornelly	Limestone				n/a	n/a	n/a	n/a	1	Daily	Auto		Tarmac		GR, GA

ID	Desc. (Name)	Locality	Monitored Aquifer / Water Body	Source[1]	Receptor[1]	Pathway[1]	Receptor Group	Pathway for receptors	Alt receptor sites	Alt pathway sites	Response Group[2]	Mon frequency	Mon Method	Critical[1,3]	Land controlled by	Comment	WMP[5]
D (new)	Borehole	Ty Tanglwyst Farm, South Cornelly	Limestone				n/a	17a, 17b, K2b, KP, K1b, CC_5, CC_9, K4, New Mill Farm Springs		None	1	Daily	Auto		Rees & son	Replacement bh	GR, GA
D4[4]	Borehole	Merthyr Mawr Slack 2	Dune Sand				Merthyr Mawr	None	D7, D8	n/a	4	Monthly	Manual		Merthyr Mawr Estate	Dune slacks in the centre of Merthyr Mawr.	
D7[4]	Borehole	Merthyr Mawr Flood plain	Dune Sand				Merthyr Mawr	None	D4, D8	n/a	4	Monthly	Manual		Merthyr Mawr Estate	Dune slacks near Burrows Well.	
D8[4]	Borehole	Merthyr Mawr Slack 1 West	Dune Sand				Merthyr Mawr	None	D4, D7	n/a	4	Monthly	Manual		Merthyr Mawr Estate	Dune slacks near Burrows Well.	
G	Borehole	Tythegston	Limestone				n/a	34, 61, D4, D7, D8		T_95/11, T, L	3	Daily	Auto		Private		
GRS[4]	Sump (Grove Sump)	Grove Quarry	Surface water (Lst)				n/a	None (mitigation measures)		n/a	1	Daily	Auto		Tarmac		GR, GA
GAS[4]	Sump (Gaens Sump)	Gaens Quarry	Surface water (Lst)				n/a	None (mitigation measures)		n/a	1	Daily	Auto		Rees & son		GR, GA
H	Borehole	T'yn-y-caeau	Limestone				n/a	20, 21, 23		21	2	Daily	Auto		Private		GR, GA
K1a	Borehole	Kenfig	Sand and Gravel				n/a	K1b, CC_5, CC_9, K4		B-a, A-a, N (piezo 3), KP, A-b, K2a, K2b	3	Monthly	Manual		Kenfig Corp		GR, GA
K1b	Borehole	Kenfig	Dune Sand				Kenfig	CC_5, CC_9, K4	CC_5, CC_9, K2b, KP	17a, 17b, D (new), C (new), B-a, A-a, K1a, N (piezo 3), KP, A-b, K2a, K2b	4	Monthly	Manual		Kenfig Corp	Dunes west of KP	GR, GA

ID	Desc. (Name)	Locality	Monitored Aquifer / Water Body	Source[1]	Receptor[1]	Pathway[1]	Receptor Group	Pathway for receptors	Alt receptor sites	Alt pathway sites	Response Group[2]	Mon frequency	Mon Method	Critical[1,3]	Land controlled by	Comment	WMP[5]
K2a	Borehole	Kenfig	Sand and Gravel				n/a	K2b, KP, K1b, CC_5, CC_9, K4		17a, 17b, D (new), C (new), B-a, A-a, N (piezo 3), A-b	3	Monthly	Manual		Kenfig Corp	Pathway to Kenfig (S&G aquifer)	GR, GA
K2b	Borehole	Kenfig	Dune Sand				Kenfig	KP, K1b, CC_5, CC_9, K4	CC_5, CC_9, K1b, KP	17a, 17b, D (new), C (new), B-a, A-a, N (piezo 3), A-b, K2a	4	Monthly	Manual		Kenfig Corp	Dunes south west of KP	GR, GA
KP[4]	Pond (Kenfig Pool)	Kenfig	Surface water (Dune Sand/S+G)				Kenfig	K1b, CC_5, CC_9, K4	CC_5, CC_9, K1b, K2b	K1a, N (piezo 3), A-b, K2a, K2b	3	Monthly	Manual		Kenfig Corp		GR, GA
L	Borehole	Merthyr Mawr	Dune Sand				n/a	34, 61, D4, D7, D8		T_95/11, T, G	4	Monthly	Manual		Merthyr Mawr Estate	Limestone aquifer in dry dunes area	
N (piezo 3)	Borehole	Kenfig	Limestone				n/a	K2b, KP, K1b, CC_5, CC_9, K4		17a, 17b, D (new), C (new), B-a, A-a, A-b, K2a	3	Monthly	Manual		Private	Note – piezometers installed at 3 levels in this hole but all currently show almost exactly the same level	GR, GA
PM	Sump	Pant Mawr	Surface water (Lst)				n/a	None (mitigation measures)		n/a	1	Daily	Auto		Tarmac		GR, GA
S	Borehole	Cornelly Quarry	Limestone				n/a	None		n/a	2	Monthly	Manual		Tarmac	New borehole	
T	Borehole	Newton Down	Limestone				n/a	34, 61, D4, D7, D8		T_95/11, G, L	3	Daily	Auto		Private	New borehole. Limestone to south of Cornelly	
T_95/01	Borehole	Airfield, Cornelly Quarry	Limestone				n/a	34, 61, D4, D7, D8		T, G, L	2	Daily	Auto		Private	Limestone to east of Cornelly	

ID	Desc. (Name)	Locality	Monitored Aquifer / Water Body	Source[1]	Receptor[1]	Pathway[1]	Receptor Group	Pathway for receptors	Alt receptor sites	Alt pathway sites	Response Group[2]	Mon frequency	Mon Method	Critical[1,3]	Land controlled by	Comment	WMP[5]
U shallow	Borehole	Merthyr Mawr	Dune Sand				n/a	D4, D7, D8		U deep, T95/01, T, 34, 61, G, L	4	Monthly	Manual		Merthyr Mawr Estate		
U deep	Borehole	Merthyr Mawr	Limestone				n/a	D4, D7, D8		U shallow, T95/01, T, 34, 61, G, L	4	Monthly	Manual		Merthyr Mawr Estate		

1. Shaded = “yes”, unshaded = “no”
2. The Response Group reflects how rapidly the site responds to changes in level at the Quarry (1 is most rapid and 4 least rapid). The corresponding monitoring frequency is based on the rapidity of response so that responses can be seen in days for Group 1 whereas they may take months or years for Group 4.
3. Critical sites are defined in Section 1 and further discussion of site criticality is made in Section 4.1.1..
4. These sites are currently monitored by third parties. These are considered to be the most critical data sets collected by third parties and require a rapid response by the Quarry Operator should third party monitoring cease. Note that whilst Grove is currently operated by Tarmac, the monitoring is treated as third party as this could conceivably change in future.
5. Sites that are also included in the monitoring requirements of Grove and Gaens’ WMPs are noted (GR - Grove, GA - Gaens’)

It is assumed that as part of the separate water management plans for Grove Quarry and Gaens' Quarry that there will be a requirement for water monitoring at sumps within respective operational quarry areas, and that the information arising from such monitoring will be disseminated between the Quarry companies as a continuation of the current joint approach to assessing the hydrogeological effects of both the individual and cumulative quarrying operations.

Monitoring of Receptors is subject to the agreement of the owners of the site and it is assumed that, as the monitoring is in their interest, this can be arranged by the Quarry Operator without any excessive penalties. Monitoring has only been proposed at those Receptors at which effects have been predicted from the proposed activities at the Quarry (SLR, 2014).

Monitoring at some of the Pathway sites is subject to ongoing agreements with the relevant landowners. These agreements cannot be guaranteed by the Quarry Operator in the long term. Procedures for dealing with a site that becomes unavailable for monitoring are given in Section 4.2.3.

The reference datum of each water level monitoring site will be re-surveyed at ten year intervals or at any point at which there is a step change in monitored water levels which might indicate that the datum has changed.

The depth of each borehole or dip well will be checked annually immediately prior to the issue of the Annual Report.

To ensure that the risk of lost data is minimised, there should always be two replacement loggers located at the Quarry site offices for use in the event of logger failure.

A.3 Surface Water Flows

The network of surface flow monitoring sites is shown on Figure A.1 and listed in Table A.3. All of these sites are defined as Receptor Monitoring Sites.

Table A.3 Stream Flow Monitoring

ID	Name	Type	Frequency
HL 6	Afon Fach	Stream	Monthly in summer
HL 11	Stormy Spring	Ephemeral Spring	Monthly in winter
HL13	Candleston spring	Ephemeral Spring	Monthly in winter
HL14	Candleston spring	Ephemeral Spring	Monthly in winter
HL 15	Burrows Well	Ephemeral Spring	15 minutes

Note: Summer in the context of this table includes the period April-September each year. Winter includes the period October to March.

A.4 Rainfall (Background)

The Quarry Operator will monitor rainfall in the Quarry by means of a tipping bucket rain gauge linked to a data logger to allow values to be measured at 15 minute intervals.

Rainfall is also monitored by Natural Resources Wales at Schwyll STW, Llety Brongu and Margam and by Bridgend County Borough Council at Kenfig (see more details of these sites in Appendix D). Until the Quarry Operator has collected sufficient data from the new rain gauge to allow a good correlation with data from these existing sites, for the purposes of understanding the relationship between current rainfall and historical rainfall, continuation of monitoring at these sites by third parties is essential to the operation of the WMP.

A.5 Groundwater Quality

Water samples will be collected as set out in Table A.4.

Table A.4 Water Quality Monitoring Sites

ID	Name	Type	Frequency	Sampling Method
CL	Cornelly Lagoon	Source	Monthly	Pumped/sump

Each sample will be analysed for the following parameters:

Field Parameters — Temp, EC, pH, Alkalinity

Laboratory Determinands — Major Ions (Ca, Mg, Na, K, Cl, HCO_3, SO_4, NO_3, NH_4, Sr)

A.6 Monitoring by Third Parties

Some hydrometric monitoring is carried out in the area by third parties as listed in Table A.5. The locations of the Critical sites are shown on Figure A.2.

The continuation of this monitoring is of benefit in providing additional information on the hydrogeological conditions in the area. Third party data that are considered to be Critical to the operation of the WMP are highlighted in **Bold** in Table A.5. These sites are duplicated in Sections A.2 to A.4 as appropriate.

Table A.5 Monitoring by Third Parties

ID	Name	Monitoring Activity	Frequency	Third Party
GRS	**Grove Quarry Sump**	**Pumping Rates**	**-**	**Quarry Operator[1]**
GRS	**Grove Quarry Sump**	**Water Level**	**-**	**Quarry Operator[1]**
GAS	**Gaens' Quarry Sump[17]**	**Pumping Rates**	**-**	**Quarry Operator[2]**
GAS	**Gaens' Quarry Sump**	**Water Level**	**-**	**Quarry Operator[2]**
SC	South Cornelly	Water Levels	15 minutes	Natural Resources Wales
KP	**Kenfig Pool**	**Water Levels**	**15 minutes**	**Natural Resources Wales**
	Schwyll Spring rain gauge	**Rainfall**	**Daily**	**Natural Resources Wales**
	Llety Brongu rain gauge	**Rainfall**	**Daily**	**Natural Resources Wales**
	Margam rain gauge	**Rainfall**	**Daily**	**Natural Resources Wales**
CC_3,2	**Kenfig rain gauge**	**Rainfall**	**Weekly**	**Nature reserve staff**
I_BH18	Tythegston Landfill	Water Levels	Monthly	Landfill operator
I_COTTAGE	Tythegston Landfill	Water Levels	Monthly	Landfill operator
I_ROAD	Tythegston Landfill	Water Levels	Monthly	Landfill operator
I_TUSCA	Tythegston Landfill	Water Levels	Monthly	Landfill operator
I_WOODS	Tythegston Landfill	Water Levels	Monthly	Landfill operator
CC_1	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC

[17] Note – Dewatering at Gaens' Quarry has not yet started and so there is currently no monitoring of the sump level of dewatering rates

ID	Name	Monitoring Activity	Frequency	Third Party
CC_2	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_24e	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_3	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_3,2	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_3,2	Kenfig Dunes	Rain Gauge	Twice weekly	Bridgend CBC
CC_3,2a	Kenfig Dunes	Water Levels	Daily	Bridgend CBC
CC_34	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_4	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_5	**Kenfig Dunes**	**Water Levels**	**Monthly**	**Bridgend CBC**
CC_6	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_6,1	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_7	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_8	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_9	**Kenfig Dunes**	**Water Levels**	**Monthly**	**Bridgend CBC**
CC_10	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_11	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_117	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_12	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_139	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
CC_A0124	Kenfig Dunes	Water Levels	Monthly	Bridgend CBC
D1	Sewage treatment plant	Water Levels	Monthly	NRW
D2	Candleston Stream	Water Levels	Monthly	NRW
D3	Slack3	Water Levels	Monthly	NRW
D4	**Slack2**	**Water Levels**	**Monthly**	**NRW**
D5	Slack1 East	Water Levels	Monthly	NRW
D6	Slack1 mid	Water Levels	Monthly	NRW
D7	**Flood plain**	**Water Levels**	**Monthly**	**NRW**
D8	**Slack1 West**	**Water Levels**	**Monthly**	**NRW**
MM1	**Merthyr Mawr Ist**	**Water Levels**	**Monthly**	**NRW**

1. At present Grove Quarry is not operational. The Quarry Operator is Tarmac Ltd. In future Grove Quarry will operate under its own WMP. The Monitoring requirements of that WMP have not been set yet.
2. At present there is no dewatering ongoing at Gaens' Quarry. The Quarry Operator is Rees and Sons. In future Gaens' Quarry will operate under its own WMP. The Monitoring requirements of that WMP have not been set yet.

Procedures for the situation where a third party ceases to monitor a site or does not make the information available or where the Quarry Operator considers that the QA procedures being applied do not conform to the requirements of Appendix B are set out in Section 4.2.4 of the WMP.

A.6 Additional Monitoring Under Different WMPs

Although not required under this WMP, some additional hydrometric monitoring will be carried out in the area under different WMPs (Grove and Gaens Quarry WMPs) as listed in Table A.6. The locations of these sites are shown on Figure A.2.

Table A.6 Additional Monitoring Under Different WMPs

ID	Name	Monitoring Activity	Frequency	WMP[1]
14[2]	Royal Porthcawl Golf Club	Borehole	Monthly	Gr, Ga
18b	Ty Talbot Farm	Borehole	Monthly	Gr
36 A[3]	Royal Porthcawl Golf Club	Borehole	Monthly	Gr, Ga
36 B[3]	Royal Porthcawl Golf Club	Borehole	Monthly	Gr, Ga
40	Grove Golf Club	Borehole	Daily	Gr, Ga
E		Borehole	Daily	Ga
O		Borehole	Monthly	Gr, Ga
P		Borehole	Daily	Gr, Ga
Q		Borehole	Monthly	Ga
R		Borehole	Monthly	Gr, Ga
RWC105		Borehole	Daily	Gr
RWC106		Borehole	Daily	Gr
HL9A1	u/s New Mill springs	Stream Gauging	Monthly in summer	Gr, Ga
HL9B	d/s New Mill Springs	Stream Gauging	Monthly in summer	Gr, Ga
GAS	Grove sump	Water quality	Monthly	Gr
GRS	Gaens sump	Water quality	Monthly	Ga

[1] Ga-Gaens', Gr-Grove
[2] Existence to be confirmed. To be removed from schedule if not present
[3] Collectively referred to as "36" in previous revisions of this document

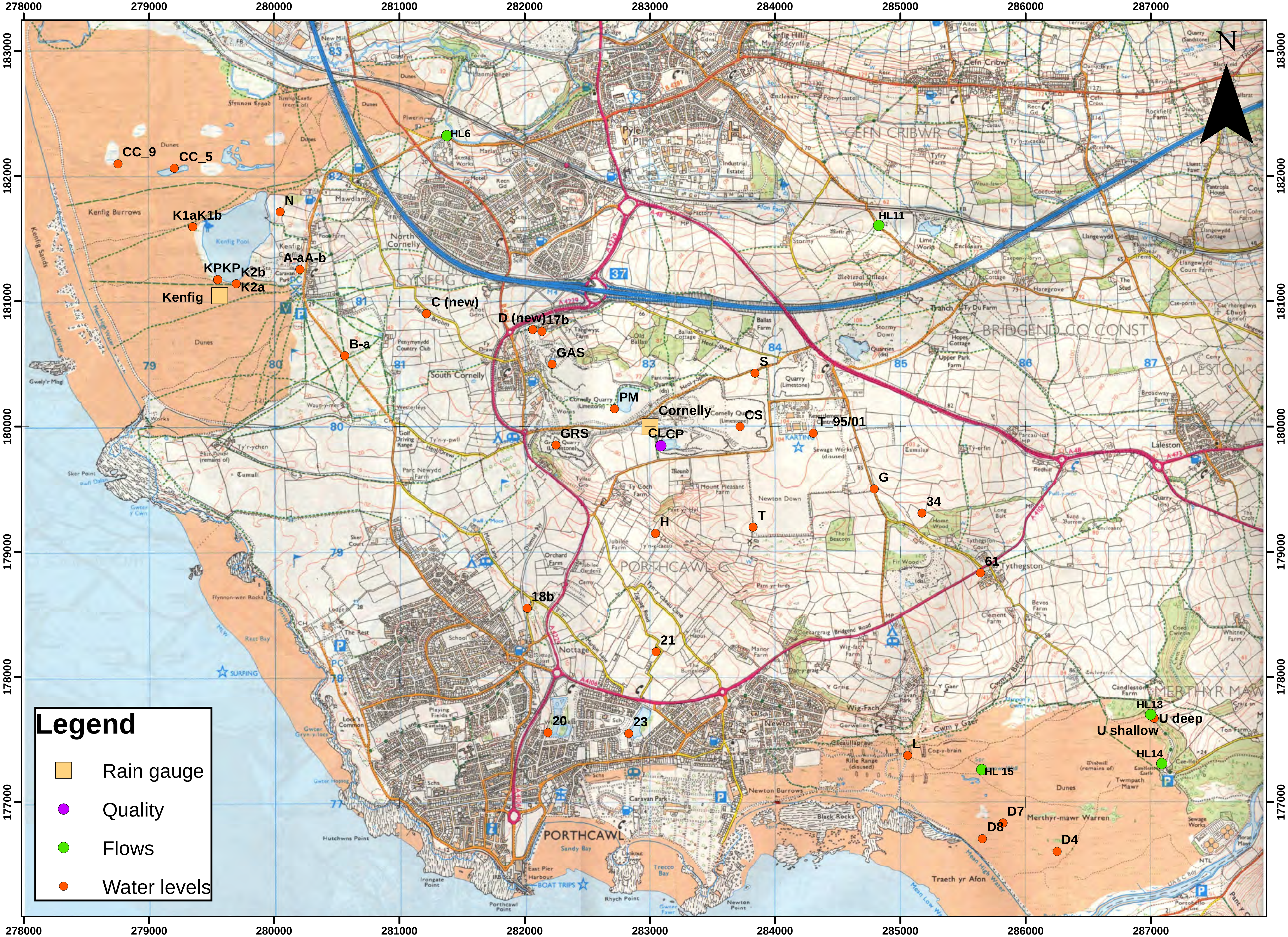


Figure A.1
Tarmac and critical 3rd party monitoring points for Cornelly Quarry under this WMP

Date	Aug 2015	Drawn	KHB
Scale	1:30,000	Checked	MJS
Original	A3	Revision	7

File Reference
O:\6227_Cornelly\reports\R17 EIA\Post submission WM \Figures\Figure A1_ cornelly Rev6 (Cornelly WMP 5.3)

esi Environment Specialists

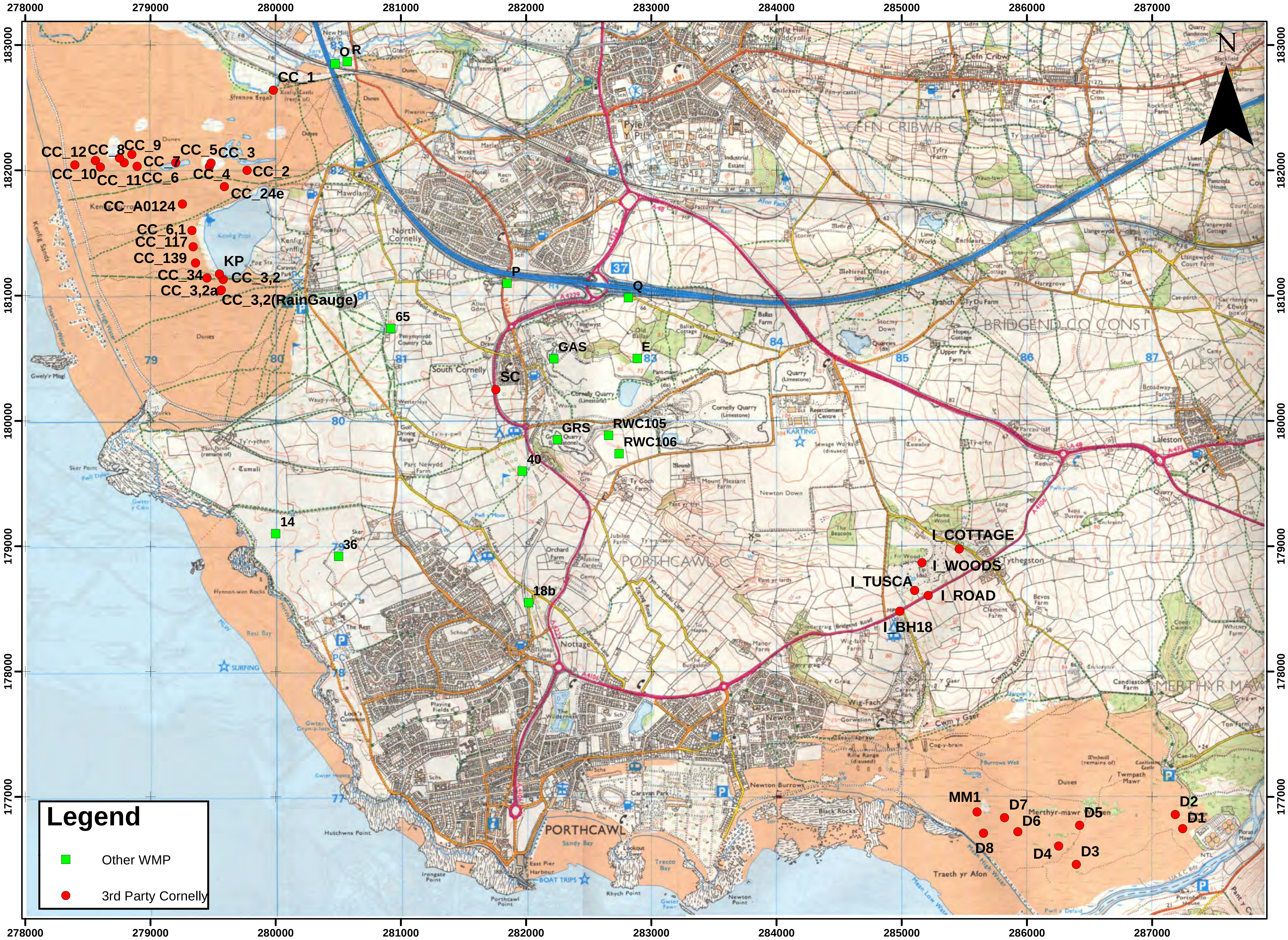


Figure A.2
3rd Party monitoring points for Cornelly Quarry WMP
and monitoring under Grove and Gaens' WMPs

Date July 2015	Drawn KHB
Scale 1:30,000	Checked MJS
Original A3	Revision 4
File Reference O:\6227_Cornelly\reports\R17 EIA\Post submission WMP\Figures\Figure A2_ cornelly Rev4	

Environment Specialists

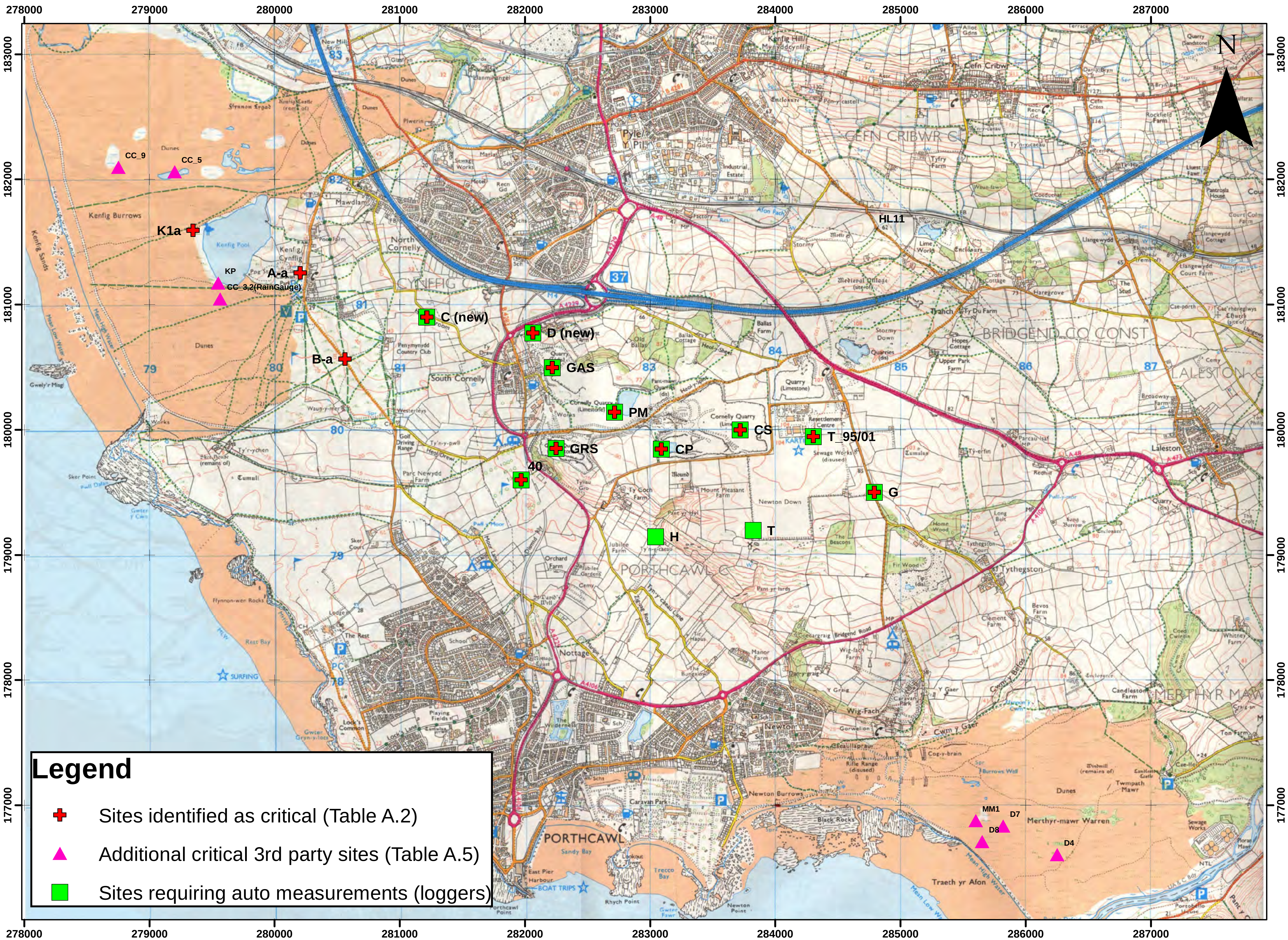


Figure A.3
Location of auto (Logger) and critical groundwater level sites for Cornelly Quarry under all WMPs

Date August 2015	Drawn KHB
Scale 1:30,000	Checked BCH
Original A3	Revision 2
File Reference O:\6227_Cornelly\reports\R17 EIA\Post submission WMP\Figures\Figure A3_ cornelly Rev2 (Cornelly WMP 5.4).mxd	

Appendix B Quality Assurance (QA) Requirements

A rigorous approach will be adopted to ensuring the quality of all data collected during the monitoring period.

B.1 General Procedures

Quarry Abstractions: New meters have been fitted at the site and discussion with the manufacturers has indicated that the meters are within their calibration period. Meters will be re-calibrated as recommended by the manufacturers.

Water Levels: All monitoring datum points have been accurately surveyed in. All recent boreholes have been logged in detail (using geophysics in many cases) and constructed over selected intervals. A carefully designed field monitoring sheet is used for all field records (see example sheet). Water levels measured by data loggers are compared with manual readings on a monthly basis and any differences recorded and the loggers re-set. Water level measurements will comply with relevant sections of BS 6316: 1992.

A backup resource of two data loggers will be maintained to ensure continuity of monitoring.

Water Quality: All field measurements will be carried out to a standard specification using calibrated instruments. Laboratory analysis will be carried out by UKAS accredited laboratories.

Stream Flow Monitoring: The stream gauging exercise will be carried out as prescribed in BS 3680 Part 3Q: 1993.

An important part of QA for any monitoring network is regular review of the data (see Section 5).

B.1 Specific Monthly QA Checks

The Quarry Operator will apply a monthly QA check to the data collected. The details of these checks will be collated and presented in the Annual Report (Section 5.1). The monthly QA checks will include:

- An assessment of the completeness of the dataset. Where data are missing, recommendation consistent with the steps described in Section 4.2 will be taken.
- An assessment of any modifications to Planned Mitigation Measures that may be required.
- An assessment as to whether any of the information collected suggests that Contingency Measures are required (see Section 8 for a definition of what triggers Contingency Measures).

Cornelly Quarry water monitoring scheme; Record of monthly manual measurements

Date: 26th & 27th June '06

Weather at time of visit : 26th - Light rain, 27th - Dry

Weather during previous '24hrs : 25th - Dry with some rain overnight

Operative: J.Linton

Date	Time	Reference	Location Description	Water Level (m below datum):	Additional Notes		Comments			
26/06/2006	11:30	**95/01**	Cornelly (Airfield)	38.29	Level reported by logger:	38.419	Logger downloaded:	OK	Battery:	99.05%
26/06/2006	11:25	**CR96/11**	Cornelly (Airfield)	63.38						
		95/04	Cornelly (Stormy)				Submerged			
26/06/2006	09:15	**RWC100**	Grove	21.15	Level reported by logger:	21.123	Logger downloaded:	OK	Battery:	94.12%
26/06/2006	16:05	**A(1)**	50mm Blue Pipe	15.48						
		A(2)	20mm Black Pipe	14.11						
26/06/2006	16:10	**B(1)**	50mm Blue Pipe	23.1						
		B(2)	20mm Black Pipe	2.38						
26/06/2006	15:55	**C**		29.78						
26/06/2006	15:45	**D**		16.37						
26/06/2006	14:25	**G**		15.76	Note any ground water across field?		None			
26/06/2006	14:05	**H**		33.78	Level reported by logger :	33.801	Logger downloaded:	OK	Battery:	65.58%
26/06/2006	14:55	**I**		Below	Blockage at 4.7m					
26/06/2006	14:50	**L**		1.45						
27/06/2006	12:10	**K1 50mm**		2.28						

		K1 25mm		0.57		
27/06/2006	11:45	**K2 50mm**		1.79		
		K2 25mm		1.65		
27/06/2006	11:45	**K3**		4.01		
27/06/2006	11:55	**N1 50mm**		4.01		
		N2 25mm		4.02		
		N3		3.99		
27/06/2006	14:00	**36(A)**	50mm Blue Pipe	16.13	Note Last Pumping Period	Last used 25/06/2006
		36(B)	20mm Black Pipe	Dry		
27/06/2006	10:05	**17**	Pond	0.1	Gauge Board	
27/06/2006	10:00	**17b**	Private Well	34.34		
26/06/2006	15:30	**20**	Pond	1.625		
26/06/2006	15:25	**23**	Pond	1.10		
26/06/2006	14:30	**34**	Pond	0	Gauge Board	
26/06/2006	14:35	**35**	Pond	Dry	Gauge Board	
26/06/2006	15:40	**40**	Well	17.77		Alternate borehole
26/06/2006	11:05	**Cornelly Pond**	Settlement Pond	4.28	Dipped from top of gauge board support	
26/06/2006	09:25	**Grove Sump**	Pond	0.48	Dipped from top of gauge board support	
		Pant Mawr	Pond	H&S Access Issues	Dipped from top of gauge board support	
		Stormy Down	Pond	H&S Access Issues		

Appendix C Assessment Criteria

C.1 Trigger Levels

Trigger Level Assessment Criteria have been defined for all for water level monitoring sites for which the development of Climate Based Assessment Criteria are not judged to be appropriate at present.

The Trigger Level Assessment Criteria set out in Table C.1 have been defined based on the minimum water level recorded at these sites in 2005 (a period of low groundwater level). Note that this excludes sites for which there was insufficient data in 2005 or for sites defined as Source monitoring points.

Table C.1 Trigger Levels Based on Summer 2005 Levels

ID	Trigger Level (mAOD)	Comment
17a	48.7	Pond
20	2.9	Pond
21	5.1	Tidal fluctuations.
23	3.7	Pond
34	65.2	Well dries up each year
61	-	No monitoring to date
A-b	-	Perched – dries up each summer
H	3.31	Tidal fluctuations.

C.2 Climate Based Assessment Criteria

The Climate Based Assessment Criteria for the remaining water level monitoring sites are illustrated in the following sheets and comments on the CBAC models are provided in Table C.2.

Table C.2 Climate Based Assessment Criteria

ID	Name/ Setting	Rainfall station	Description and recommendations	Overall quality of fit	WL trends observed	Cu-sum thresh old range	Std Dev error (of baseline data) (m)	Baseline data	Data excluded from baseline*
17b	Well	Margam	Abstraction well affected by periods of pumping; outlying low water level values are treated as suspect data. Under prediction of summer low levels in 2013 and of winter peak levels throughout.	Good	None	-10, 10	3.11	March 2002 – September 2014 (excluding pumping affected data)	17 measured points anticipated to be affected by pumping in the borehole.
40	Well	Margam	Abstraction well affected by periods of pumping; outlying low water level values are treated as suspect data. Model is over-predicting several large winter peaks. Good prediction of summer lows.	Very good	None	-10, 10	2.07	April 2002 – March 2013 (excluding pumping affected data)	03/02/2012 and 25/0202012 data does not reflect known winter high, possible abstraction.
A-a	Triassic	Margam	Data patchy from 2008 to 2013. Good prediction of summer lows.	Very good	None	-10, 10	0.88	September 2002 – March 2015 (not inclusive of excluded and suspect data)	All data pre-September 2002, poor fit to modelled data.19/05/2011 and 29/02/2012 suspect data.
B-a	Triassic	Margam	Under-prediction of peak values in recent years. Good prediction of summer lows.	Very good	None	-10, 10	0.90	September 2002 – March 2015 (not inclusive of excluded data)	All data pre-September 2002, poor fit to modelled data. 25/02/2012 suspect data.
Burrows Well (flow)	Limestone	Margam	Under prediction of winter 2008 high, over prediction of 2012 winter high. Review model calibration once further monitoring data is obtained.	Good	None	-20, 20	0.06 (m/s)	February 2008 – December 2010	January 2008 and all data post-2010, poor fit to modelled data.

ID	Name/ Setting	Rainfall station	Description and recommendations	Overall quality of fit	WL trends observed	Cu-sum thresh old range	Std Dev error (of baseline data) (m)	Baseline data	Data excluded from baseline*
C	Limestone	Margam	Large data gap followed by replacement of borehole. Model is calibrated to old borehole data, calibration to be reviewed following 3 years of new borehole data. Fit to new borehole data (since 2012) is good.	Very good	None	-10, 10	1.43	October 2001 – March 2008	All data from new borehole excluded
CC_5	Kenfig dunes	Kenfig	Under prediction of 2001/02 winter levels. Over prediction of summer 2011 levels. Measured groundwater levels are subject to long-term fluctuations resulting from inherent wet and dry periods.	Good	None	-10, 10	0.14	February 2007 – March 2015 (excluding poor fit data)	All data pre-2007 and March2011 – Oct 2012 data excluded. Higher frequency of monitoring in early data to 1990. Poor fit to modelled data.
CC_9	Kenfig dunes	Kenfig	Under prediction of elevated levels 2007 – 2011 and data over reporting period. Measured groundwater levels are subject to long-term fluctuations resulting from inherent wet and dry periods.	Good	None	-10, 10	0.18	February 2003 – March 2015 (excluding poor fit data)	All data pre-2003 and June 2011 – Dec 2012 data excluded. Higher frequency of monitoring in early data to 1990. Poor fit to modelled data.
D	Limestone	Margam	Large data gap followed by replacement of borehole. Model is calibrated to old borehole data, calibration to be reviewed following 3 years of new borehole data. Fit to new borehole data (since 2012) is good.	Good	None	-10, 10	2.11	January 2003 – April 2009	All data from new borehole excluded
D4	Merthyr Mawr Slack 2	Schwyll	Model is simultaneously under and over-predicting groundwater levels in the period 2007 – 2010.	Very good	None	-10, 10	0.11	January 2010 – March 2015	All data pre-2010, poor fit to modelled data.
E	Limestone	Margam	Location in close proximity to Cornelly and Gaens' quarries. Model fit to match early data - groundwater drawdown over data period (2004-2015).	Very good (baseline data only)	Drawdown of 6.8m over 11 year period	-10, 10	3.95	March 2002 – July 2004	All data post-July 2004 excluded due to declining groundwater trend.

ID	Name/ Setting	Rainfall station	Description and recommendations	Overall quality of fit	WL trends observed	Cu-sum thresh old range	Std Dev error (of baseline data) (m)	Baseline data	Data excluded from baseline*
G	Limestone	Margam	Poor fit to early data, not all summer lows well simulated.	Good	None	-10, 10	4.99	January 2003 – March 2015	All data pre-2003, poor fit to modelled data.
K1a	S&G aquifer	Kenfig	Simulation poor over review period, under-prediction of winter 2014/15 data. Affected by proximity to Kenfig Pool.	Very good	None	-10, 10	0.32	April 2003 – January 2015 (excluding suspect data)	February 2011 – August 2012, suspect data.
K1b	Dunes	Kenfig	Model over-predicting winter 2012/13 water levels and under-predicting 2014 levels. Affected by proximity to Kenfig Pool.	Very good	None	-10, 10	0.16	April 2003 – January 2015 (excluding suspect data)	June 2011 – December 2013, suspect data.
K2a	S&G aquifer	Kenfig	Good match to summer lows, some under prediction of high winter levels. Affected by proximity to Kenfig Pool.	Very good	None	-10, 10	0.43	March 2003 – March 2015 (excluding suspect data)	November 2011 – August 2012, suspect data.
K2b	S&G aquifer	Kenfig	Under prediction of 2014/15 winter water levels. Affected by proximity to Kenfig Pool.	Very good	None	-15, 15	0.42	August 2003 – March 2015 (excluding suspect data)	April 2012 – March 2013, suspect data.
KP	Pond	Kenfig	No change to calibration from previous years due to lack of data since 2010. Recalibrate model once further monitoring data is obtained.	-	-	-	-	-	-

ID	Name/ Setting	Rainfall station	Description and recommendations	Overall quality of fit	WL trends observed	Cu-sum thresh old range	Std Dev error (of baseline data) (m)	Baseline data	Data excluded from baseline*
L	Merthyr Mawr	Schwyll	Review model calibration once further monitoring data is obtained.	Very good	None	-10, 10	0.22	May 2001 – June 2013	None
N-a	Limestone	Margam	Model under-predicts highest peaks. Review model calibration once further summer monitoring data is obtained.	Very good	None	-10, 10	0.30	December 2002 – February 2015 (excluding suspect data)	30/05/2013, 26/06/2013 and 18/09/2013 suspect data.
O-a	Triassic	Margam	Model under predicts highest winter peaks, good match to summer lows.	Very good	None	-10, 10	0.21	October 2002 – March 2015 (excluding suspect data)	07/10/2010, 25/02/2012, 05/06/2013, and 07/05/2014 suspect data. June 2006 – February 2007 poor fit to modelled data.
P	Limestone	Margam	No new data since July 2013 – review model calibration once further monitoring data is obtained.	Very good	None	-10, 10	1.58	January 2004 – July 2013	All data pre-2004, poor fit to modelled data.
Q	Limestone	Margam	No new data since 2013 – review model calibration once further monitoring data is obtained.	Accept-able	None	-10, 10	6.10	October 2002 – May 2013	None
Quarry pumping (Cornelly)	Limestone	Margam	Preliminary CBAC to be finalised following sufficient data from an enhanced monitoring scheme for the quarry.	-	-	-	-	-	-
R-a	Triassic	Margam	Model poorly predicts winter peaks, good simulation to summer lows.	Very good	None	-10, 10	0.19	October 2002 – March 2015 (excluding suspect data)	05/06/2013, suspect data.

ID	Name/ Setting	Rainfall station	Description and recommendations	Overall quality of fit	WL trends observed	Cu-sum thresh old range	Std Dev error (of baseline data) (m)	Baseline data	Data excluded from baseline*
RWC105	Limestone	Margam	Location in close proximity to Cornelly and Grove quarries, early data (1998-2003) affected by pumping. Groundwater levels appear stable from 2004 onwards.	Good	Drawdown of 10 m over 7 years. Levels now stable.	-10, 10	2.63	January 2003 – March 2015	All data pre-2003, data influenced by pumping.
RWC106	Limestone	Margam	Same comments apply as for RWC105.	Good	Drawdown of 6 m over 7 years. Levels now stable.	-10, 10	3.25	January 2003 – March 2015	All data pre-2003, data influenced by pumping. 01/06/2006 and 29/06/2012, suspect data.
South Cornelly	Limestone	Margam	Simulation poor prior to 2003. Large Cu-sum axis due to higher frequency of monitoring. Cu-sum suggests increase in water levels since late 2013.	Good	Increase since late 2013	-300, 300	1.24	Sept 2002 – January 2013	Apr 1995 – March 2002 poor fit to modelled data. March 2002 – Sept 2002 suspect data.
T_95/01	Airfield	Margam	Location in close proximity to Cornelly quarry, early data (1995 – 2003) affected by pumping. Model under predicts winter peaks, summer lows are better simulated. Large Cu-sum axis due to higher frequency of monitoring.	Accept-able	Levels fluctuating pre-2003. Levels now stable.	-300, 300	6.93	January 2003 – March 2015	All data pre-2003, data influenced by pumping.

~A downward value trend (shown as an upward line on the graph) in Cu-sum (Si) statistics indicates that groundwater levels are under-simulated by the model and vice versa.
*Where a poor data fit is present, error statistics are enlarged reducing their sensitivity to groundwater level trends. Such data have been removed where indicated.

Sites for which there are currently insufficient data to define either a Trigger Level or a CBAC are listed in Table C.3 with the sites that are considered to represent conditions at that site.

Table C.3 Sites with Insufficient Data and Alternative Sites

ID	Name/Setting	Nearest representative CBACs/Trigger level	Distance to nearest CBACs/Trigger level location (m)
A-b	Sand and gravel	K2a	520
D7	Dune sand	D4	610
D8	Dune sand	D4	490
S	Limestone	T/95_01	670
T	Limestone	G	1010
U (shallow)	Dune sand	D4	1310
U (deep)	Limestone	L	1990
14	Well	40	2030
65	Well	B-a	1540
18b	Well	40	1050
36	Well	40	1610

C.3 Assessment Criteria for Flow Sites

There is currently insufficient data available from the stream flow monitoring sites (HL6, HL9, Hl11, HL13, HL14, HL15) to allow reasonable Trigger Level or Climate Based Assessment Criteria to be developed. For these sites, Deviations will in the short term be assessed by reference to the Assessment Criteria of nearby water level monitoring sites as set out in Section 6.7.3.

C.4 Assessment Criteria for Quarry Dewatering

As discussed in Section 6.4.3, there is currently insufficient data available from the complex water management system at the Quarry to allow a reasonable Trigger Level or Climate Based Assessment Criteria to be developed. In the short term, Deviation at this site will be assessed by means of the CBACs for water levels in the nearby boreholes.

Runoff Calculation Parameters (Location 17b)

N.B. This is an abstraction well so is affected by pumping

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0.01	0.035	0.275
20	0	0.01	0.025

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1420082	0.01	14
GW	1420082	0.01 fracture	

Rainfall Multiplier 1
PE Multiplier 1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	80	days
T Fast	80	days
Slow store max	100	mm

Stats

Baseline dataset for calculation of error statistics:
March 2002 - September 2014 (excluding pumping affected data)

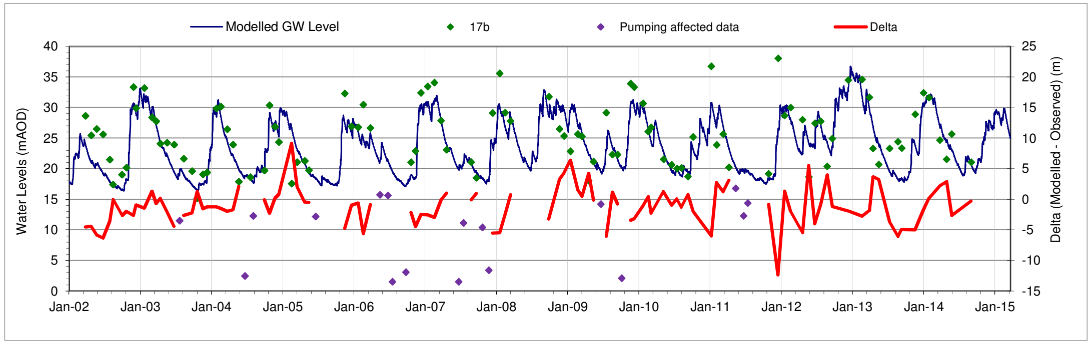
K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-1.08	m
ST Dev Error	3.11	m
Dummy value for Z_i	0	

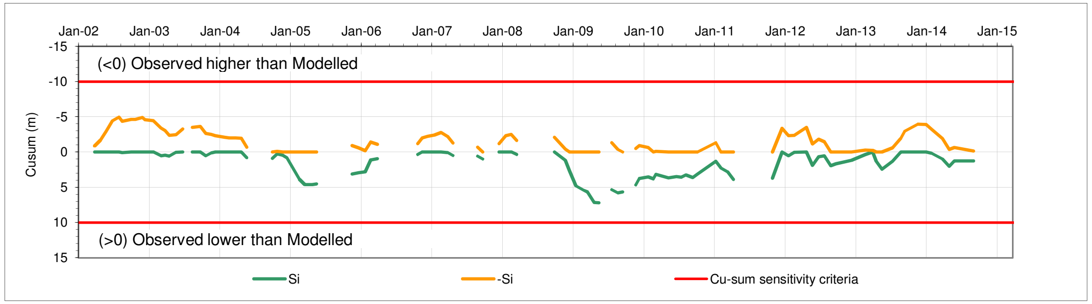
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**5570**

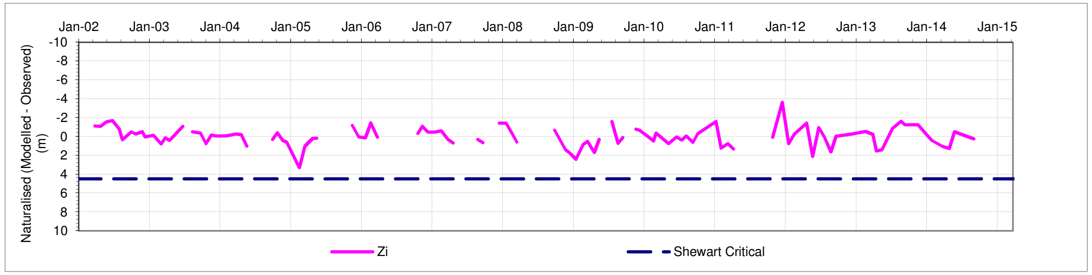
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Location 40)

N.B. This is an abstraction well so is affected by pumping

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	5	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,400,082	0.015	2
GW	1,400,082	0.015 fracture	

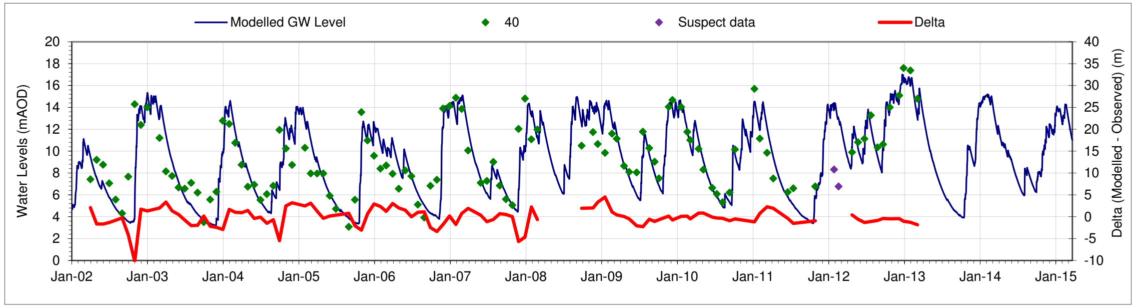
Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

Runoff multiplier	1	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	90	%
T Slow	95	days
T Fast	95	days
Slow store max	150	mm



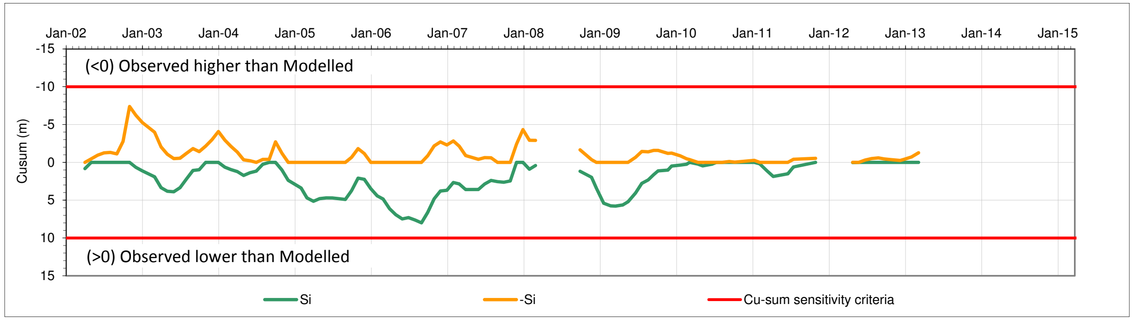
Stats

Baseline dataset for calculation of error statistics:
April 2002 - March 2013 (excluding suspect data)

K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.16	m
ST Dev Error	2.07	m
Dummy value for Z_i	0	

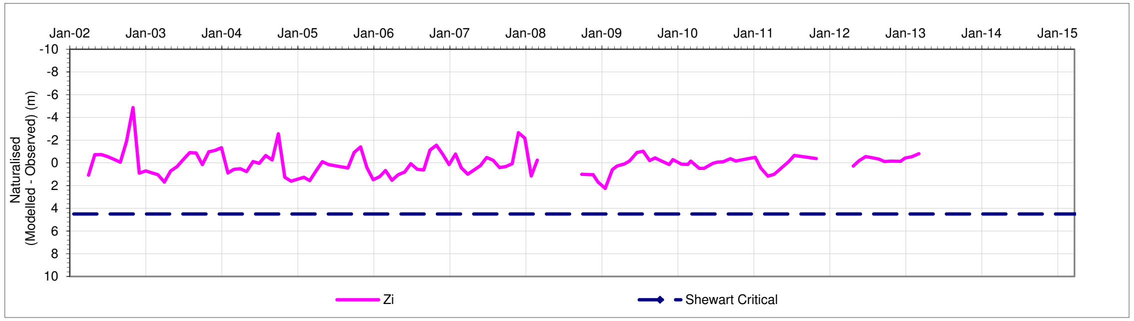
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**1953**

* If PEST is used - PEST and spreadvalues should be equal, showing consistant calculations



PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	



Runoff Calculation Parameters (Location A-a)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.30
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0.00	0.00	0.00
20	0.00	0.00	0.00

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1 SW discharge
0 GW discharge

Number of days 10682.00

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.033	7.500
GW	1,756,799	0.033 fracture	

Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	90	%
T Slow	93	days
T Fast	93	days
Slow store max	150	mm

Stats

Baseline dataset for calculation of error statistics:
September 2002 - March 2015 (excluding pumping affected data)

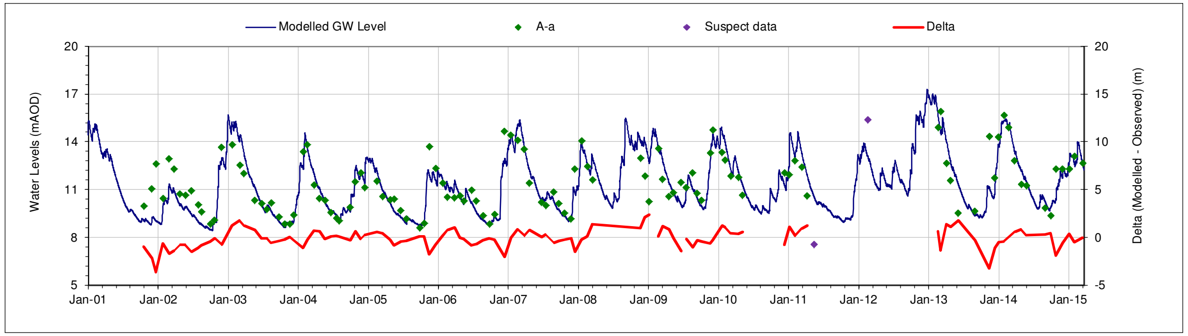
K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	0.08	m
ST Dev Error	0.88	m
Dummy value for Z_i	0	

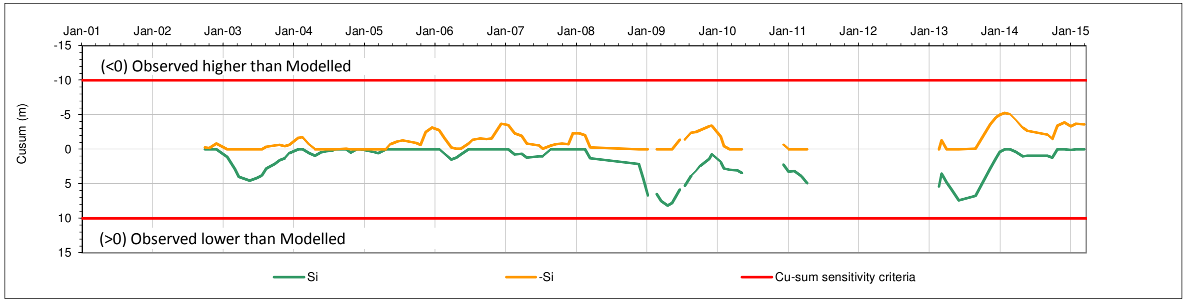
Phi_calibration - last loaded PEST run	n/a
Phi_calibration - spreadsheet calcs	668

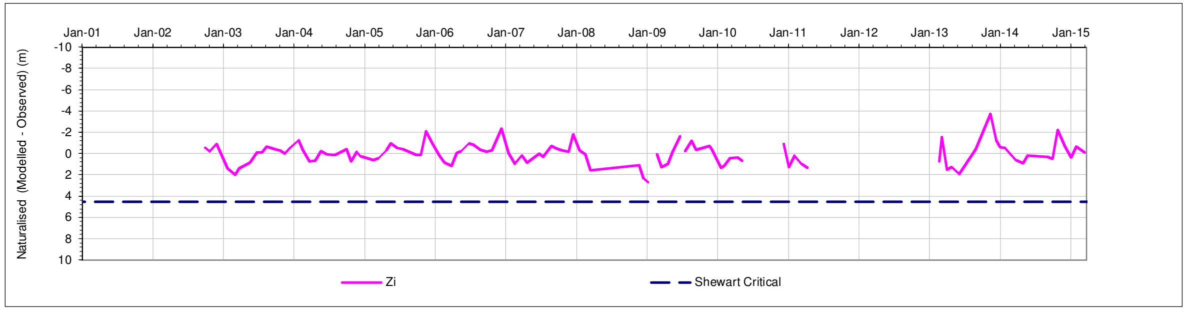
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Location B-a)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.04	5.7
GW	1,756,799	0.04 fracture	

Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	90	%
T Slow	90	days
T Fast	90	days
Slow store max	150	mm

Stats

Baseline dataset for calculation of error statistics:
September 2002 - March 2015 (excluding suspect data)

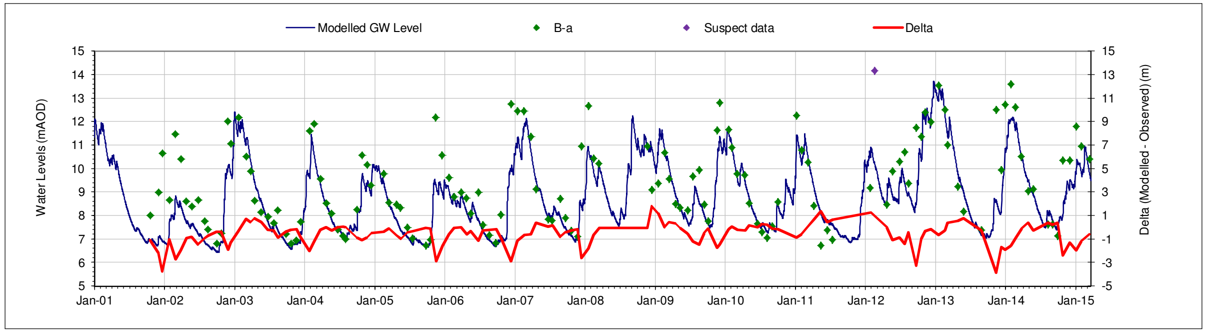
K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.46	m
ST Dev Error	0.90	m
Dummy value for Z_i	0	

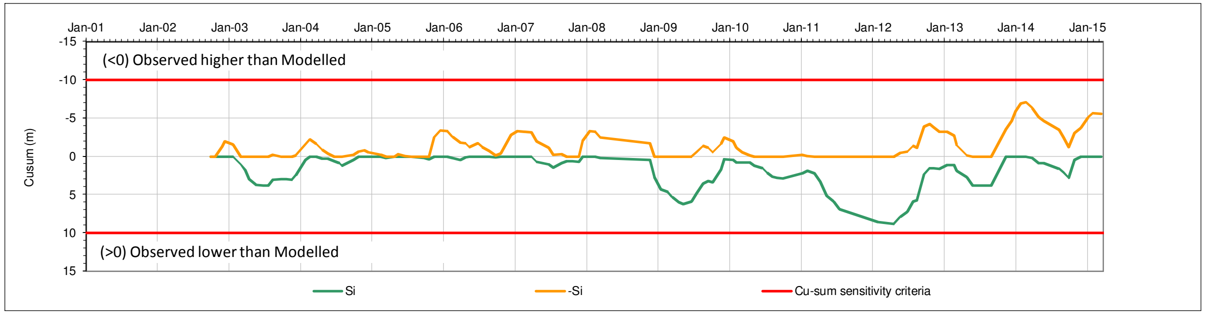
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**762**

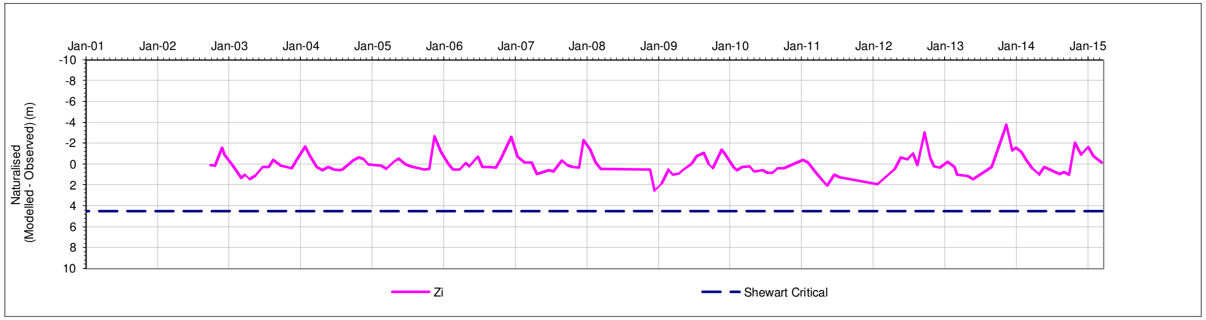
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Burrows Well)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	10	0.3

SMD1_start (mm)	SMD2_start (mm)
0	0

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Schwyll

General parameters | **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	2,500,000	0.002	45
GW	2,500,000	0.002	

Rainfall Multiplier	1
PE Multiplier	1
Runoff multiplier	1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

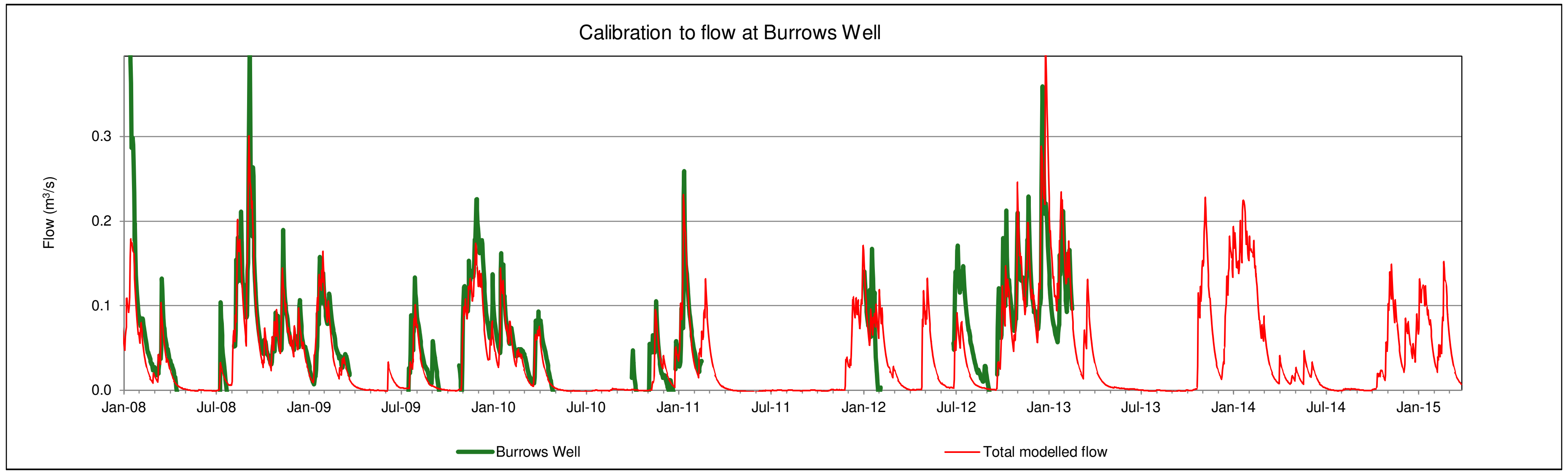
Stores Parameters

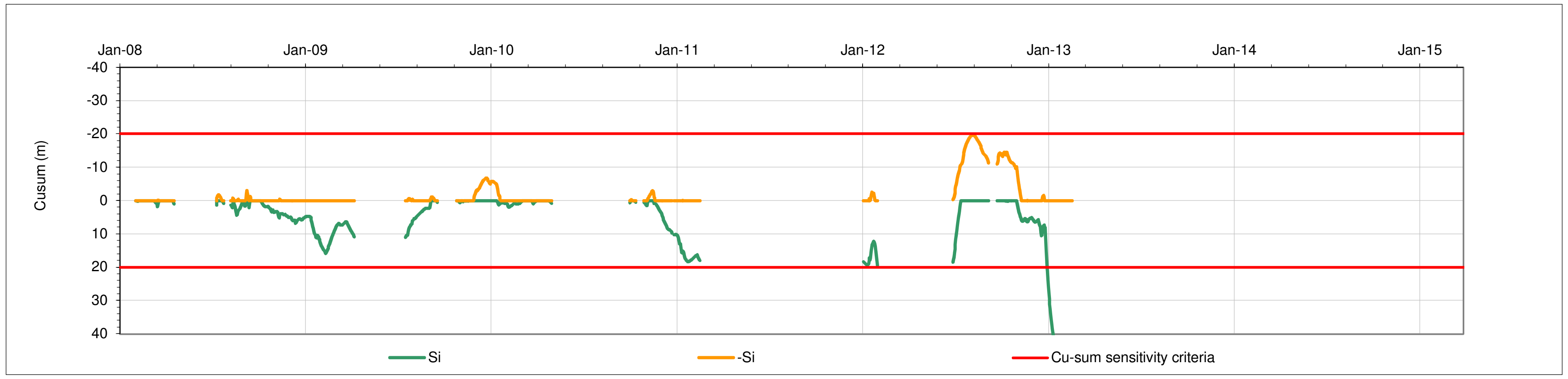
% Slow	100	%
Fast_store_Starting_Volume	0	mm
Slow_store_Starting_Volume	0	mm
GW_Abstractions__Ml_d	0	Ml/d
Slow_flow_split	1	-
Slow_store_max	200	mm
TFast	70	days
TSlow	10	days

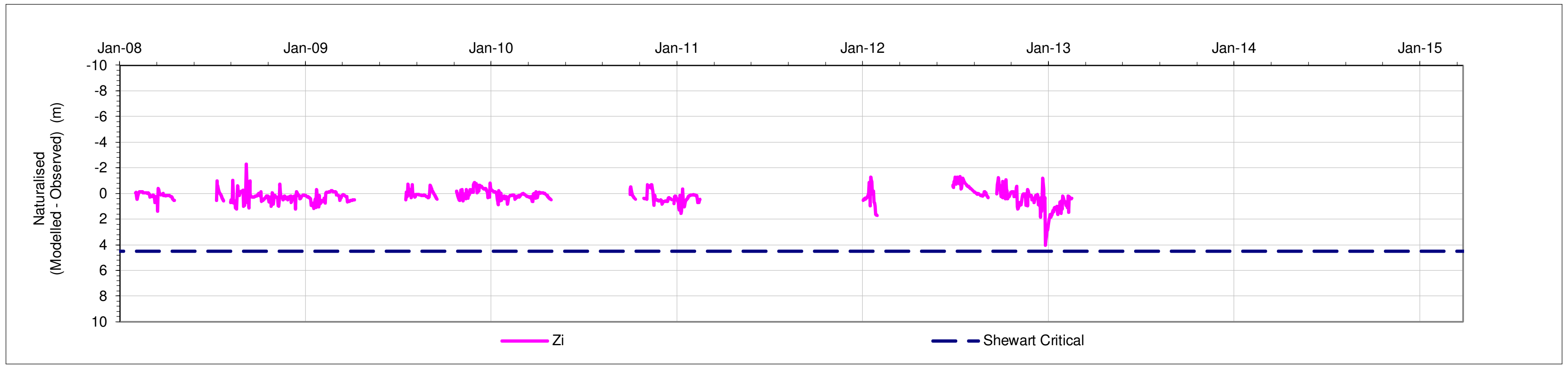
Baseline dataset for calculation of error statistics:
February 2008 - December 2010

K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.02	m3/s
ST Dev Error	0.05	m3/s
Dummy value for Z_i	0	

LTA Burrows Well flow rate *January 1986 - April 2015*	0.04	m3/s
Actual average Burrows Well flow rate *January 2008 - February 2013*	0.09	m3/s







Runoff Calculation Parameters (Location C)

N.B. Model is calibrated to Old borehole C only

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters | **Head Change Calculation**

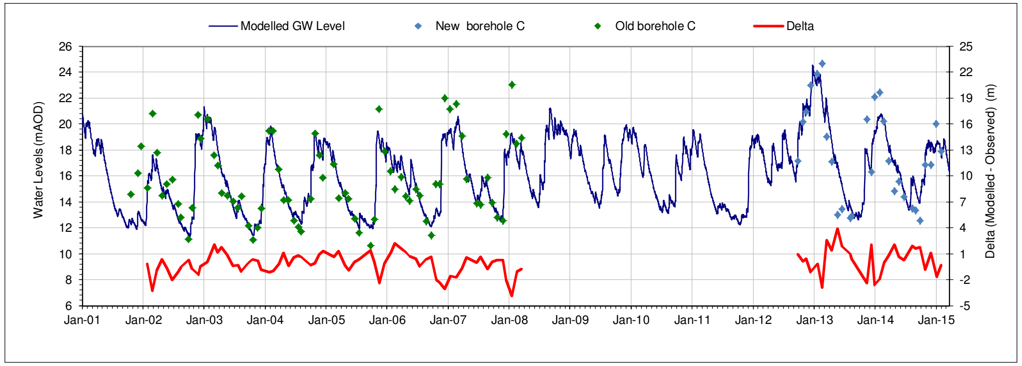
	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.013	8.8
GW	1,756,799	0.013 fracture	

Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	100	days
T Fast	100	days
Slow store max	60	mm



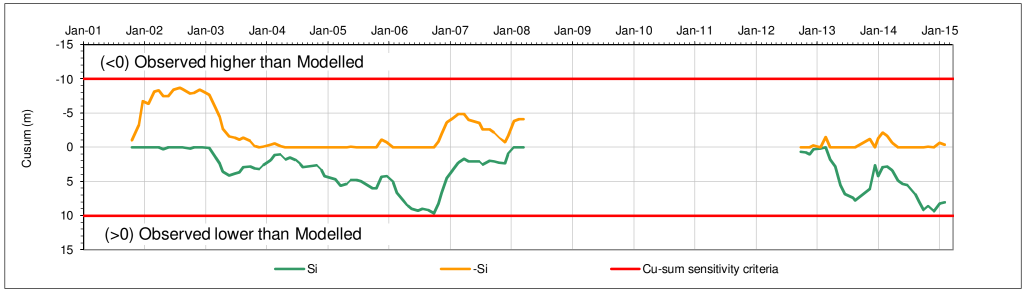
Stats

Baseline dataset for calculation of error statistics:
October 2001 - March 2008

K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.33	m
ST Dev Error	1.43	m
Dummy value for Z_i	0	

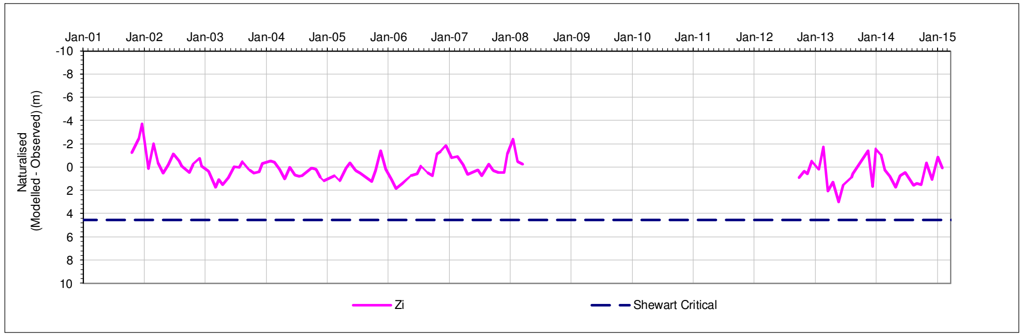
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**581**

* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations



PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	



Runoff Calculation Parameters (CC_5)

N.B. K value for dune sand CBACs is lower than the standard (0.25 m)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Kenfig

GW Abstractions (Ml/d)

0	

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	3,560,000	0.2	9.5
GW	3,560,000	0.2 fracture	

Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

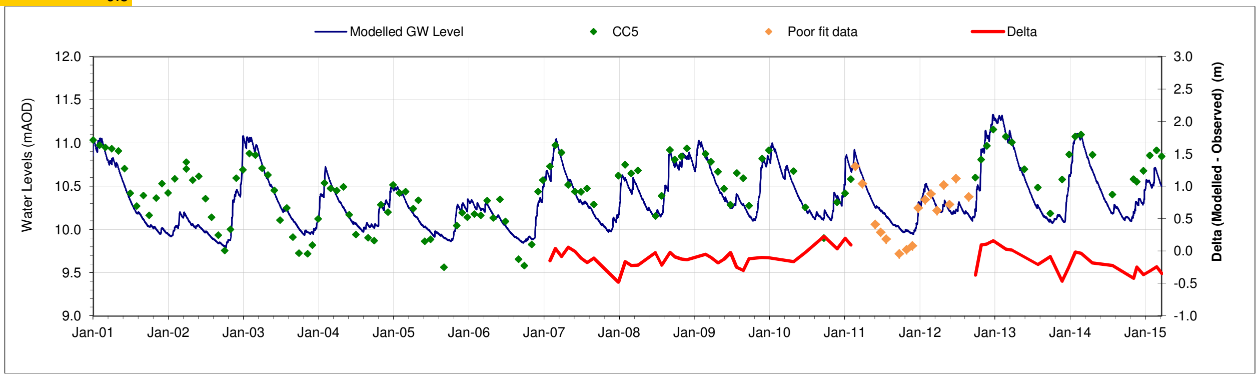
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

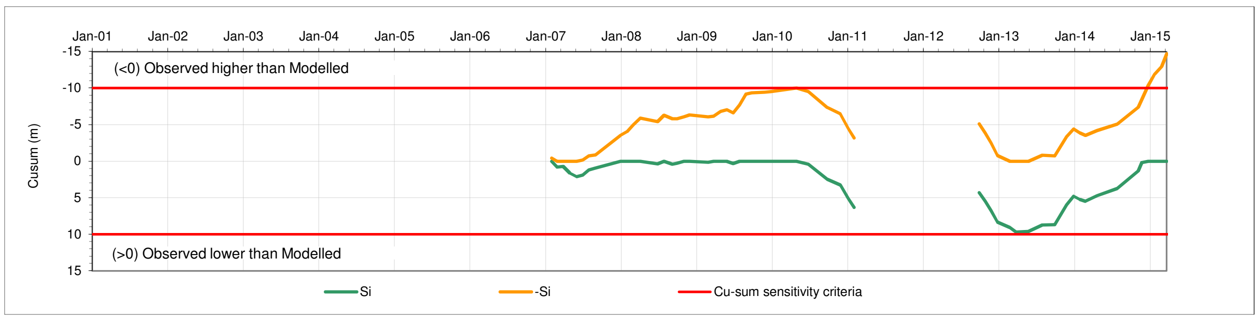
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	150	days
T Fast	150	days
Slow store max	200	mm

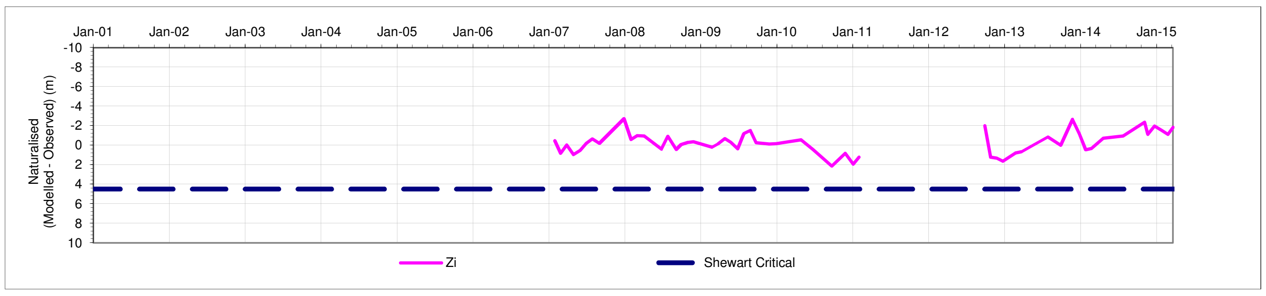
Stats

Baseline dataset for calculation of error statistics:
February 2007 - March 2015 (excluding poor fit data)

K (not permeability!!)	0.05	m
Mean Error (Modelled - Observed	-0.08	m
ST Dev Error	0.14	m
Dummy value for Z_i	0	

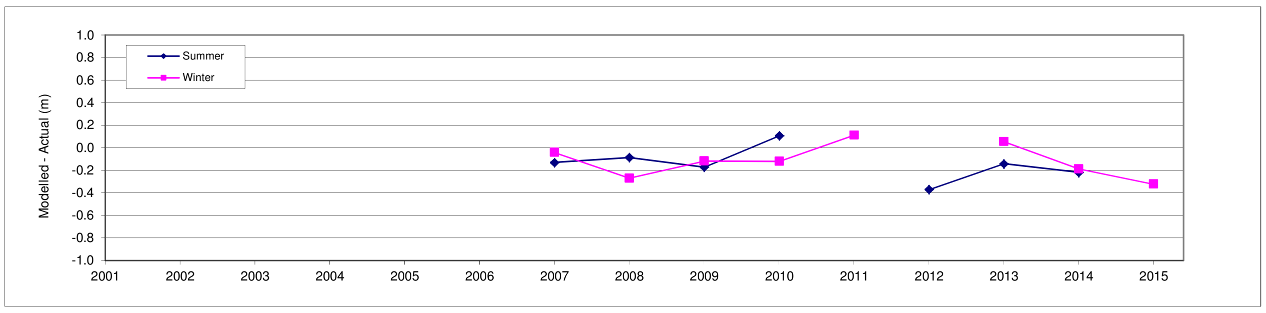


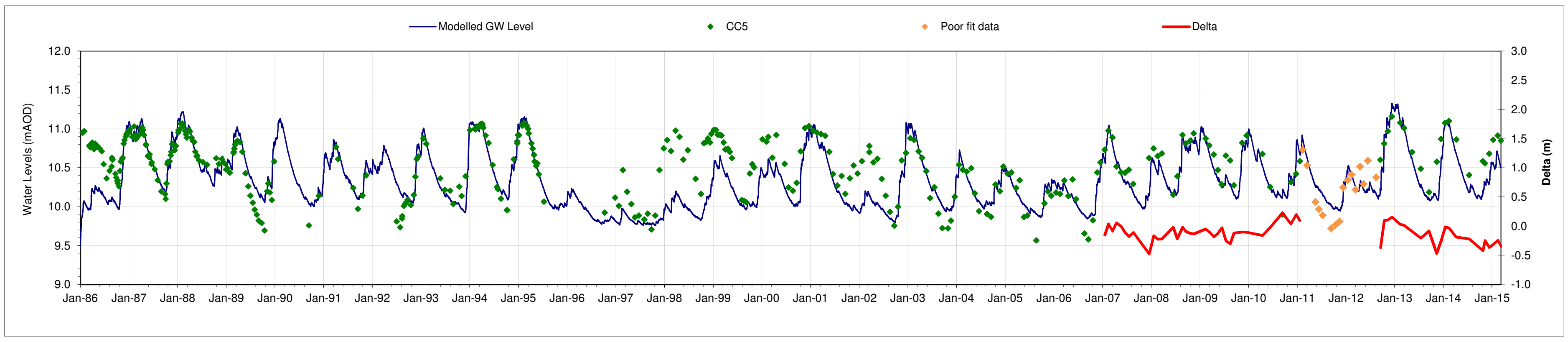




NOTE: Summer goes from July to October Included;
Winter goes from November to June the following year.

Mean summer error	-0.15	m
Max Summer error	0.11	m
Min Summer error	-0.37	m





Runoff Calculation Parameters (Location CC_9)

N.B. K value for dune sand CBACs is lower than the standard (0.25 m)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Kenfig

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

Rainfall Multiplier 1
PE Multiplier 1

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	3,560,000	0.18	8.1
GW	3,560,000	0.18 fracture	

User-defined time series

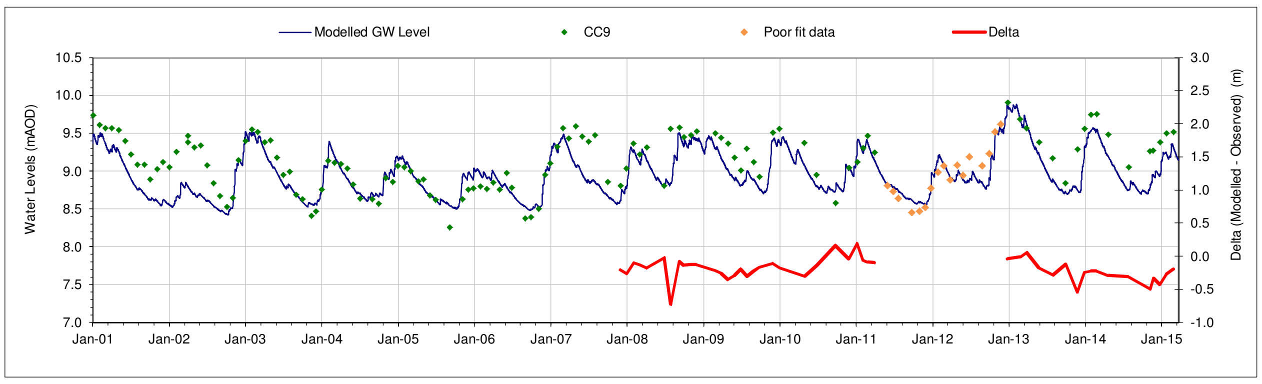
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

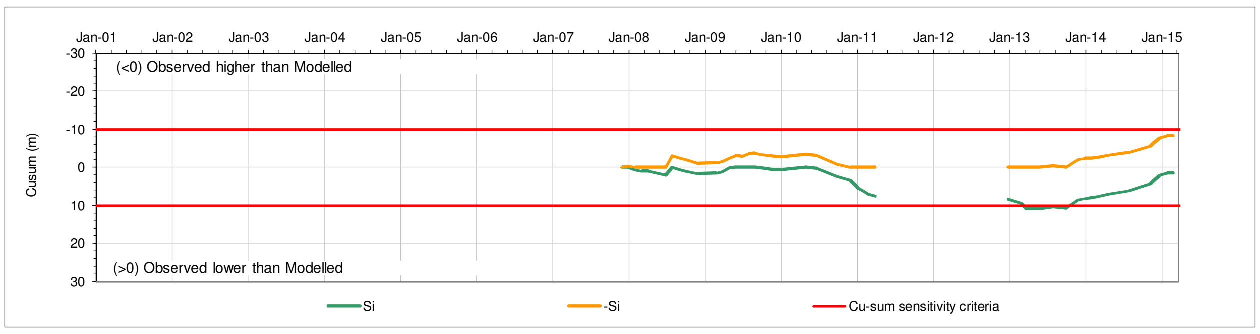
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	90	%
T Slow	150	days
T Fast	150	days
Slow store max	120	mm

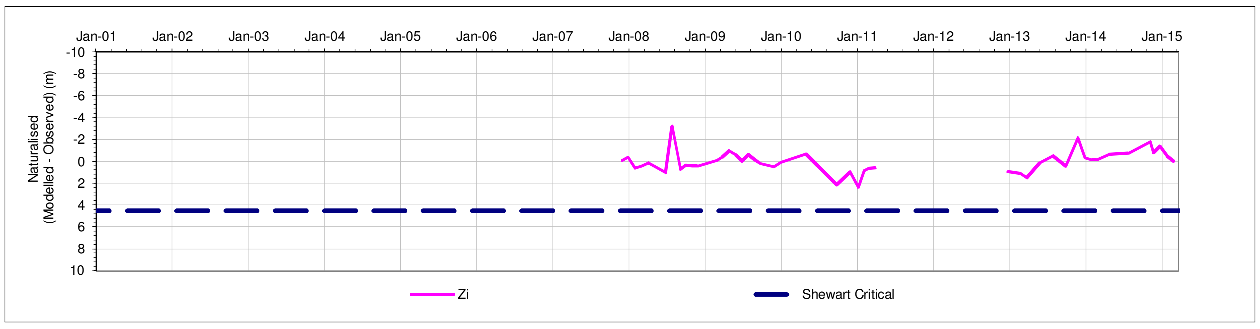
Stats

Baseline dataset for calculation of error statistics:
February 2003 - March 2015 (excluding poor fit data)

K (not permeability!!)	0.05	m
Mean Error (Modelled - Observedl)	-0.19	m
ST Dev Error	0.16	m
Dummy value for Z_i	0	

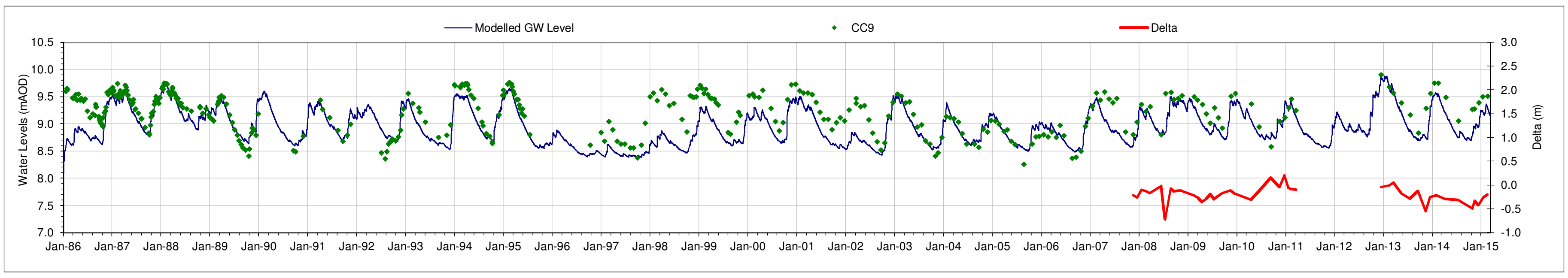






NOTE: Summer goes from July to October Included;
Winter goes from November to June the following year.

Mean summer error	-0.15	m
Max Summer error	0.17	m
Min Summer error	-0.37	m



Runoff Calculation Parameters (Location D)

N.B. Model is calibrated to old borehole D only

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.016	17
GW	1,420,082	0.016 fracture	

Rainfall Multiplier 1
PE Multiplier 1

User-defined time series

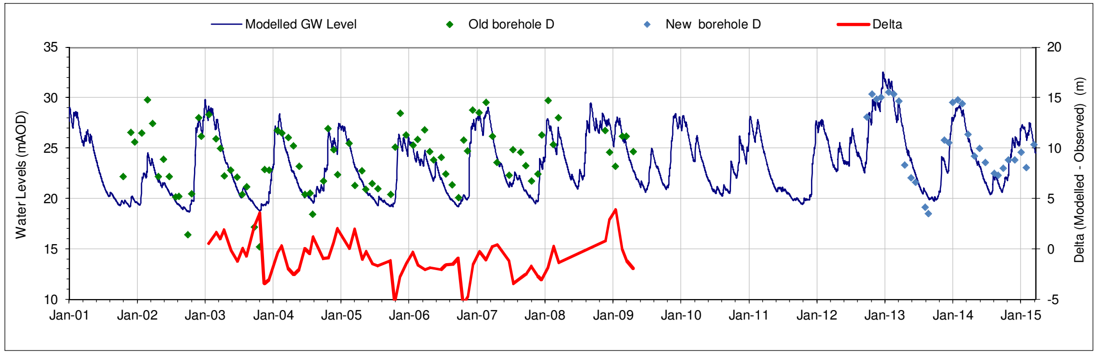
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

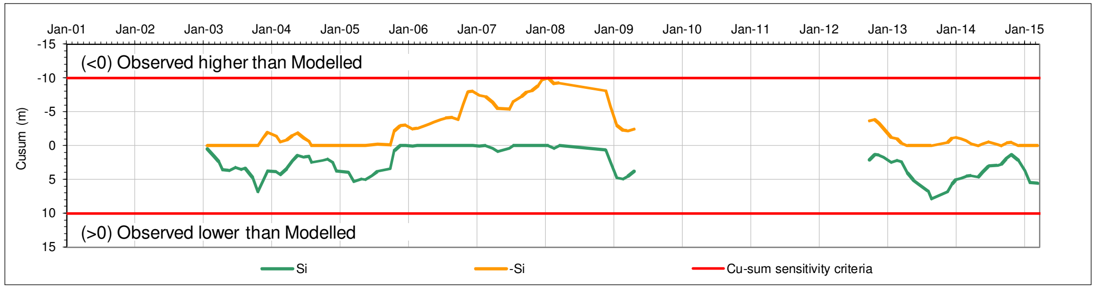
Runoff multiplier	1	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	95	%
T Slow	85	days
T Fast	85	days
Slow store max	100	mm

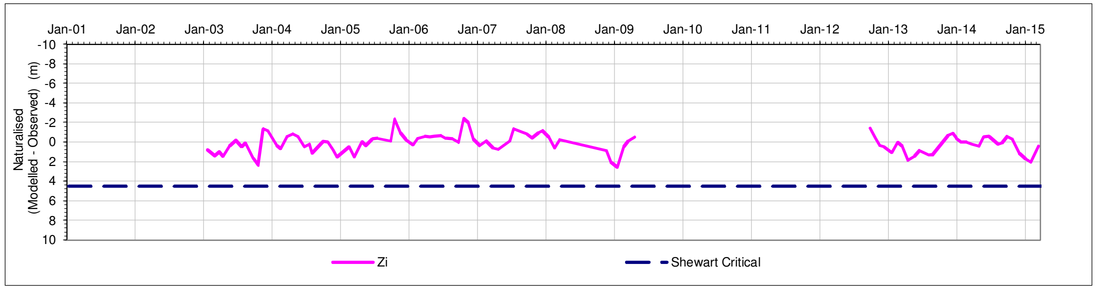
Stats

Baseline dataset for calculation of error statistics:
January 2003 - April 2009

K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed	-0.86	m
ST Dev Error	1.89	m
Dummy value for Z_i	0	







Runoff Calculation Parameters (Location D4)

N.B. K value for dune sand CBACs is lower than the standard (0.25 m)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Schwyll

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1756599	0.24	7.5
GW	1756599	0.24	fracture

Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

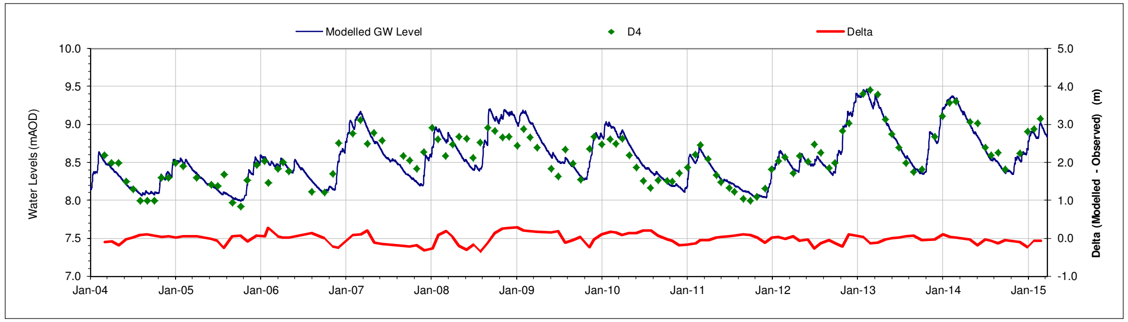
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

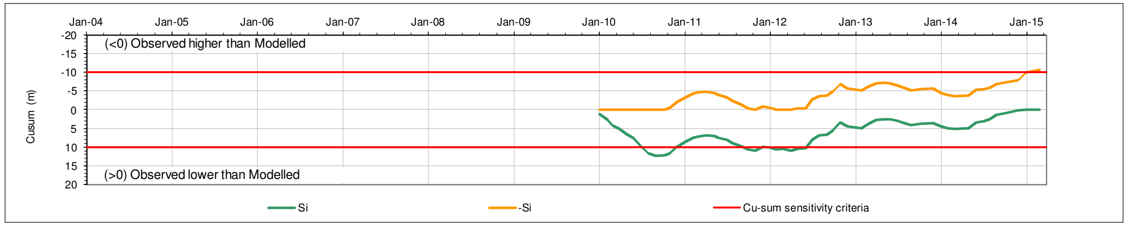
Runoff multiplier	1	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	90	%
T Slow	200	days
T Fast	200	days
Slow store max	220	mm

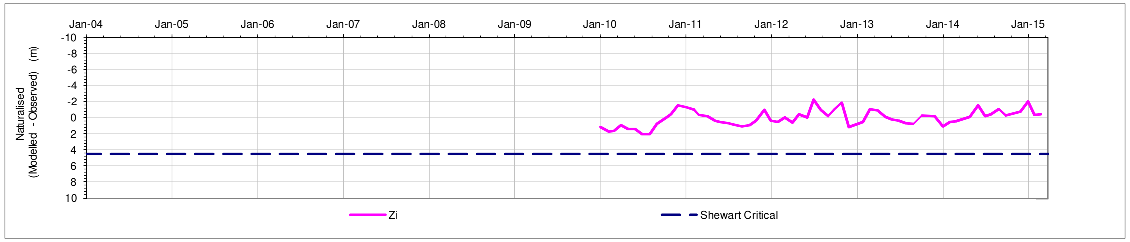
Stats

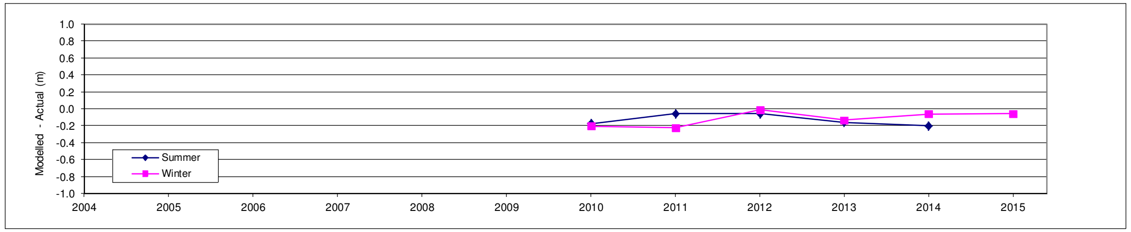
Baseline dataset for calculation of error statistics:
January 2010 - March 2015

K (not permeability!!)	0.05	m
Mean Error (Modelled - Observed)	-0.01	m
ST Dev Error	0.11	m
Dummy value for Z_i	0	









NOTE: Summer goes from July to October Included;
Winter goes from November to June the following year.

Mean summer error	-0.13	m
Max Summer error	-0.01	m
Min Summer error	-0.22	m

Runoff Calculation Parameters (Location E)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	5	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1 SW discharge
0 GW discharge

Number of days 10682

General parameters / **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.007	18.5
GW	1,420,082	0.007 fracture	

Rainfall Multiplier 1
PE Multiplier 1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	70	%
T Slow	50	days
T Fast	50	days
Slow store max	100	mm

Stats

Baseline dataset for calculation of statistics:
March 2002 - July 2004

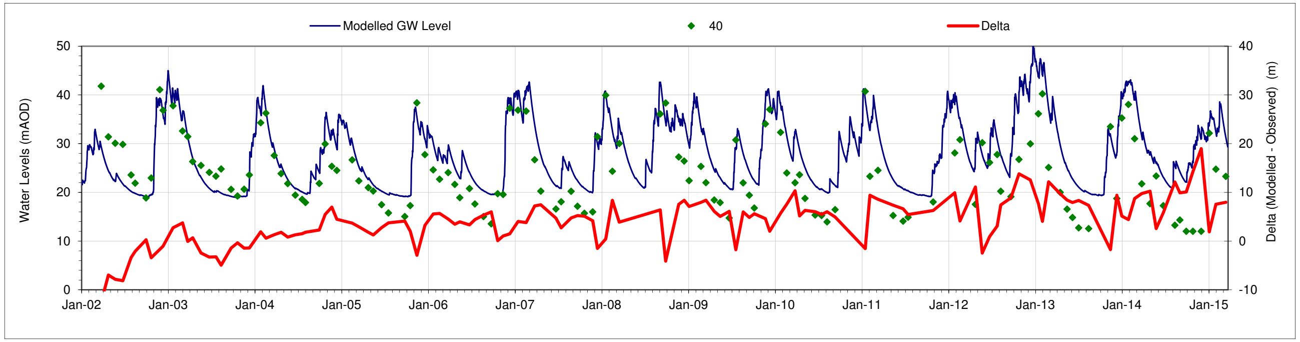
K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	0.51	m
ST Dev Error	3.95	m
Dummy value for Z_i	0	

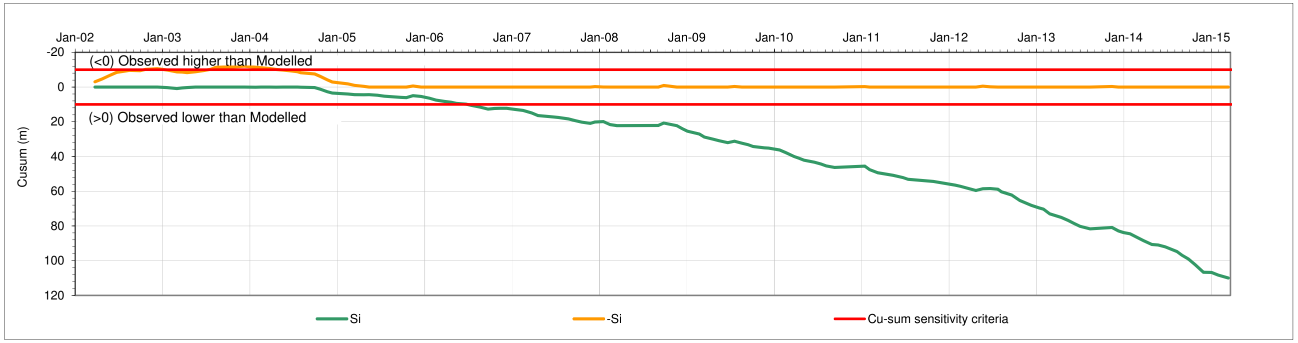
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**18416**

* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

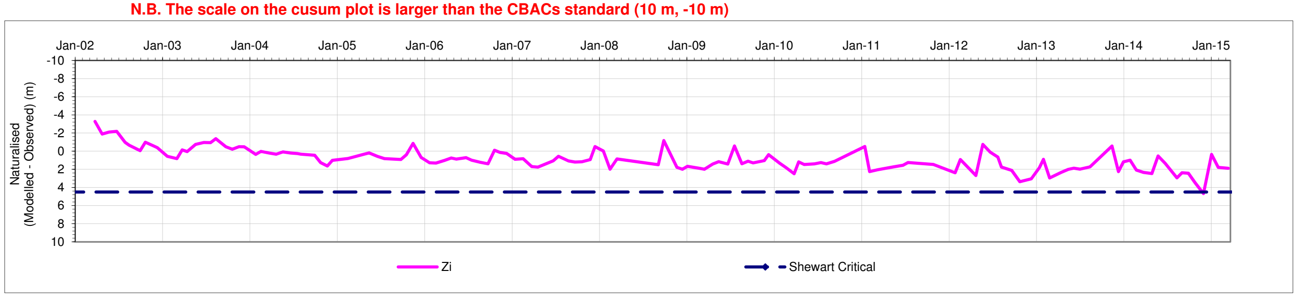
PEST weightings

Default weight for minimum annual values 20.0
Default weight for maximum annual values 10.0
Default standard weight is 1.0





N.B. The scale on the cusum plot is larger than the CBACs standard (10 m, -10 m)



Runoff Calculation Parameters (Location G)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

Rainfall Multiplier 1

PE Multiplier 1

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.004	30.00
GW	1,420,082	0.004 fracture	

User-defined time series

Precipitation (mm) - Sheet SMB calcs

Potential evapotranspiration (mm) - Sheet SMB calcs

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	95	%
T Slow	120	days
T Fast	120	days
Slow store max	90	mm

Stats

Baseline dataset for calculation of error statistics:
January 2003 - March 2015

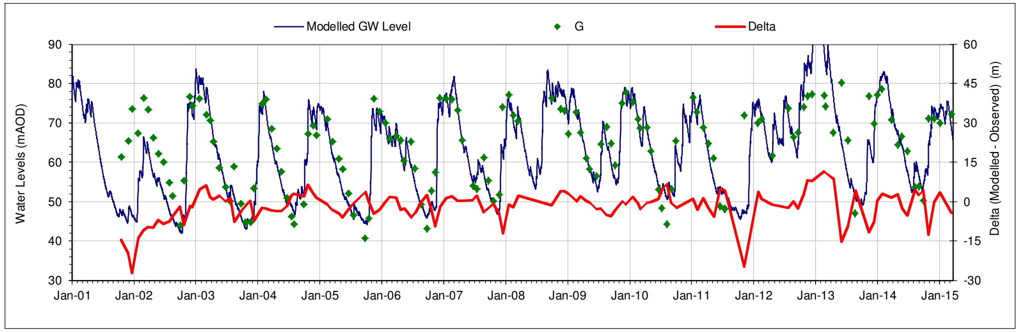
K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.54	m
ST Dev Error	4.99	m
Dummy value for Z_i	0	

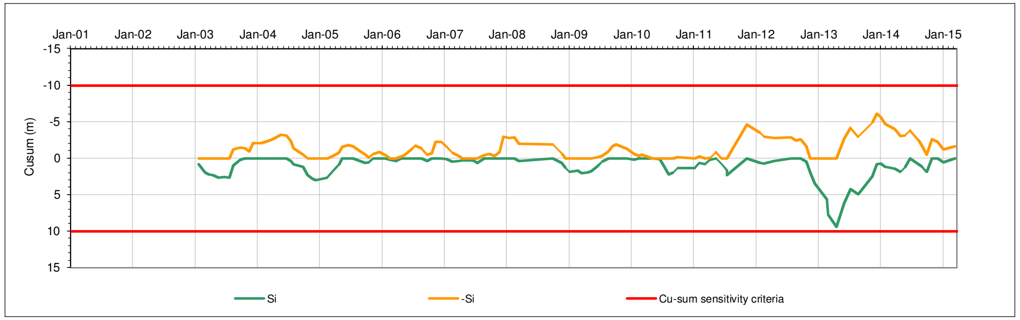
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**5362**

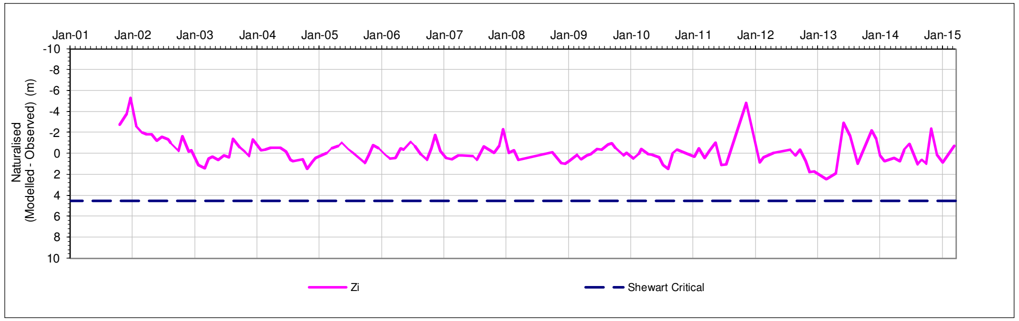
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Location K1a)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	10	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Kenfig

GW Abstractions (Ml/d) 0

Slow flow split

1 SW discharge
0 GW discharge

Number of days 10682

General parameters **Head Change Calculation**

Rainfall Multiplier 1
PE Multiplier 1

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.11	7.5
GW	1,756,799	0.11 fracture	

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	95	%
T Slow	110	days
T Fast	110	days
Slow store max	250	mm

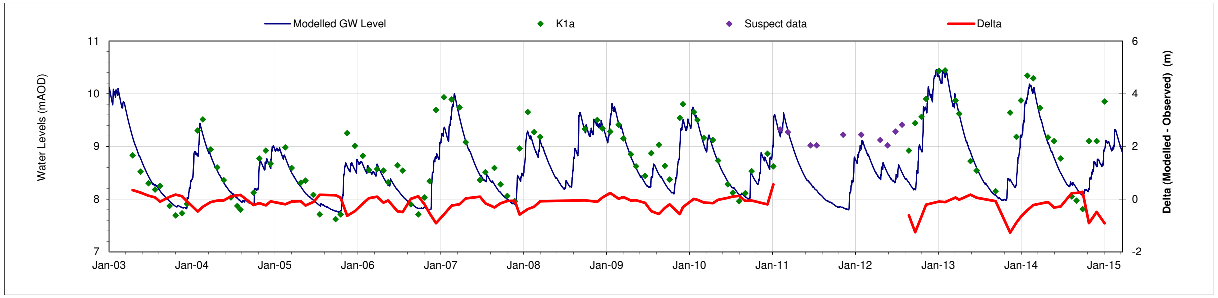
Stats

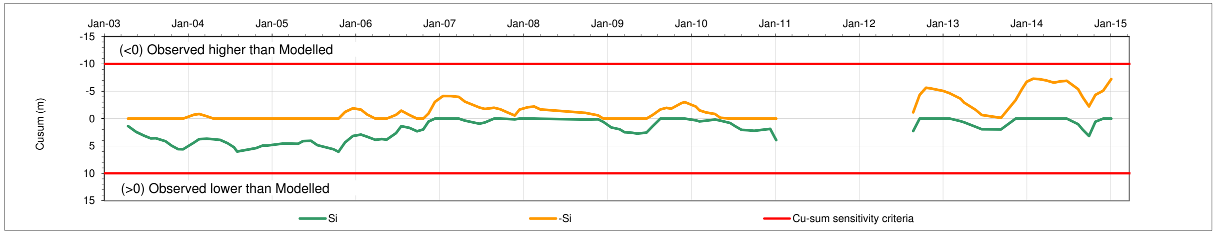
Baseline dataset for calculation of error statistics:
April 2003 - January 2015 (excluding suspect data)

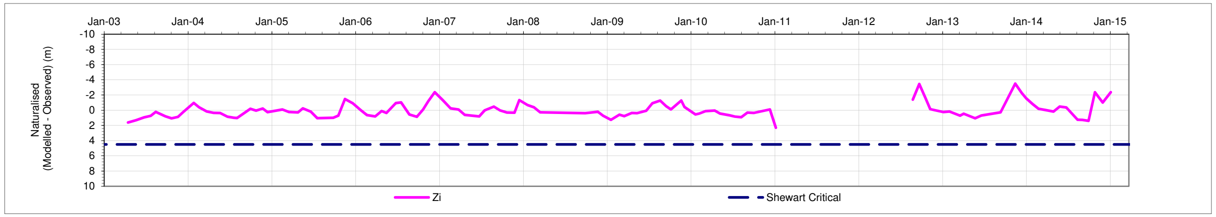
K (not permeability!!) 0.25 m

Mean Error (Modelled - Observed) -0.16 m
ST Dev Error 0.32 m

Dummy value for Z_i 0

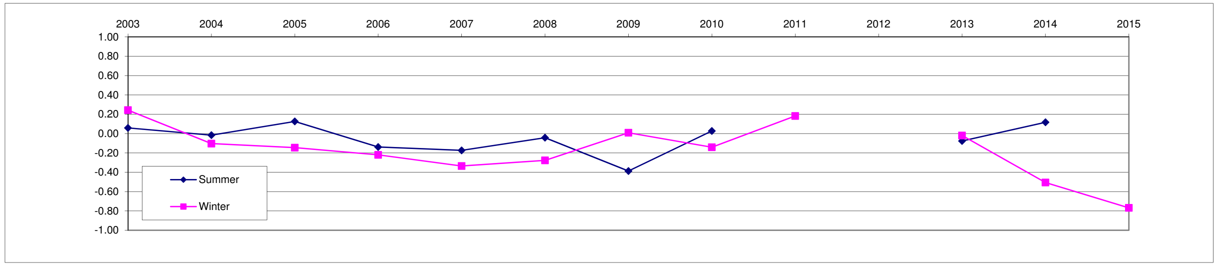






NOTE: Summer goes from July to October Included;
Winter goes from November to June the following year.

Mean Summer error -0.05 m
Max Summer error 0.13 m
Min Summer error -0.39 m



Runoff Calculation Parameters (Location K1b)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Kenfig

GW Abstractions (Ml/d)

0

Slow flow split

1 SW discharge
0 GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	3,560,000	0.13	9.2
GW	3,560,000	0.13 fracture	

Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

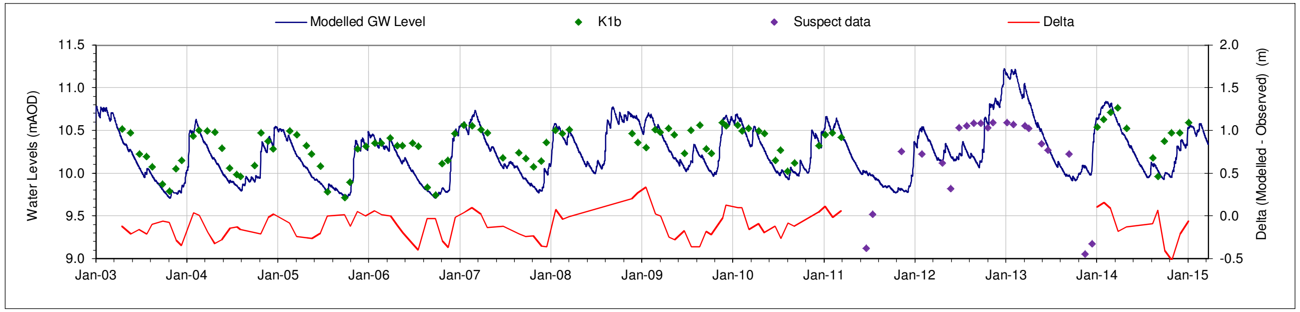
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

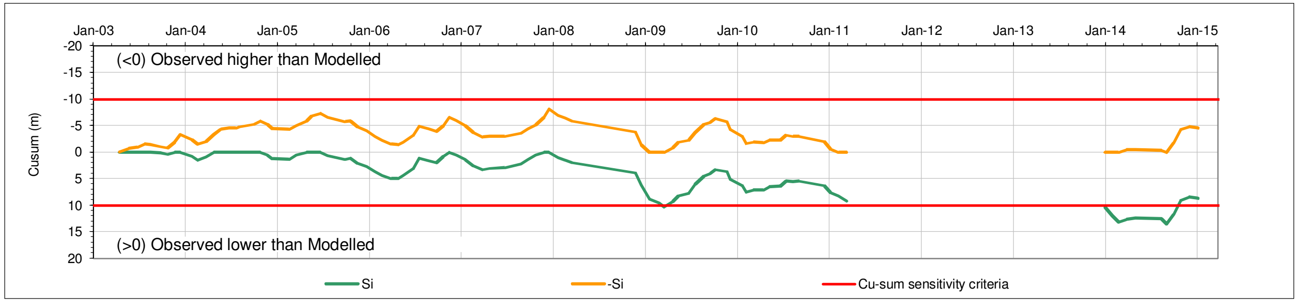
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	95	%
T Slow	150	days
T Fast	150	days
Slow store max	80	mm

Stats

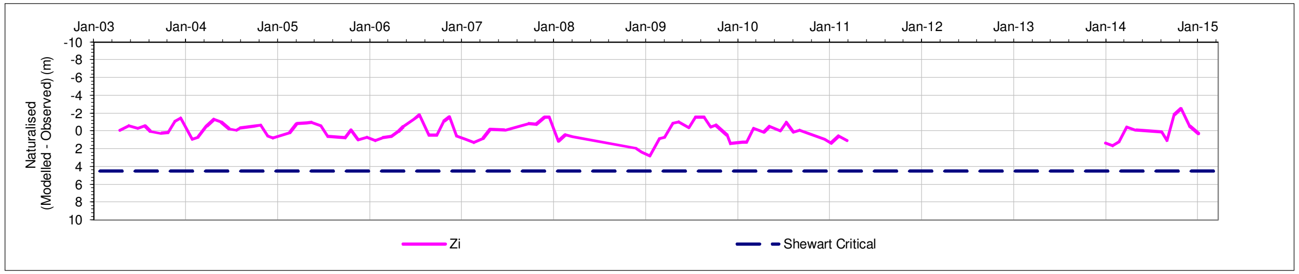
Baseline dataset for calculation of error statistics:
April 2003 - January 2015 (excluding suspect data)

K (not permeability!!)	0.05	m
Mean Error (Modelled - Observed)	-0.10	m
ST Dev Error	0.16	m
Dummy value for Z_i	0	





N.B. The scale on the cusum plot is larger than the CBACs standard (15 m, -15 m)



Runoff Calculation Parameters (Location K2a)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	10	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Kenfig

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.08	7.3
GW	1,756,799	0.08 fracture	

Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

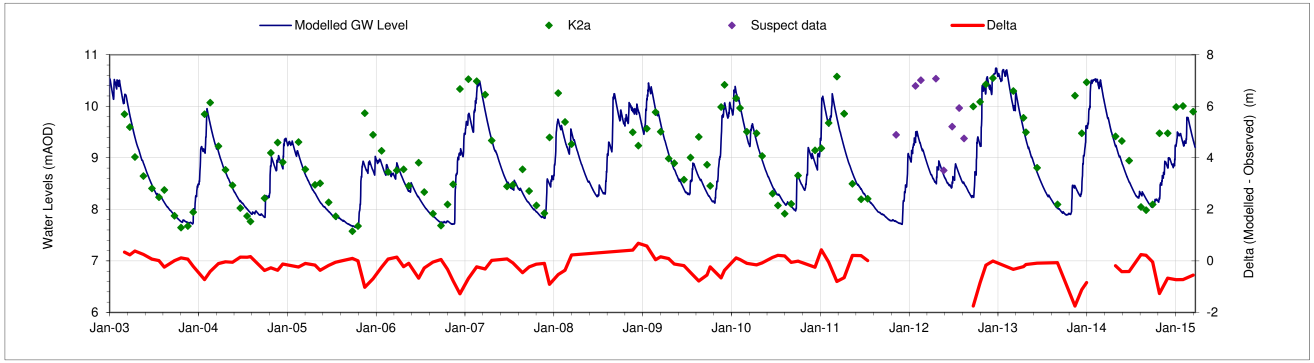
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

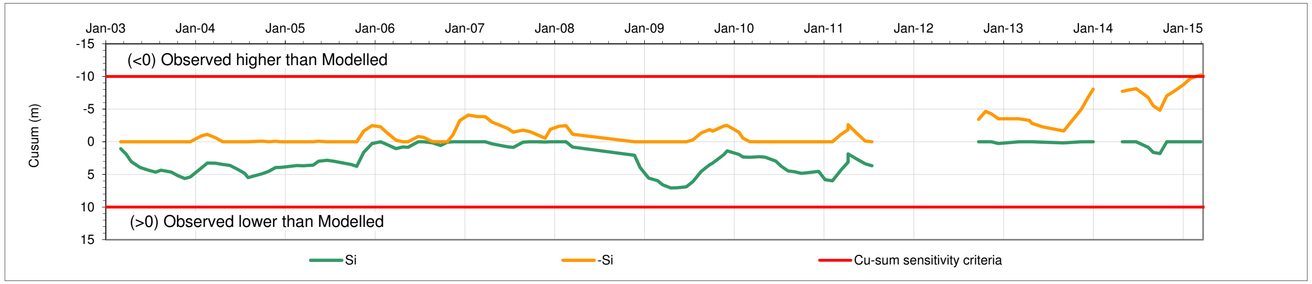
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	110	days
T Fast	110	days
Slow store max	220	mm

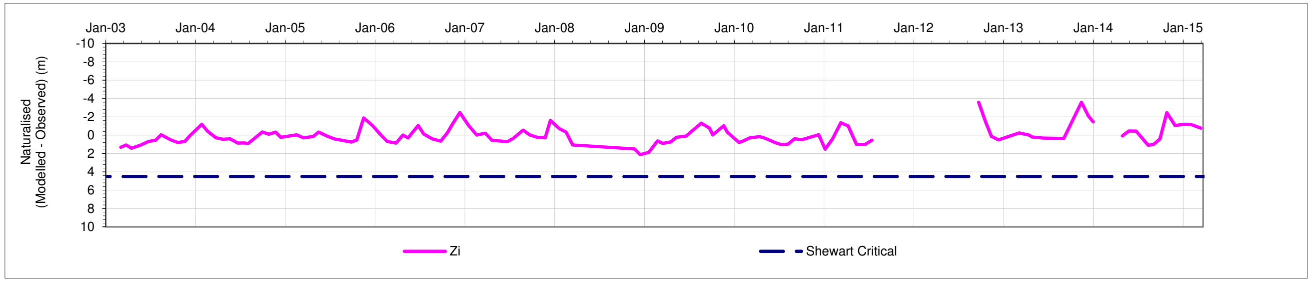
Stats

Baseline dataset for calculation of error statistics:
March 2003 - March 2015 (excluding suspect data)

K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.22	m
ST Dev Error	0.43	m
Dummy value for Z_i	0	







Runoff Calculation Parameters (Location K2b)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Kenfig

GW Abstractions (Ml/d)

0

Slow flow split

1 SW discharge
0 GW discharge

Number of days 10682

Rainfall Multiplier 1
PE Multiplier 1

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	3,560,000	0.05	7.3
GW	3,560,000	0.05 fracture	

User-defined time series

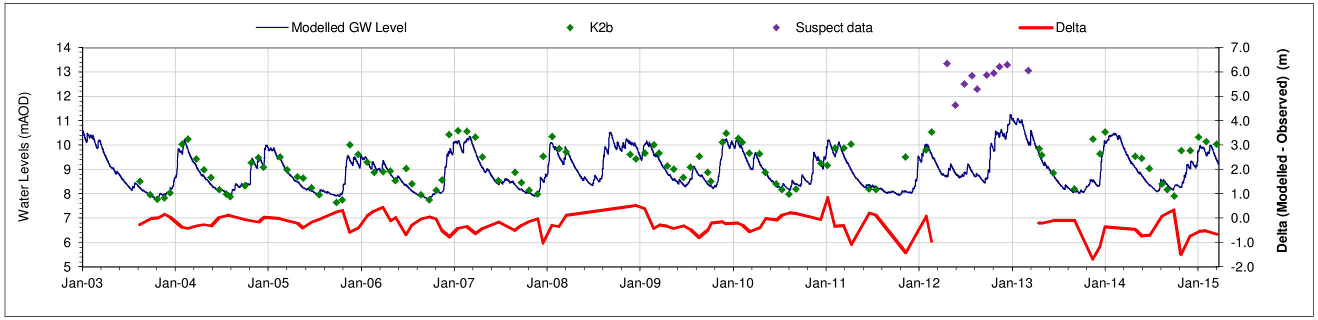
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

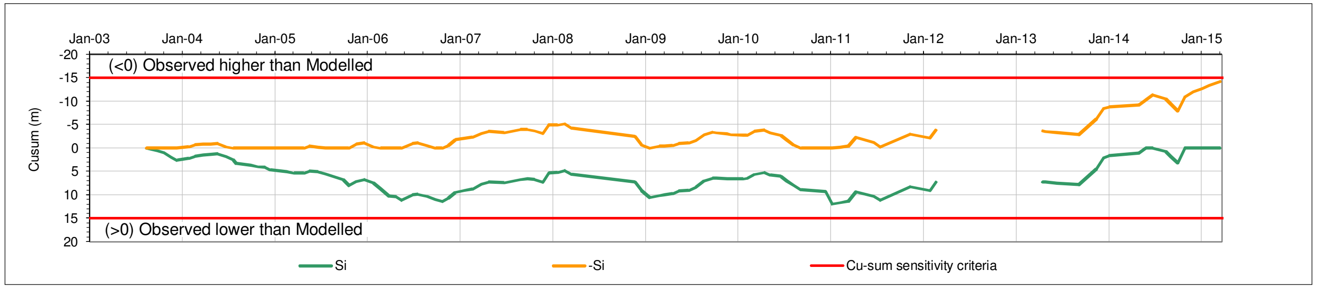
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	85	days
T Fast	85	days
Slow store max	80	mm

Stats

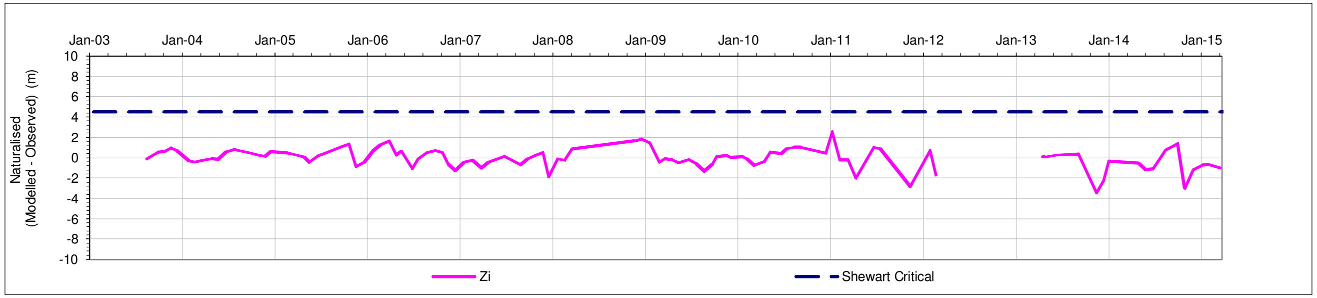
Baseline dataset for calculation of error statistics:
August 2003 - March 2015 (excluding suspect data)

K (not permeability!!)	0.05	m
Mean Error (Modelled - Observed)	-0.24	m
ST Dev Error	0.42	m
Dummy value for Z_i	0	





N.B. The scale on the cusum plot is larger than the CBACS standard (10 m,-10 m)



Runoff Calculation Parameters (Location L)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Schwyll

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

Rainfall Multiplier 1
PE Multiplier 1

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.13	10
GW	1,756,799	0.13 fracture	

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Runoff multiplier	1	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	90	%
T Slow	110	days
T Fast	110	days
Slow store max	100	mm

Stats

Baseline dataset for calculation of error statistics:
May 2001 - June 2013

K (not permeability!!) 0.25 m

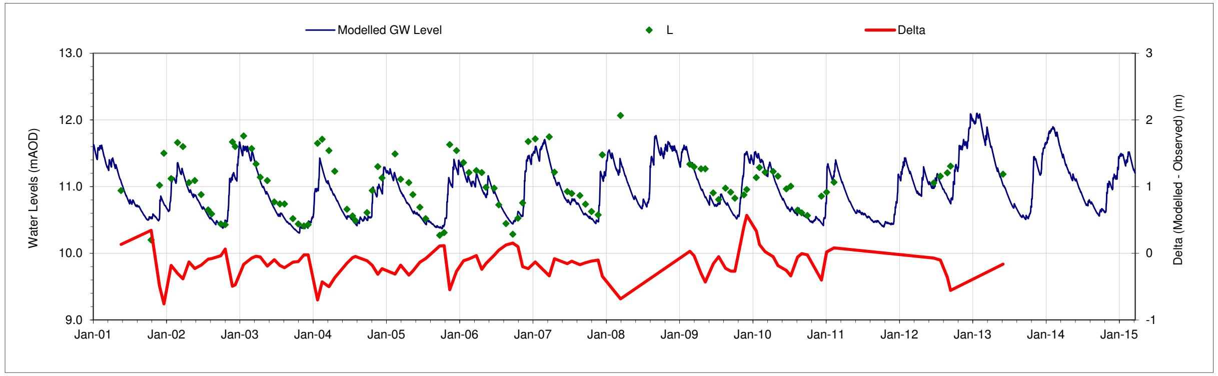
Mean Error (Modelled - Observed) -0.15 m
ST Dev Error 0.22 m
Dummy value for Z_i 0

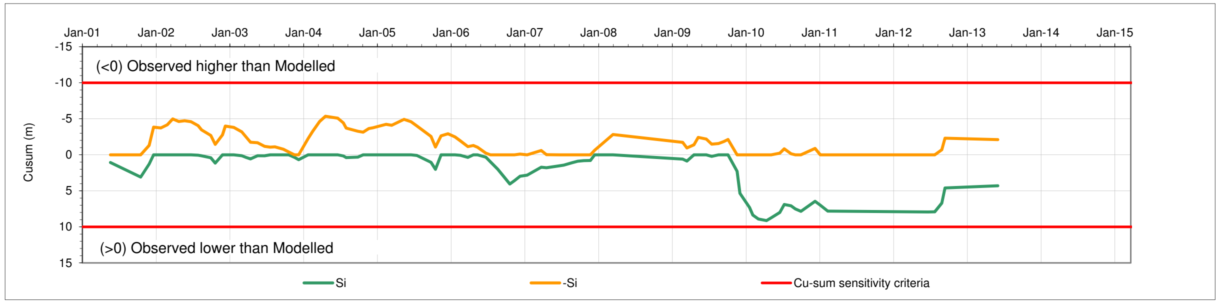
Phi_calibration - last loaded PEST run	n/a
Phi_calibration - spreadsheet calcs	32

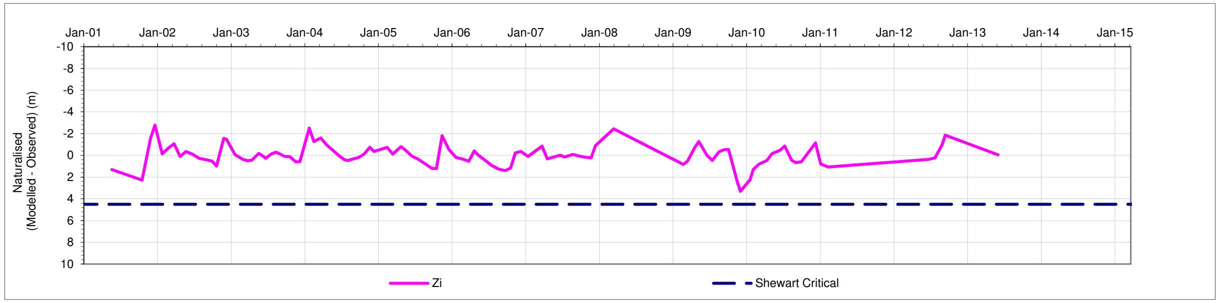
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values 20.0
Default weight for maximum annual values 10.0
Default standard weight is 1.0







Runoff Calculation Parameters (Location N-a)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	10	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1 SW discharge
0 GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1756799	0.065	7.5
GW	1756799		

Rainfall Multiplier 1
PE Multiplier 1

User-defined time series

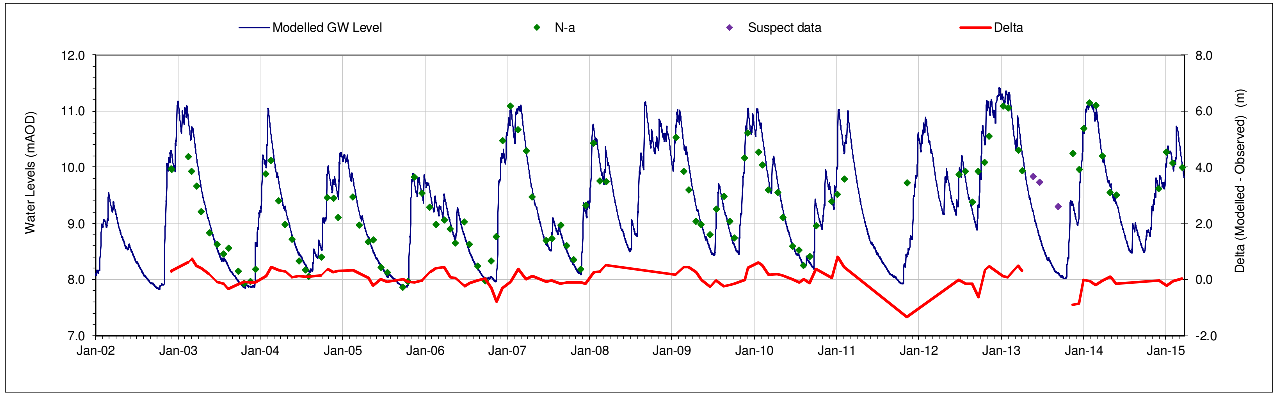
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs
Nb Change cells references on water balance sheet

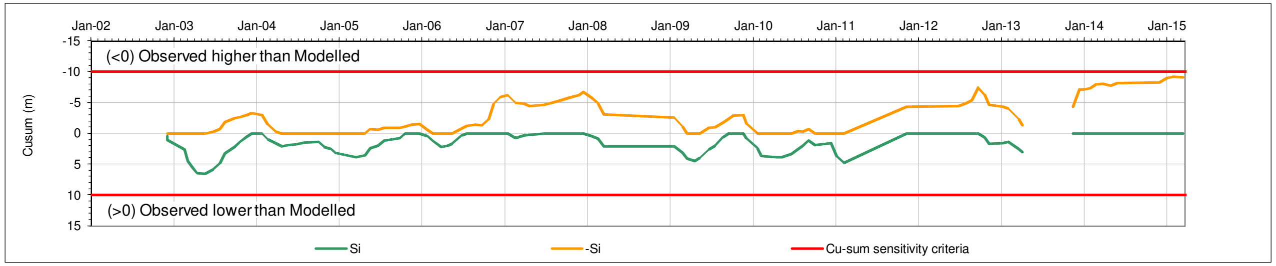
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	90	days
T Fast	90	days
Slow store max	200	mm

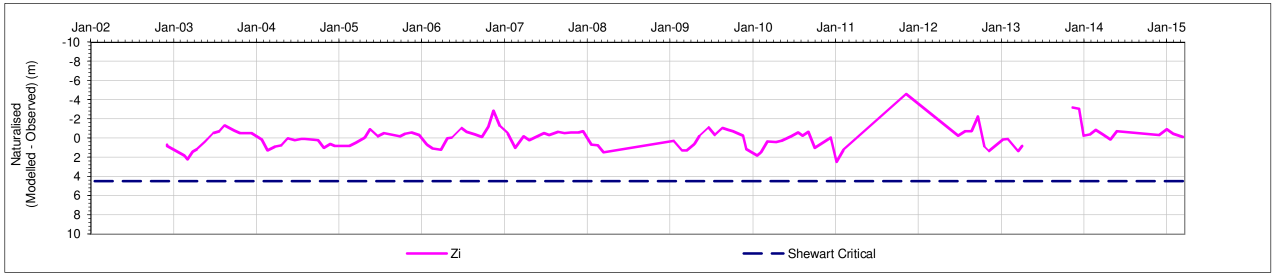
Stats

Baseline dataset for calculation of error statistics:
December 2002 - February 2015 (excluding suspect data)

K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	0.08	m
ST Dev Error	0.30	m
Dummy value for Z_i	0	







Runoff Calculation Parameters (Location O-a)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
50	20	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall Station: Margam

GW Abstractions (Ml/d) 0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters / **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.15	7.2
GW	1,756,799	0.15 fracture	

Rainfall Multiplier 1
PE Multiplier 1

User-defined time series
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters		
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	80	days
T Fast	80	days
Slow store max	250	mm

Stats
Baseline dataset for calculation of error statistics:
October 2002 - March 2015 (excluding suspect data)

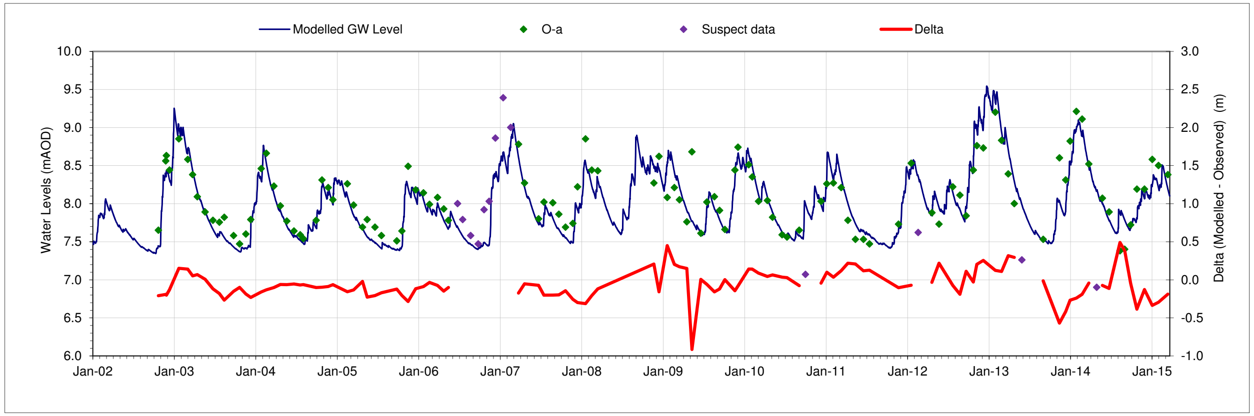
K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.06	m
ST Dev Error	0.19	m
Dummy value for Z_i	0	

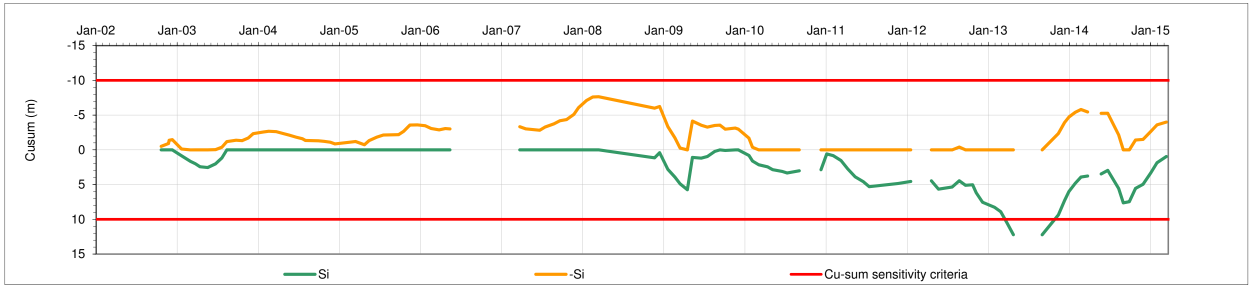
Phi_calibration - last loaded PEST run	n/a
Phi_calibration - spreadsheet calcs	22

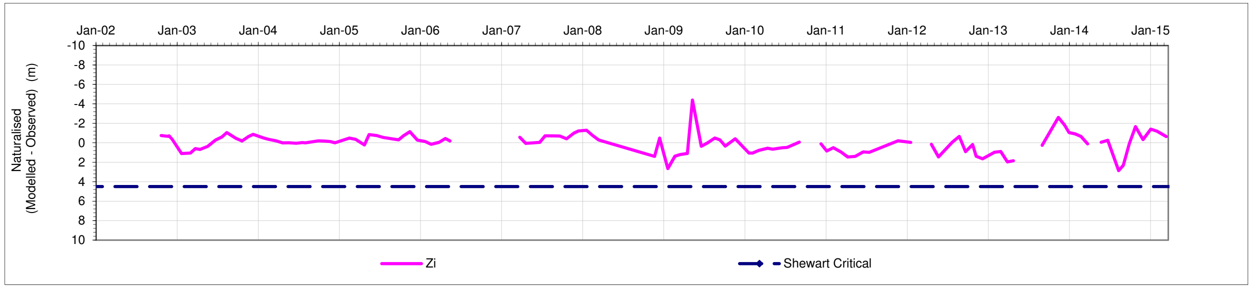
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Location P)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d) 0

Slow flow split
1 SW discharge
0 GW discharge

Number of days 10682

Rainfall Multiplier 1
PE Multiplier 1

General parameters / **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.015	12.5
GW	1,420,082	0.015 fracture	

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs
Nb Change cells references on water balance sheet

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	95	%
T Slow	110	days
T Fast	110	days
Slow store max	110	mm

Stats

Baseline dataset for calculation of error statistics:
January 2004 - July 2013

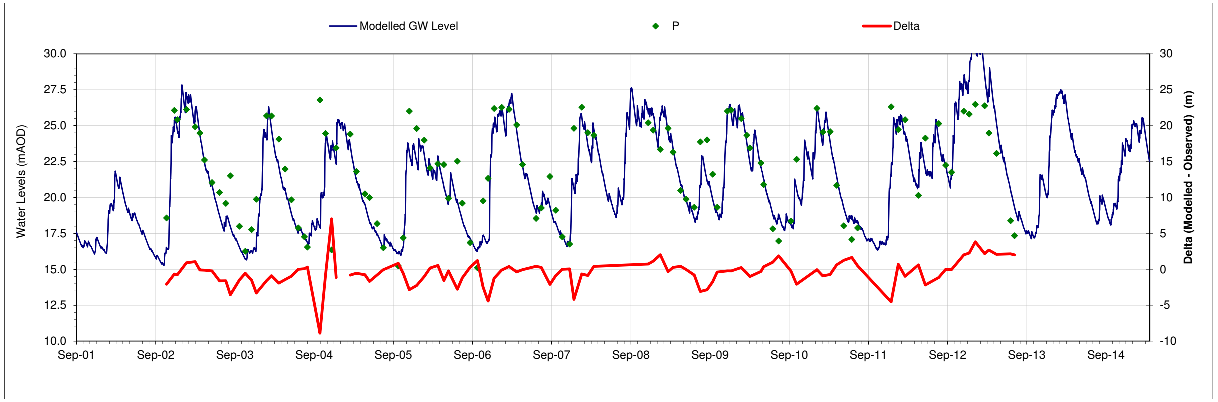
K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.26	m
ST Dev Error	1.58	m
Dummy value for Z_i	0	

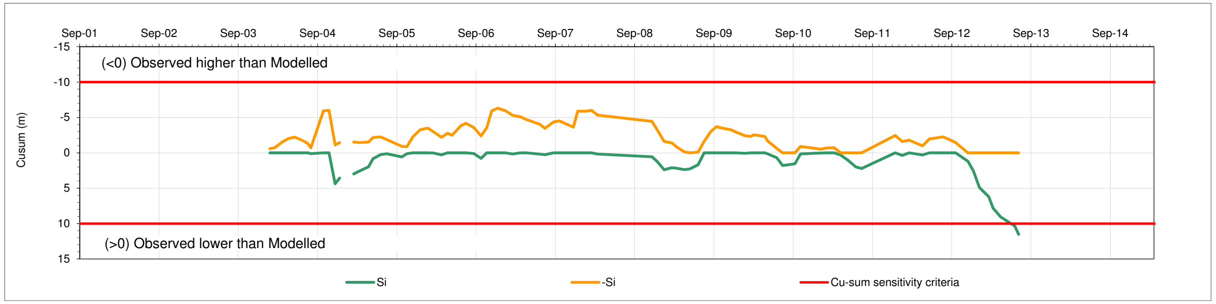
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**2626**

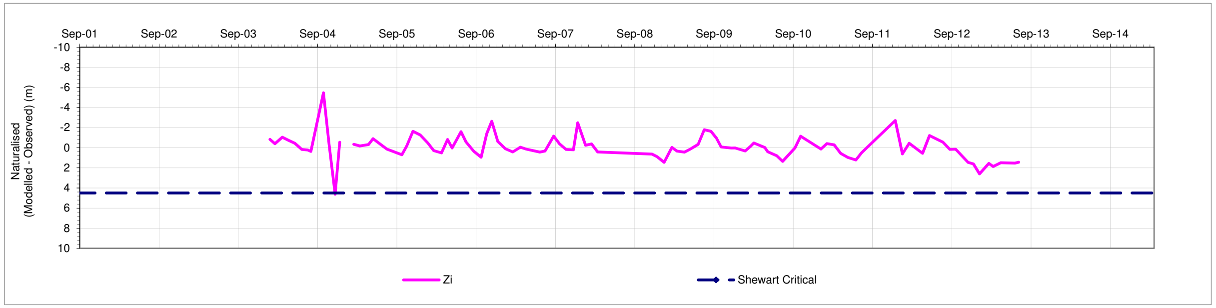
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Location Q)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	5	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

Rainfall Multiplier 1
PE Multiplier 1

General parameters / **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.008	21
GW	1,420,082	0.008 fracture	

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs
Nb Change cells references on water balance sheet

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	90	%
T Slow	83	days
T Fast	83	days
Slow store max	200	mm

Stats

Baseline dataset for calculation of error statistics:
October 2002 - May 2013

K (not permeability!!)	0.2 m
Mean Error (Modelled - Observed)	-2.15 m
ST Dev Error	6.10 m
Dummy value for Z_i	0

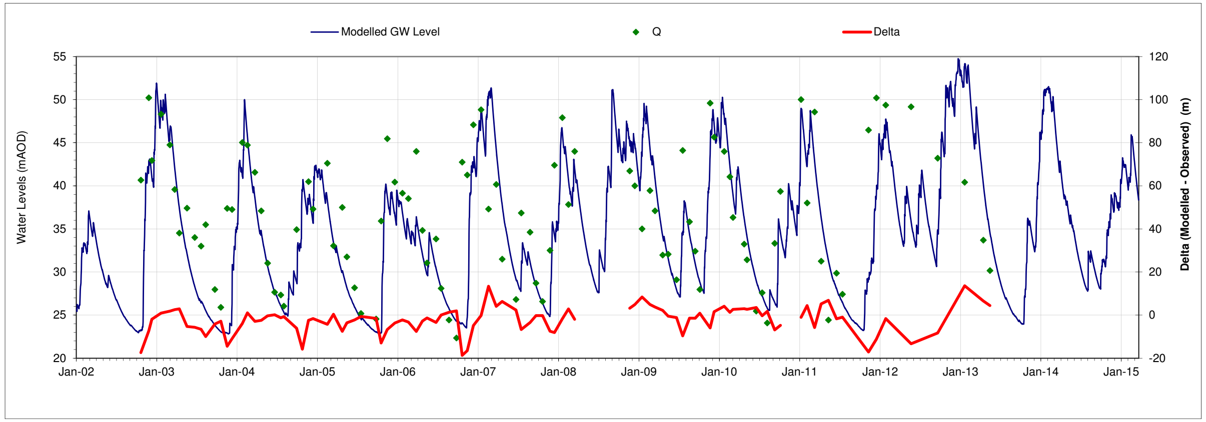
Phi_calibration - last loaded PEST run n/a

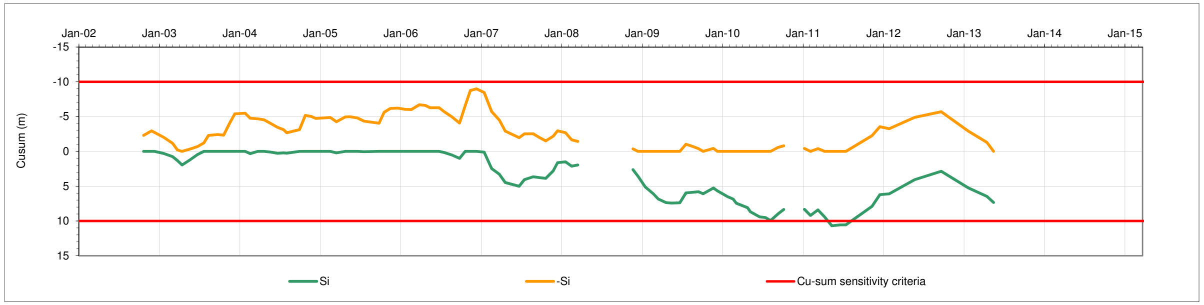
Phi_calibration - spreadsheet calcs #N/A

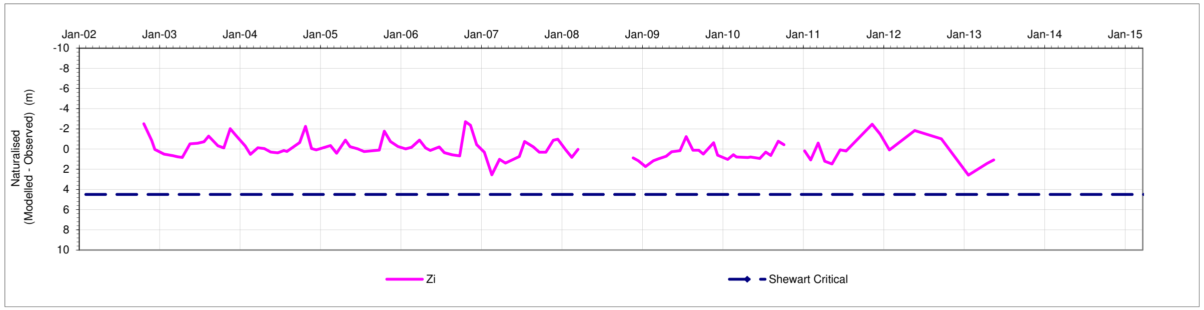
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Cornelly Quarry Pumping)

N.B. Pumping rates used are average fortnightly rates out of Cornelly floor (m3/d)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

General parameters | **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	3,800,000	0.004	30
GW	3,800,000	0.004	

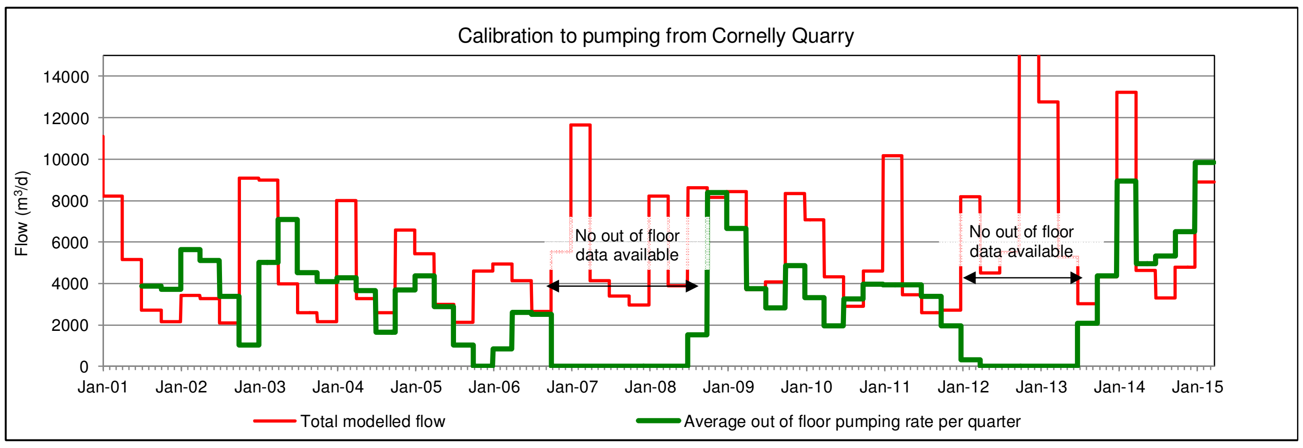
Rainfall Multiplier	1
PE Multiplier	1
Runoff multiplier	1

User-defined time series

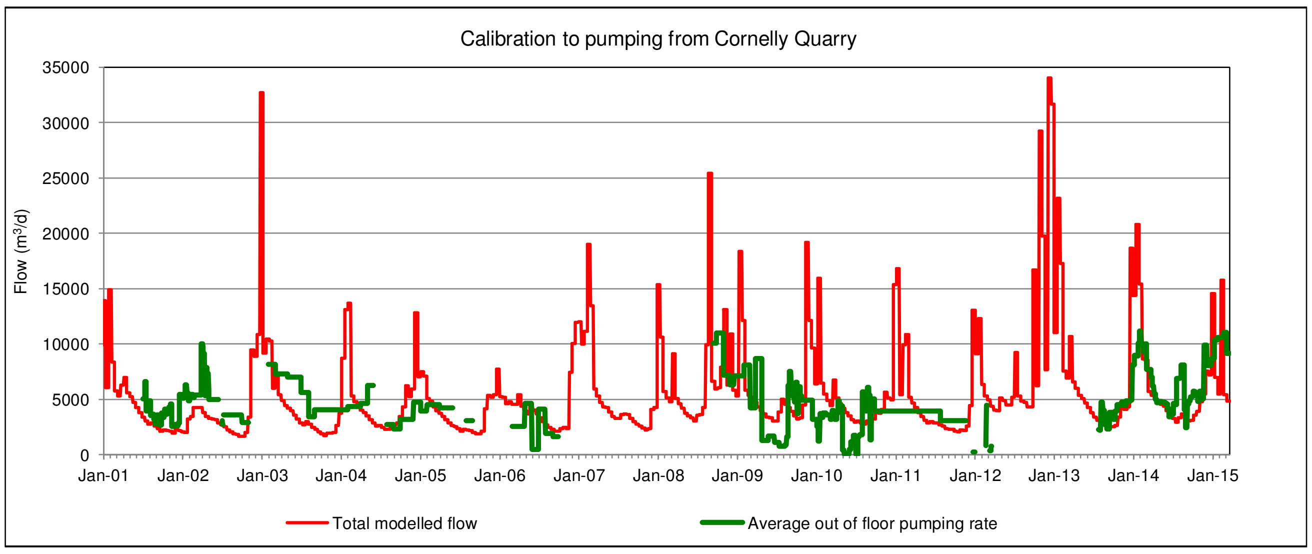
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

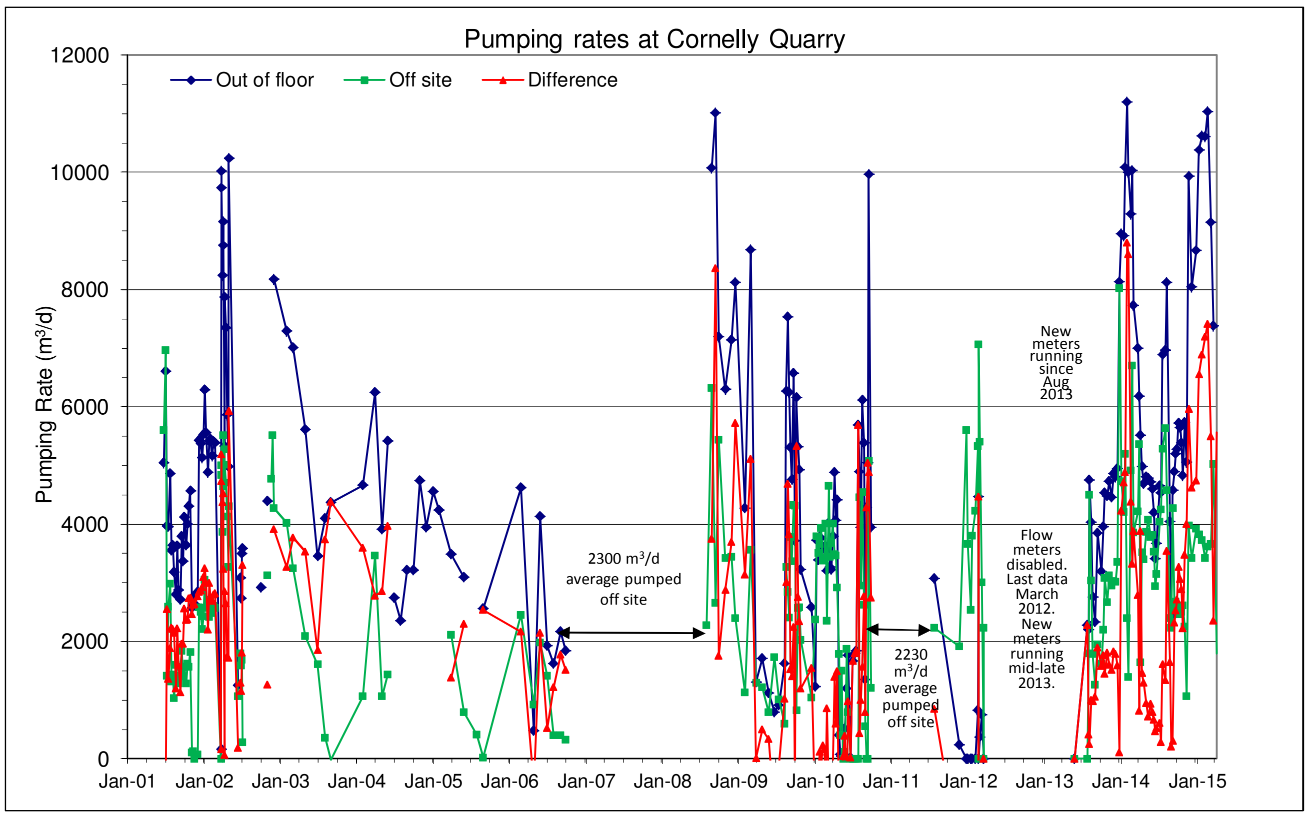
% Slow	95	%
Fast_store_Starting_Volume	0	mm
Slow_store_Starting_Volume	0	mm
GW_Abstractions__Ml_d	0	Ml/d
Slow_flow_split	1	-
Slow_store_max	90	mm
TFast	120	days
TSlow	120	days



LTA quarry pumping rate	5948.68	m3/d
January 1986 - April 2015		
Actual average quarry pumping rate	6317.57	m3/d
August 2013 - April 2015		



N.B. The pumping rates at Cornelly Quarry graph provides an indication of gaps in the data record



Runoff Calculation Parameters (Location R-a)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d) 0

Slow flow split

1 SW discharge
0 GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.15	7.4
GW	1,756,799	0.15 fracture	

Rainfall Multiplier 1
PE Multiplier 1

User-defined time series
Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	65	days
T Fast	65	days
Slow store max	250	mm

Stats
Baseline dataset for calculation of error statistics:
October 2002 - March 2015 (excluding suspect data)

K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	0.01	m
ST Dev Error	0.19	m
Dummy value for Z_i	0	

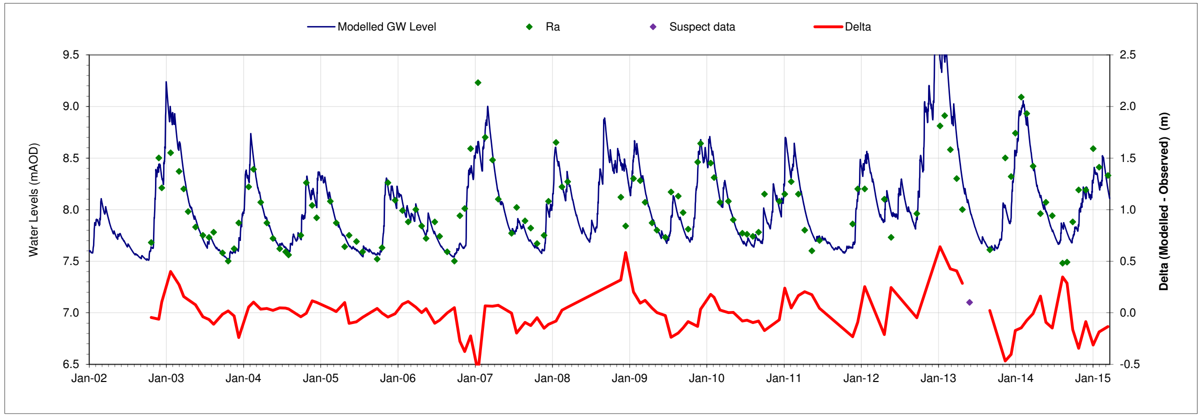
Phi_calibration - last loaded PEST run n/a

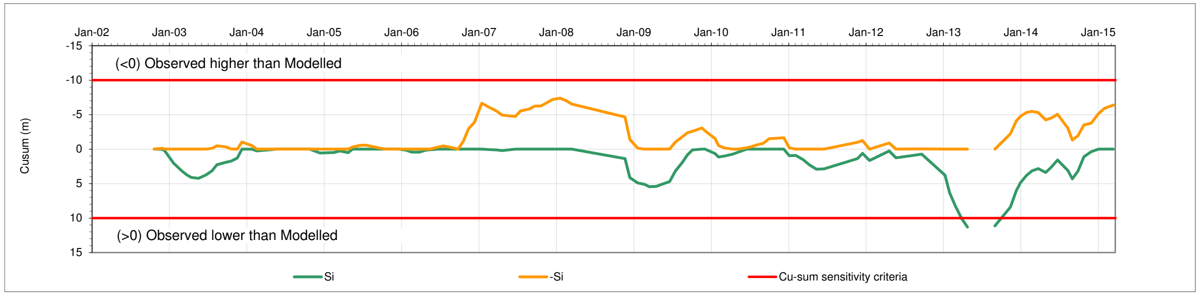
Phi_calibration - spreadsheet calcs 26

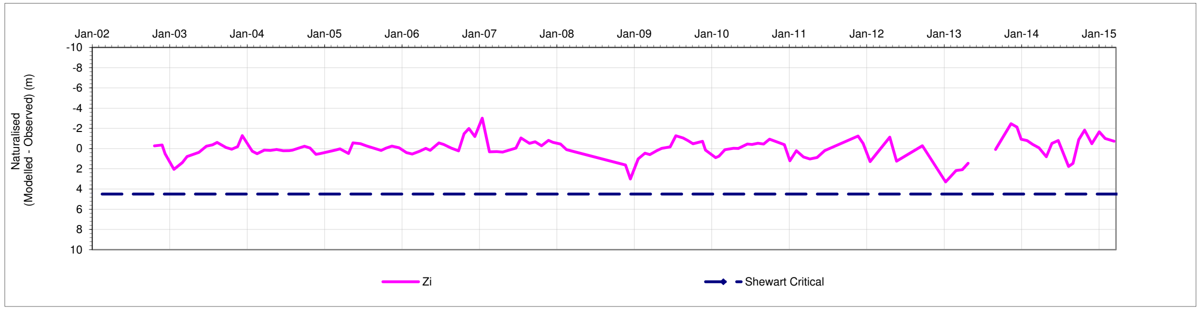
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Location RWC105)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

Rainfall Multiplier 1
PE Multiplier 1

General parameters / **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.012	11
GW	1,420,082	0.012 fracture	

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	80	days
T Fast	80	days
Slow store max	150	mm

Stats

Baseline dataset for calculation of error statistics:
January 2003 - March 2015

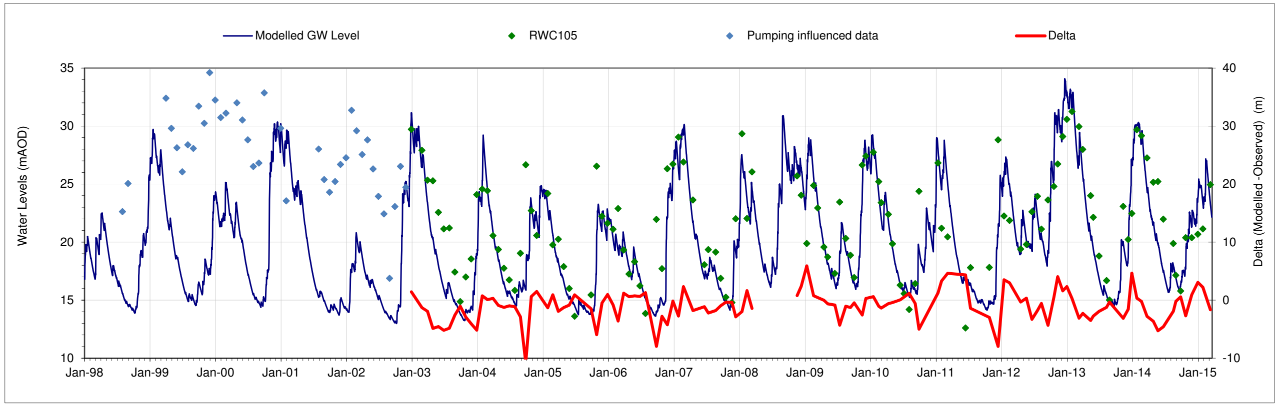
K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	-0.98	m
ST Dev Error	2.63	m
Dummy value for Z_i	0	

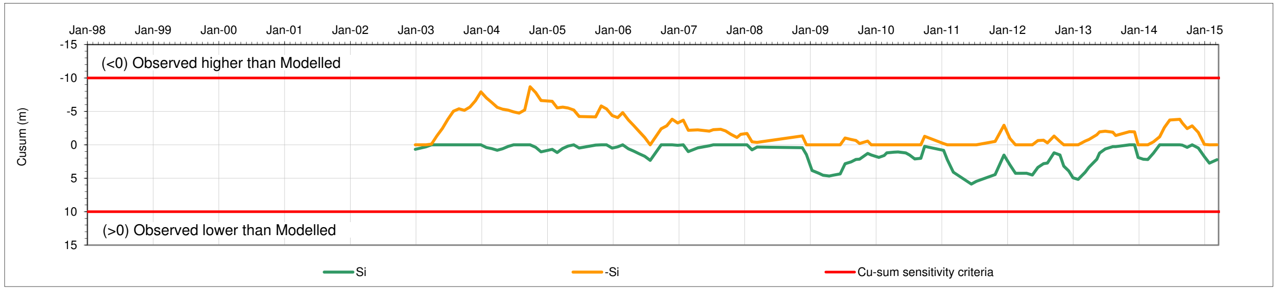
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**22586**

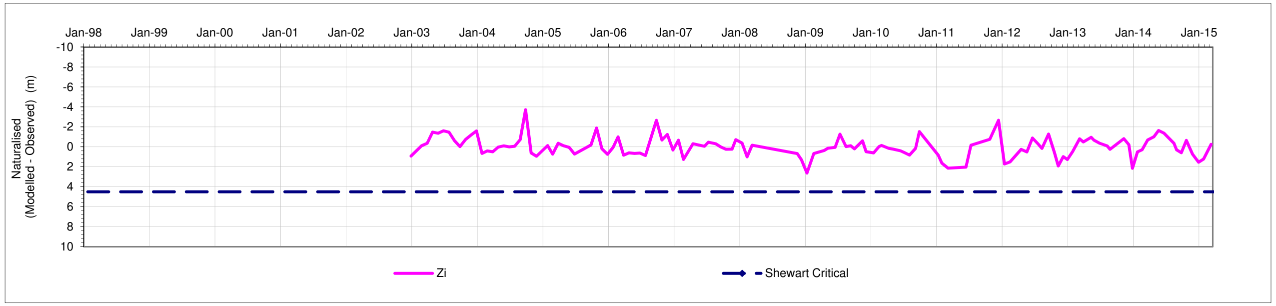
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Location RWC106)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.012	10
GW	1,420,082	0.012 fracture	

Rainfall Multiplier 1
PE Multiplier 1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	80	days
T Fast	80	days
Slow store max	150	mm

Stats

Baseline dataset for calculation of error statistics:
January 2003 - March 2015 (excluding suspect data)

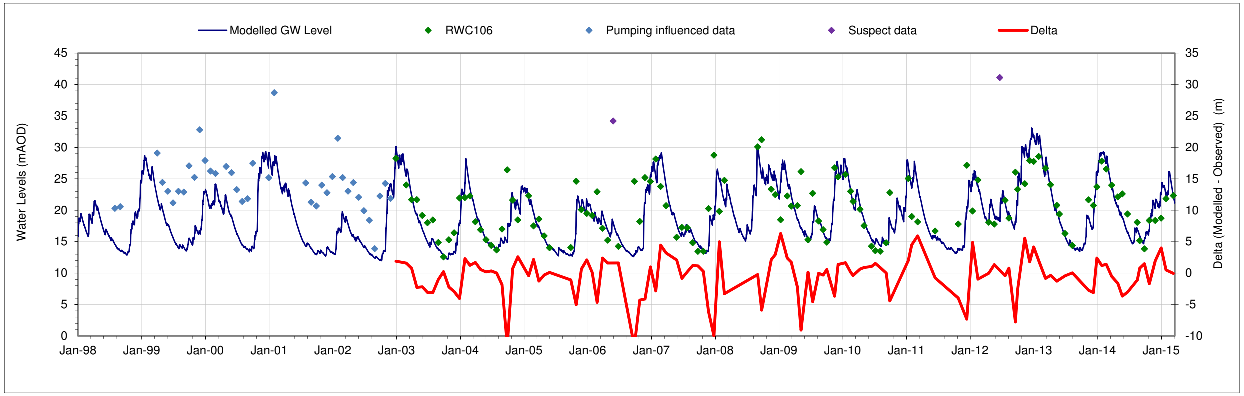
K (not permeability!!)	0.25	m
Mean Error (modelled - Actual)	-0.43	m
ST Dev Error	3.25	m
Dummy value for Z_i	0	

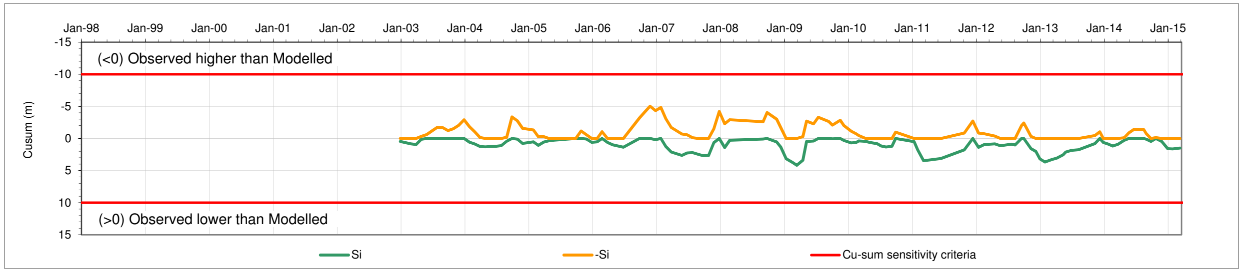
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**4949**

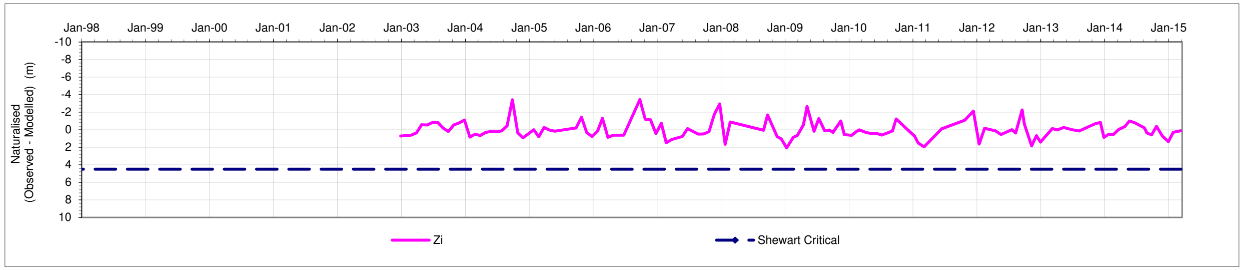
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	







Runoff Calculation Parameters (Location South Cornelly)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d) 0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters

Head Change Calculation

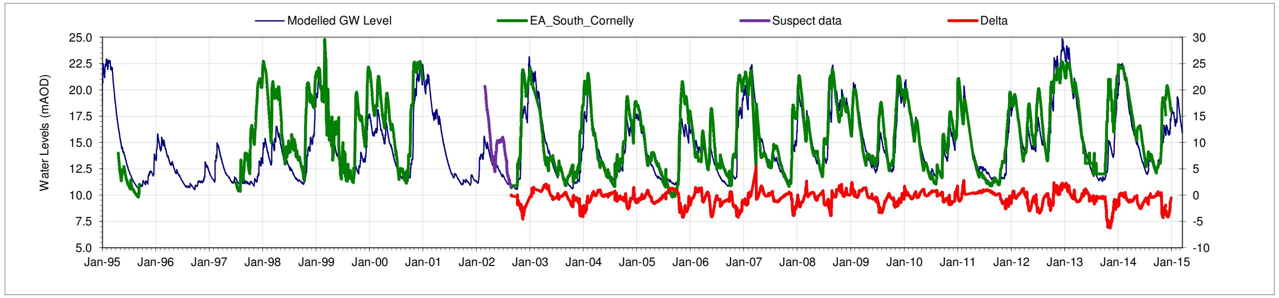
Rainfall Multiplier 1
PE Multiplier 1

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.018	9.5
GW	1,756,799	0.018 fracture	

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters		
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	70	days
T Fast	70	days
Slow store max	160	mm



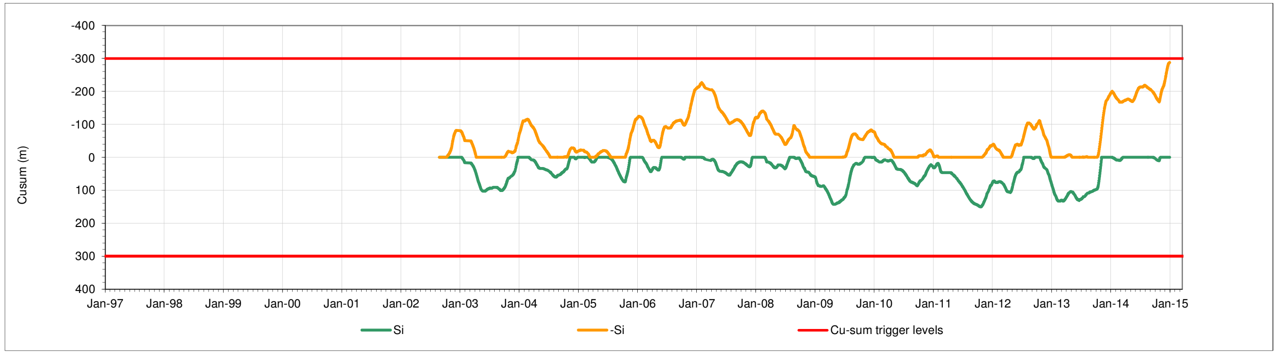
Stats

Baseline dataset for calculation of error statistics:
September 2002 - January 2013

K (not permeability!!)	0.25	m
Mean Error (modelled - Actual)	-0.51	m
ST Dev Error	1.24	m
Dummy value for Z_i	0	

Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**27022**

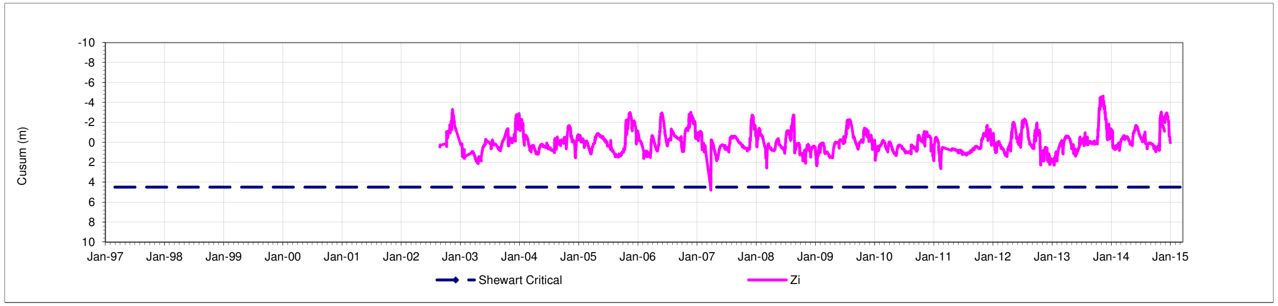
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations



PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	

N.B. The scale on the cusum plot is larger than the CBACs standard (10 m, -10 m)



Runoff Calculation Parameters (Location T95/01)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0.01	0.01	0.01
20	0.01	0.01	0.01

Rainfall station: Margam

GW Abstractions (Ml/d) 0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters / **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1420082	0.0028	20
GW	1420082	0.0028 fracture	

Rainfall Multiplier 1
PE Multiplier 1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs
Nb Change cells references on water balance sheet

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	80	days
T Fast	80	days
Slow store max	80	mm

Stats

Baseline dataset for calculation of error statistics:
January 2003 - March 2015

K (not permeability!!) 0.25 m

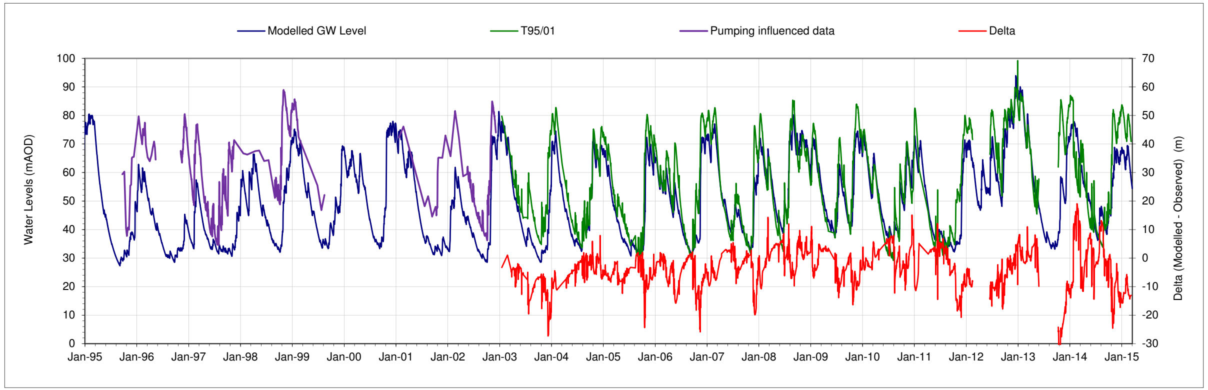
Mean Error (Modelled - Observed) -3.77 m
ST Dev Error 6.93 m
Dummy value for Z_i 0

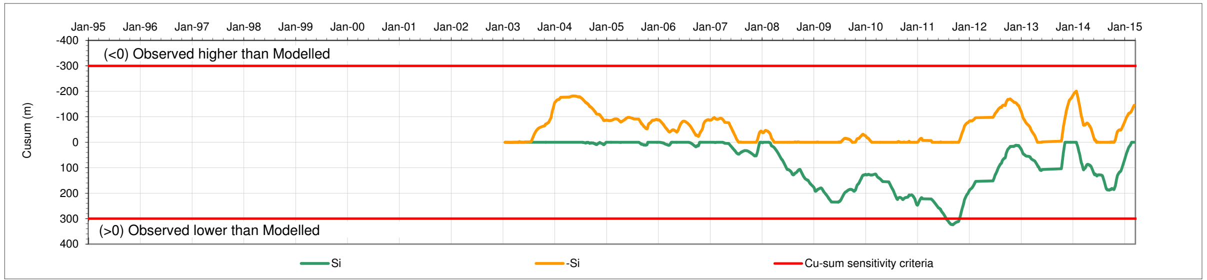
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**257497**

* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

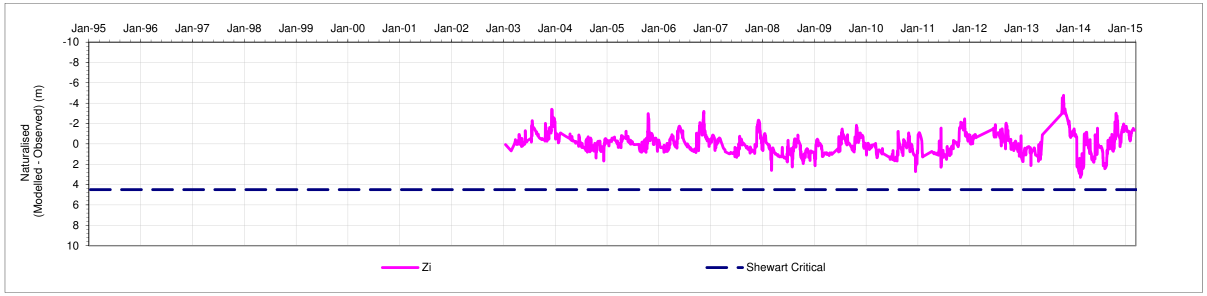
PEST weightings
Default weight for minimum annual values 20.0
Default weight for maximum annual values 10.0

Default standard weight is 1.0





N.B The scale on this cusum plot is larger than the CBACs standard (10 m, -10 m)



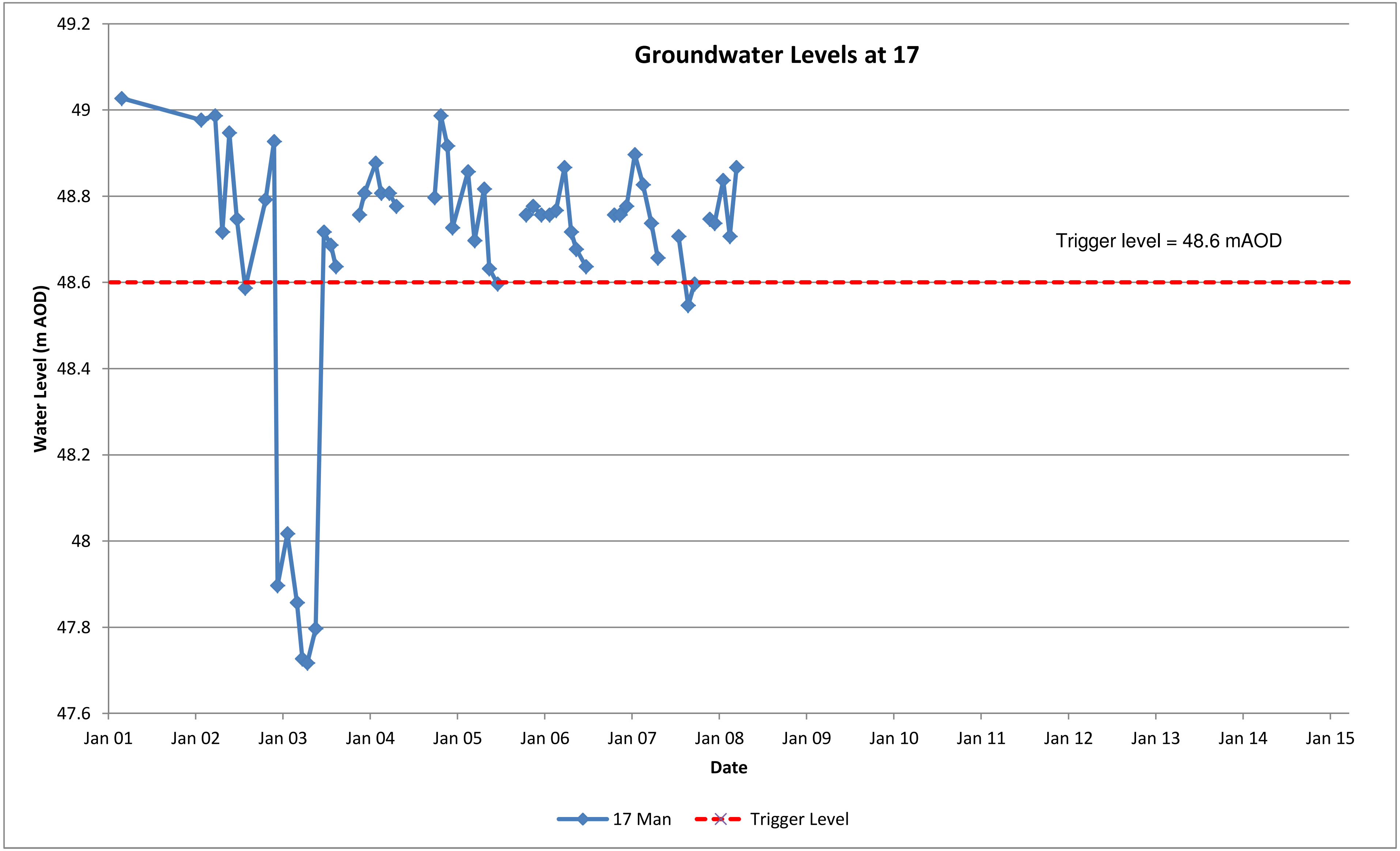


Figure H.1

Groundwater levels at 17 (north of Cornelly Quarry) and trigger level

Date Jun-15	Drawn KHB
Scale dns	Checked BCH
Original A4	Revision 1
File Reference O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.1 17.xlsx]H1	

Environment Specialists

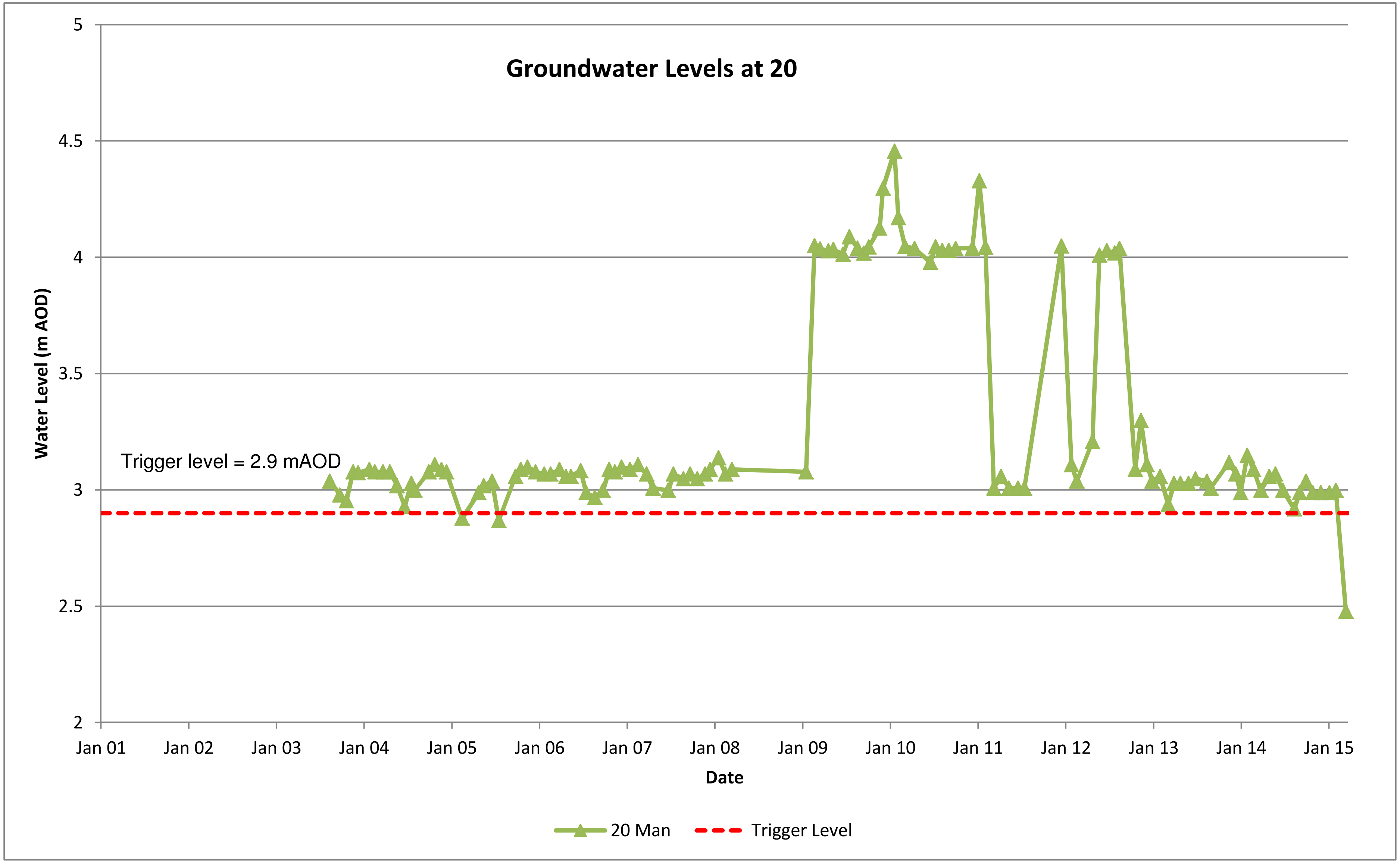


Figure H.2

Groundwater levels at 20 (Porth Cawl) and trigger level

Date Jun-15	Drawn KHB
Scale dns	Checked BCH
Original A4	Revision 1
File Reference O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.2.xlsx]H2	

Environment Specialists

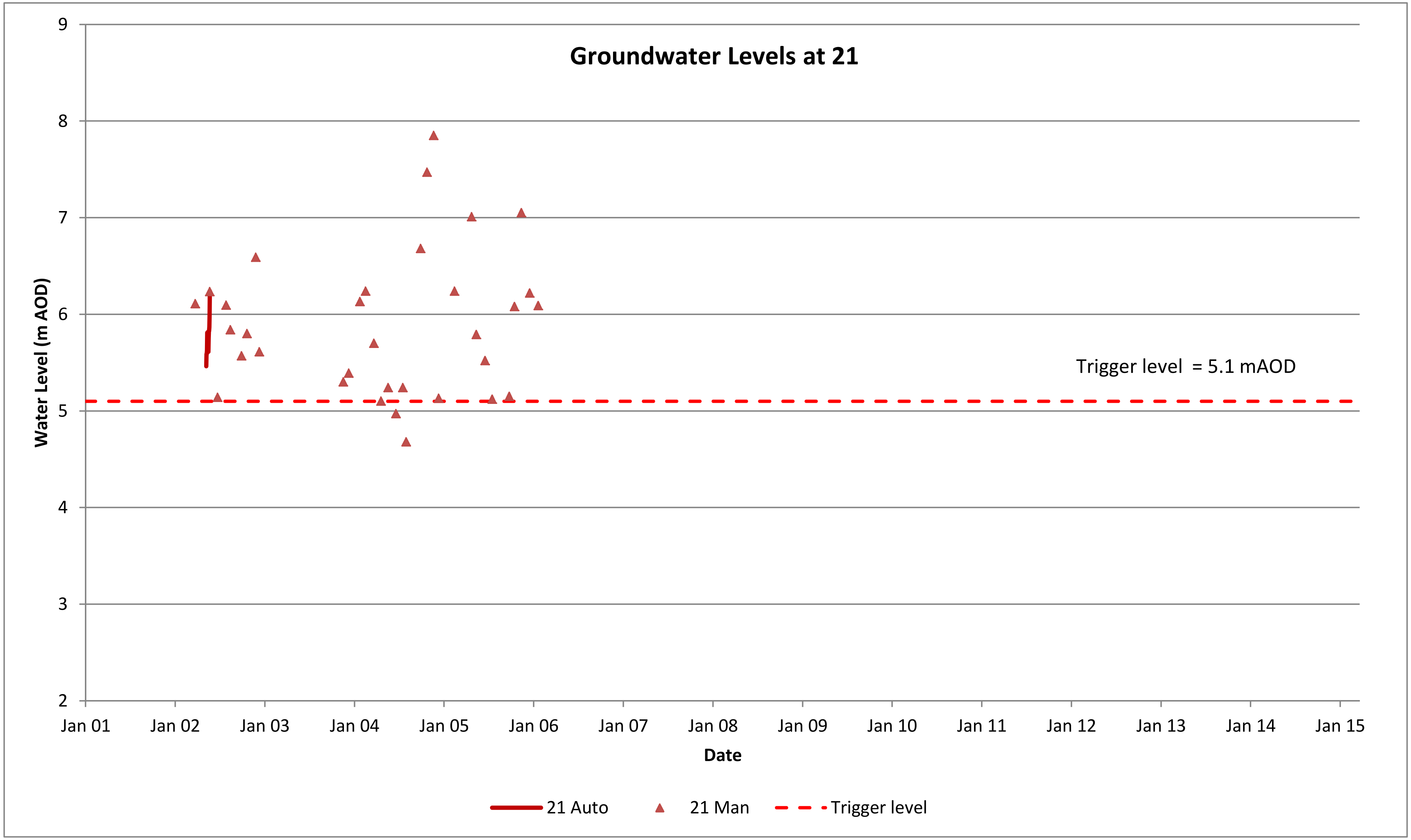


Figure H.3

Groundwater levels at 21 (Porth Cawl)

Date Jun-15	Drawn KHB
Scale dns	Checked BCH
Original A4	Revision 1
File Reference O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.1 17.xlsx]H1	

Environment Specialists

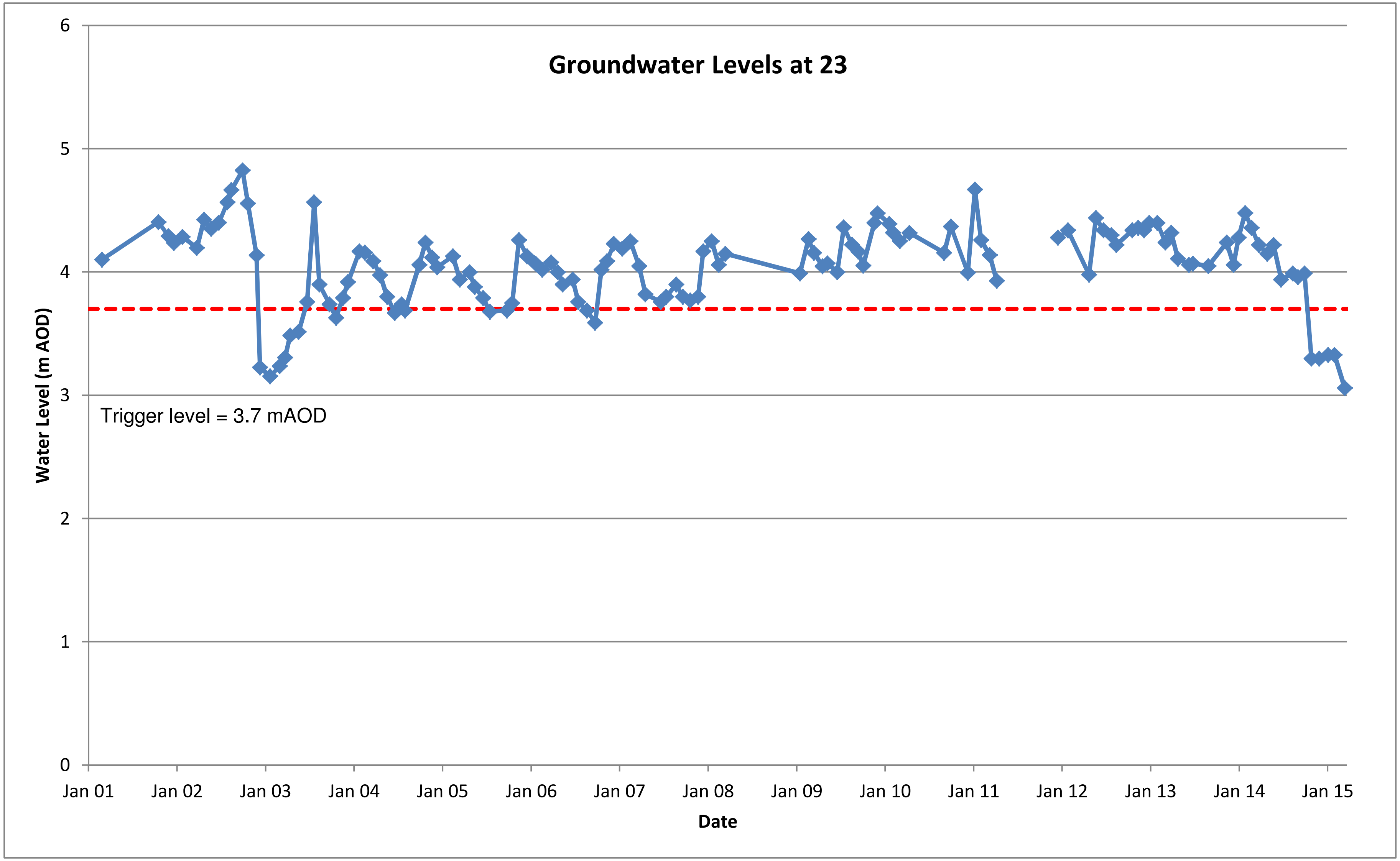


Figure H.4

Groundwater levels at 23 (Porth Cawl) and trigger level

Date	Drawn
Jun-15	KHB
Scale	Checked
dns	BCH
Original	Revision
A4	1

File Reference
O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.4.xlsx]H4

Environment Specialists

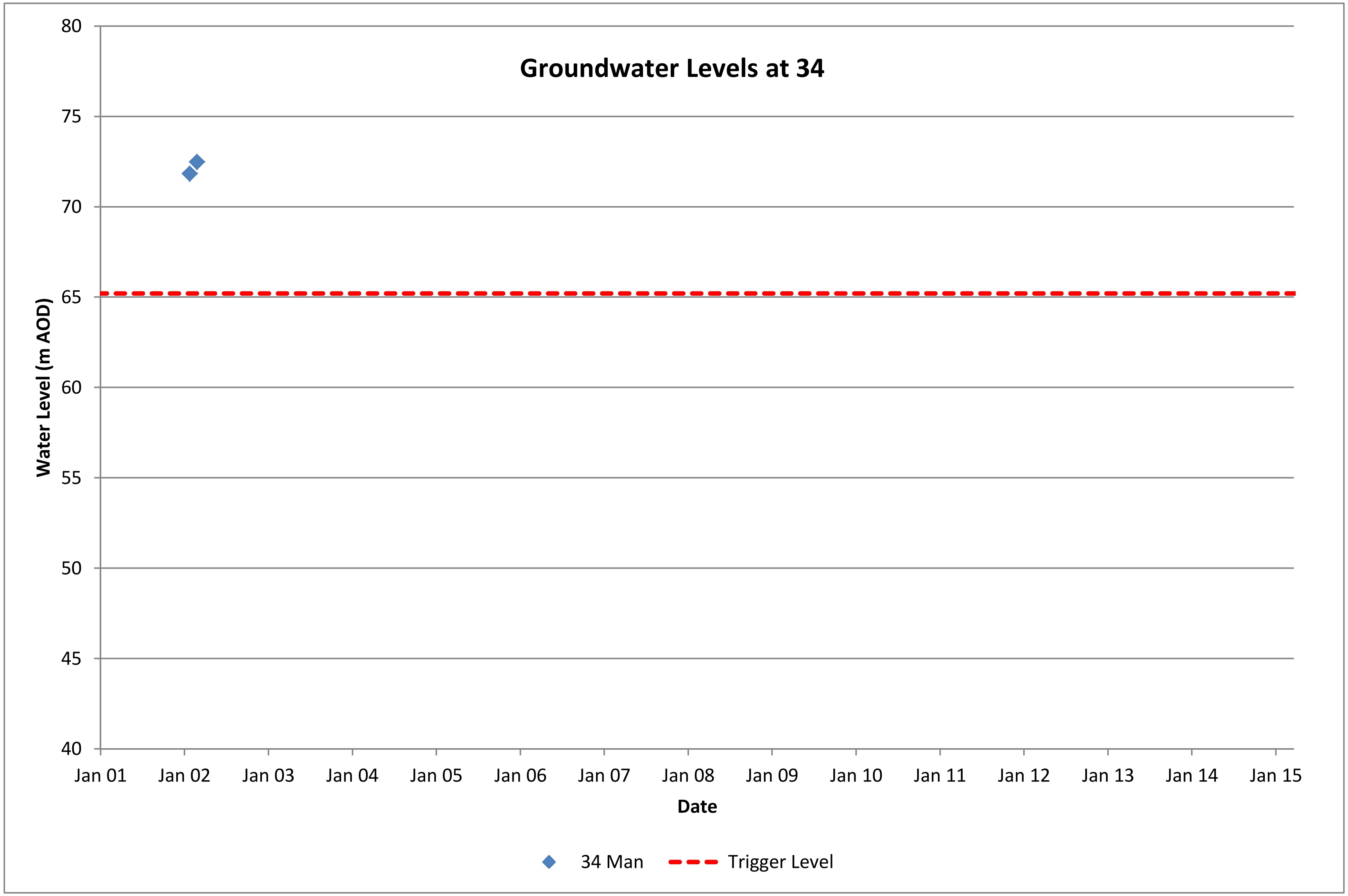


Figure H.5

Groundwater levels at 34 (Tythegston landfill) and trigger level

Date	Drawn
Jun-15	KHB
Scale	Checked
dns	BCH
Original	Revision
A4	1

File Reference
O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.5.xlsx]H5

esi Environment Specialists

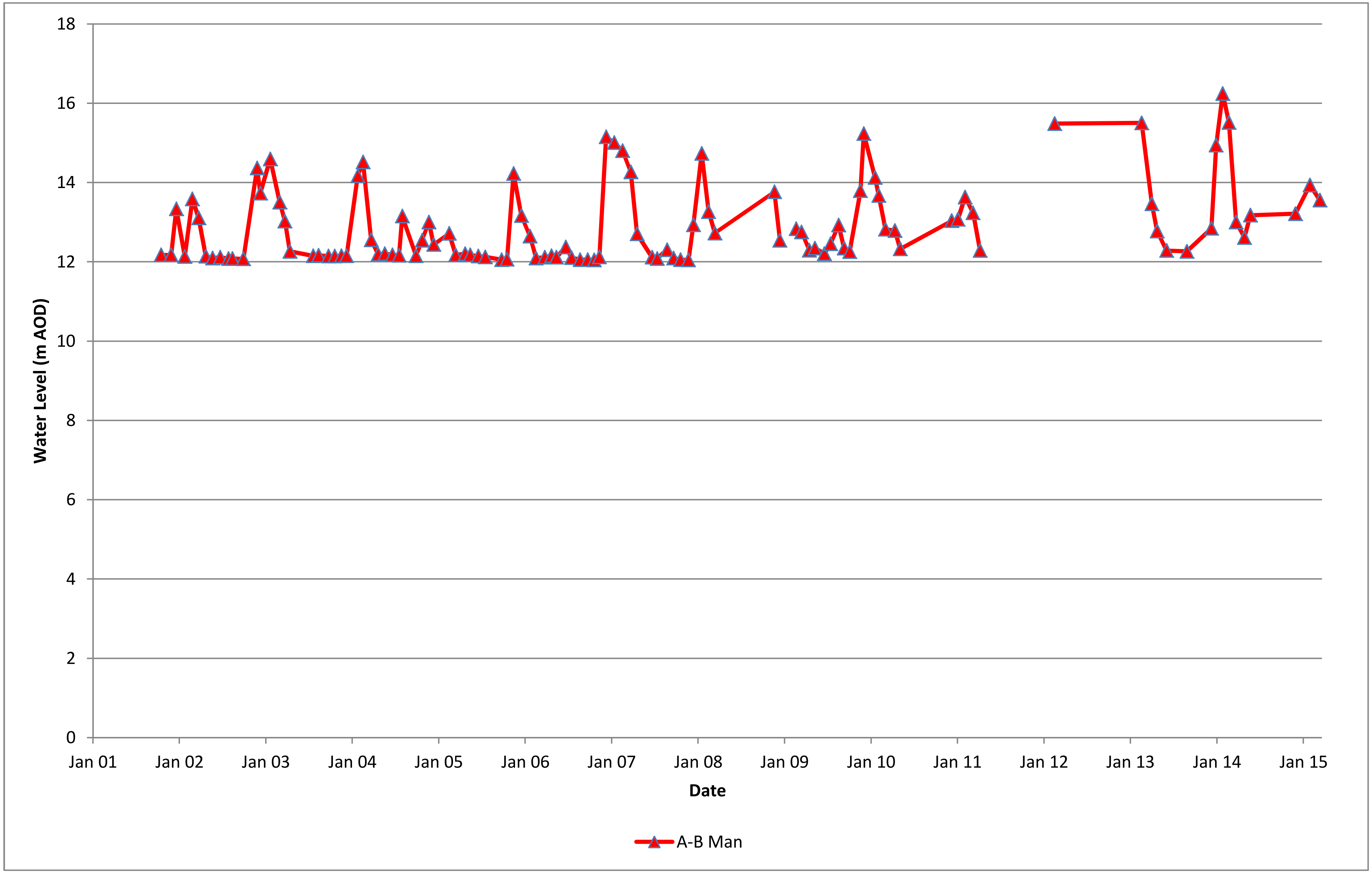


Figure H.6

Groundwater levels at A-b (Kenfig Pool)

Date Jun-15	Drawn KHB
Scale dns	Checked BCH
Original A4	Revision 1
File Reference O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.6.xlsx]H6	

esi Environment Specialists

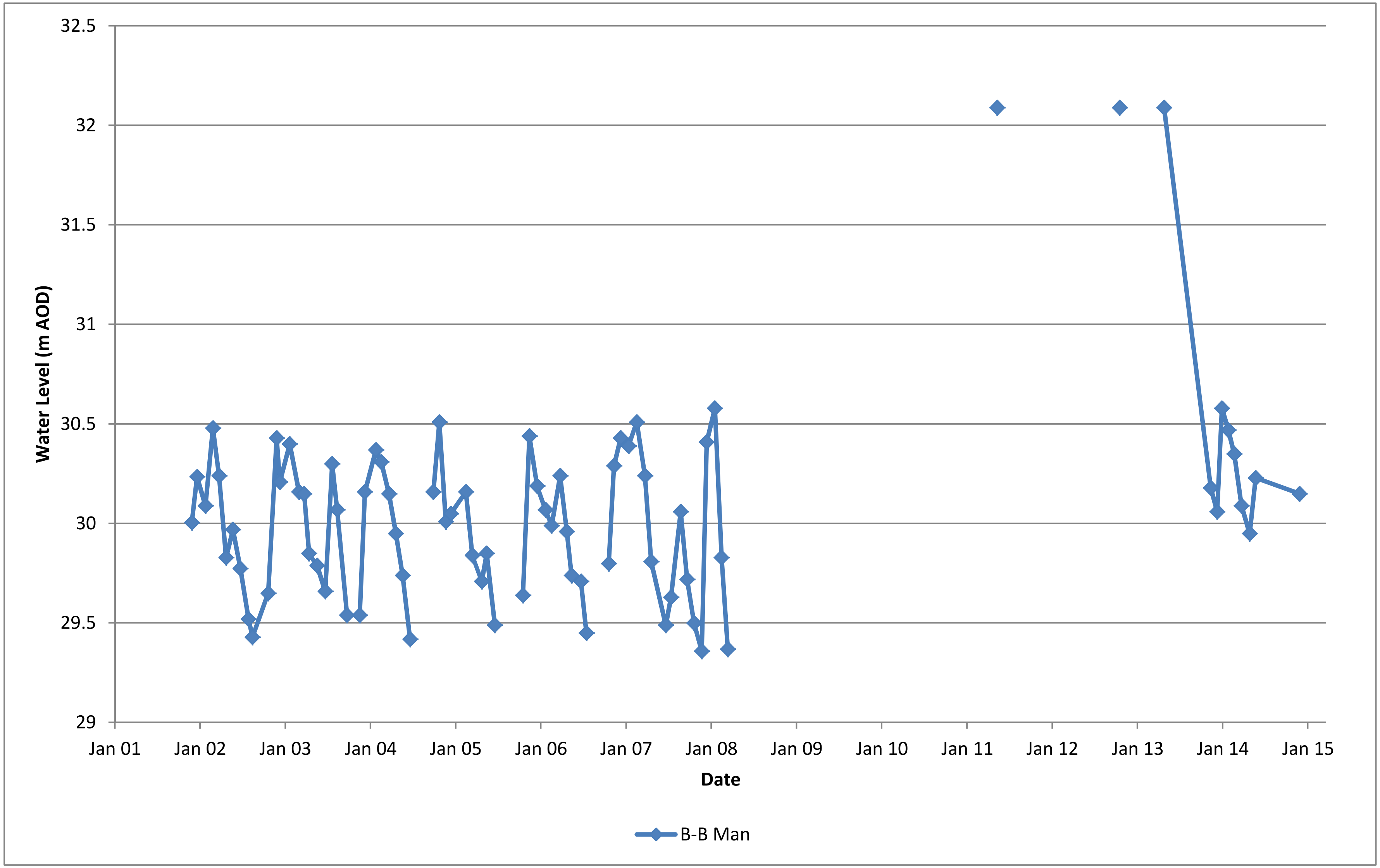


Figure H.7

Groundwater levels at B-b (Sker)

Date	Drawn
Jun-15	KHB
Scale: dns	Checked: BCH
Original: A4	Revision: 1

File Reference
O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.7.xlsx]Data

Environment Specialists

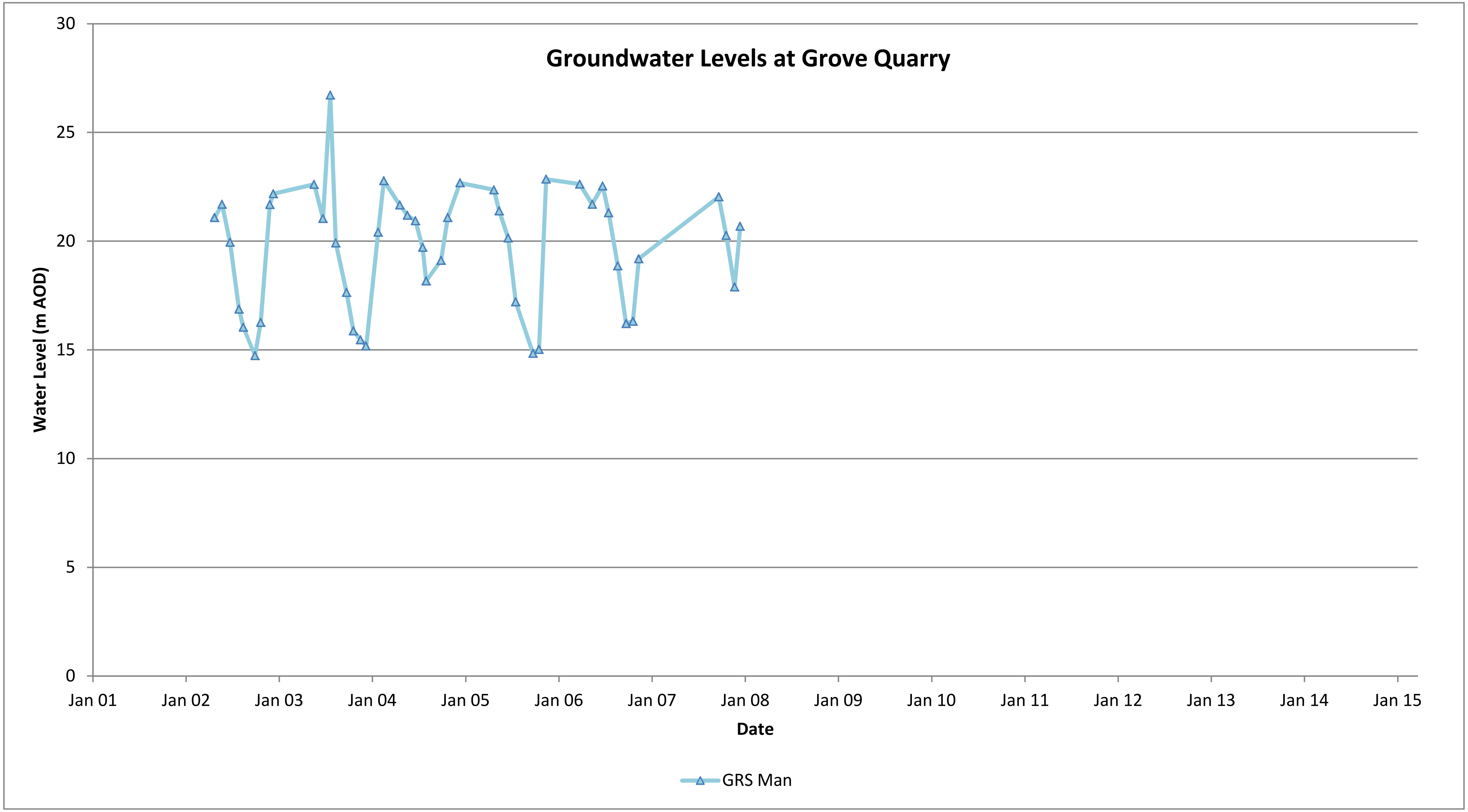


Figure H.8

Groundwater levels at GRS (Grove Quarry)

Date Jun 15	Drawn KHB
Scale dns	Checked BCH
Original A4	Revision 1
File Reference O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.8.xlsx]H8	

esi Environment Specialists

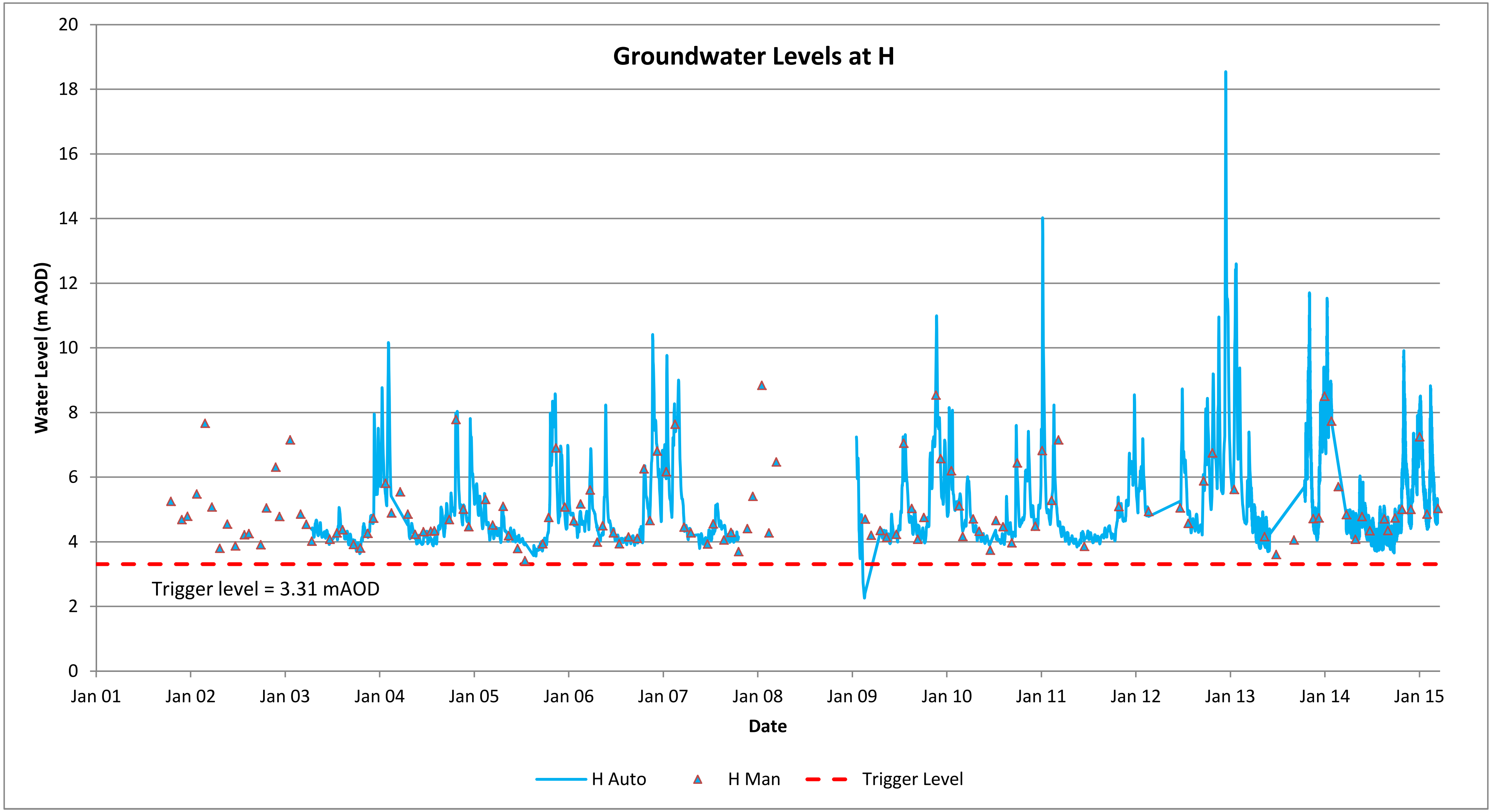


Figure H.9

Groundwater levels at H (Grove Quarry)

Date	Drawn
Jun 15	KHB
Scale	Checked
n/a	BCH
Original	Revision
A4	1

File Reference
O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\Monitoring data\Water level reports\13_June15\[H.9.xlsx]H9

Environment Specialists

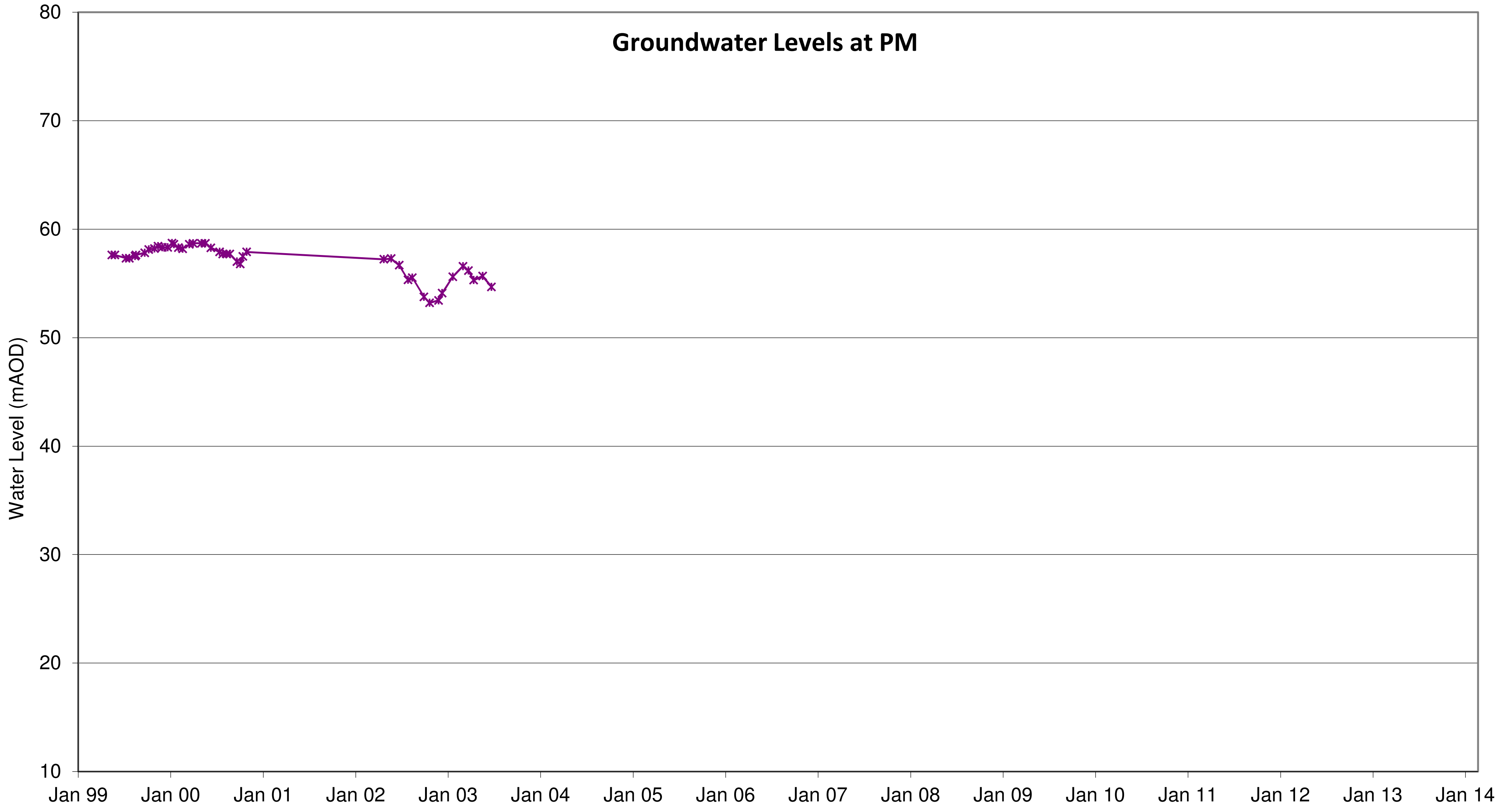


Figure H.10

Groundwater levels at PM (Cornelly Quarry)

Date Apr 14	Drawn KHB
Scale dns	Checked BCH
Original A4	Revision 1
File Reference O:\6227_Cornelly\data\Raw (incoming) or pre 2013 Data\monitoring\water level reports\12_April14\[H.10.xlsx]H10	

Environment Specialists

APPENDIX D

Technical Note on Calculation of Climate Based Assessment Criteria and associated statistical tests

Appendix D1 - Technical Note on Calculation of Climate Based Assessment Criteria and Associated Statistical Tools

Report reference: 6227 WMP Cornelly Quarry, August 2007
Report status: WMP Update August 2007

CONTENTS

FIGURES

APPENDICES

1 INTRODUCTION

1.1 Background

Cornelly Quarry (the “Quarry”) is the largest quarry in Wales providing over 1 million tonnes of limestone per year, principally for the steel mill at Port Talbot. It is also an important supplier of aggregates into the local construction industry.

In 1997, applications were made to Bridgend County Borough Council under the Environment Act, 1995 (Review of old mineral permissions – ROMP), for determination of a scheme of conditions in respect of the area of the Quarry covered by those planning permissions (the “ROMP application”). Separate applications were made in respect of the nearby Grove and Gaens’ Quarries. The applications were referred to the Secretary of State for Wales in May 1998 (Gaens’) and July 1998 (Cornelly and Grove). Due to the commonality of issues at these sites, it was decided that they should be determined as a group. The National Assembly for Wales (now the Welsh Assembly Government) subsequently took on the role of determining authority for the applications.

An Environmental Impact Assessment (EIA) in connection with the ROMP applications for the Quarry was submitted voluntarily in 2004 (WynThomasGordonLewis, 2004). The EIA was based on the continuation and extension of current water management practices at the Quarry. The EIA included a set of proposed planning conditions.

One of the proposed new planning conditions submitted in the EIA was the requirement to develop a Water Management Plan (WMP) for the Quarry (WynThomasGordonLewis, 2004 Appendix 8, C No. 9). The objective of the WMP is to guide the Quarry Operator in its management of water at the Quarry such that any adverse environmental impacts resulting from these activities can be minimised. In order to achieve this, the WMP will:

- Specify the monitoring activities required;
- Outline how the resultant data should be reviewed in order to determine whether the operation of the Quarry has affected any of the monitoring sites;
- Outline the options for management of water at the Quarry and how these could be adjusted in light of any effects detected at any of the monitoring sites.

1.2 Objectives of this Technical Note

For the purposes of the WMP, the Quarry Operator and Regulator need to be able to determine whether any future variations in monitoring data at any of the monitoring sites are due to the effects of climate or are due to other causes (such as land use change, private abstraction and quarry dewatering). There are two components to this technical issue:

1. A mechanism is required that can allow the behaviour of water levels at a monitoring site to be predicted under future climatic conditions (a Climate Based Assessment Criterion);
2. Statistical tools are required that will allow an assessment to be made as to the timing and scale of any Deviation[1] between the water levels predicted by the Climate Based Assessment Criterion and those measured in the future.

1.3 Approach

This technical note presents details of the two tools described above. Section 2 presents a generic description of calculations to be used for generating Climate Based Assessment Criteria. These calculations were originally presented as part of the conceptual model report that underpinned the EIA and were reviewed in detail by the Environment Agency at that time. The calculations have been updated with more recent climate data using several demonstration datasets from the monitoring sites in the area.

[1] In this context, Deviation is defined as the occurrence of a statistically significant difference between the behaviour measured at a site and the behaviour that would be anticipated under ‘natural’ conditions.

Section 3.1 presents details of statistical techniques that it is proposed should be used to determine whether a Deviation has occurred. This is a two stage process:

1. Firstly standard control chart techniques are applied to identify periods during which there is a sudden or sustained change in the relationship between the observed data and the Climate Based Assessment Criterion.
2. Then statistical tests are applied to confirm whether there has been a statistically significant change in the relationship between the observed data and the Climate Based Assessment Criterion during this period. If a statistically significant change is confirmed, this is considered to be a Deviation.

The use of these techniques is demonstrated in Section 3.2 by artificially adjusting a segment of time series data of a sample data set by a fixed amount to illustrate the sensitivity of the techniques to small changes in water level.

Note that, in this technical note, the techniques are only discussed in terms of water levels. However, they could be equally applicable to flow data.

2 CALCULATION OF CLIMATE BASED ASSESSMENT CRITERIA

2.1 Introduction

This section provides a generic discussion of the calculations that will be used to derive Climate Based Assessment Criterion and the data that they require as inputs. It then illustrates how these calculations can be used to generate a time series of predicted water levels at a site for given antecedent climatic conditions.

The calculations to derive Climate Based Assessment Criteria are based on daily soil moisture balance calculations which use rainfall and potential evapotranspiration data as inputs. The calculations have a number of parameters that affect the way in which the soil moisture balance operates and which control the division of outputs between actual evapotranspiration, runoff and infiltration to groundwater.

The infiltration to groundwater is passed into a ‘1D store’. This is a simple algebraic device that is used as a ‘groundwater model’: the rate of outflow in the store is proportional to the level of water in the store. The constant of proportionality of the 1D store is one of the parameters that can be used to adjust the temporal behaviour of both the water levels in the store and the resultant outflows. The water level in the store can be converted to an equivalent measured groundwater level by means of a ‘specific yield’.

The values of the parameters used in the calculations presented here were selected partially on the basis of values commonly used for these parameters in regional water resource assessments and partly by ‘calibration’ against local flow data (e.g. quarry abstraction rates, some stream flow data). These values have not been adjusted since the calculations were originally developed to support the conceptual model in 2003. The match between the simulated and measured water levels at these sites since that time provides a measure of confidence in the calculations and their parameterisation for those sites.

2.2 Data

2.2.1 Rainfall data

The following rainfall data sets are available from the Environment Agency:

Cefn Cribwr (1) – Daily rainfall data for the period Jan 1981 to Jan 02 (with some gaps)

Cefn Cribwr (2) – Daily rainfall data for the period Jan 02 to Dec 05 (with some gaps)

Schwyll - Daily rainfall data for the period Dec 91 to Sept 06 (with some gaps)

Margam - Daily rainfall data for the period Feb 93 to July 06 (with some gaps)

In addition, staff at Kenfig National Nature Reserve monitor rainfall at Kenfig at intermittent (daily/weekly intervals). Data are available for the period Jan 2000 to May 06.

The calculations presented in the conceptual model report (ESI, 2003) were based on the Cefn Cribwr (1) data series. This is an appropriate site for the calculation of the limestone block around the quarry as it is at a similar elevation. As monitoring at this site has been discontinued and there is relatively little overlap with the new monitoring site here, gaps in the data series have primarily been filled by reference to the Schwyll rainfall series. Conversion was by means of the equation Cefn Cribwr (1) = 1.27 x Schwyll (based on the ratio of long term average rainfall at the two sites for periods during which reliable data are available at both sites). Ultimately, it is anticipated that this will be replaced by reference to data from a new rain gauge to be installed at Cornelly Quarry itself.

It is clear from the available data from Kenfig Nature Reserve that rainfall here is lower than at Cefn Cribwr (1) due to the lower elevation of the former. In order to convert the continuous daily time series from Cefn Cribwr (1) to an appropriate series for calculations for the sand dunes, the Cefn Cribwr (1) data have been converted by means of the equation

Kenfig = 0.885 x Cefn Cribwr (1) (based on the ratio of long term average rainfall at the two sites for periods during which reliable data are available at both sites) for the period when there is no data at Kenfig. For the period for which there are rainfall data at Kenfig, the daily rainfall at Schwyll has been factored so that the monthly totals are the same as those measured at Kenfig.

2.2.2 Potential Evapotranspiration data (PE)

Weekly PE data for MORECS square 155 were converted to daily values by distributing the weekly total evenly across each day of the week. There is less spatial variation in PE data and the outputs from the calculations are less sensitive to this parameter and so this has not been varied spatially.

2.3 Soil Moisture Balance Calculations

Recharge to the groundwater system has been calculated using a Penman two store soil moisture balance model implemented in an Excel spreadsheet.

Prior to passing rainfall to the soil moisture store, any runoff is removed. In areas in which the ground surface is relatively impermeable this may be a relatively significant amount (say 10-20%). On areas of permeable aquifer (e.g. limestone or dune sands) runoff is likely to be relatively low although water may effectively bypass the soil zone (see below).

The Penman store model consists of an upper and a lower soil store. The depth of the upper store is the depth up to which roots are able to draw as much water as required. At greater depths of store, water is only available to plants at a reduced rate. A bypass mechanism allowing direct percolation to the unsaturated zone via e.g. macropores or root channels may also be included. Referring to the schematic diagram in Figure 2.1 (a), the Penman store model works in the following manner.

The status of the model is wetting if precipitation is greater than potential evapotranspiration (i.e. $P\text{-}PE>0$), otherwise it is drying ($P\text{-}PE<0$).

In wetting mode, the direct percolation (i.e. bypass of the soil zone) is a constant percentage of the effective precipitation, i.e. $f\ (P\text{-}PE)$, where f is the proportional factor (1). The remaining water $(1\text{-}f)\ (P\text{-}PE)$ infiltrates the upper soil store (2). When the upper store is full, the excess begins to saturate the lower soil store (3). When the lower soil store is full the excess leaves the lower soil store as percolation to the unsaturated zone (4).

In drying mode, whilst the upper soil store is not dry (5), the soil moisture deficit of the store increases by the shortfall in potential evapotranspiration once precipitation has been taken into account, i.e.

$$\Delta SMD_1 = (PE - P) \quad \text{if} \quad SMD_1 < D_c$$

where

SMD_1 is the soil moisture deficit of the upper store

ΔSMD_1 is the change in the soil moisture deficit of the upper store

D_c is the drying constant.

When the upper soil store is dry, drying of the lower store takes place at a lower rate:

$$\Delta SMD_2 = \gamma (PE - P) \quad \text{if} \quad SMD_1 = D_c$$

where the factor γ represents the drying curve slope

Typical parameter values are as follows f=15%, D_c=75 mm, γ=0.3. For the karstic Carboniferous Limestone areas it is likely that the bypass percentage will be higher and a value of 25% has been used.

The output from the soil moisture deficit model (infiltration to groundwater) has then been processed by passing through a two stage store as illustrated on Figure 2.1 (b). The store is characterised by three parameters:

Time constant for lower release

Time constant for upper release

Level for upper release to be activated

The methodology effectively uses catchment averaged rainfall and PE data series to calculate total catchment flow (e.g. in a river). This approach has proved to be very successful in simulating saturated flow in small to medium sized aquifer systems and is used extensively by the Environment Agency in Thames Region (Catchmod).

2.4 Comparison with Data

Whilst the approach described above has been proven to be widely applicable in a variety of settings (including Carboniferous Limestone areas), the effectiveness of the calculations needs to be demonstrated by comparison with field data for the current study area. Comparison of outputs with observed river flows is presented in Appendix D of ESI, 2003. The text below focuses on comparison with observed groundwater levels as this is the primary interest of this technical note.

The status of the ‘groundwater store’ provides a prediction of groundwater levels in the aquifer. A good match between store volume and groundwater levels indicates that the calculations are effectively simulating the temporal variation in groundwater recharge and discharge from the aquifer system.

2.4.1 Kenfig Dunes

Calculations were developed for the sand dune system at Kenfig using the synthesised daily Kenfig time series (see Section 2.2.1). Key parameters used are:

Sy=0.2 (dune sands)
Store time constant = 180 days
Runoff= 8% (average)
Drying constant (D_c)= 75 mm
Drying curve (γ) = 0.3
Direct percolation (f) = 25%

The results of this calculation are shown in Figure 2.2. Clearly there are a number of simplifications in trying to simulate a complex structure such as the dunes in such a simple manner. However, overall the qualitative fit to the data is reasonable. The summary statistics for the calculations include:

LTA (Feb 93- Jul 06) effective precipitation = 632 mm/a

Percentage of recharge ‘overtopping’ = 2% (not much ‘overtopping’ effect in this hydrograph)

The overall range of the simulated and observed groundwater levels during the period of overlap is very close (8.94 to 10.51 mAOD and 8.91 to 10.50 mAOD respectively). There is a slight bias of the calculations to simulate levels lower than those observed (0.1 m on average). However, the current simulation was retained as, on average it was considered to simulate levels better during the critical summer periods. This difference is relatively small compared to the range of levels simulated (7% of range).

2.4.2 Carboniferous Limestone

A similar calculation was set up to simulate recharge processes in the Carboniferous Limestone around Cornelly Quarry. The following parameters were used in the calculations:

Sy=0.005
Runoff=*0%,*
f=25%,
D_c=75 mm,
γ=0.3

Figure 2.3 shows the comparison between the simulated groundwater levels and actual data for borehole 96/11 (just to the east of Cornelly Quarry). There is a good qualitative fit between simulated and observed data. The parameterisation of the calculations has not been modified for the presence of the quarry as it is not clear whether the nature of the workings will increase or decrease the total recharge available (reduced evaporation due to the absence of plants but increased evaporation in areas of open water). The surface of the quarry floors is generally permeable due to the effects of blasting and there does not appear to be significant amounts of runoff.

There is some indication that there has been some drawdown at this site over the period simulated and this is consistent with its position in the immediate vicinity of the quarry.

2.4.3 New Mill Farm Catchment

In this case the groundwater levels in the Triassic marginal facies at the South Cornelly Borehole were simulated. The following parameters were used in the calculations:

Sy=0.015
Runoff=*0%,*
f=25%,
D_c=75 mm,
γ=0.3

The observed and simulated groundwater levels are shown on Figure 2.4. Again, there is a reasonable degree of correlation between the

2.5 Summary

The proposed approach for assessing the effect of climatic variations (principally rainfall rates) on groundwater levels has been shown to be generally successful for the main types of hydrogeological conditions of relevance to the WMP. It is therefore concluded that this approach is appropriate for the purposes required by the WMP.

3 STATISTICAL TOOLS

Control charts are a method commonly used in to monitor processes and produce an early warning whenever a situation deviates from 'normal'. The two main types of control charts used in groundwater monitoring are the Shewart and the Cu-Sum charts. These techniques are used to identify periods during which there is a sudden or sustained change in the relationship between the observed data and the Climate Based Assessment Criteria.

Once such a period has been identified, supplementary statistical tests can be applied to confirm whether there is a statistically significant change in the relationship between the observed data and the Climate Based Assessment Criteria during this period compared to the relationship beforehand (baseline). The choice of tests depends on whether the differences between the observed data and the Climate Based Assessment Criteria are normally distributed or not. The two sample t-test is a well known test that is appropriate for use with populations that are normally distributed with the same variance around their respective means. The Wilcoxen Rank-Sum Test for Two Groups is a non-parametric test that can be used with non-normally distributed datasets.

Section 3.1 presents a brief technical description of the implementation of these methods. This is followed in Section 3.2 by an illustration of the application of these techniques to determine whether there is any deviation between observed water level data and outputs from the calculations presented in Section 2.

3.1 Approach

3.1.1 Shewart Charts

The Shewart control chart is used to detect relatively sudden changes in a process under investigation (e.g. rapid increase/decrease of groundwater level).

Assuming that $x_1, x_2, \dots, x_n$ are n differences between the simulated and measured groundwater levels at the times $t_1, t_2, \dots, t_n$., a Shewart control chart of these differences is obtained by standardising the values of x_i as follows:

$$z_i = \frac{x_i - m}{s}; \qquad i = 1, 2, \dots, n$$

where: m and s are the average and the unbiased standard deviation of the x_i, $i = 1, 2, \dots, n$,

and then plotting them versus the times $t_1, t_2, \dots, t_n$.

In order to identify when the process has deviated from 'normal' the standardised data z_i are compared to a threshold Z (control limit). When the z_i exceed the control limit the process is declared to be 'beyond normal range'. Gibbons suggests that a value of Z of 4.5 should be taken as a level at which a statistically significant change is considered to have occurred.

3.1.2 Cu-Sum Charts

The Cumulative Summation (Cu-Sum) approach not only focuses on the current monitoring value, but also incorporates information from the previous observations. The main advantage of a Cu-Sum over a Shewart chart, is that the Cu-Sum chart is suitable to detect slower, but systematic processes or trends which would not appear as evident by analysing the time series of the raw data or the Shewart chart. This is perhaps more common in the diffuse systems common in hydrogeology.

Assuming that $x_1, x_2, \dots, x_n$ are n differences between the simulated and measured groundwater levels at the times $t_1, t_2, \dots, t_n$.

The Cu-Sum control chart of these differences is obtained by calculating the quantity:

$$S_i = max(0, z_i - k + S_{i-1})$$

Where:

z_i are the standardised differences described in Section 3.1.1;

k is a parameter representing ½ the change that it is appropriate to try and detect (see more discussion on selection of this parameter in Section 3.2);

S_{i-1} is the value of S_i at the previous observation event.

In order to detect a when the process has fallen out of normal range, the values of S_i are compared to a threshold (or control limit) *h*. The selection of the value of *h* should be based on an assessment of the maximum value of S_i that is appropriate – this could be determined by consideration of the typical range of values of S_i during a period in which no Deviation is considered to occur. Note that, the value selected may in part be determined by the frequency of the data (i.e. a larger Cu-Sum will accumulate with daily data if the observed and simulated deviate over a 6 month period than if monthly data is used). If the frequency of monitoring changes then some allowance for this will need to be made (either by sampling the higher frequency data set to a lower frequency or by interpolating between the values in the less frequent data set).

For technical, statistical reasons the value of S_i should not fall below zero. In order to detect trends in the opposite direction, a 'negative' Cu-Sum is calculated. (i.e. the positive Cu-Sum could be used to detect when the observed data falls below the simulated level whilst the 'negative' Cu-Sum could be considered to detect when the observed data rises above that simulated).

The use of the combined Shewart-Cu-Sum control chart gives the advantages of being able to detect sudden changes in the system as well as gradual and consistent shifts, which would not be easily detected by a simple time series plot.

3.1.3 The Wilcoxon Rank-Sum test for Two Groups

The Wilcoxon Rank-Sum Test for Two Groups (Lehmann, 1975) is used to compare a two datasets to check for an increasing/decreasing average value. This is a non-parametric test and, as such, it is robust to outliers and non-detects.

In groundwater monitoring this test is often used to compare a historic dataset with a recent one in order to detect a statistical difference between the two.

To run the Wilcoxon Rank-Sum test the compliance and background data are combined and ranked from 1 to N. The Wilcoxon statistic W is then calculated as:

$$\boldsymbol{W} = \sum_{\boldsymbol{i}=1}^{\boldsymbol{n}} \boldsymbol{C}_{\boldsymbol{i}} - \frac{1}{2}\boldsymbol{n}(\boldsymbol{n}+1)$$

where:

C_i denotes the ranks of the compliance samples, and

n denotes the number of compliance samples.

In order to determine whether the null hypothesis of no decreased average can be accepted an approximate Z-score for the Wilcoxon Rank-Sum test has to be compared to a critical value of W. The approximate Z-score for the Wilcoxon test is:

$$\boldsymbol{Z} \approx \frac{\boldsymbol{W} - \boldsymbol{E}(\boldsymbol{W}) - 1/2}{\boldsymbol{SD}(\boldsymbol{W})};$$

where:

- *W* is the Wilcoxon statistic as above defined;

- $E(W) = \frac{1}{2}mn$ represents the expected value of *W*;
- *m* is the number of values in the background sample;
- $SD(W) = \sqrt{\frac{1}{12}mn(N+1)\left(1 - \sum_{i=1}^{g}\frac{t_i^3 - t_i}{N^3 - N}\right)}$ is the standard deviation of the *W* statistic adjusted for tied values;
- t_i represents the number of ties in the i^{th} group;
- *g* represents the number of groups of distinct tied observations.

The critical value of *W* is the upper 0.01 percentile of the standard Normal distribution $z_{0.01}$=2.326.

If the Z-score is greater than 2.326, the null hypothesis of no significant difference may be rejected.

An appropriate choice of the background and compliance datasets allows us to use the Wilcoxon Rank-Sum Test for Two Groups as a means to identify a statistical evidence of decreasing average.

3.1.4 The two sample t-test

The t-test is the most widely used method for comparing two independent groups of data, however it presents some problems when applied to non normal datasets.

The null hypothesis of the test is that the difference between the averages of the two datasets equals a number δ_0. The test statistics is:

$$t_0 = \frac{(\overline{X} - \overline{Y}) * \delta_0}{s_p\sqrt{\frac{1}{m} + \frac{1}{n}}} \qquad (1)$$

where:

$\overline{X}$ is the average of the data over the period during which a change appears to have occurred;

$\overline{Y}$ is the average of all the rest of the data;

$s_p = \sqrt{\frac{(m-1)*s_x^2 + (n-1)*s_y^2}{m+n-2}}$ is the pooled standard deviation estimate;

s_x and s_y the sample variances of the two populations;

<u>*m*</u> and *n* the sample sizes of the x and y datasets respectively

In the case that the test statistics is greater than the critical value $t_{m+n-2,1-\alpha}$ (which should be looked up in the test statistical tables), the null hypothesis should be rejected.

3.2 Application

3.2.1 Existing data sets

The application of these techniques is illustrated by reference to the observed and simulated data for the Kenfig Dunes sites as discussed in Section 2.4.1.

First the existing sequence of observed and simulated data were taken to form a 'baseline' for the statistical techniques. This created a series of pairs of observed:simulated data values at approximately monthly intervals for the period Jan 1997 to May 2006. Figure 3.1 shows the combined Cu-Sum and Shewart chart for the differences between the observed and simulated data (lower plot). The actual observed and simulated data are shown in the upper plot for comparison.

The Shewart chart shows that the control limit is not exceeded at any point in the historical time sequence.

The 'positive' Cu-Sum chart, conversely, shows that in the early part of the time series (1997 drought) there are some small but consistently positive differences between the simulated and observed data, whereas the 'negative' Cu-Sum chart shows a similar consistency in negative differences in the following part of the time series (through to the heavy rainfall in 2000). Following this there is relatively little consistent difference between simulated and observed data for the remaining time period. These differences can be seen in the observed and simulated data can be seen in the upper plot. It is not clear whether these differences are due to limitations of the calculations or inaccuracies in the input rainfall time series during this period.

The maximum (minimum) value represented in the positive (negative) Cu-Sum chart is less than +20 (greater than -26 respectively). If the calculations can be qualitatively accepted as an appropriate simulation of the groundwater conditions at this site (see discussion in Section 2.4.1) and it is considered that there is no general background trend in the differences during this period then, given that the period includes some fairly extreme climatic conditions (drought and flood), this range of Cu-Sum values can be considered to be appropriate levels at which to detect that a significant change has occurred. If the calculations could be improved to provide a more consistently good fit between observed and simulated levels, then the critical values of Cu-Sum can also be reduced.

3.2.2 Application to 'future' scenario with applied drawdown

In order to assess how effective the technique is at detecting the presence of a small but consistent drawdown in groundwater levels, a sequence of three years was added to the end of the time series and then manipulated to introduce a consistent difference between observed and simulated levels.

The data pairs for 2002 (which was considered to be a 'typical year') were repeated three times to create the 'future' sequence. This 'future' sequence was then modified by reducing the observed groundwater levels by a constant value (i.e. equivalent to a non-climate related drawdown occurring in the data). The Cu-Sum and Shewart charts were then calculated to see what size of deviation between the measured data and the simulated groundwater levels could be detected.

The results of this exercise are shown in Figures 3.2, 3.3 and 3.4 for drawdowns of 0.1, 0.2 and 0.3 m respectively. K was set at 0.05 m for this exercise, but in general will be set to half the difference that needs to be detected – for instance the Significance Criteria. The sensitivity of these results to K is shown in Figure 3.5.

From inspection of these figures, it can be seen that the Shewart approach does not detect these small but consistent changes (a change of around 0.6 m would be required to breach the Shewart control limit). The change of 0.1m would be confirmed in around 28 months (although the upward trend would have been apparent for the whole of this period), the change of 0.2 m would be confirmed in 9 months).

Comparison of the observed and simulated hydrographs in the upper plots shows that it is unlikely that a change of 0.1 m would be detected by visual comparison alone and that even a change of 0.2 m would be hard to be confident about.

A number of points are apparent from this exercise:

- The Cu-Sum approach is more sensitive and objective than visual inspection of the hydrographs.
- The length of time that the Cu-Sum takes to detect a change is inversely related to the size of the change (i.e. bigger changes are detected more quickly).
- The length of time that the Cu-Sum takes to detect a change is also related to the quality of the calculations (changes will be detected more quickly with a better match between observed and simulated data).
- The Shewart Chart is less sensitive than the Cu-Sum approach in detecting small but consistent changes. However, it would be effective at detecting a larger but more abrupt change.

3.2.3 Statistical Confirmation

The Cu-Sum chart method is dependent on time correlation effects and so, where water level changes are very gradual in comparison to the frequency of monitoring, this methodology may falsely indicate a systematic change in water levels. Once the Cu-Sum chart detects an apparent systematic change, it is therefore important to double check that a statistically significant difference is present in the data.

To achieve this, the two sample t-test or the Wilcoxon test can be used to compare the model residuals during the ‘baseline’ and apparently affected periods. In this case, the Wilcoxon test was used to confirm that there was a statistically significant change between the last three years of data (i.e. the period over which a change in the data was artificially applied) and the rest of the dataset. The Wilcoxon test was used as the model residuals were not normally distributed.

3.3 Summary

The example presented above suggests that the combined Shewart-Cu-Sum approach should be effective at detecting both abrupt changes in observed and simulated water levels and small but consistent changes. The sensitivity of these techniques in detecting changes in water level is primarily controlled by the quality of the fit between the observed and simulated data over a representative ‘baseline’ period. Where a good fit cannot be achieved, simpler approaches may be appropriate.

Once a period of apparent variation between the Climate Based Assessment Criterion and the observed data has been identified, it is important to carry out supplementary statistical tests to confirm this conclusion. To achieve this, the two sample t-test or the Wilcoxon test can be used.

In all cases, conditions at adjacent sites should be considered wherever possible in order to confirm the conclusions of techniques such as these.

4 REFERENCES

ESI, 2003. Cornelly Group of Quarries: Conceptual model of the local hydrogeology

R. Gibbons "Statistical Methods for Groundwater Monitoring" John Wiley & Sons, Inc

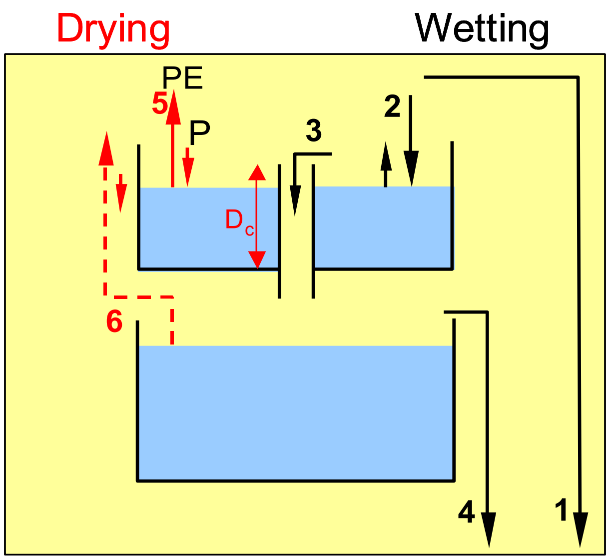
Lehmann, E.L. (1975) Nonparametrics: Statistical Methods Based on Ranks. San Francisco: Holden-Day, Inc.

WynThomasGordonLewis, 2004. Environment Act 1995: Review of Mineral Planning Permissions Cornelly Quarry Environmental Impact Assessment

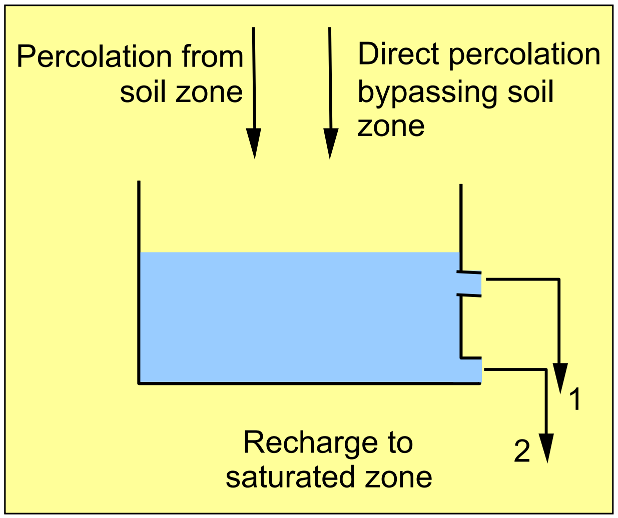
Appendix D.1 Parameters for Climate Based Assessment Criteria at Each Site

To be completed after first annual review after formal adoption of WMP.

(a)



(b)



(b) 'Two Stage' Linear Store Model

Outflow rate is proportional to volume in store

Recharge to saturated zone comprises

1. Outflow once volume (saturation) has reached critical level

2. Slower release also dependent on volume in store

Figure 2.1

(a) PENMAN TWO STORE SOIL MOISTURE BALANCE MODEL

(b) LINEAR CATCHMENT STORE MODEL FOR UNSATURATED ZONE

Date: Dec 06	Drawn: MJS
Scale: nts	Chk'd: MJS
Original: A4	Rev: 1
File Reference: O:\6227_Cornelly\calcs\WMP supporting calcs\recharge\SMB	

esi soil & groundwater

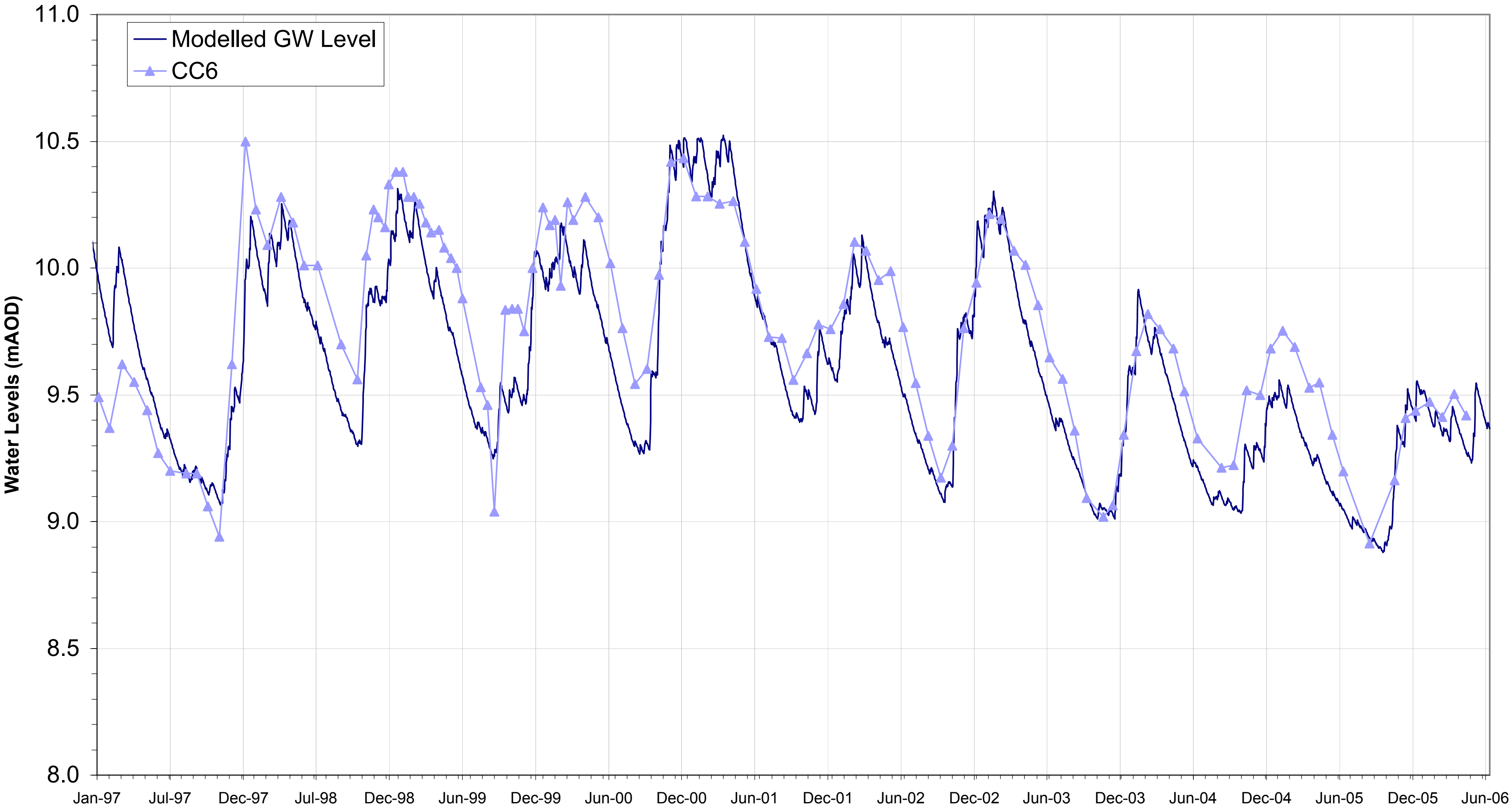


Figure 2.2

Modelled and Actual Groundwater Levels - Kenfig Dunes

Date: Sep 06	Drawn: MJS
Scale: nts	Chk'd: MJS
Original: A4	Rev: 1
File Reference: 6227\calcs\WMP Calcs\recharge\Dune Sand Recharge Revised Rainfall.xls	

soil & groundwater

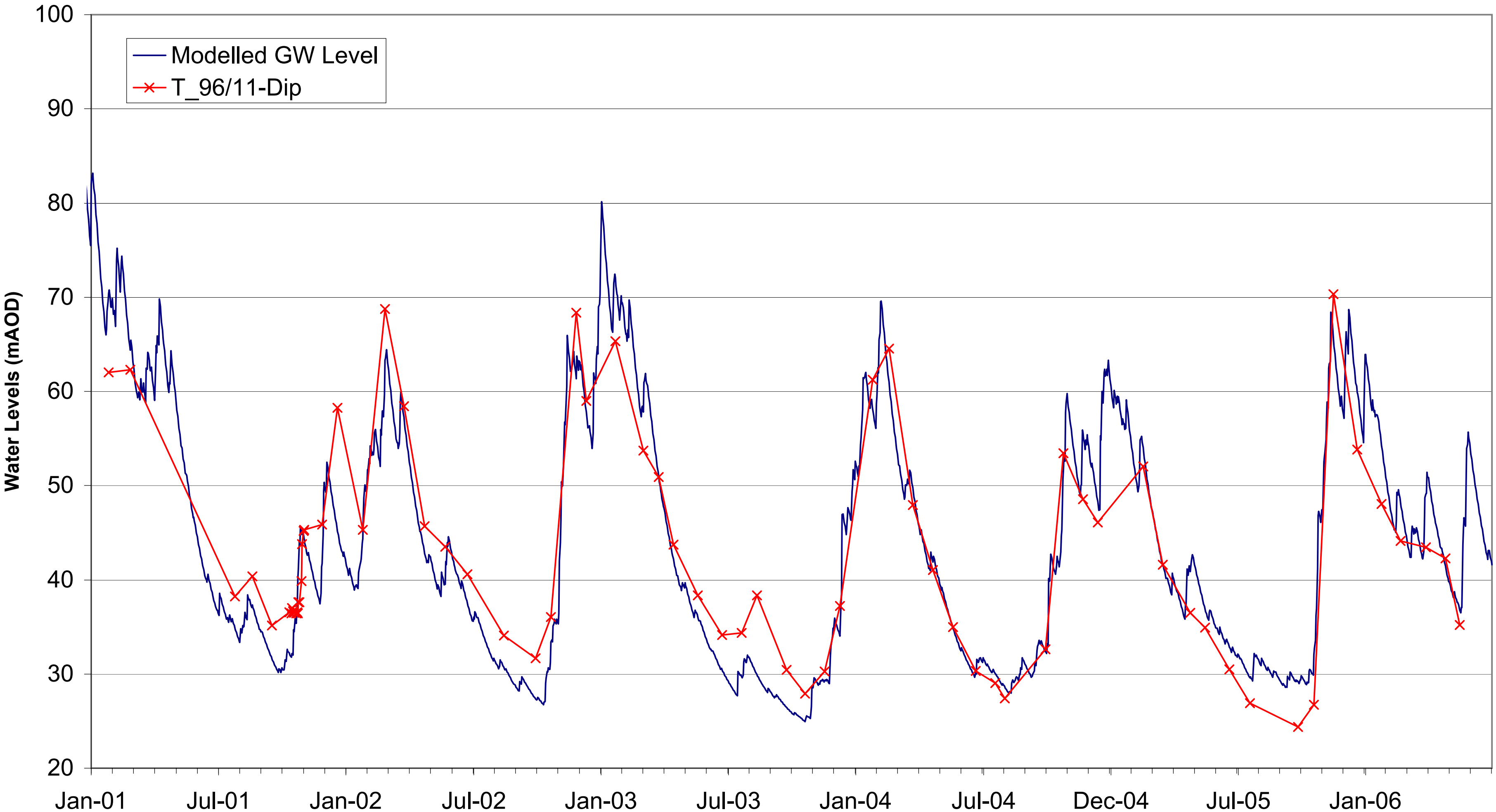


Figure 2.3

Simulated and observed groundwater levels in the Carboniferous Limestone

Date:	Drawn:
Dec 06	MJS
Scale: nts	Chk'd: MJS
Original: A4	Rev: 1

File Reference: O:\6227_Cornelly\calcs\WMP supporting calcs\recharge\Carb Lst Recharge.xls

esi soil & groundwater

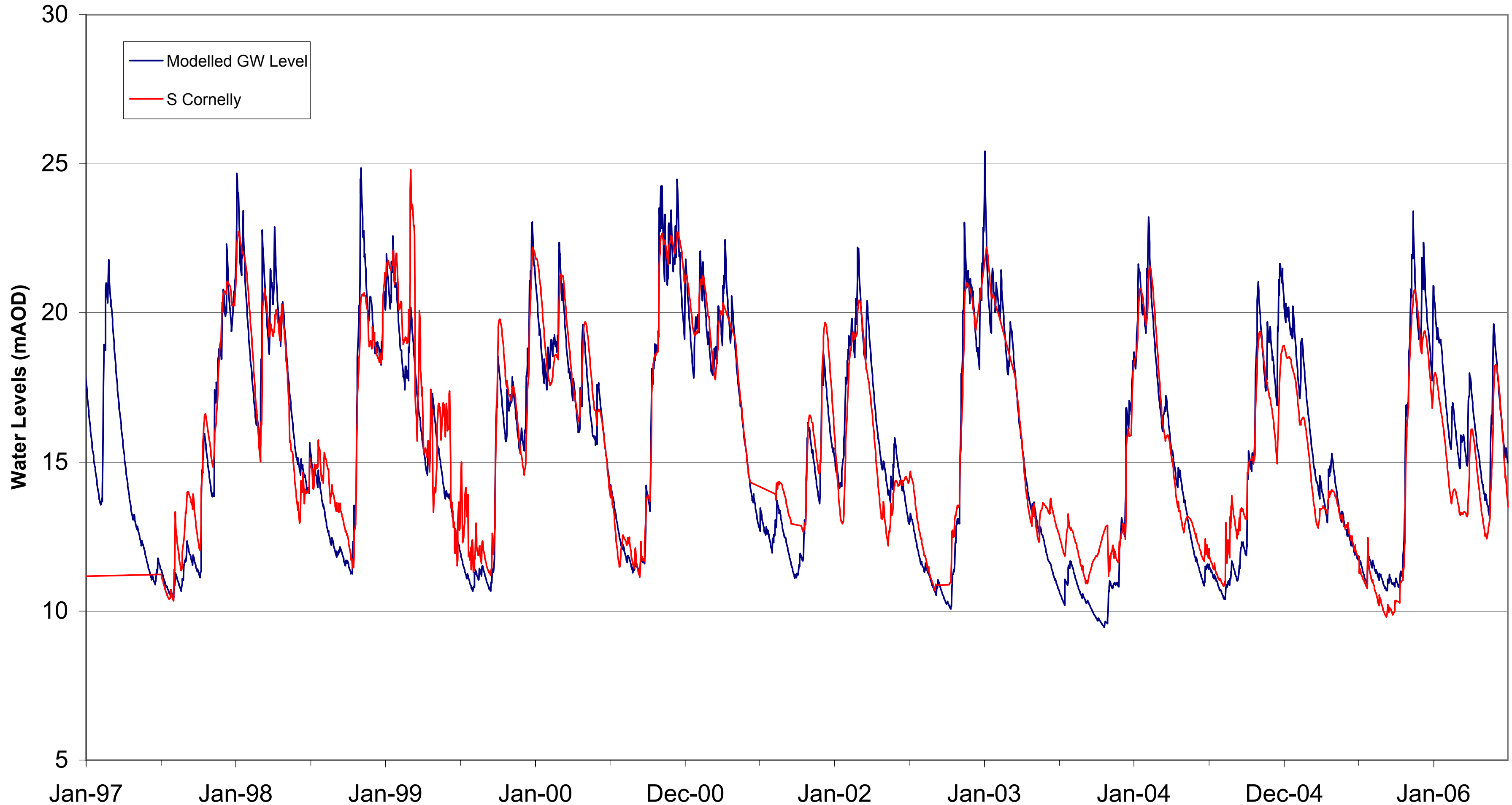
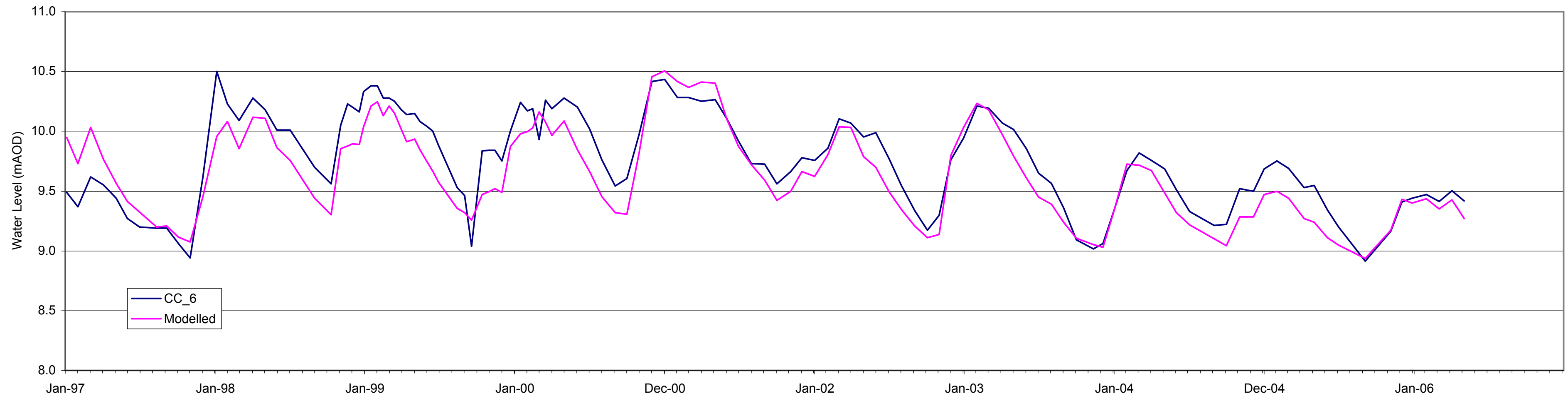


Figure 2.4

Simulated and observed groundwater levels in the Triassic

Date: Dec 06	Drawn: MJS
Scale: nts	Chk'd: MJS
Original: A4	Rev: 1
File Reference: O:\6227_Cornelly\calcs\WMP supporting calcs\recharge\Carb Lst Recharge.xls	

csi soil & groundwater



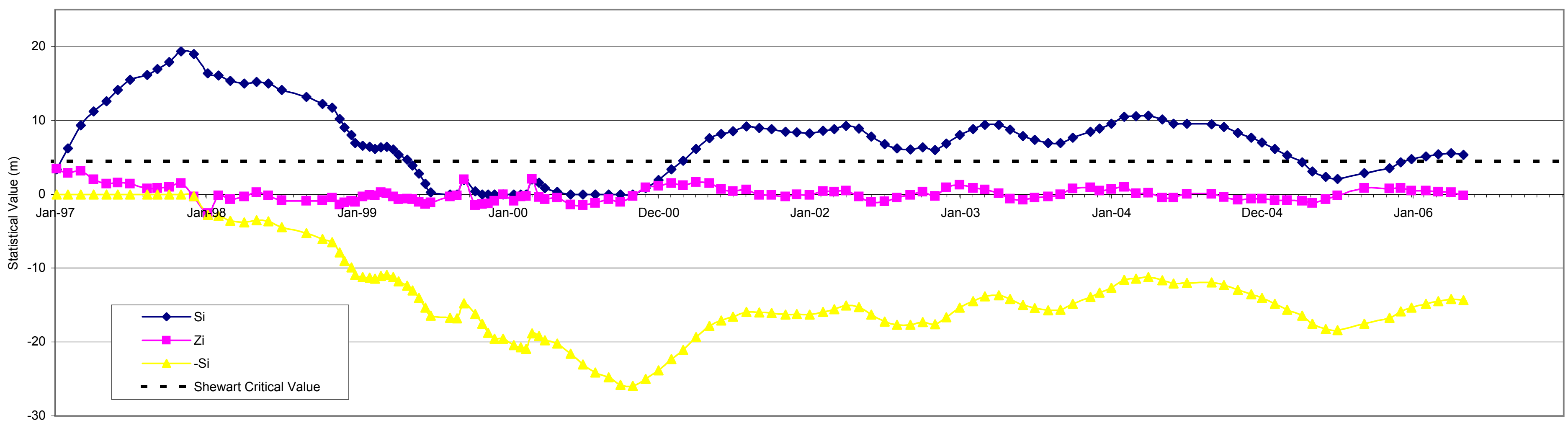


Figure 3.1

Measured and simulated time series data and resultant Shewart and Cusum charts

Historical data only

K = 0.05

Date: Dec 06	Drawn: MJS
Scale: nts	Chk'd: MJS
Original: A4	Rev: 1
File Reference: 6227\calcs\WMP Calcs\stats\Cu-Sum and Shewart charts.xls	

soil & groundwater

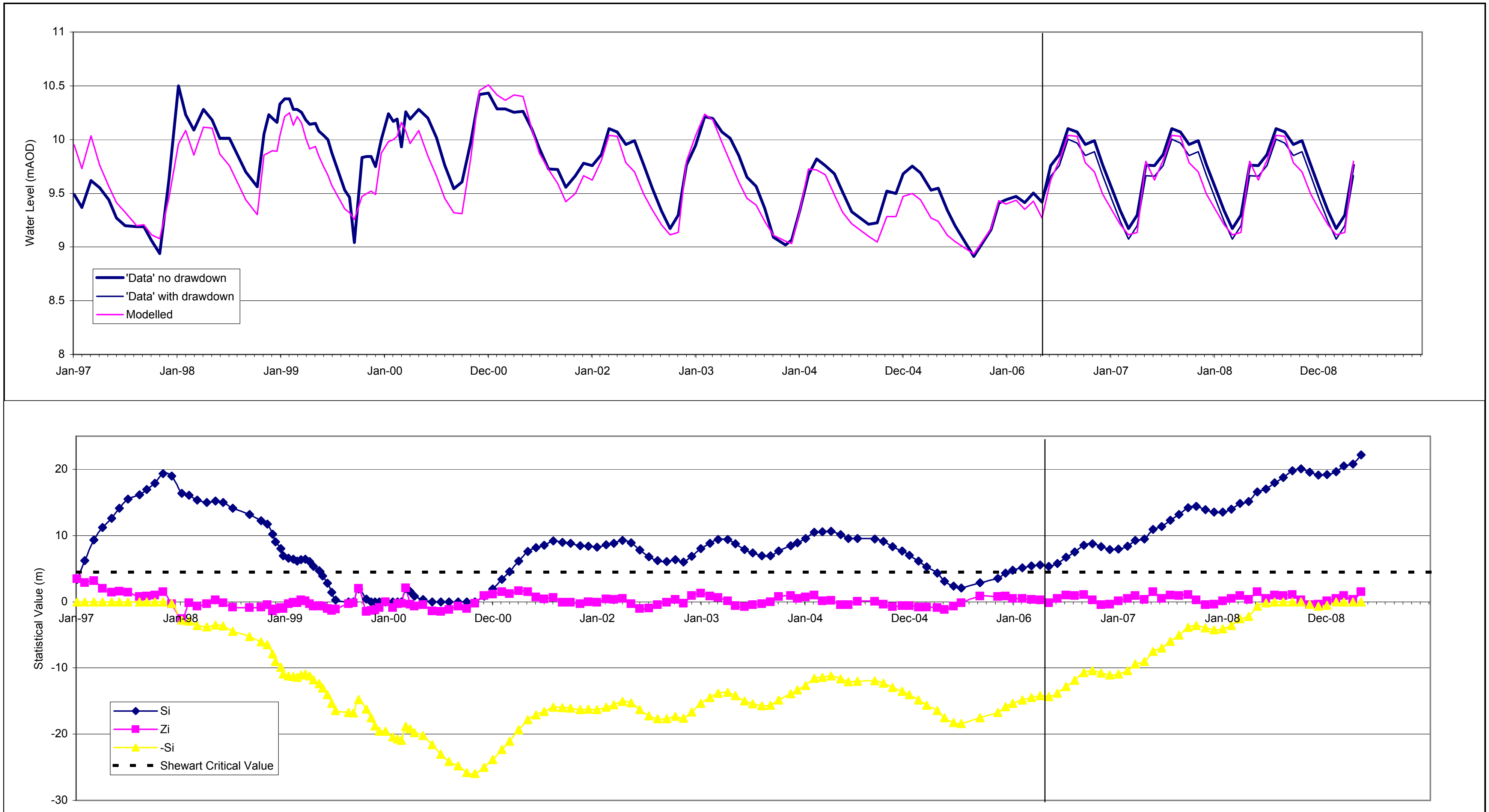


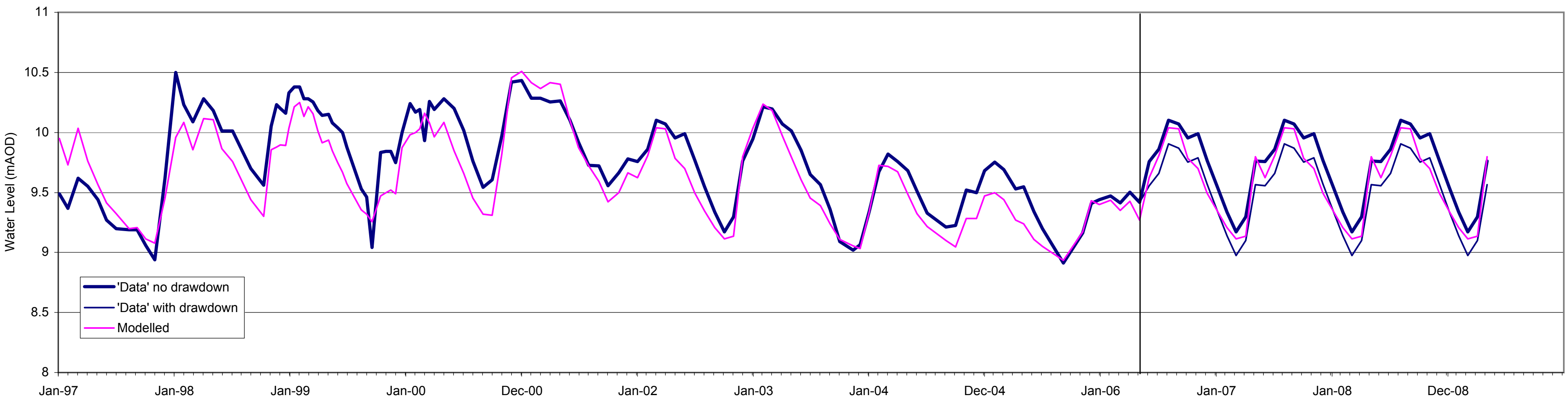
Figure 3.2

Measured and simulated time series data and resultant Shewart and Cusum charts

Includes a 3 year repeated cycle beyond May 2006 K = 0.05 Drawdown = 0.1 m

Date:	Drawn:
Dec 06	MJS
Scale: nts	Chk'd: MJS
Original: A4	Rev: 1
File Reference: 6227\calcs\WMP Calcs\stats\Cu-Sum and Shewart charts.xls	

soil & groundwater



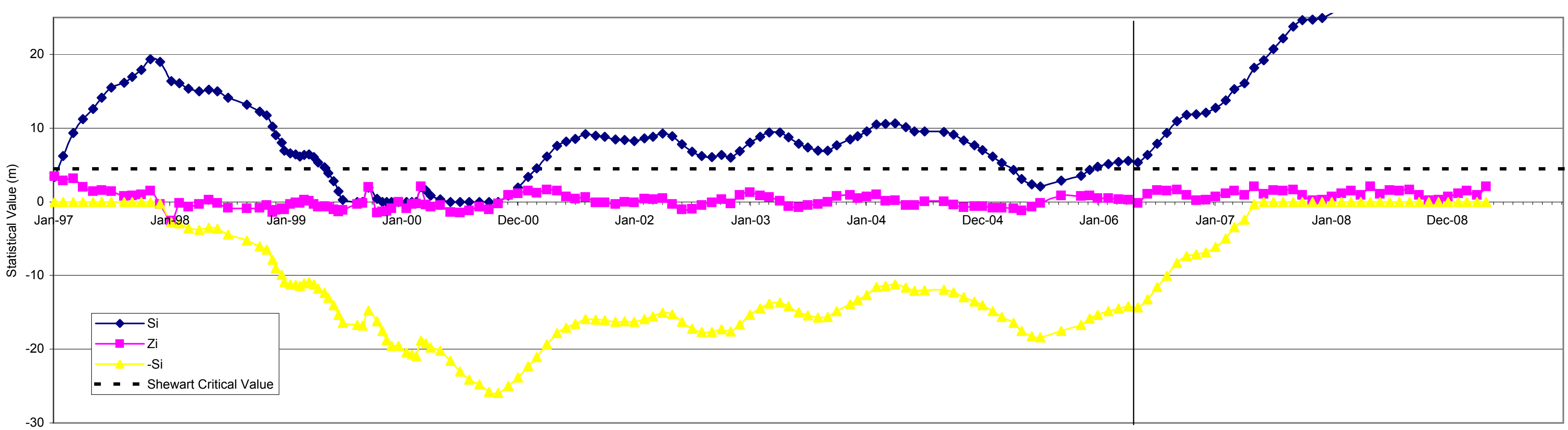


Figure 3.3

Measured and simulated time series data and resultant Shewart and Cusum charts

Includes a 3 year repeated cycle beyond May 2006 K = 0.05 Drawdown = 0.2 m

Date: Dec 06	Drawn: MJS
Scale: nts	Chk'd: MJS
Original: A4	Rev: 1
File Reference: 6227\calcs\WMP Calcs\stats\Cu-Sum and Shewart charts.xls	

esi soil & groundwater

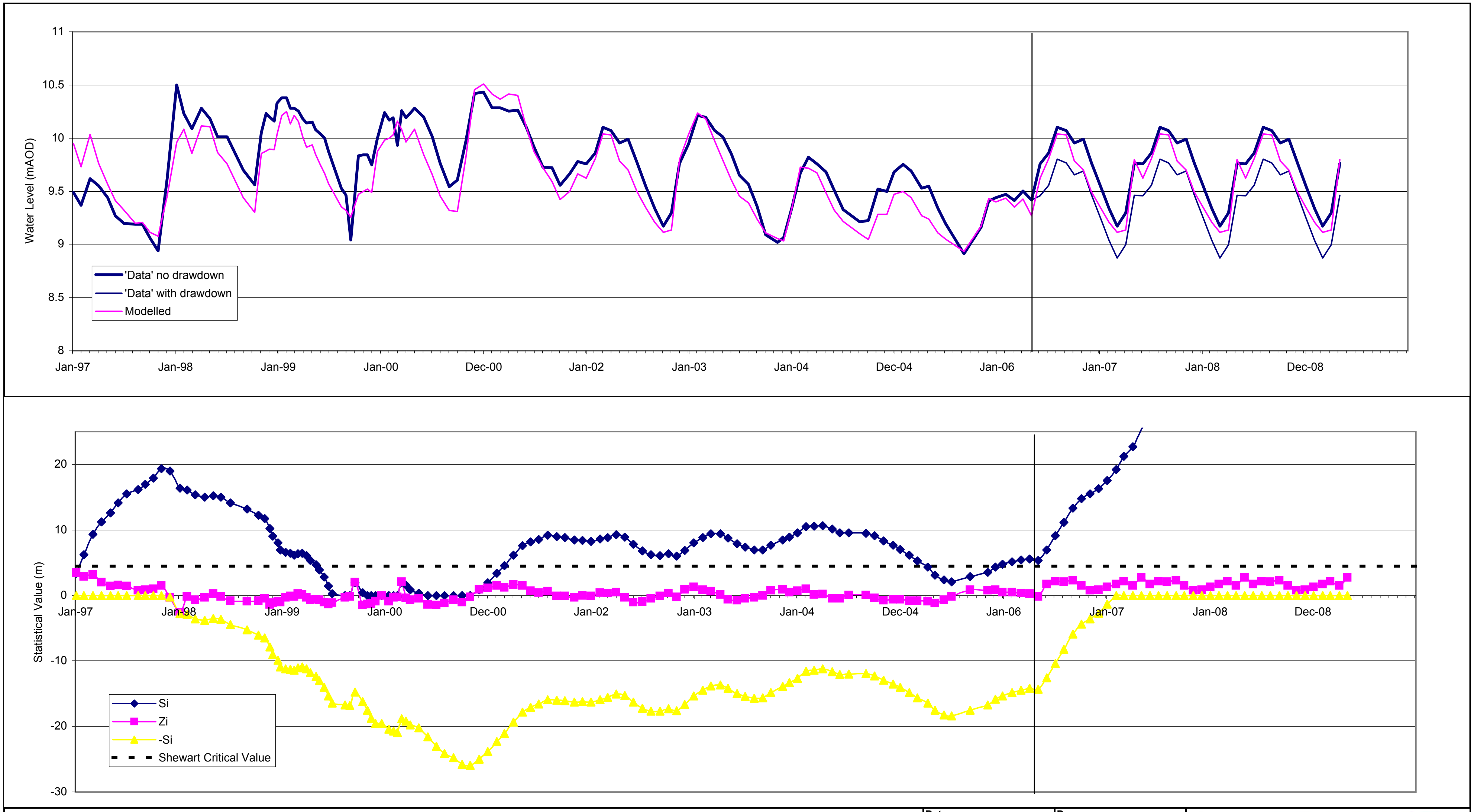


Figure 3.4

Measured and simulated time series data and resultant Shewart and Cusum charts

Includes a 3 year repeated cycle beyond May 2006 K = 0.05 Drawdown = 0.3 m

Date: Dec 06	Drawn: MJS
Scale: nts	Chk'd: MJS
Original: A4	Rev: 1
File Reference: 6227\calcs\WMP Calcs\stats\Cu-Sum and Shewart charts.xls	

esi soil & groundwater

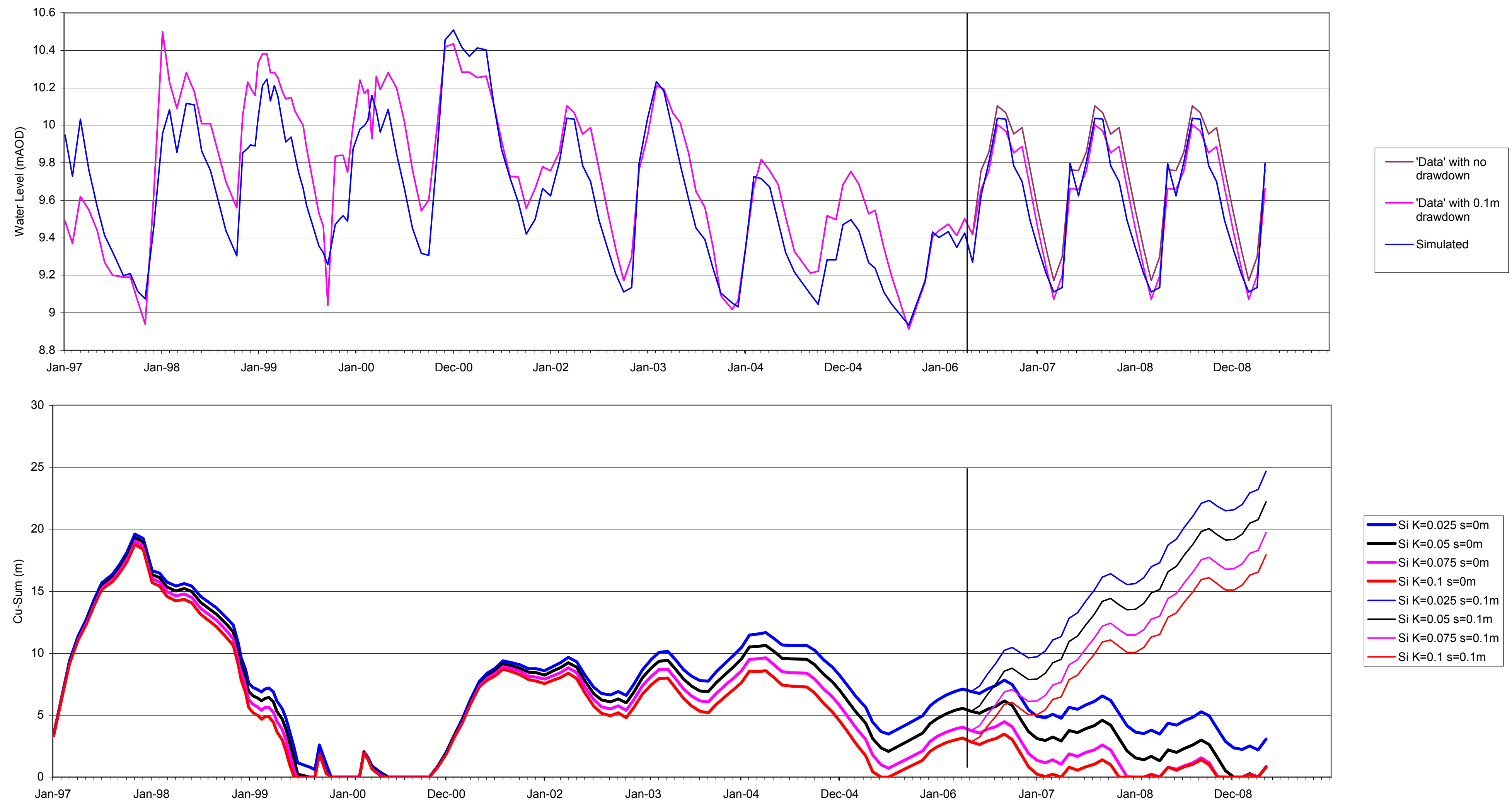


Figure 3.5

Sensitivity of Cusum results to value of K

Date: **Dec 06**	Drawn: **MJS**
Scale: **nts**	Chk'd: **MJS**
Original: **A4**	Rev: **1**
File Reference: 6227\calcs\WMP Calcs\stats\Sensitivity analysis.xls	

esi soil & groundwater

Appendix D2 – Technical Note on the conceptual model and method used in Climate Based Assessment Criteria

Prepared for Lafarge Tarmac Ltd

Report reference: 6227 WMP Cornelly Quarry, July 2015

Confidential
Prepared by
ESI Ltd

New Zealand House,160 Abbey Foregate, Shrewsbury, SY2 6FD, UK
Tel *+44(0)1743 276100* ***Fax*** *+44 (0)1743 248600* ***email*** ***info****@esinternational.com*
Registered office: New Zealand House, 160 Abbey Foregate, Shrewsbury, SY2 6FD. Registered in England and Wales, number 3212832

CONTENTS

FIGURES

TABLES

1 INTRODUCTION

1.1 Background

Cornelly Quarry (the “Quarry”) is the largest quarry in Wales, providing over 1 million tonnes of limestone per year, principally for the steel mill at Port Talbot. It is also an important supplier of aggregates into the local construction industry.

Cornelly Quarry is currently the subject of an Environment Act ‘ROMP Review’ which will update the planning conditions controlling future operations at the Quarry. The Applicant, Lafarge Tarmac Ltd, has proposed a series of updated planning conditions as required by the Review, including a commitment to carry out the development in accordance with a ‘Water Management Plan’ (WMP).

The WMP is intended to guide the Quarry Operator in its management of water at the Quarry such that any adverse environmental impacts resulting from these activities may be prevented and/or reversed. As such the WMP will specify the following;

- details of water management
- monitoring requirements and activities required
- outline the process for review and reporting of collected data
- provide guidance on the mechanism for determining whether a significant deviation has occurred and identifying resulting actions
- outline available planned mitigation measures and instructions on their implementation

1.2 Objectives and Approach

The WMP requires the Quarry Operator and Regulator to determine whether any future variations in the data collected from any of the monitoring sites are due to the effects of water management at the quarry. As most of the monitored parameters (principally water levels and flows) are strongly affected by antecedent rainfall, it is necessary to assess what effect rainfall would have had on these data so that Deviation[1] from expected conditions can be identified. For the Cornelly WMP this is achieved by means of Climate Based Assessment Criteria. The background to the approach used is set out in detail in Appendix D1 of the WMP. This technical note describes the implementation of the Climate Based Assessment Criteria for the Cornelly WMP.

Section 2.1 discusses the conceptual model used in the transient water balance calculations that generate the Climate Based Assessment Criteria and is followed in Section 2.3 by a description of the process used to estimate ‘natural water level/flow’ conditions. Section 3.3 presents three case studies which demonstrate the correct use of the statistical tools to highlight any trends in measured groundwater level.

.

[1] In this context, Deviation is defined as the occurrence of a statistically significant difference between the behaviour measured at a site and the behaviour that would be anticipated under ‘natural’ conditions.

2 CLIMATE BASED ASSESSMENT CRITERIA

2.1 Conceptual Model

A schematic diagram of the conceptual model used to generate the Climate Based Assessment Criteria is shown in Figure 2.1.

The method to derive the modelled groundwater levels used in Climate Based Assessment Criteria is based on a Penman soil moisture balance model and a subsequent system of 1-D 'stores'.

The parameters which affect the way the soil moisture balance operates and which control the division of outputs between actual evapotranspiration, runoff and infiltration to groundwater are presented in detail in Appendix D1.

Infiltration to groundwater from the unsaturated zone (soil moisture balance) is passed into one of two stores; slow (matrix) store and fast (fracture) store. Together these form a simple 'groundwater model' as described in Section 2.3. Modelled groundwater levels are derived by converting the sum of the stores into an equivalent measured groundwater level using a specific yield.

2.2 Model Parameters

The model stores parameters defined in Table 2.1 below and displayed on the control page of each CBAC sheet are used to calculate the volume of water in each store and resultant discharge volume.

Table 2.1 User-defined parameters used to calculate modelled groundwater levels

<table>
<tr><th>Parameter</th><th>Units</th><th>Description</th></tr>
<tr><td>Direct percolation</td><td>%</td><td>The percentage of recharge which bypasses the soil moisture balance calculations and flows directly to groundwater, entering the fast store.</td></tr>
<tr><td>Slow store starting volume</td><td rowspan="2">mm</td><td rowspan="2">The model calculates the daily change in volume in groundwater stores and tracks the dischargeable volume of groundwater held in stores.

This parameter is used to set a starting volume in each store. Because the store calculations are based on a unit area, volumes are expressed in mm; they are multiplied by the catchment area and divided by 1000 to derive a true volume of water (m^3).

Due to the long period between the model beginning and calibration to measured water levels this parameter is not important in this case and values are set to 0 mm for all models.</td></tr>
<tr><td>Fast store starting volume</td></tr>
<tr><td>% Slow</td><td>%</td><td>The percentage of drainage water from the soil zone which infiltrates to the slow store (all remaining drainage water enters the fast store).</td></tr>
<tr><td>T Slow</td><td rowspan="2">Days</td><td rowspan="2">Used in calculating the volume of water discharged from the Slow/Fast stores. Each day, the rate of discharge (m^3/d) from a store is given by V/T where V is the volume within the store (m^3) and T is measured in days.</td></tr>
<tr><td>T Fast</td></tr>
</table>

Parameter	Units	Description
Slow store max	mm	The depth of water in the slow store at which overtopping occurs.
Specific yield	dimensionless	Used to convert the sum of the store levels into a groundwater level. Separate values are assigned to the matrix and fracture stores.
Starting head	mAOD	The starting value for modelled groundwater

2.3 Stores Processes

Descriptions of the processes which occur within the groundwater model are presented below, in accordance with Figure 2.1. A detailed description of the soil moisture balance calculations is presented in Appendix D1.

2.3.1 Inflow

Water leaving the soil zone and entering the saturated zone originates from two processes:

1. Direct percolation (recharge bypassing the soil zone). This is calculated as a user-defined proportion of the excess rainfall (rainfall-runoff-potential evaporation).
2. Drainage from the soil zone (calculated by the soil moisture balance).

Slow store: the slow store receives a user-defined percentage (*% slow*) of the drainage from the soil zone.

Fast store: The fast store receives the bypass recharge. Additionally, the remaining proportion of water draining from the soil zone enters the fast store.

2.3.2 Outflow

The volume of water discharged from each store is calculated as the volume in the store divided by a user defined value (*T_fast* or *T_slow*).

An overtopping facility within the slow store enables all water above a user-defined level (*slow store max*) to be directly discharged.

The model allows for calculation of runoff, which is removed prior to entering the soil moisture balance and added to discharge from the stores to make up total daily discharge (m^3/d). However, for the Cornelly Quarry calculations, runoff is predicted to be very little as water is expected to infiltrate into the permeable aquifers (e.g. limestone or dune sands), therefore no runoff is included.

It is this total daily discharge which is used to calibrate both the Burrows Well and Cornelly Quarry Pumping flow CBACs.

2.3.3 Modelled groundwater level

Following the removal of discharge from the stores, the levels are converted to mAOD using a user-defined starting head;

$$Modelled\ groundwater\ level\ (mAOD) = Starting\ head\ (mAOD) + \frac{Fast\ store\ (mm)}{(Sy\ fracture\ x\ 1000)} + \frac{Slow\ store\ (mm)}{(Sy\ matrix * 1000)}$$

This modelled groundwater level is used in the groundwater level CBACs to calibrate to a measured groundwater level time series.

3 APPLICATION OF METHODOLOGY

3.1 Model Calibration

Each transient water balance model was calibrated manually, taking into consideration the standard deviation and mean error statistics. The resultant calibration models (with all the associated parameters) are appended to this document.

In general there was a good degree of commonality in the parameters used and, where these had a physical basis (e.g. specific yield) the results used were consistent with the local conceptual understanding of the aquifers.

3.2 Use of Statistics

The difference between observed and modelled water levels/flows is assessed statistically using the Shewart and Cusum approaches as discussed in Appendix D1. The two key statistics used are:

> z_i – the standardised error (difference between observed and modelled water levels/flows normalised for mean error and standard deviation) and
>
> *CuSum* – a statistic that accumulates sequential values of z_i to highlight periods during which model and observed consistently differ in one direction.

In order to accurately and rapidly observe any future trends deviations between observed and modelled water levels/flows, an appropriate baseline dataset must first be defined. The quality of model fit in the baseline period can be assessed through the mean error and standard deviation error. Should these statistics incorporate groundwater trends or poorly fitted data (non-baseline data), the errors will be larger and subsequently the standardised error (Zi) will be less sensitive to minor changes in groundwater level. This will also lead to large trends in CuSum during the baseline period.

In general the baseline period has been set to the end of the current period of data availability as discussion between staff from Natural Resources wales and ESI (on behalf of Lafarge Tarmac) had concluded that only a few sites showed any potentially significant deviation between observed and simulated data to date. The exceptions are discussed below.

The WMP sets out that a Deviation has occurred when either: z_i exceed 4.5 or the CuSum exceed a specific value (set individually for each site and generally based on the largest value of CuSum observed in the baseline period). The Deviation should be confirmed by carrying out further statistical tests of the data before and after the occurrence of the apparent Deviation to confirm that they are statistically different (as described in Appendix D).

3.3 Case Studies

The following case studies are presented to demonstrate the application of the methodology and to highlight the importance of a carefully chosen baseline in identifying trends in groundwater levels using cu-sum statistics.

3.3.1 Location E calibration

Observed groundwater levels at OBH E show a decline of 6.8 m compared to modelled groundwater levels over the 13 year period of available data. This decline seems to start shortly after the end of the period when water was being discharged to the nearby Pant Mawr quarry (end 2002) although, as monitoring at E only started in 2002, it is not entirely clear that what the trends were before this point.

Figure 3.1 shows the CBAC model for OBH E calibrated to fit the early data using a visual calibration. In this case, the calculation of the statistics includes all available time series data. The resultant CuSum plot does not begin to highlight any immediate decline in groundwater levels: initially the CuSum rises (z_i is generally negative) and then only falls later. This is because it is calculating an average error for the whole period and so, in the early stages, the error (modelled minus observed) is negative.

The baseline dataset for this location has therefore been re-defined for a reduced period: from the beginning of the time series until July 2004 when the decline in levels starts to become apparent. Figure 3.2 now clearly identifies the start of the period of decline in groundwater values following the end of the baseline dataset.

In future, given that water levels now appear to have largely stabilised again, the baseline period could be re-defined to the more recent period (and the model re-calibrated to this) so that the CBAC could be used to detect any further changes.

3.3.2 South Cornelly

Similarly to location E, when all available data is included in the calculation of mean error and standard deviation error statistics, the plot of CuSum statistics at South Cornelly is potentially misleading. Figure 3.3 shows the South Cornelly CBAC model where statistics (mean error and standard deviation) are calculated using all available time series data. The CuSum plot suggests that a long-term declining groundwater level trend is occurring; however visual observation of the plot of measured and modelled data does not confirm this.

Figure 3.4 highlights that the use of baseline data for a shorter period (September 2002 – March 2015) to calculate mean and standard deviation errors and removal of the poorly-fitted data (1995 – 2001) from the CuSum statistics produces a more accurate picture of trends in groundwater levels.

This implies that generally there were no potentially significant changes in water levels at the site until 2012/13 when observed water levels started to be above modelled levels (by an average of 0.8 m). There are some inadequacies in the pumping rate data for the site over this period but there does appear to have been an increase in the discharge to Grove Quarry. This would therefore demonstrate the potential effectiveness of this Planned Mitigation Measure in raising water levels as required.

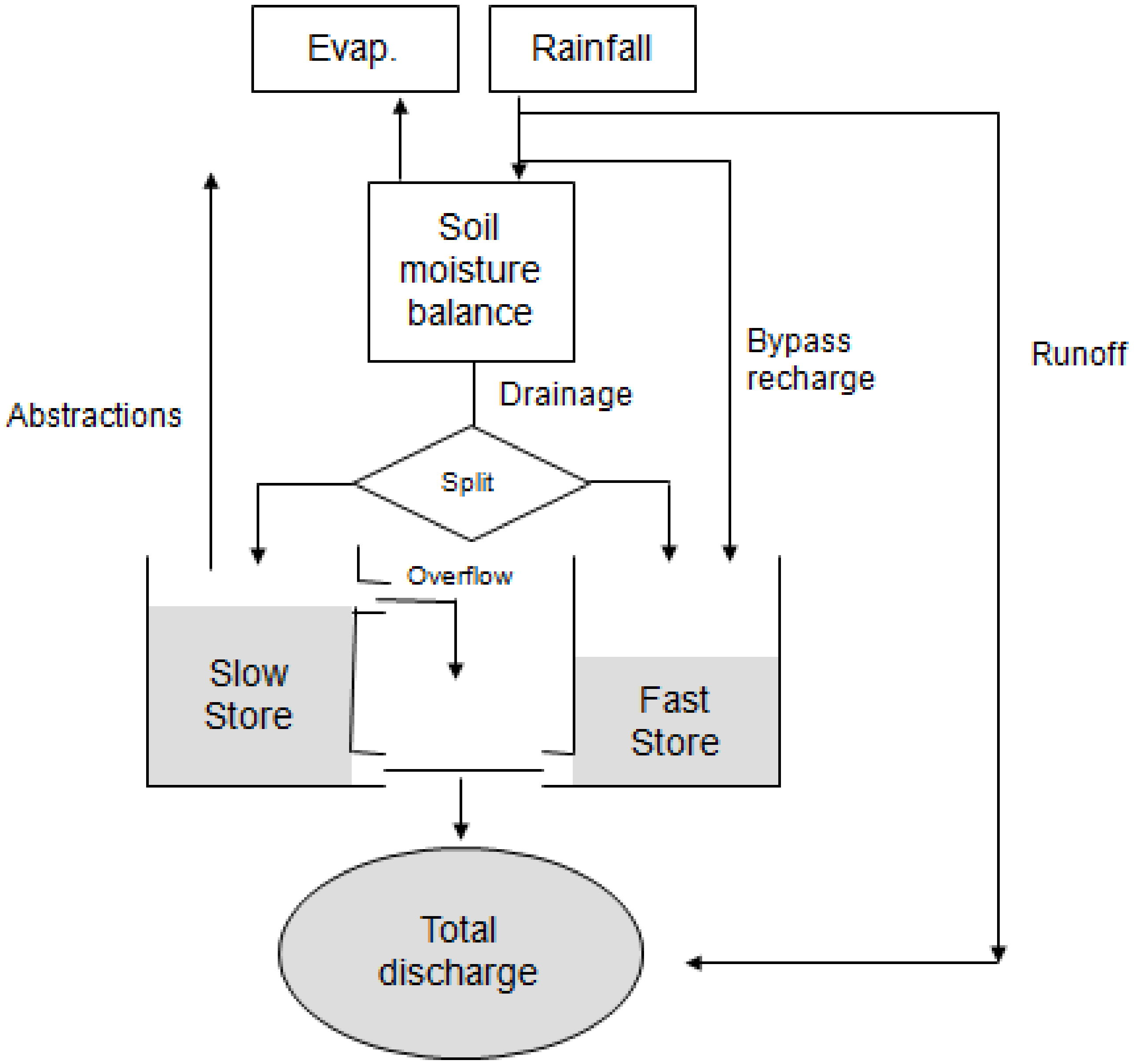


Figure 2.1
Climate Based Assessment Criteria conceptual model flow diagram

Date July 2015	Drawn KHB
Scale A4	Checked JRR
Original A4	Revision 1
File Reference O:\6227\Reports\New Draft WMP\Appendices\Figure2.1.doc	

esi Environment Specialists

Runoff Calculation Parameters (Location E)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	5	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0	

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.007	18.5
GW	1,420,082	0.007 fracture	

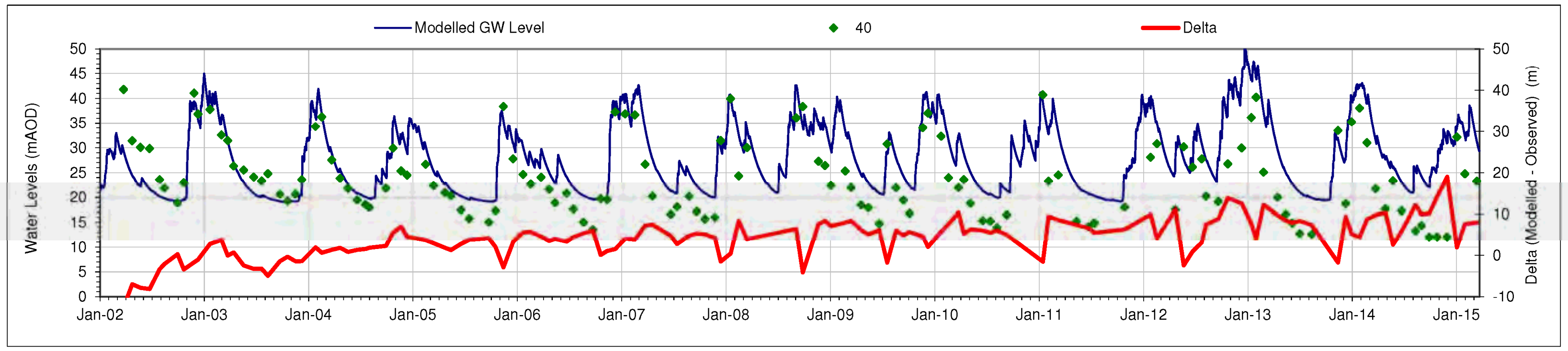
Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	70	%
T Slow	50	days
T Fast	50	days
Slow store max	100	mm



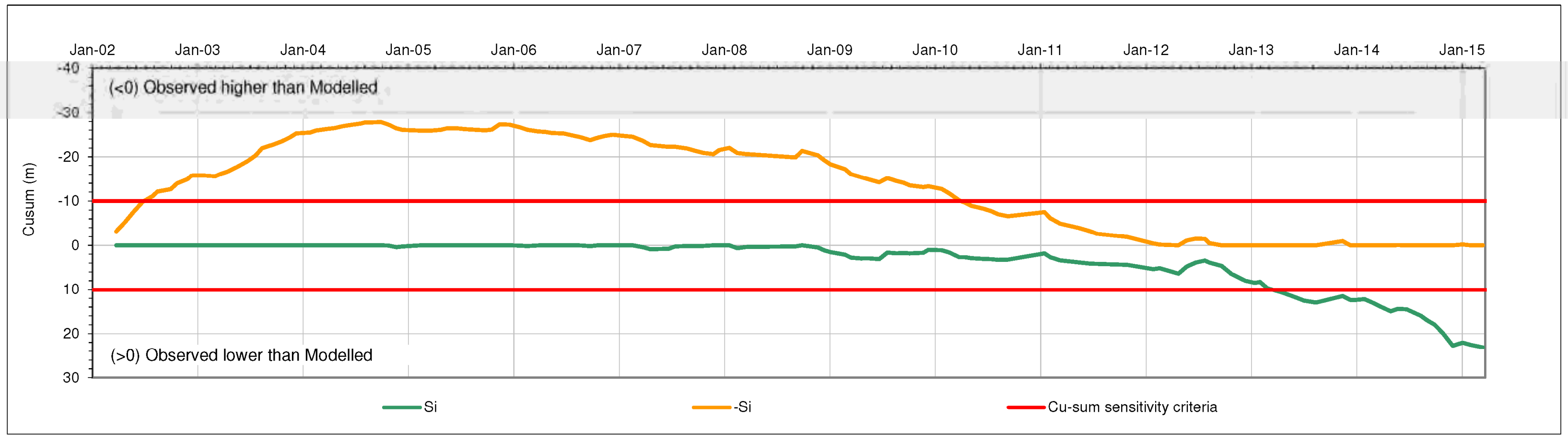
Stats

Baseline dataset for calculation of statistics:
n/a

K (not permeability!!)	0.25	m
Mean Error (Modelled - Observed)	4.03	m
ST Dev Error	4.77	m
Dummy value for Z_i	0	

Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**18416**

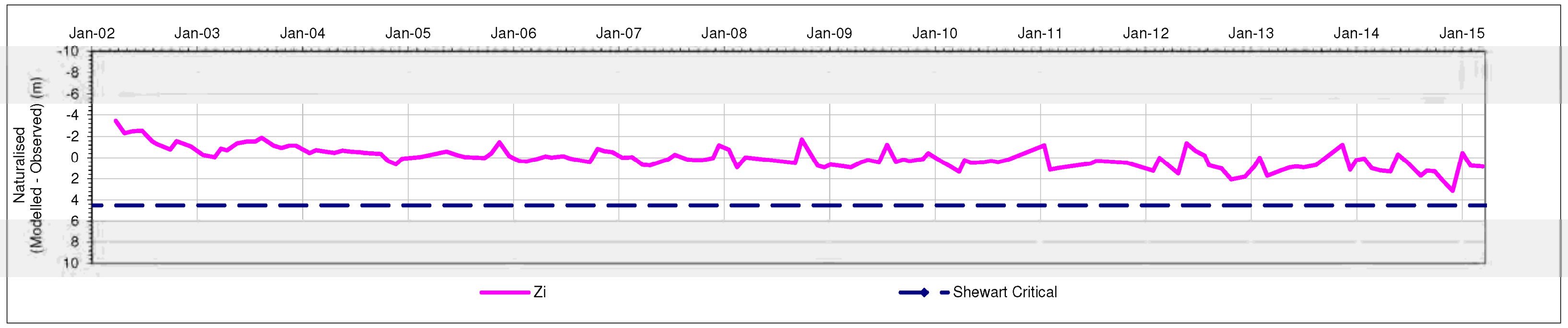
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations



N.B. The scale on the cusum plot is larger than the CBACs standard (10 m, -10 m)

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	



O:\6227_Cornelly\calcs\WMP supporting calcs\CBAC spreadsheets\E_new store 2015.xlsm Parameters 16/07/2015 08:55

Figure 3.1
Location E Climate Based Assessment Criteria calibration (all data used for statistics)

Date July 2015	Drawn KHB
Scale n/a	Checked MJS
Original A3	Revision 1
File Reference O:\6227\Reports\R17 EIA\Post submission WMP\Figures\Figure 3.1.doc	

Environment Specialists

Runoff Calculation Parameters (Location E)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	5	0.3

SMD1_start (mm)	SMD2_start (mm)
0	0

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,420,082	0.007	18.5
GW	1,420,082	0.007 fracture	

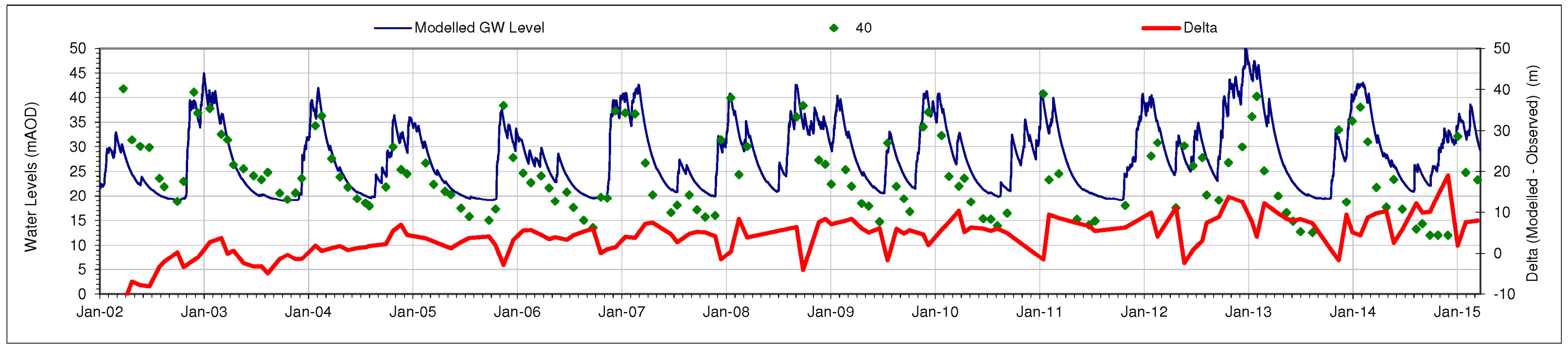
Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters

Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	70	%
T Slow	50	days
T Fast	50	days
Slow store max	100	mm



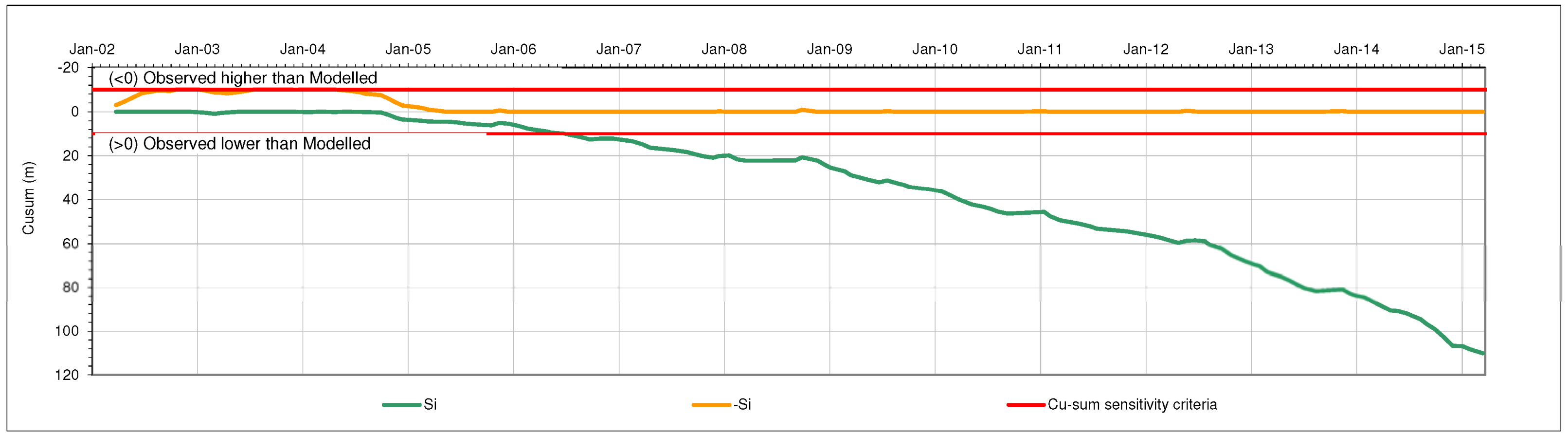
Stats

Baseline dataset for calculation of statistics:
March 2002 - July 2004

K (not permeability!!)	0.25 m
Mean Error (Modelled - Observed)	0.51 m
ST Dev Error	3.95 m
Dummy value for Z_i	0

Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**18416**

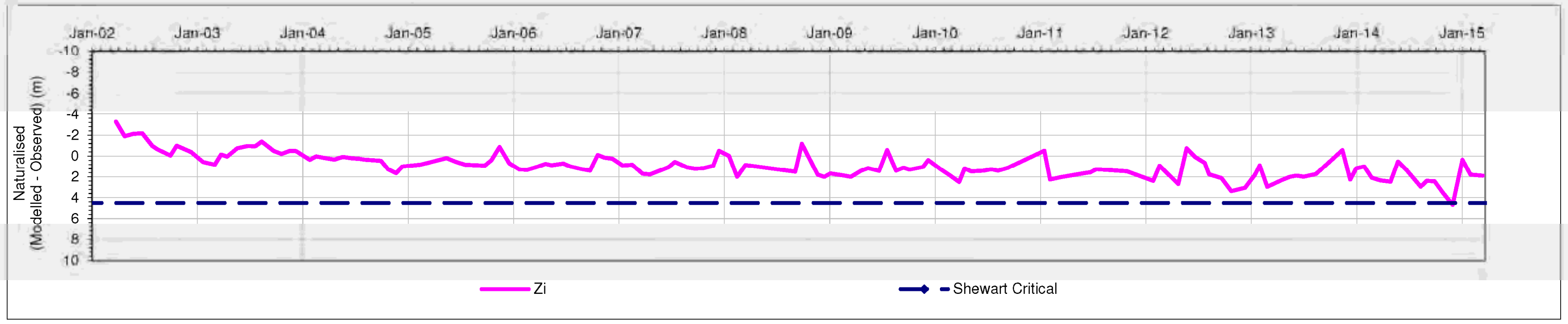
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations



PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	

N.B. The scale on the cusum plot is larger than the CBACs standard (10 m, -10 m)



O:\6227_Cornelly\calcs\WMP supporting calcs\CBAC spreadsheets\E_new store 2015.xlsm Parameters 16/07/2015 08:53

Figure 3.2
Location E Climate Based Assessment Criteria calibration (baseline data used for statistics)

Date: July 2015	Drawn: KHB
Scale: n/a	Checked: MJS
Original: A3	Revision: 1
File Reference: O:\6227\Reports\R17 EIA\Post submission WMP\Figures\Figure 3.2.doc	

Environment Specialists

Runoff Calculation Parameters (Location South Cornelly)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1	SW discharge
0	GW discharge

Number of days 10682

General parameters **Head Change Calculation**

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.018	9.5
GW	1,756,799	0.018 fracture	

Rainfall Multiplier	1
PE Multiplier	1

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters		
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	70	days
T Fast	70	days
Slow store max	160	mm

Stats

Baseline dataset for calculation of error statistics:
n/a

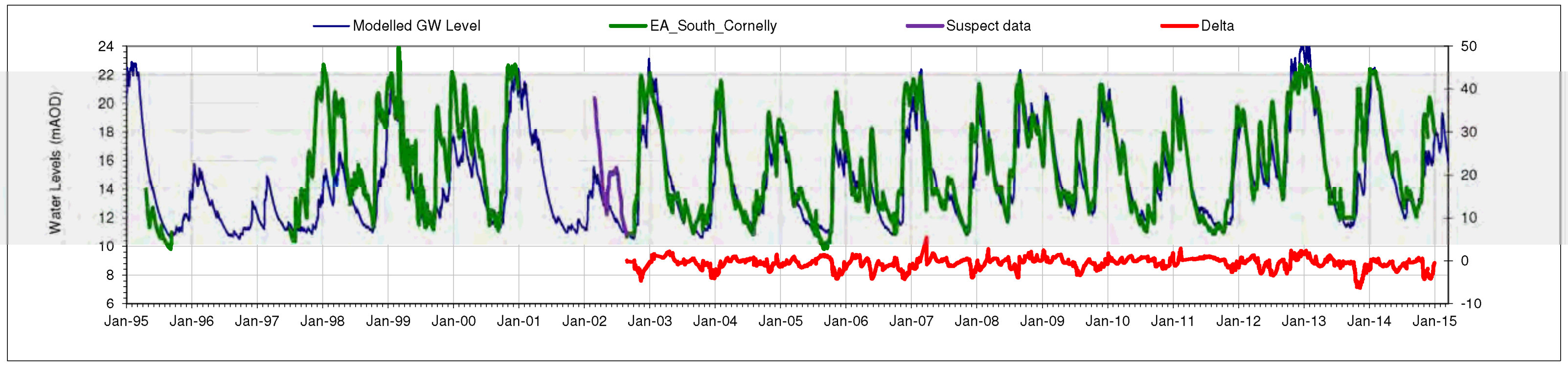
K (not permeability!!)	0.25 m
Mean Error (modelled - Actual)	-0.95 m
ST Dev Error	1.77 m
Dummy value for Z_i	0

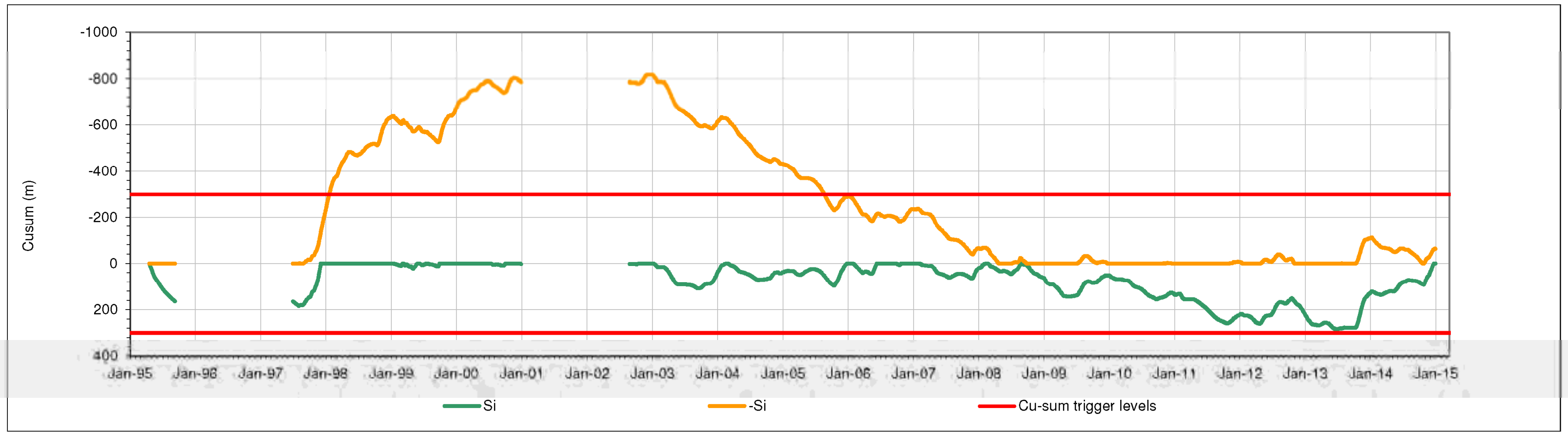
Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**27022**

* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations

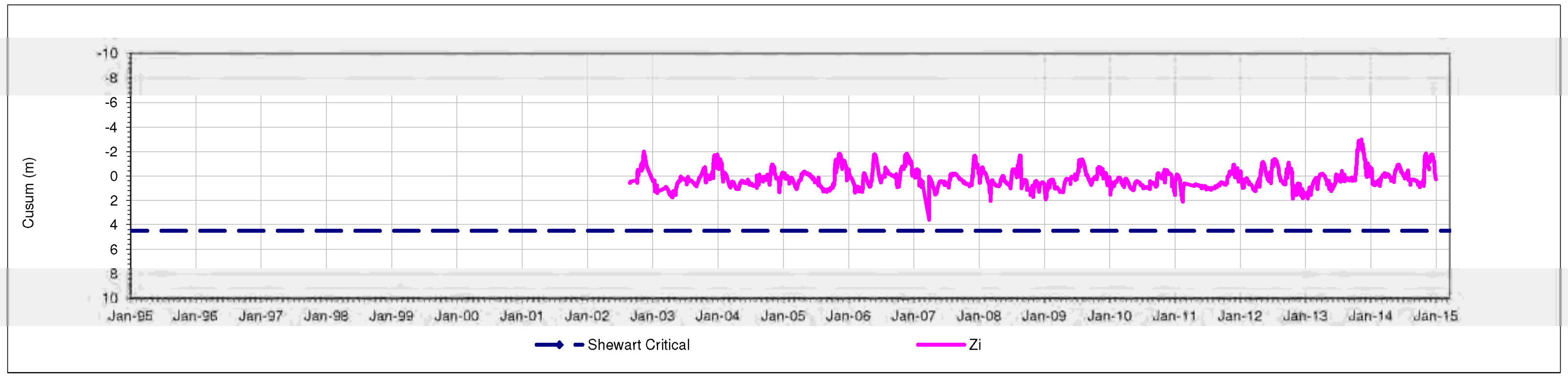
PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	





N.B. The scale on the cusum plot is larger than the CBACs standard (15 m, -15 m)



O:\6227_Cornelly\calcs\WMP supporting calcs\CBAC spreadsheets\South Cornelly_new store 2015.xlsm Parameters

16/07/2015 09:02

Figure 3.3

South Cornelly Climate Based Assessment Criteria calibration (all data used for statistics)

Date July 2015	Drawn KHB
Scale n/a	Checked MJS
Original A3	Revision 1
File Reference O:\6227\Reports\R17 EIA\Post submission WMP\Figures\Figure 3.3.doc	

esi Environment Specialists

Runoff Calculation Parameters (Location South Cornelly)

Parameters for Soil Moisture Balance

Drying constant (mm)	Direct percolation (%)	Drying curve slope
75	25	0.3
SMD1_start (mm)	SMD2_start (mm)	
0	0	

All Parameters provided

Runoff Parameters

SMD	5	30	
0	0	0	0
20	0	0	0

Rainfall station: Margam

GW Abstractions (Ml/d)

0

Slow flow split

1 SW discharge
0 GW discharge

Number of days 10682

General parameters **Head Change Calculation**

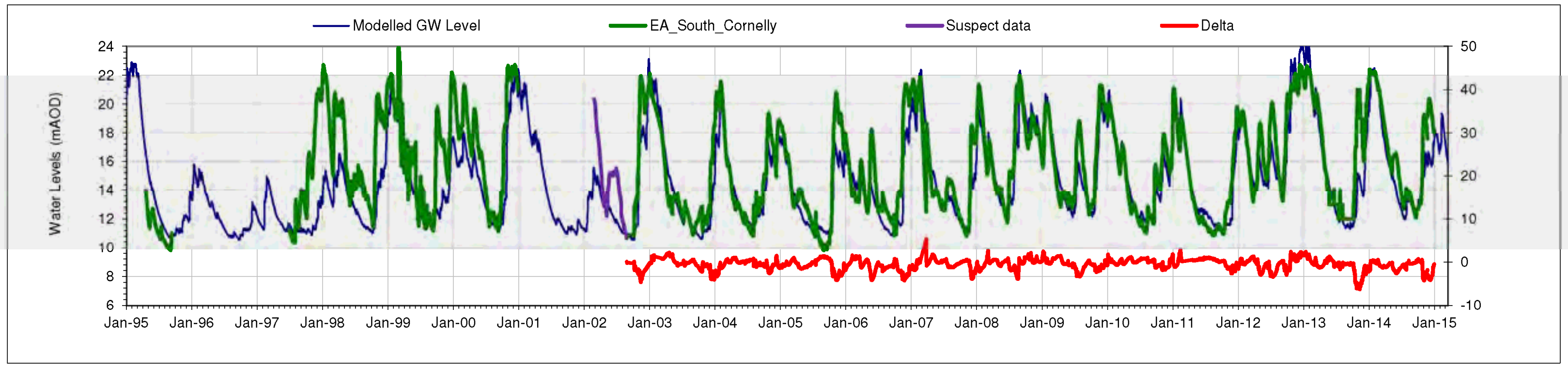
Rainfall Multiplier 1
PE Multiplier 1

	Catchment_Area (m2)	Specific_Yield	Starting_Head (mAOD)
SW	1,756,799	0.018	9.5
GW	1,756,799	0.018 fracture	

User-defined time series

Precipitation (mm) - Sheet SMB calcs
Potential evapotranspiration (mm) - Sheet SMB calcs

Stores Parameters		
Runoff multiplier	0	
Slow store Starting Volume	0	mm
Fast store Starting Volume	0	mm
% Slow	100	%
T Slow	70	days
T Fast	70	days
Slow store max	160	mm



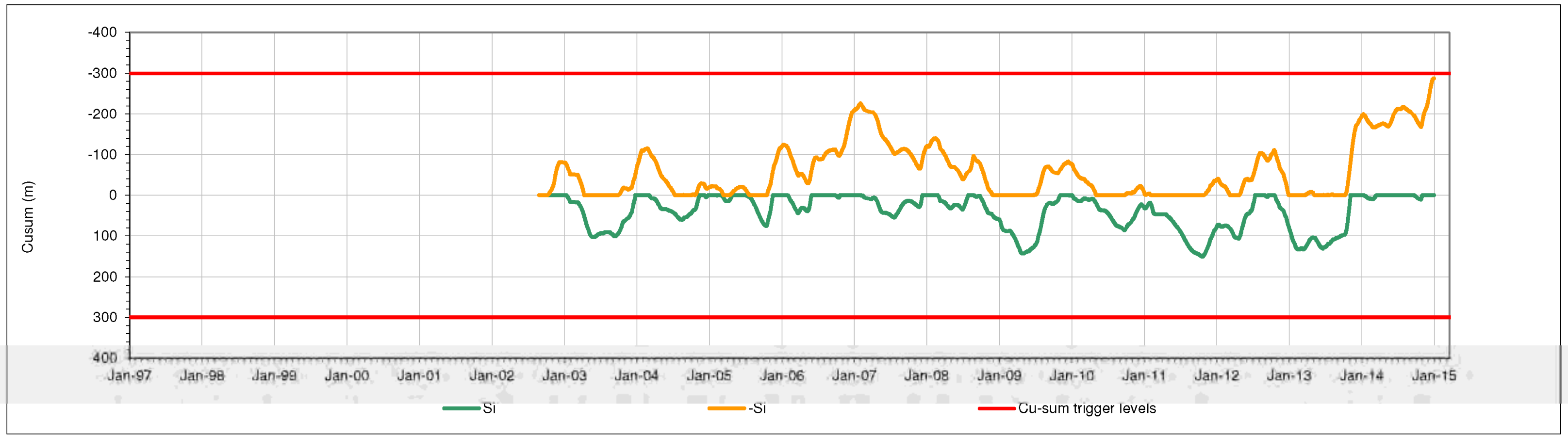
Stats

Baseline dataset for calculation of error statistics:
September 2002 - January 2013

K (not permeability!!)	0.25	m
Mean Error (modelled - Actual)	-0.51	m
ST Dev Error	1.24	m
Dummy value for Z_i	0	

Phi_calibration - last loaded PEST run	**n/a**
Phi_calibration - spreadsheet calcs	**27022**

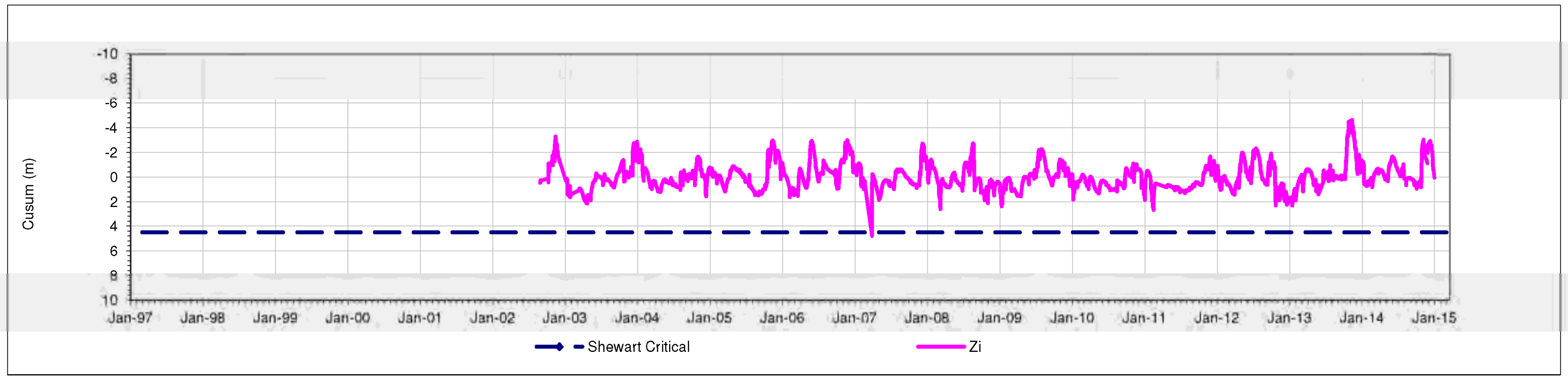
* If PEST is used, PEST and spreadvalues should be equal, showing consistant calculations



N.B. The scale on the cusum plot is larger than the CBACs standard (15 m, -15 m)

PEST weightings

Default weight for minimum annual values	20.0
Default weight for maximum annual values	10.0
Default standard weight is 1.0	



O:\6227_Cornelly\calcs\WMP supporting calcs\CBAC spreadsheets\South Cornelly_new store 2015.xlsm Parameters

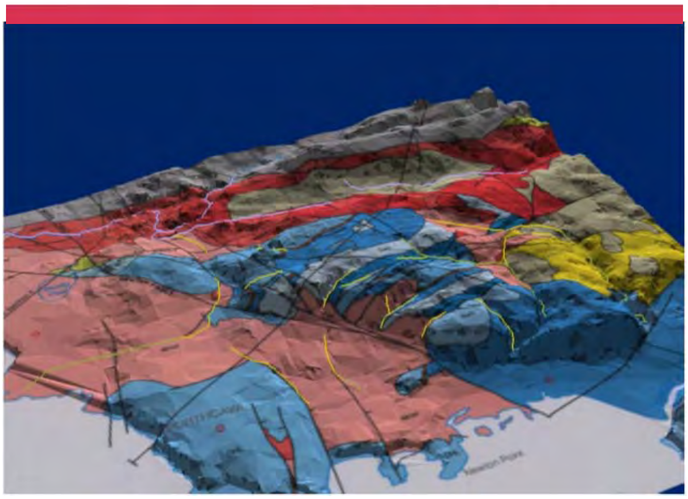
16/07/2015 08:58

Figure 3.4
South Cornelly Climate Based Assessment Criteria calibration (baseline data used for statistics)

Date July 2015	Drawn KHB
Scale n/a	Checked MJS
Original A3	Revision 1
File Reference O:\6227\Reports\R17 EIA\Post submission WMP\Figures\Figure 3.4.doc	

Environment Specialists

APPENDIX E
Flow Network Model
(Appendix 7.3 from SLR, 2014)



Cornelly Group of Quarries: Transient Flow Network Model

Cornelly Group of Quarries: Transient Flow Network Model

Prepared for

Lafarge Tarmac Ltd
Millfields Road
Ettingshall
Wolverhampton
WV4 6JP

Report reference: 6227 Appendix 7.3, March 2014
Report status: Final

Confidential
Prepared by
ESI Ltd

New Zealand House,160 Abbey Foregate, Shrewsbury, SY2 6FD, UK
Tel *+44(0)1743 276100* ***Fax*** *+44 (0)1743 248600* ***email*** *info@esinternational.com*
Registered office: New Zealand House, 160 Abbey Foregate, Shrewsbury, SY2 6FD. Registered in England and Wales, number 3212832

Cornelly Group of Quarries: Transient Flow Network Model

Confidential
Prepared by
ESI Ltd

New Zealand House,160 Abbey Foregate, Shrewsbury, SY2 6FD, UK
Tel *+44(0)1743 276100* ***Fax*** *+44 (0)1743 248600* ***email*** *info@esinternational.com*
Registered office: New Zealand House, 160 Abbey Foregate, Shrewsbury, SY2 6FD. Registered in England and Wales, number 3212832

6227 Appendix 7.3. Final

	Name	Signature	Date	Issued to
Author	Simon Arthur		04/03/14	Project Team
Checked by	Barnaby Harding		04/03/14	Project Team
Reviewed by	Mike Streetly		04/03/14	Project Team

Revision record:

Issue	Date	Status	Comment	Author	Checker	Reviewer
1	04/03/2014	Final		SRA	BCH	MJS
2						
3						
4						

Confidential
Prepared by
ESI Ltd

New Zealand House,160 Abbey Foregate, Shrewsbury, SY2 6FD, UK
Tel +44(0)1743 276100 Fax +44 (0)1743 248600 email info@esinternational.com
Registered office: New Zealand House, 160 Abbey Foregate, Shrewsbury, SY2 6FD. Registered in England and Wales, number 3212832

CONTENTS

FIGURES

ILLUSTRATIONS

TABLES

1 INTRODUCTION

This technical appendix describes the development, calibration and use of a transient flow network model which has been developed to support the assessment of the potential effects of the future development of the Connelly Group of Quarries on the local hydrology.

1.1 Background

In the first hydrogeological impact assessment report for Cornelly Quarry (ESI, 2004), a complex steady state "groundwater flow network model" was developed. The model was almost entirely designed to simulate bedrock groundwater flow with the exception of a cell representing the sand and gravel layer which lies beneath the Blown Sands at Kenfig.

Due to the limitations of the groundwater flow network model, additional detailed calculations were undertaken to determine the impact of changes in groundwater level and flow on the Blown Sand aquifers at Kenfig and Merthyr Mawr. The conclusions from these detailed calculations were as follows:

- At Kenfig: Drawdowns of between 4.6 and 6.1 m are required in the sands and gravels in order to induce an average 0.1 m change in head (the sensitivity threshold identified by CCW (now NRW)) in the dunes over the period.
- At Merthyr Mawr: Reduction in inflows from the north would need to be greater than 5% (probably around 10%) to induce a 0.1 m change in average summer groundwater level.

Subsequent discussions with NRW for the current phase of work have identified a need to assess transient aspects of dewatering at the Cornelly group of quarries (the rate at which the effects of a sudden increase in abstraction would transmit away from the quarries, the effects and duration of recovery at the end of pumping) and also an incorporation of the variation in hydrogeological conditions at Kenfig and Merthyr Mawr.

In order to do this it has been decided to adapt the existing groundwater flow network model to work in transient mode and also to directly simulate conditions at Kenfig and Merthyr Mawr through the incorporation of additional model cells. The updated model construction and results are described in the following sections.

1.2 Structure of this Document

The planning context etc. is described in the main Environmental Statement. The conceptual model on which the model is based is described in Appendix 7.1 of the Environmental Statement.

After this introduction, Section 2 describes the transient flow model in detail. Section 3 describes the model calibration whilst Section 4 explains how the predictive scenarios were set up. The results of the predictive scenarios are set out in Appendix 7.4.

2 MODEL DESCRIPTION

2.1 Modelling Approach

The model has been developed as an Excel spreadsheet and VBA code, and designed to simulate daily time series for groundwater heads and discharges.

Modelling is undertaken using explicit timestepping and changes in groundwater levels in each zone are derived from recharge, from groundwater flows between connected zones and discharges to boundary conditions (either to springs, drains, dewatering abstractions or the sea).

2.2 Model Zones

Model zones were defined on the basis of the conceptual model (Appendix 7.1) and are broadly consistent with the areas represented in the steady state model undertaken in a previous assessment (ESI, 2004). These zones were further subdivided to represent the areas around the quarries (to allow a more accurate assessment of the quarry inflows and outflows) in addition to refinement and layering around Kenfig dunes and Merthyr Mawr.

A schematic representation of the model zones used in the simulations is shown on Figure 2.1 and is described in more detail in the following sections.

2.3 Recharge

The derivation of the recharge input for the model is described in the Conceptual Model Report (Appendix 7.1). It is based on the soil moisture balance approach previously used at Cornelly both for the conceptual model (Appendix 7.1) and for the water Management Plan (Climate based assessment criteria).

Daily recharge values in the model are spatially distributed between zones to correspond with the sites for which the recharge input calculations were undertaken (see some discussion on different areas in Appendix I of Appendix 7.1). The rate at which water allowed to recharge the groundwater system is therefore determined by the recharge values and the area of each model zone.

The change in groundwater flux due to recharge $\Delta Q_{rec,j}$ in each j'th zone at time t is calculated from:

$$\Delta Q_{rec,j} = (1 - \alpha_j).R_{j,t}.\mathrm{A}_j.$$

where $\propto$ is fractional runoff(-),

R is recharge (m/day),

A is the zone area (m^2)

When the quarry is restored to open water there is the potential that the rate of evaporation will be different from that assumed in the recharge model. The degree of difference is hard to quantify as, although (for equivalent climatic conditions) the evaporation rate from open water is typically higher than for grass (the assumption of the recharge model), the rate of potential evaporation is very dependent on sunshine, humidity and wind speed. In a deep, steep sided quarry it is very likely that sunshine and wind speed (which promote evaporation) will be lower and humidity (which reduces evaporation) will be higher. It is thus possible that the potential evaporation rate at the water surface will be lower than would be assumed by standard calculations.

However, in order to assess the potential significance of this uncertainty, the recharge model has been re-run in a way that simulates the effects of open water whilst ignoring the effect of the factors discussed above. The results of this model are as follows:

Recharge rate (grass) 822 mm/a (average for period 1993 To 2003)

Recharge rate (open water) 719 mm/a (average for period 1993 To 2003)

Difference 103 mm/a.

Applying this difference over the potential area of open water (~25 ha) suggests an equivalent abstraction rate of around 70 m3/d. This effective abstraction rate is very small relative to current and predicted dewatering rates in the quarry and is not likely to have any discernible effect on the regional groundwater flow system. On this basis it has not been considered further in the modelling.

2.4 Discharge

The model allows for discrete discharges (e.g. local abstractions) to be input as time series for each zone over the duration of the simulation. By default discharges are input as -ve. Water can also be added to each zone using +ve values. Change in groundwater flux in each j'th zone due to discrete discharges $\Delta Q_{dis,j}$ at time t is calculated from

$$\Delta Q_{dis,j} = D_{j,t}$$

where D is discharge at time t (m^3/day)

2.5 Connectivity

The connection of the groundwater system is modelled as a series of zones representing the saturated zone in the main formations in the area. The saturated zone acts to transfer groundwater down hydraulic gradient between each zone.

The total groundwater flow between each j'th zone from each i'th zone at time t ($\Delta Q_{\sum i,j}$) is calculated from:

$$\Delta Q_{\sum i,j} = \sum_{i=1}^{N_{zone}} (h_{t-1,j} - h_{t-1,i}).\frac{T_{i,j}.w_{i,j}}{x_{i,j}}$$

where $h_{t-1,j}$ is the groundwater head from the previous timestep (m),

$T_{i,j}$ is the transmissivity between each zone (m^2/day),

$w_{i,j}$ is the flow width (m),

$x_{i,j}$ is the flow distance (m).

As more than one geology type may be described between nodal points and each flow path, the transmissivities are calculated using a harmonic mean approach (see Illustration 2.1).

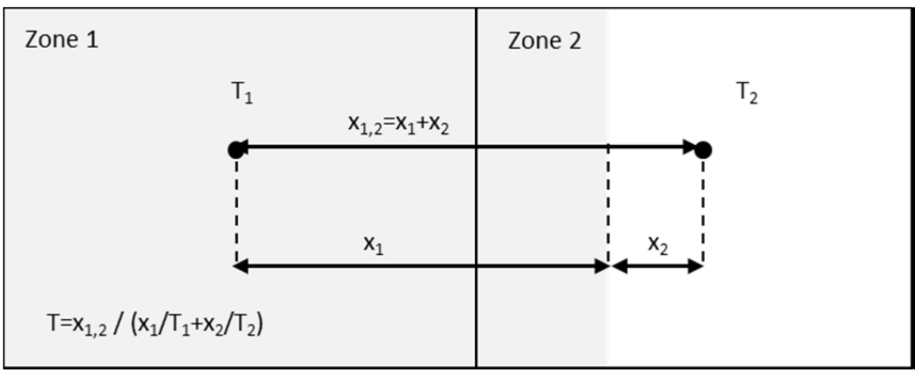


Illustration 2.1 Calculation of bulk transmissivity

The resulting transmissivity between each i'th and j'th zone is defined as:

$$T_{\mathrm{i,j}} = \mathrm{x}_{i,j} \;/\; \sum_{k=1}^{N_{trans}} \frac{x_k}{T_k}$$

where $x_{i,j}$ is the distance between zones (m),

x_k is the distance across a particular geology type (m),

T_k is the transmissivity of a particular geology type (m^2/day),

Parameterisation of the transmissivity of individual formations is discussed in Section 3.3.

2.5.1 Variation of hydraulic conductivity with depth (VKD)

An additional complication in the estimation of transmissivity is the concept of variable hydraulic conductivity with depth (or VKD). This is consistent with both the description of palaeokarst in the area (Appendix H of Appendix 7.1) and a review of the groundwater level information (see Section 3.3.2). The implementation of the VKD element in the model comprises up to three distinct hydraulic conductivity layers (see Illustration 2.3).

If deemed appropriate, transmissivity between each zone can be replaced with the VKD representation. VKD is recalculated at the beginning of each timestep using the previous estimates of groundwater head. Parameterisation of this feature is set out in Section 3.3.2.

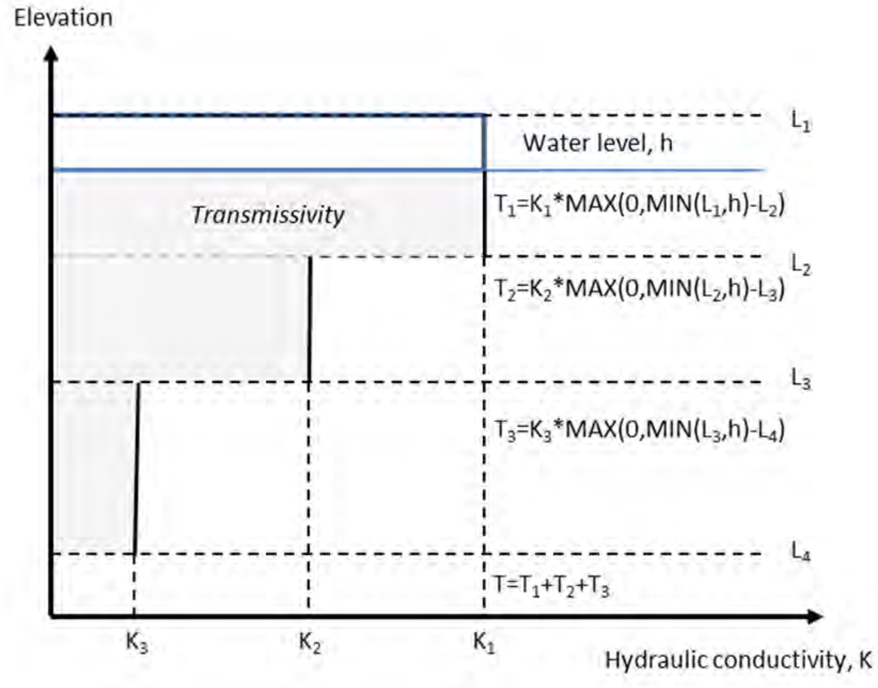


Illustration 2.2 Calculation of VKD

2.5.2 Vertical flow

The model allows for the incorporation of intervening layers between model zones (to represent a low hydraulic conductivity layer such as till for example). These intervening layers are not explicitly modelled (they are not a zone for which a groundwater head is computed).

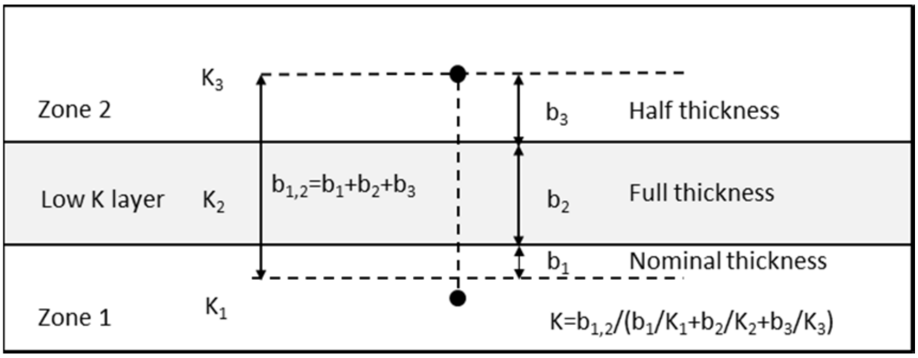


Illustration 2.3 Calculation of vertical hydraulic conductivity

The resulting hydraulic conductivity is calculated using the harmonic mean (see Illustration 2.3). This is calculated using a nominal thickness of the bottom layer (1m), the full thickness of the intervening layer and the half thickness of the overlying layer.

$$K_{\mathrm{ver,i,j}} = \mathrm{b}_{i,j} \;\; / \sum_{k=1}^{N_{cond}} \frac{b_k}{K_k}$$

where $K_{\mathrm{ver,i,j}}$ is the vertical hydraulic conductivity between zones (m/day),

$\mathrm{b}_{i,j}$ is the distance between zones (m),

b_k is the distance across a particular layer (m),

K_k is the vertical hydraulic conductivity of the k'th layer (m/day),

Apart from the interaction between these cells being vertical, the mathematics is similar as for the other cells. Vertical flow $\Delta Q_{ver,i,j}$ is calculated as:

$$\Delta Q_{ver,i,j} = (h_{t-1,j} - h_{t-1,i}).\frac{K_{ver,j}.A_j}{b_j}$$

where $h_{t-1,j}$ is the groundwater head from the previous timestep (m),

b_j is the thickness between zones (m).

2.6 Boundary Conditions

2.6.1 General head boundary

Discharges to downstream boundaries, such as the sea, are simulated using a general head boundary. The change in groundwater flow in each j'th zone due to flow to the general head boundaries ($\Delta Q_{ghb,j}$) are determined using:

$$\Delta Q_{ghb,j} = -(h_{t-1,j} - h_{ghb,j}).\frac{T_{ghb,j}.w_{ghb,j}}{x_{ghb,j}}$$

where $h_{ghb,,j}$ is the head assigned as the boundary value in each zone(m),

$T_{ghb,j}$ is transmissivity along the flow path to the general head boundary (m^2/day),

$w_{ghb,j}$is the width along the flow path to the general head boundary (m),

$x_{ghb,j}$ is the distance to the general head boundary (m).

2.6.2 Spring

A similar expression can be used to represent spring flows, although discharge is subject to a head constraint. The spring is only active if the heads exceed the spring elevation. Spring discharge $\Delta Q_{spr,j}$ from each j'th zone are determined using:

$$\Delta Q_{spr,j} = (h_{t-1,j} - h_{spr,j}).\frac{T_{spr,j}.w_{spr,j}}{x_{spr,j}} \qquad if\ h_{t-1,j} > h_{spr,j}$$

$$\Delta Q_{spr,j} = 0 \qquad if\ h_{t-1,j} \le h_{spr,j}$$

where $h_{spr,,j}$ is the head assigned as the spring boundary value in each zone(m),

$T_{spr,j}$ is transmissivity along the flow path to the spring (m^2/day),

$w_{spr,j}$is the width along the flow path to the spring (m),

$x_{spr,j}$ is the distance to the spring (m).

Spring transmissivity can be specified using a fixed value, or use dynamic values calculated using VKD.

2.6.3 Drain

The drain boundary condition is used to simulate overtopping, for example where Kenfig Pool has been observed to overtop and flow westwards into the dune slacks during periods of high groundwater levels.

A volume of water in a store above drain elevation $\Delta Q_{dra,j}$ is removed from the model as drain flow.

$$\Delta Q_{dra,j} = -(h_{t-1,j} - h_{dra,j}).\mathrm{A}_j.S_j/\Delta t \qquad if\ h_{t-1,j} > h_{dra,j}$$

$$\Delta Q_{dra,j} = 0 \qquad if\ h_{t-1,j} \le h_{dra,j}$$

2.6.4 Sump

Flow calculations were modified in the vicinity of the quarries, where the mass balance equations do not take into account radial flow. A tractable approach is to use the analytical equation of unconfined radial flow to a well. Flow is established from the head difference at two radial distances from the sump. If we assume that these heads (sump levels and head at a given radius from the sump) are constant over one timestep the flow field will be radial. Under this assumption, radial flow through any 'cylinder' must be identical to the sump dewatering rate $\Delta Q_{sum,j}$. This is effectively the unconfined Thiem-Dupuit radial flow equation for groundwater flow toward the pumping wells:

$$\Delta Q_{sum,j} = \frac{\pi.K_{h,j}.((h_{t-1,j} - \mathrm{b}_j)^2 - (s_{t-1,j} - \mathrm{b}_j)^2)}{2.3.\log(r_{h,j}/r_{s,j})}$$

where h_j and s_j are the zone and sump head respectively (m),

$r_{h,j}$ and $r_{s,j}$ are the zone and sump radius respectively (m),

b_j is the base of the aquifer (m),

$K_{h,j}$is the horizontal hydraulic conductivity (m/day),

The sump head represents the dewatered level (the sump level) within the quarry itself (considered to extend 10 m below the base of the lowest working bench level) provided as a time series representing the quarry development. The zone head is representative of groundwater heads at a given radius outside of the immediate quarry boundaries, calculated for each zone in which active dewatering is occurring.

Hydraulic conductivity was limited to the zone of active aquifer in the vicinity of the quarry sump (up to the zone groundwater water level predicted by the model). This assumes that most of the groundwater inflow to the quarry sump occurs laterally rather than vertically. Depth dependent hydraulic conductivity can be accounted for by simple averaging.

2.6.5 Boundary condition re-direction

All spring, drain and sump flows can be routed to discharge to other model zones. For example, to simulate pumping from quarries, or discharge from springs into other areas. The discharge ΔQ_{red} is implemented at each timestep using spring, drain or sump flows from the preceding timestep.

Flows can be redistributed according to fixed proportions (i.e. part of each flow can be redistributed to more than one zone). The model also allows flows to be redistributed according to a series of logic statements. The logic statements work in combination with the concept of 'additional storage' (see Section 2.8) in which redirection to several zones can be simulated based on the volume of the additional storage.

2.7 Change in Storage

For each zone, the resulting change in storage is calculated from the sum of all inflows and outflows for each zone as:

$$\Delta Q_{sto} = \Delta Q_{rec} + \Delta Q_{dis} + \Delta Q_{\sum i,j} + \Delta Q_{ver} + \Delta Q_{ghb} + \Delta Q_{spr} + \Delta Q_{dra} + \Delta Q_{sum} + \Delta Q_{red}$$

2.8 Additional Storage

There are a number of features in the model area that may potentially contain significant volumes of water and may locally affect heads. For example, part of each model zone may include settlement lagoons, dune slacks and pools that may contribute to additional storage. This additional storage volume may also become active only when groundwater levels rise above a particular elevation (for example the sump level, or base of pool).

An additional storage area can be incorporate within each zone as shown in Illustration 2.4.

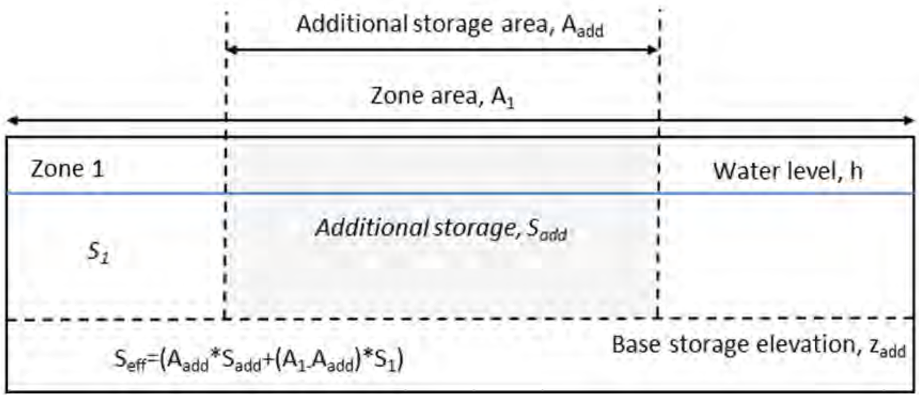


Illustration 2.4 Calculation of additional storage

The user needs to specify an additional storage area, the value of additional storage (i.e. 1.0 for open water) and the elevation above which this additional storage becomes active. Groundwater levels within each zone are still assumed to be constant and an effective storage $S_{eff,j}$. for each zone can be calculated when the set elevation is exceeded:

$$S_{eff,j} = (S_j(A_j - A_{add,j}) + S_{add,j}A_{add,j})/A_j \qquad if\ h_{t-1,j} > z_{add,j}$$

$$S_{eff,j} = S_j \qquad if\ h_{t-1,j} \leq z_{add,j}$$

where $S_{add,j}$ is the additional storage (-),

$A_{add,j}$ is additional storage area (m^2).

2.9 Change in Groundwater Head

Following changes in storage from the sum of all inflows and outflows in each zone there is a response in groundwater levels. For each j'th catchment store the change in groundwater head (Δh_j) at time t is calculated from:

$$\Delta h_j = {\Delta Q_{sto,j}} / {S_{eff,j}.\mathrm{A}_j} . \Delta t$$

The new head at time t is therefore:

$$h_t = h_{t-1} + \Delta h$$

2.10 Model Geometry

In order to address some of the concerns raised in previous consultations, the sand dunes in Kenfig and Merthyr Mawr have been explicitly represented in this model. Using the layered model the groundwater flow network model can be used directly to assess potential effects of additional quarry development on water levels within the dune systems. This required the addition of model cells at a scale appropriate to model potential impacts that effectively overlie the cells representing the 'solid' geology.

2.10.1 Kenfig

The conceptual model of the layered system at Kenfig is discussed in detail in the conceptual model report (Appendix 7.1) and can be broadly summarised as:

- The blown sand act as a fairly homogeneous system. They are fed by direct rainfall and discharge occurs laterally via groundwater flow to the coast and, to a lesser extent, via downwards leakage into the underlying geology;
- A series of glaciofluvial sands and gravels underlie the blown sand. Groundwater levels are generally lower and show distinctly different behaviour. This is believed to be due to an extensive intervening layer of low hydraulic conductivity estuarine clay that limits the connection between the dunes and the underlying sands and gravels;
- The extent of the estuarine clay underlying the blown sand and Kenfig Pool is uncertain;
- Glaciofluvial sands and gravels underlying the estuarine clay are fed by recharge in the area of outcrop (east of Kenfig Pool), groundwater flow (from potentially well-connected underlying geology) and leakage from the overlying formations;
- The glaciofluvial deposits/till around Borehole A acts as a minor, perched aquifer to feed the ephemeral springs that flow to Kenfig Pool.
- The glaciofluvial system is not well connected to the underlying 'solid geology' groundwater flow system around the south of the pool but appears to be in closer connection to the north east (borehole N).
- A low hydraulic conductivity till limits the connection between the sands and gravels and underlying solid geology, although the extent of this till layer is not certain. Connection between the sands and gravels and the coast may also be restricted by this till layer;
- Kenfig pool may receive some ephemeral inflows from seeps to the east. At high water levels the pool overflows to the south west.

Schematic illustrations of the Kenfig dune system demonstrating the model connectivity (and conceptual uncertainty in these connections) are shown in Illustration 2.5 to Illustration 2.12 below.

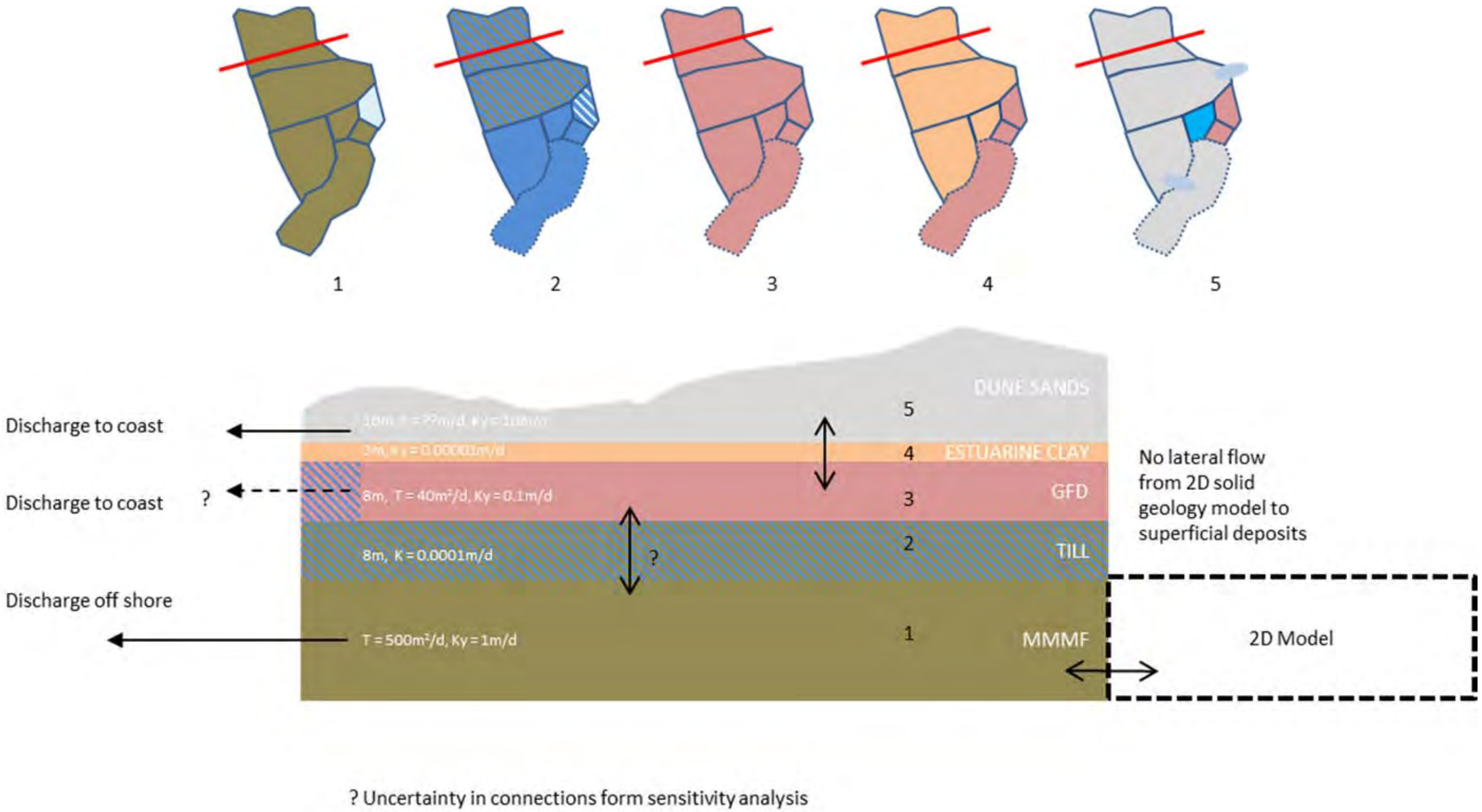


Illustration 2.5 Kenfig model section 1

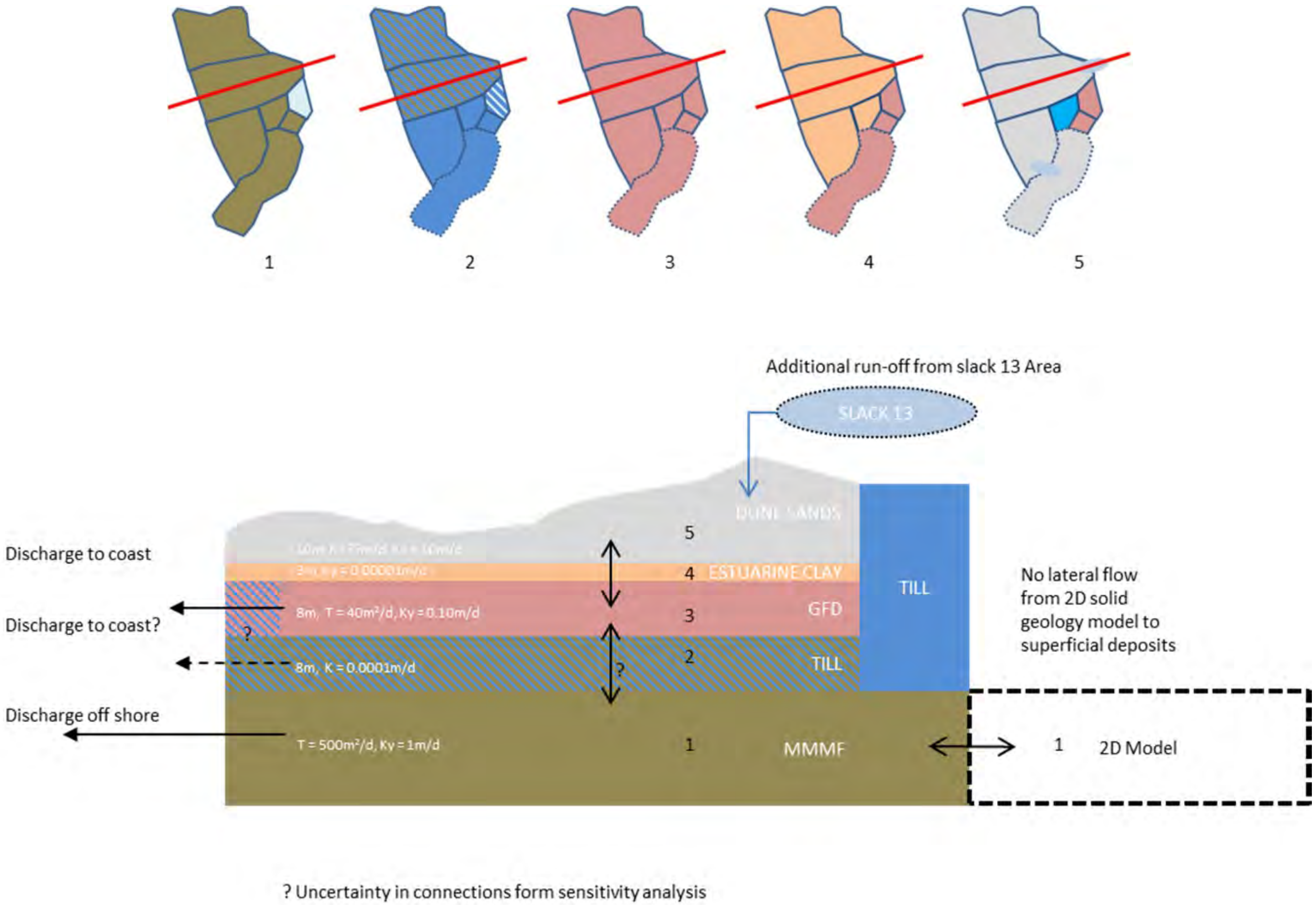


Illustration 2.6 Kenfig model section 2

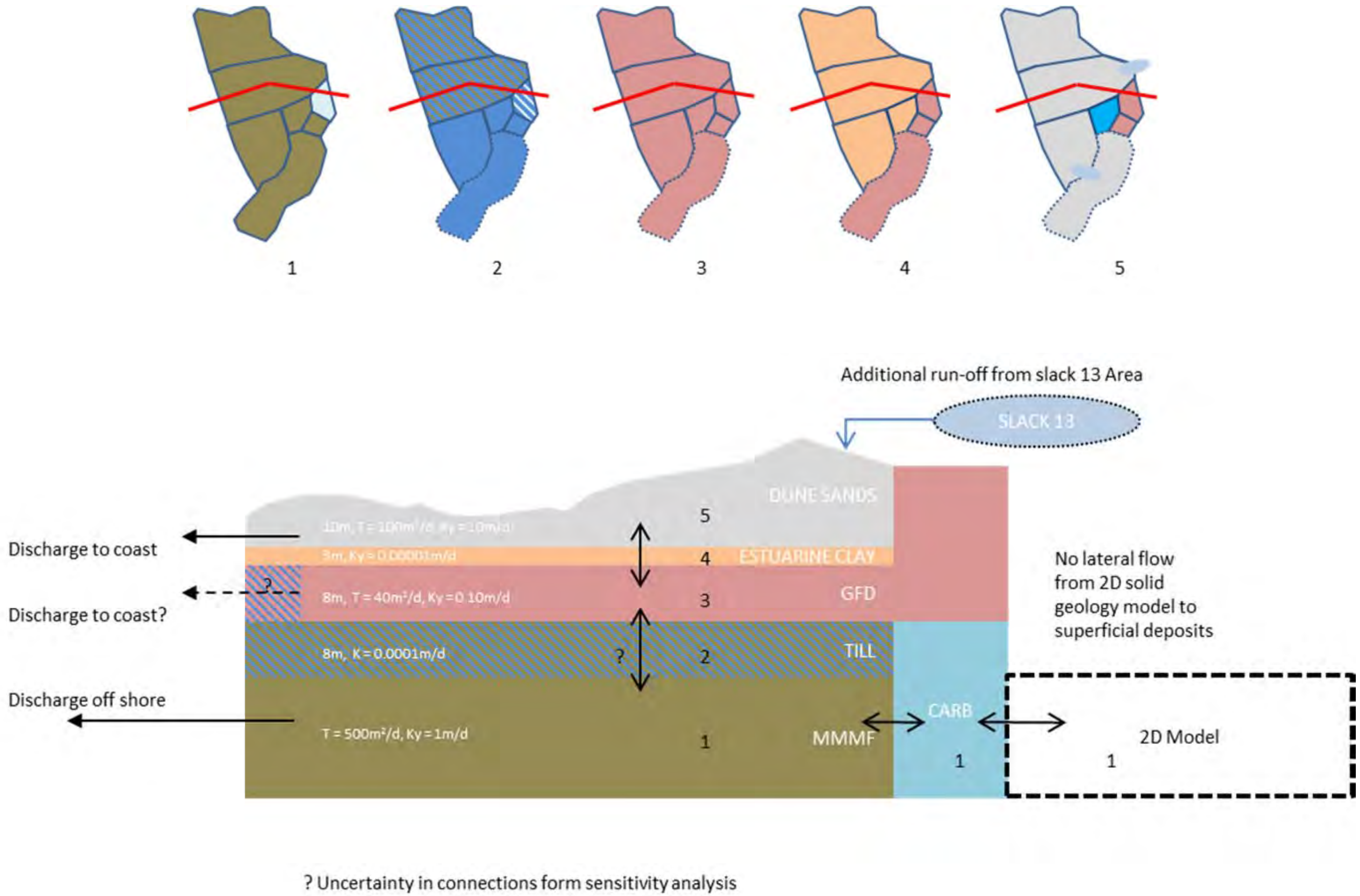


Illustration 2.7 Kenfig model section 3

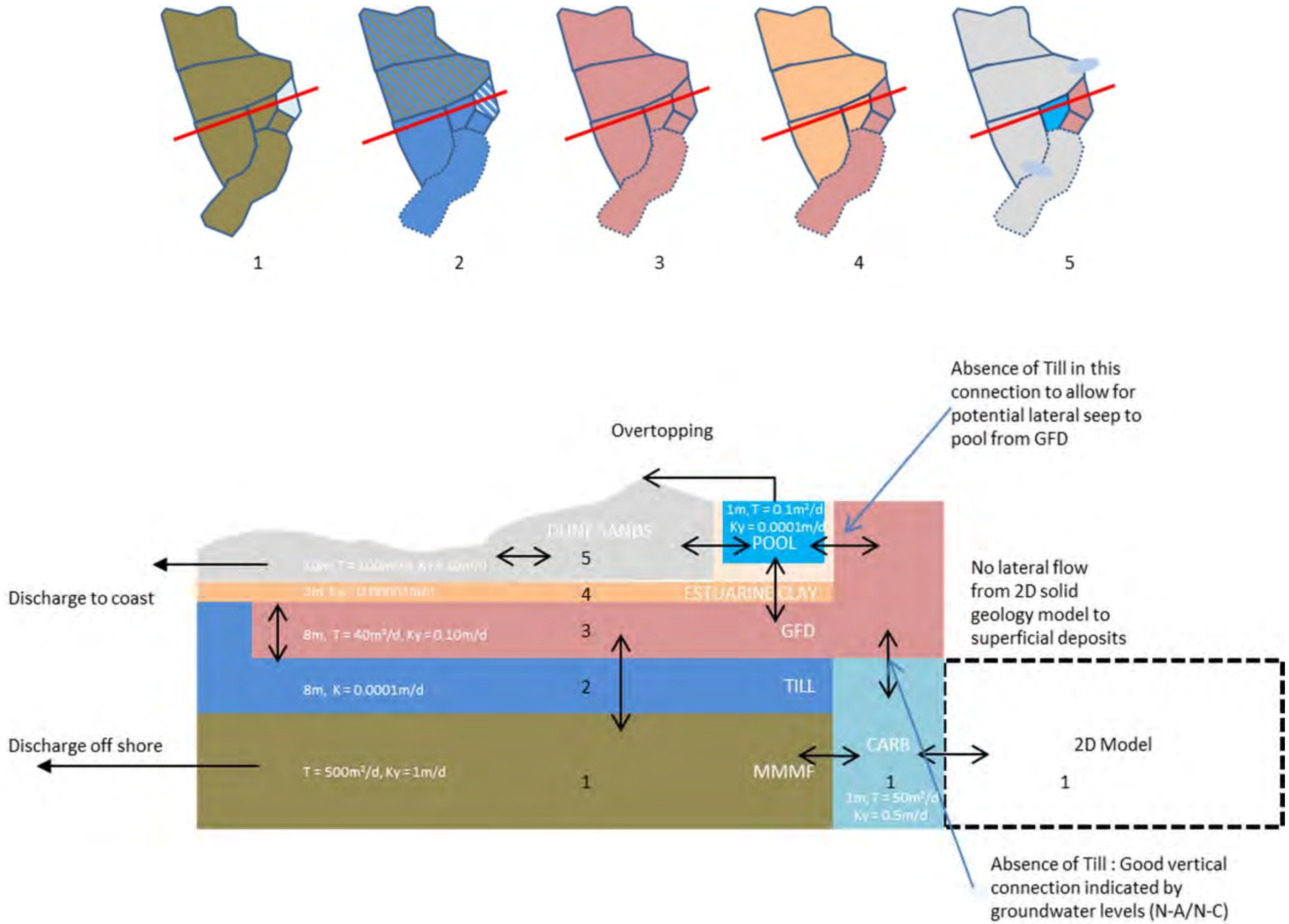


Illustration 2.8 Kenfig model section 4

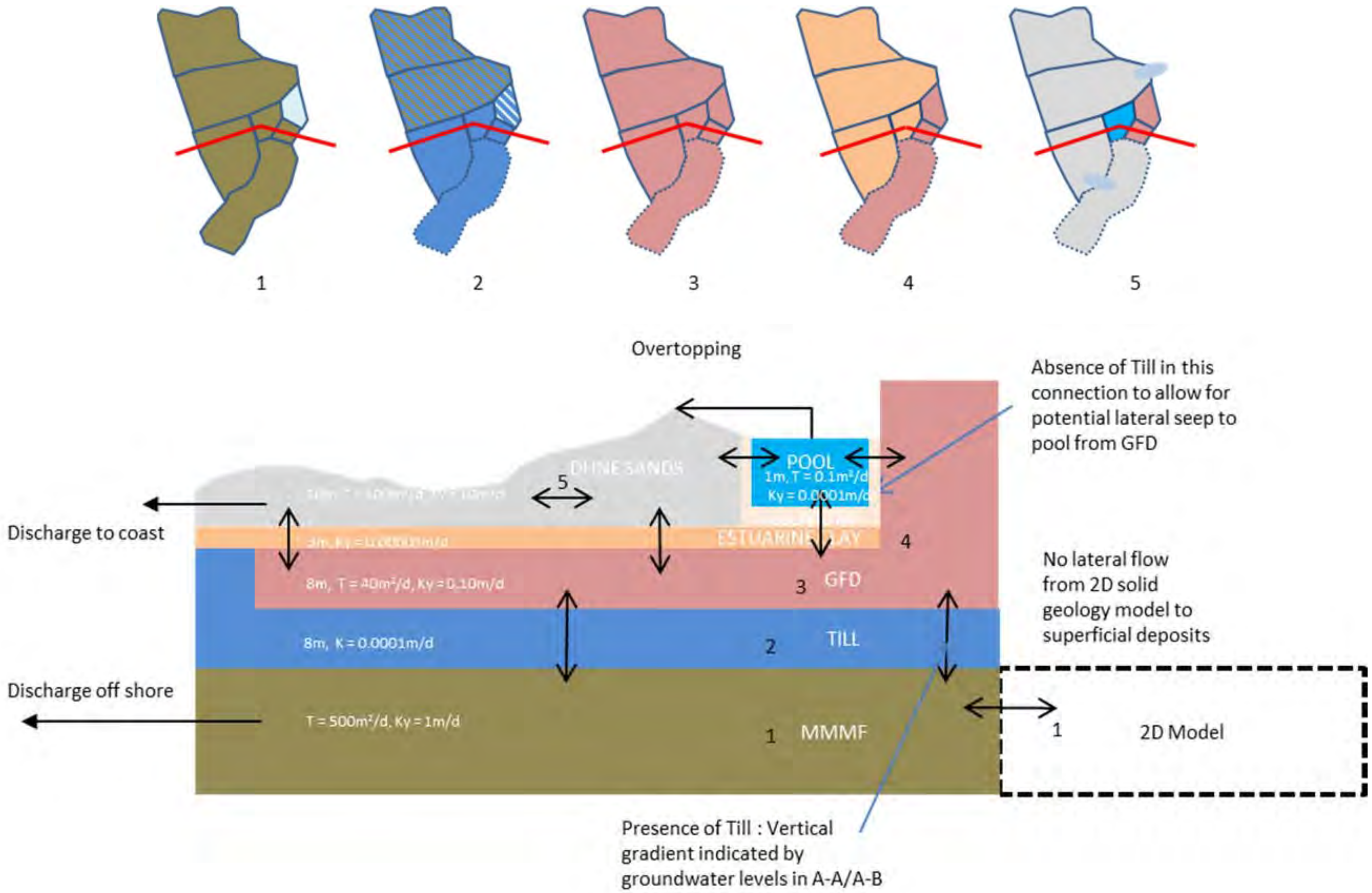


Illustration 2.9 Kenfig model section 5

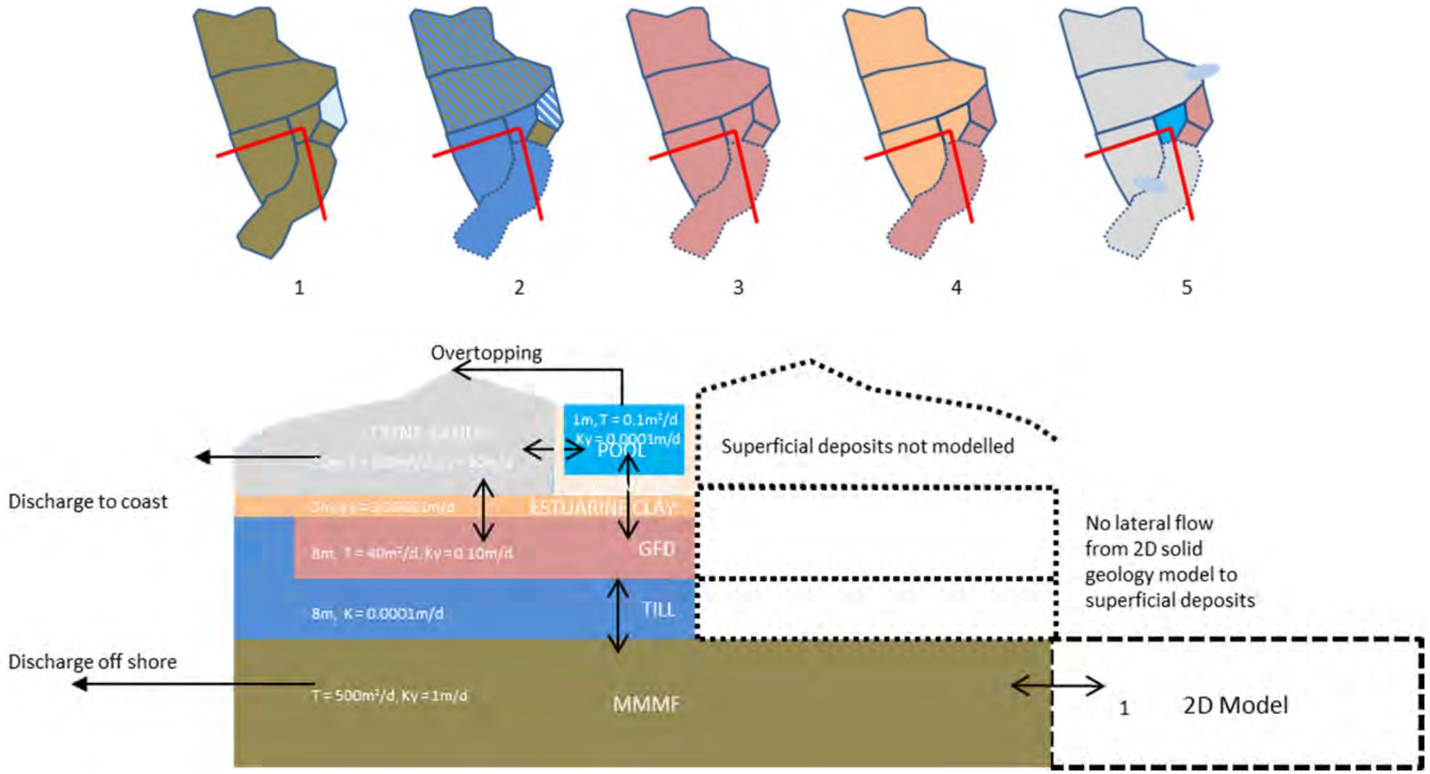


Illustration 2.10 Kenfig model section 6

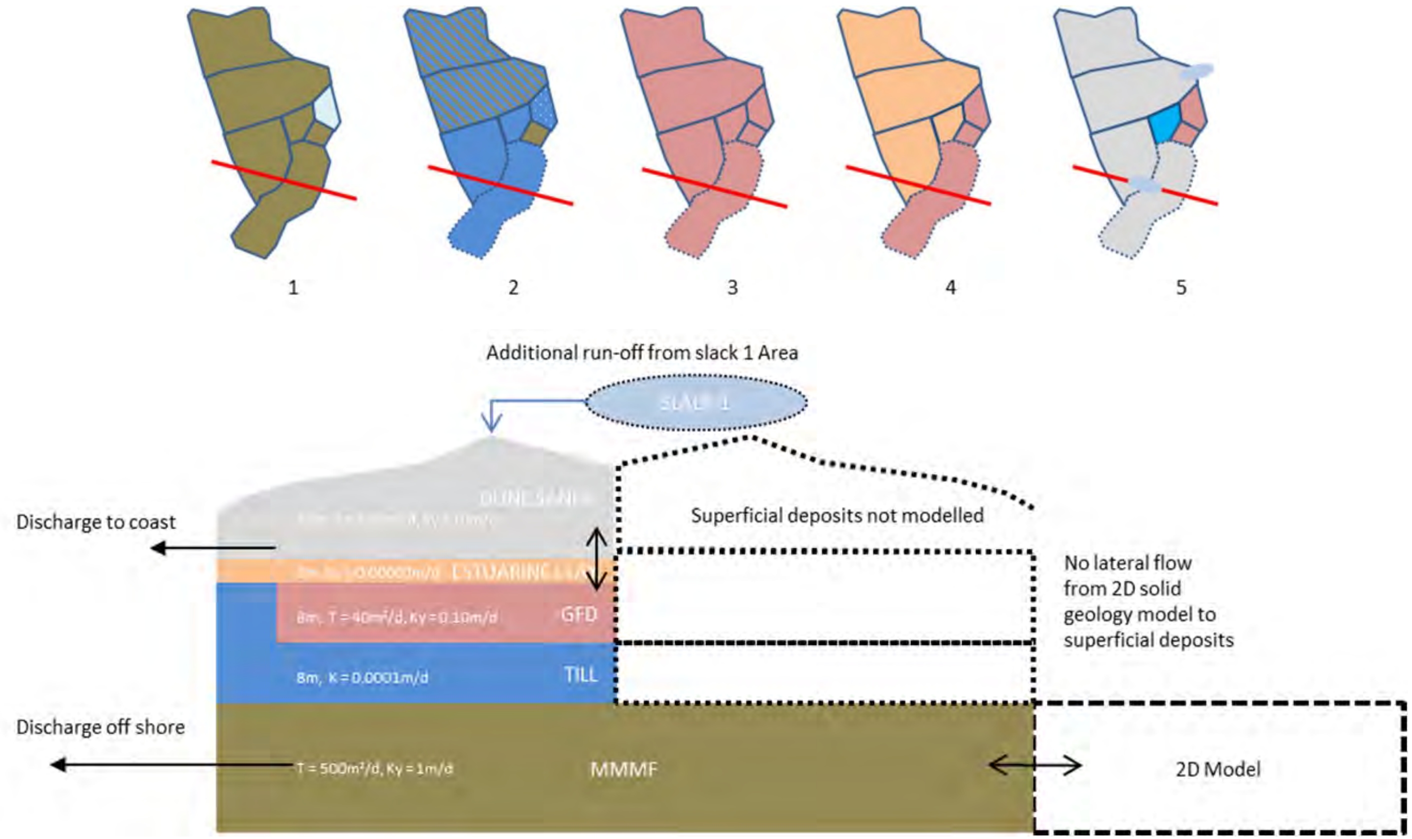


Illustration 2.11 Kenfig model section 7

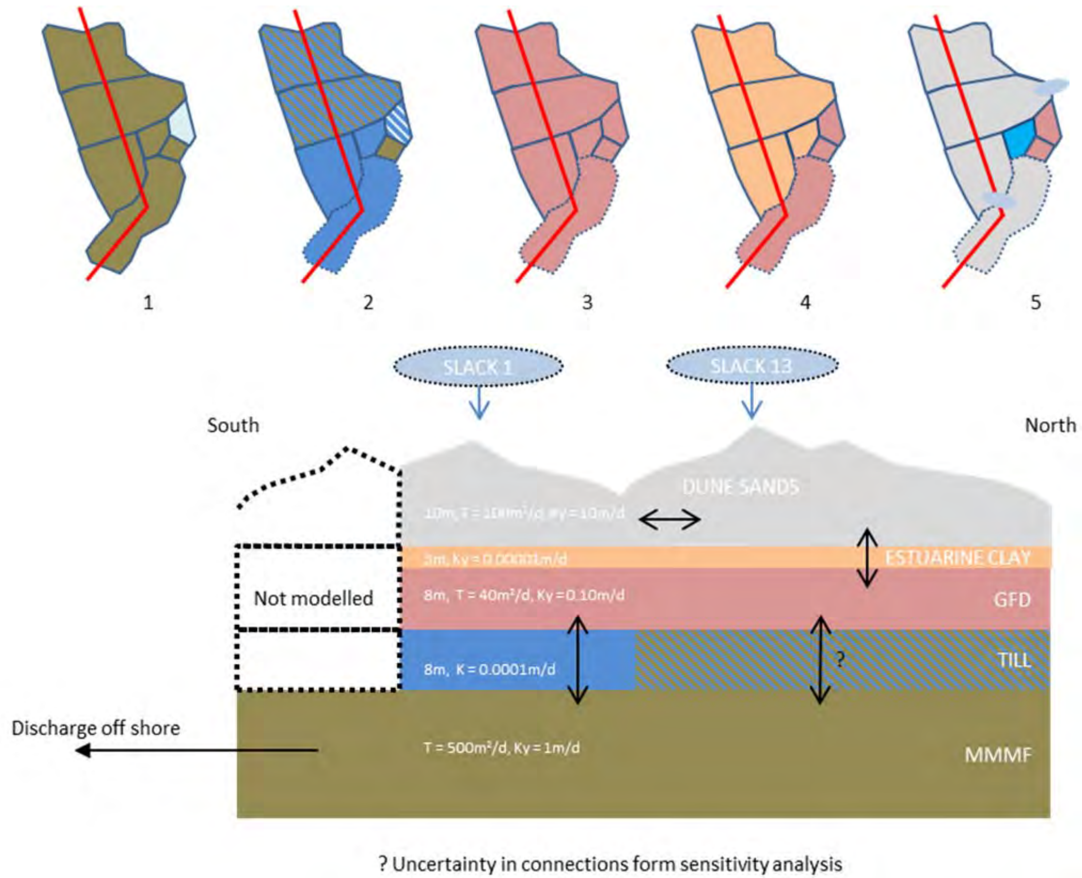


Illustration 2.12 Kenfig model section 8

2.10.2 Merthyr Mawr

The conceptual model at Merthyr Mawr is discussed in detail in the conceptual model report (Appendix 7.1) and can be broadly summarised as:

- The blown sand receive direct recharge groundwater inflow from the Carboniferous Limestone (Burrows Well).
- Discharge in the blown sand occurs laterally via groundwater flow and overland via series of pool and dune slacks to the coast.
- Discharge in the blown sand also occurs via downwards leakage. Connection between the dunes and the underlying limestone is via an extensive but thin (1 m) underlying clay layer;
- South of Burrows Well, water levels are affected by the discharge of limestone groundwater levels into the blown sand which causes large areas to pond.
- When the spring stops flowing, these water levels drop rapidly and the groundwater system in this area is not typical of dune slacks more generally. SWS, 2010 suggest that this area may be perched on a thin clay layer.
- Groundwater gradients are locally predominantly downwards from the blown sand to limestone.

A schematic illustration of the Merthyr Mawr dune system demonstrating the model connectivity is shown below.

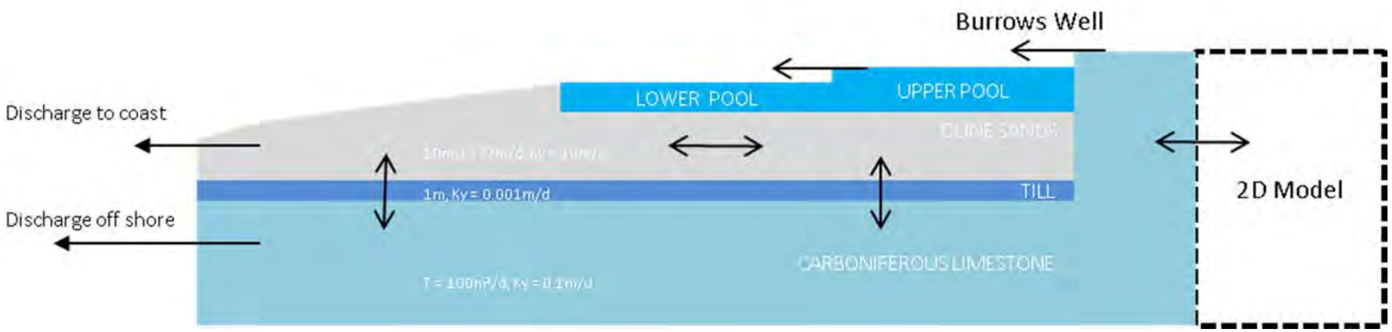


Illustration 2.13 Merthyr Mawr model section 1

3 MODEL CALIBRATION

3.1 Calibration Targets

The purpose of model calibration is to adjust certain model parameters (transmissivity, storage, etc.) within credible ranges in order to derive a close correlation between observed and simulated conditions. In this case, the model has been calibrated to the following targets:

- observed groundwater levels (including assessment of likely groundwater levels at Cornelly prior to the start of dewatering),
- observed flows at New Mill Farm springs,
- observed flows at Burrows Well, and
- dewatering flows from within Cornelly quarry

Location of the calibration targets are shown in Figure 3.1.

3.1.1 Groundwater level targets

Thirty-two observation boreholes (summarised in Table 3.1) were selected as targets across the model area. Calibration targets were selected on the basis of location (ideally as close as possible to the centre of each zone), record length, frequency of measurement and perceived quality of the data.

Table 3.1 Calibration head targets

Borehole	X	Y	Count	From	To	Zone
TQ3	283070	179881	1662	16/06/1995	12/06/2013	1
ESP2	283025	179725	117	26/04/1999	18/01/2009	2
TM6	283905	179854	211	31/10/1994	12/06/2013	3/4
TM4	283718	180395	1566	08/11/1992	18/08/1999	5
RWC107	282883	179954	226	20/08/1998	07/06/2013	8
RWC105	282658	179886	163	20/08/1998	07/06/2013	9/18
G	284792	179502	122	17/10/2001	10/06/2013	10/20
T95/01	284304	179947	4235	22/09/1995	10/06/2013	11
T95/04	284099	180400	53	22/09/1995	27/11/2002	12
Q	282817	180984	102	22/10/2002	23/05/2013	14
E	282887	180499	118	25/03/2002	14/06/2013	15
17B	282137	180760	111	25/03/2002	23/05/2013	23
EASC	281757	180249	4876	20/04/1995	04/03/2012	24
N-A	280047	181714	100	02/12/2002	26/06/2013	25
RWC100	282187	179831	2345	12/08/1998	24/06/2010	26/27
40	281970	179600	118	24/04/2002	04/06/2013	28
ITUSCA	285104	178646	53	29/01/1998	22/05/2003	29
T	283825	179196	14	03/10/2012	02/10/2013	30
MM1	285602	176878	692	24/11/2009	14/10/2011	33
P	281848	181099	108	22/10/2002	27/06/2013	35
O-A	280473	182851	111	22/10/2002	05/06/2013	36
A-A	280206	181254	298	17/10/2001	12/06/2013	38
B-A	280564	180567	122	17/10/2001	04/06/2013	40
21	283050	178200	48	25/03/2002	24/01/2006	41
L	285059	177372	101	20/05/2001	10/06/2013	42/44
D7	285821	176834	71	01/03/2004	01/07/2013	43
D4	286253	176607	102	01/03/2004	01/07/2013	45
N-C	280047	181714	99	02/12/2002	26/06/2013	46
A-B	280206	181254	103	17/10/2001	12/06/2013	47
KP	279549	181172	4259	16/03/1999	30/11/2010	48/53
K1A	279348	181594	104	15/04/2003	26/06/2013	50
K1B	279348	181594	101	15/04/2003	26/06/2013	55
CC5	279202	182061	501	17/01/1986	01/06/2013	56

3.1.2 Spring flow targets

Location and available data for spring flow targets are summarised in Table 3.2.

Table 3.2 Spring flow calibration targets

Borehole	Location	X	Y	Count	From	To	Zone
Burrows Well		285650	177260	1596	02/01/2008	31/03/2013	32
New Mills Farm	HL9A2 HL9B	280638 280286	182941 182919	18	15/05/2002	06/06/2004	36

<u>New Mills farm</u>

No reliable continuous gauging data are available at New Mills Farm springs due to a combination of unstable river banks and irregular flooding from the Afon Kenfig (Appendix J of Appendix 7.1). Data available in December 2002 recorded a relatively constant flow of between 60 and 80 l/s, although the period of data recording is insufficient for the purposes of model calibration.

A limited number of spot flow measurements are available to estimate longer term flows at New Mills Farm Spring. The difference in spot gauging between HL9A2 (upstream) and HL9B (downstream) represents a 400 m reach along Afon Kenfig. These data are used to provide a general assessment of the magnitude of the flows at New Mills Farm. Clearly the use of this spot gauging also means that the total flow includes contributions from both sides of the reach and the limited data means that continuous and long term flows are not well constrained.

Table 3.3 Spot gauging data at New Mills Farm spring

	Spot gauging (HL9B-HL9A2)	
Date	**l/s**	**m^3/day**
15/05/2002	121	10454
10/06/2002	531	45904
11/07/2002	72	623
29/08/2002	135	11638
10/01/2003	317	27363
12/02/2003	235	20293
12/03/2003	389	33610
22/04/2003	95	8199
03/06/2003	268	23121
08/07/2003	101	8726
28/10/2003	98	8476
23/12/2003	120	10368
30/01/2004	175	15120
24/02/2004	251	21686
11/03/2004	235	20304
26/04/2004	250	21600
18/05/2004	62	5357
09/06/2004	32	2765

Burrows Well

A stream flow logger was installed on Burrows Well in January 2008 and continuous gauged flow data are available to March 2013. The available data are shown on Illustration 3.1.

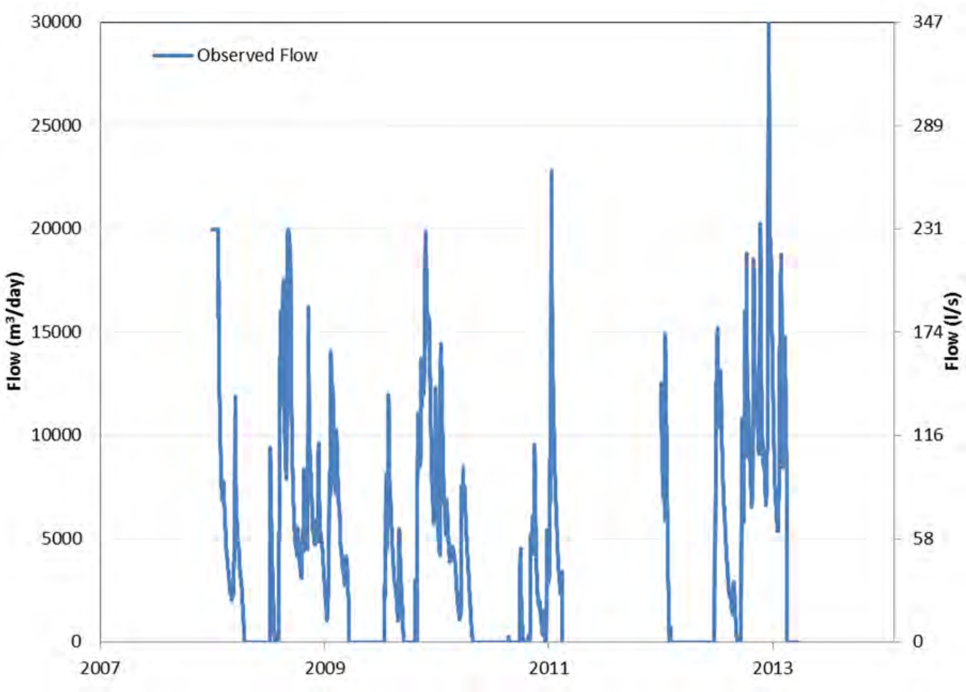


Illustration 3.1 Observed flow at Burrows Well

3.1.3 Pumping data

Cornelly Quarry is dewatered by pumping from a sump in the quarry floor to a settlement lagoon. In the past water has been pumped to Pant Mawr (and occasionally to Stormy Down), but currently water is pumped to Grove Quarry where water re infiltrates into the Carboniferous Limestone aquifer by seepage through the floor and sides of the flooded quarry.

Pumping data are available from June 2001 (Appendix N of Appendix 7.1), although the continuity and quality of the pumping records varies. Average pumping rates are summarised for different periods in Table 3.4 below.

Table 3.4 Average pumping rates at Cornelly quarry

Period	Sump	Offsite[1]	Comment
20 Jun 01 to 1 June 04	4873	1980	1202 m^3/d to Pant Mawr and 778 m^3/d to Grove
1 June 04 to 1 Oct 06	3382	1245	All to Grove from June 2004 to October 2006
1 Oct 06 and 5 Aug 08	-	2281	Assuming meter continued to run throughout
5 Aug 08 to 2 Jun 11	3735	2232	Since new meters installed
20 June 11 to 25 Mar 12	2969	2041	Since start of monitoring

[1] offsite excludes any re-circulation in the quarry itself

A complete record of inflow to Cornelly quarry has been reconstructed from the available data for the calibration period and is shown on Illustration 3.2 below. Note that the red line on this figure shows the average pumping rates for the periods where the quality of the monitoring data is considered to be reliable. Prior to available records (2001), estimates of the pumping rates have been made based on the available summary of dewatering activities at the quarry (Appendix N of Appendix 7.1). Net discharges to the lagoon and discharges offsite have also been calculated as part of the calibration process and are shown on

Illustration 3.3. Net discharges form explicit timeseries and are used as model input in respective model zones as discussed in Section 2.4.

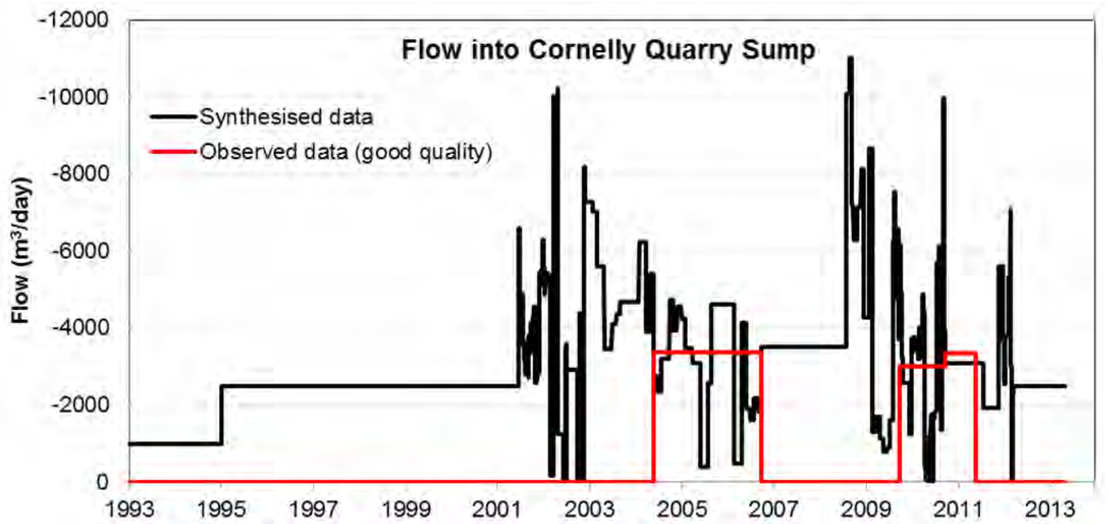


Illustration 3.2 Cornelly sump discharges used in model calibration

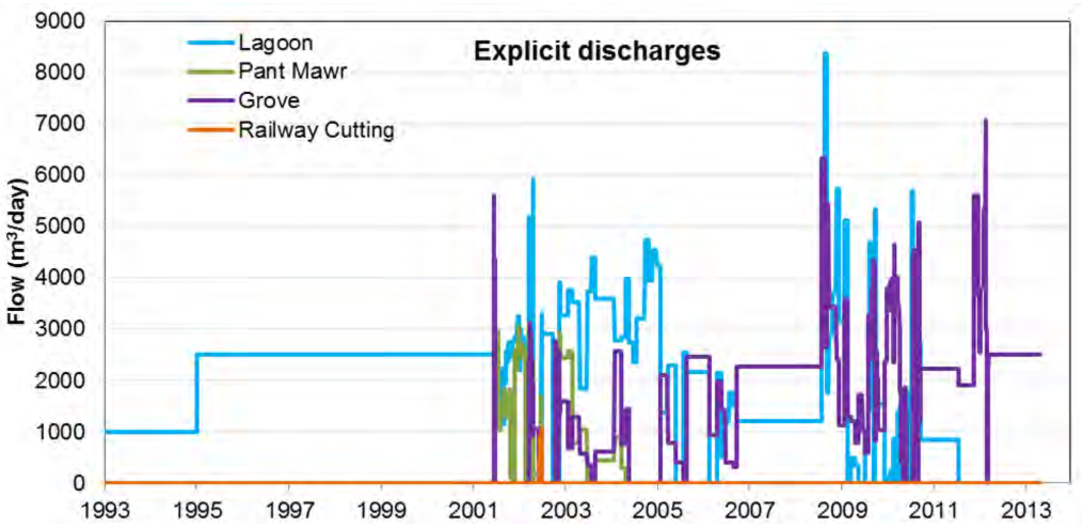


Illustration 3.3 Explicit discharges used in model calibration

Calibration of the inflows into Cornelly quarry is undertaken by using a history of development depths (see Illustration 3.4). Sump inflows are calculated from the development depths (Section 2.6) and compared to the observed (and synthesised) pumping rates from Cornelly sump. Clearly, data at different stages are more reliable than others, both due to uncertainty in the specified development depths and the reliability of the historical pumping data. Those data considered to be the more reliable data are shown on Illustration 3.2 and summarised in Table 3.5 below.

Table 3.5 Reliable pumping rates at Cornelly quarry

Period	Sump (m^3/day)
1 June 04 to 1 Oct 06	3382
5 Aug 08 to 2 Jun 11	3735

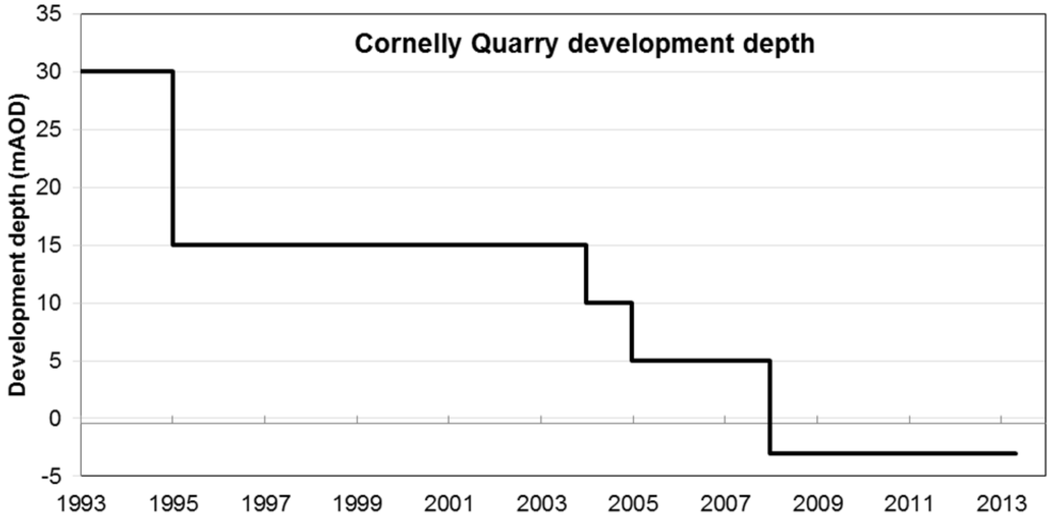


Illustration 3.4 Cornelly Quarry development depths

3.2 Initial Conditions

At the start of the simulation groundwater levels are set at an initial value using the average of field-measured head values (or interpolated values where no observation data are available for a given zone). These heads are not necessarily going to represent the groundwater system at equilibrium and response in the early time steps reflect the model under stress. The model requires some time to establish correct groundwater heads and flow (typically a period of one or two years from the start of the simulation is sufficient for the outputs to become reliable).

Initial heads used in the calibrated model in each zone are summarised in Table 3.6.

Table 3.6 Initial heads

Zone	Head	Zone	Head	Zone	Head	Zone	Head
1	42.0	16	24.0	31	16.0	46	10.2
2	34.0	17	24.0	32	12.0	47	10.8
3	60.0	18	24.0	33	5.0	48	9.7
4	60.0	19	22.0	34	20.0	49	9.0
5	60.0	20	64.0	35	22.0	50	8.4
6	57.0	21	64.0	36	8.0	51	8.6
7	57.0	22	50.0	37	6.0	52	8.3
8	39.0	23	23.0	38	9.0	53	10.4
9	34.0	24	15.0	39	12.0	54	10.0
10	60.0	25	10.0	40	10.0	55	9.0
11	56.0	26	5.0	41	6.0	56	10.3
12	58.0	27	17.0	42	12.9	57	9.9
13	31.0	28	9.5	43	8.5	-	-
14	31.0	29	61.0	44	6.1	-	-
15	24.0	30	13.8	45	8.3	-	-

3.3 Transmissivity

Groundwater flow between adjacent cells is a function of the transmissivity along the flow paths (a product of hydraulic conductivity and saturated thickness). Transmissivity is described by both geology considered to have constant transmissivities and those for which transmissivity varies as a function of the saturated thickness.

3.3.1 Fixed transmissivity

Solid geology

The final calibrated values of transmissivity for the solid geology are shown in Table 3.7. Values estimated during the development of the steady state model (ESI, 2003) are also shown for comparison.

Table 3.7 Calibrated transmissivity values for solid geology

Geology	Model transmissivity (m^2/day)		Zone
	Transient	Steady state	
Carboniferous limestone	see Table 3.9	n/a	1-33
Mercia Mudstone Marginal facies	700	1400	35,37-41
Penarth Group	20	20	34
Pant Mawr Sandstone	1	1	6,8,13,14, 18,26,27
Caswell Bay Mudstone	1	1	29
Undifferentiated Mercia Mudstone	800	20	34,36
Millstone Grit	0.1	n/a	37

The following observations were made during model calibration:

- Only one value of transmissivity per geology type was required to define the calibrated model.
- The Mercia Mudstone Marginal Facies typically exhibits higher transmissivity than the other formations (by an order of magnitude) and is within the expected range.
- The areas mapped as undifferentiated Mercia Mudstone is mapped as predominantly lower permeability mudstone[1], yet values similar to the marginal facies were required to achieve a good calibration:
    - Higher transmissivity values were necessary to obtain sufficient spring flows and maintain low groundwater heads at connection leading to New Mills Farm spring.
    - Transmissivity of other formations tended to dominate bulk transmissivity at other connections and results were less sensitive to the Mercia Mudstone value.
- Low transmissivity values for the Pant Mawr Sandstone were necessary to limit north-south connections around Grove and Pant Mawr and north of Cornelly quarry.
- An inferred low transmissivity connection between zones 36 and 37 due to the presence of Millstone Grit had only a minor effect on the overall calibration.

Superficial deposits

The final calibrated values of transmissivity for the superficial deposits at Merthyr Mawr and Kenfig are shown in Table 3.8. Note that the blown sand at Kenfig and Merthyr Mawr are modelled as unconfined; the hydraulic conductivity of the blown sand is constant, yet the transmissivity of the blown sand varies with the depth of the simulated groundwater level.

[1] Drilling of Boreholes O and R near New Mill farm springs showed that the geology in this area comprised marginal facies rather than the mudstone as mapped. This provides some justification for high transmissivities used in the model in this area.

Table 3.8 Calibrated transmissivity values for superficial deposits

Geology	Model transmissivity (m^2/day)		Zone
	Transient	Steady state	
Kenfig			
The blown sand	109-163	n/a	54-57
Sands and Gravels	50	90	46-52
Alluvium	0.5	n/a	53
Till+ Sands and Gravels [1]	0.05	n/a	49-52
Merthyr Mawr			
The blown sand	108-270	n/a	42-45

1 bulk transmissivity

The following observations were made during model calibration:

- The calibrated values for the hydraulic conductivity of the blown sand at Kenfig and Merthyr Mawr are 15 m/day and 20 m/day respectively. Jones (1993) carried out numerous falling head tests and estimated a mean hydraulic conductivity of around 9 m/day. Scoping calculations based on observed hydraulic gradients and estimated recharge suggest that the value could be up to 25 m/day (Appendix G of Appendix 7.1).
- The glaciofluvial sands and gravels at Kenfig represent a relatively permeable horizon, yet a limited connection to the sea via the till is required to support the observed groundwater levels.
- The lateral connection between the glaciofluvial deposits and the sea via the till represents a boundary connection and a bulk transmissivity. The equivalent transmissivity of the till would be approximately 0.0005-0.0009 m^2/day. Assuming a thickness of 8 m this is approximately an order of magnitude greater than the vertical till hydraulic conductivity (see Section 3.3.4).
- A relatively permeable lateral connection (via alluvium) is required from Kenfig Pool (Zone 53) to adjacent cells to achieve model calibration. Assuming a thickness of 5 m this gives a hydraulic conductivity of approximately 0.01 m/day, which is two orders of magnitude greater than the vertical hydraulic conductivity of the alluvium (see Section 3.3.4).

3.3.2 Depth dependent transmissivity

Flow into Cornelly quarry is principally via diffuse flow from fractures and fissures. Detailed work on the distribution of palaeokarst features (Appendix H of Appendix 7.1) indicates that most of the active fissures are present above 60 mbgl, with the frequency of clay filled features increasing significantly with depth. Very few fissures are observed below 100 mbgl toward the base of the quarry. Evidence also suggests that there are no significant palaeokarst features that may enhance groundwater flow from the current base of the quarry to at least -75 mAOD.

A review of the groundwater level hydrographs within the Carboniferous Limestone also suggests that a general model of enhanced permeability is applicable in a zone immediately above and below the position of the current water table. Groundwater levels fall rapidly after winter recharge, but generally most boreholes show a lower level to which groundwater levels fall. This lower level is typically controlled by the elevation of a zone of enhanced permeability.

These observations suggest up to three hydraulic conductivity horizons within the Carboniferous Limestone; with the highest values representative of an uppermost, reactivated palaeokarst zone, the middle zone representing partial reactivation and the lower zone representing an area of no reactivation.

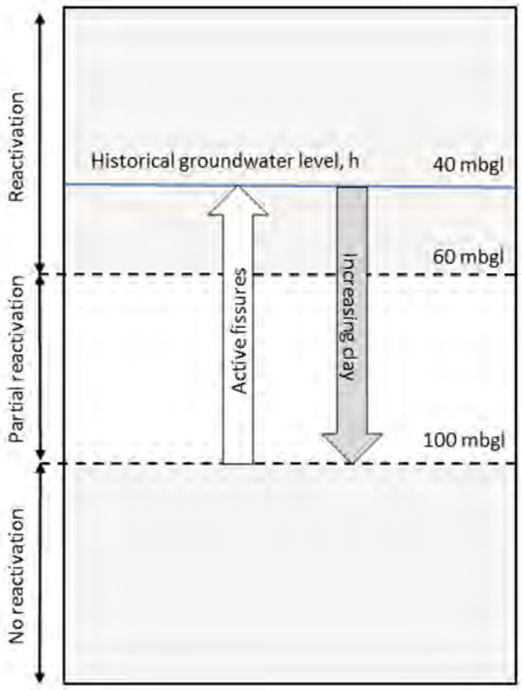


Illustration 3.5 .Palaeokarst features and VKD horizons at Cornelly quarry

Initial parameterisation of VKD was based on these three distinct hydraulic conductivity horizons in the Carboniferous Limestone. In summary, each layer elevation was defined as:

- top of layer 1, mean topographical elevation of each zone;
- top of layer 2, varies linearly with zone elevation;
- top of layer 3, top elevation of no reactivation, and;
- top of layer 4 (base of layer 3), the lower vertical limit of the model.

The top elevation of no reactivation was considered to be fixed at 0 mAOD based on the observations at Cornelly quarry. The lower bound to the model was set at -100 mAOD (at sufficient depth to consider future developments within the quarry). The base of the reactivated palaeokarst horizon (top of layer 2, $z_{j,L2}$) was considered to vary linearly with surface elevation according to:

$$z_{j,L2} = z_j . \frac{z_{max} - d_{max}}{z_{max}}$$

where z_j is the mean topographical elevation of each zone (m),

z_{max} is the maximum topographical elevation in the model area (m),

d_{max} is the depth to L2 at the maximum topographical elevation (m),

The figure below shows the resulting vertical extent of the horizons in each zone. The range of observed groundwater level variation is also shown and illustrates that the uppermost reactivated karst horizon is active at higher groundwater levels for this linear approximation.

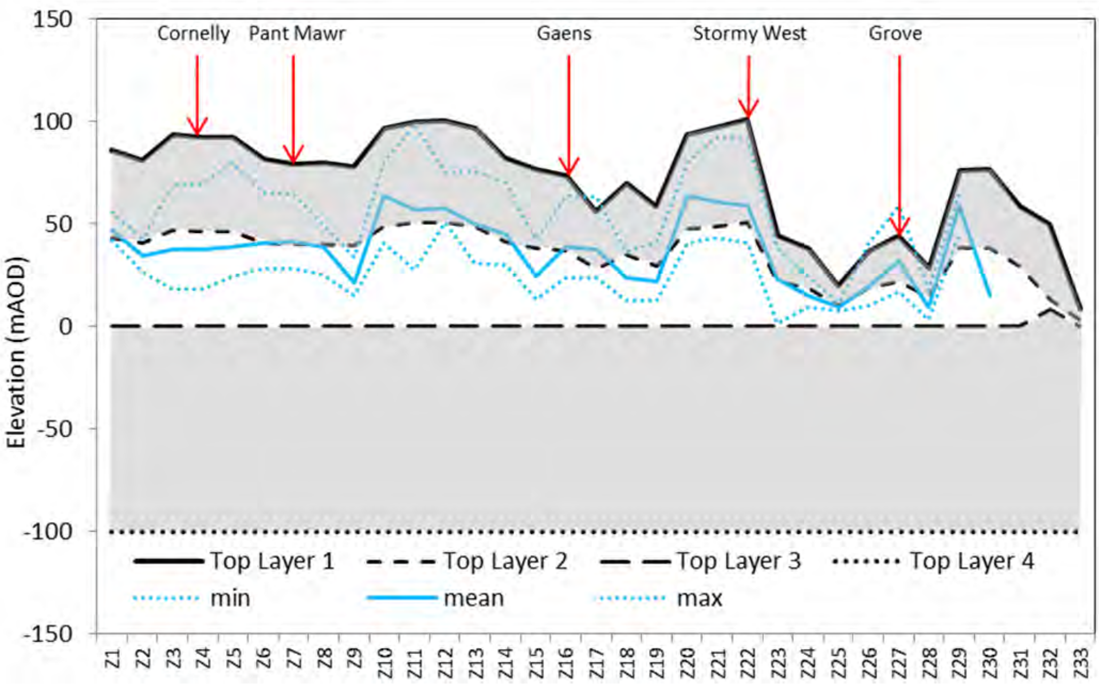


Illustration 3.6 VKD horizons by zone

In general, the initial parameterisation of layer elevations has remained unchanged during calibration. One exception is Zone 32 (associated with the outflow at Burrows well). The base of the zone of increased hydraulic conductivity at this location represents a physical discharge point from the aquifer.

A summary of the calibrated depth dependent hydraulic conductivity distribution at all Carboniferous Limestone zones is shown in Table 3.9. In order to limit issues of over parameterisation an attempt was made to restrict the number of distinct hydraulic conductivity values used. The vertical hydraulic conductivity profiles can be categorised in to broadly four categories (as shown on Table 3.9).

Table 3.9 Calibrated depth dependent hydraulic conductivity

		Layer Geometry (mAOD)				Hydraulic Conductivity (m/day)			
Id	ZONE	Top Layer 1	Top Layer 2	Top Layer 3	Top Layer 4	Layer 1	Layer 2	Layer 3	Category
Lagoon	Z1	86.1	43	0	-100	4.00	0.75	0.05	2
	Z2	81.3	41	0	-100	3.00	0.20	0.03	2
	Z3	93.6	47	0	-100	3.00	0.20	0.03	2
Cornelly Quarry	Z4	92.1	46	0	-100	4.00	0.75	0.05	2
	Z5	92.1	46	0	-100	0.01	0.01	0.01	1
	Z6	81.4	41	0	-100	3.00	0.20	0.03	2
Pant Mawr	Z7	79.0	40	0	-100	3.00	0.20	0.03	2
	Z8	80.1	40	0	-100	3.00	0.20	0.03	2
	Z9	77.8	39	0	-100	3.00	0.20	0.03	2
	Z10	96.8	49	0	-100	3.00	0.20	0.03	2
	Z11	100.1	51	0	-100	3.00	0.20	0.03	2
Stormy Down Quarry	Z12	100.5	51	0	-100	0.10	0.10	0.10	1
	Z13	96.7	49	0	-100	4.0	4.0	0.05	3
	Z14	82.1	41	0	-100	3.0	0.2	0.03	2
	Z15	76.5	39	0	-100	4.0	4.0	0.05	3
Gaens	Z16	73.9	37	0	-100	4.0	4.0	0.05	3
	Z17	55.9	28	0	-100	4.0	4.0	0.05	3
	Z18	70.0	35	0	-100	4.0	4.0	0.05	3
	Z19	58.3	29	0	-100	3.00	0.20	0.03	2
	Z20	93.8	47	0	-100	3.00	0.20	0.03	2
	Z21	97.1	49	0	-100	3.00	0.20	0.03	2
Stormy West Quarry	Z22	101.0	51	0	-100	3.00	0.20	0.03	2
	Z23	44.1	22	0	-100	5.0	5.0	0.05	3
EA South Cornelly	Z24	37.7	19	0	-100	4.0	4.0	0.05	3
	Z25	20.1	10	0	-100	4.0	4.0	0.05	3
	Z26	37.0	19	0	-100	5.0	5.0	0.05	3
Grove	Z27	44.0	22	0	-100	5.0	5.0	0.05	3
	Z28	28.8	15	0	-100	5.0	5.0	0.05	3
Itusca	Z29	76.0	38	0	-100	1.0	1.0	0.01	1
Plateau -	Z30	76.5	39	0	-100	4.0	4.0	0.01	3
Plateau -	Z31	58.3	29	0	-100	4.0	4.0	0.01	3
Plateau -	Z32	50.0	13	8.0	-100	50.0	4.0	0.01	4
Burrows Well	Z33	8.5	3	0	-100	10.0	1.0	0.01	4

3.3.3 Resultant transmissivity values

Transmissivity values between adjacent zones are calculated from the transmissivity of each geology type between adjacent cell nodal points from their harmonic mean (as detailed in Section 2.5). The transmissivity for each connection is shown on Figure 3.2. Minimum, maximum and mean transmissivity values are shown where transmissivity varies as function of the groundwater level over time.

This figure shows a large number of different transmissivities being applied between the zones both spatially and with time (derived from the smaller number of values of transmissivity within the zones).

3.3.4 Vertical hydraulic conductivity

Vertical component of flow have to be considered at Kenfig Dunes and Merthyr Mawr. Table 3.10 shows the calibrated vertical hydraulic conductivity values. The values are consistent with the range of values expected for lithologies of these types.

Table 3.10 Calibrated hydraulic conductivity values

Lithology	K_v (m/d)	Zones
Carboniferous Limestone	0.5	25,33
MMMF	1.0	37,38,39
Kenfig		
The Blown Sand	10	54-57
Sands and Gravels	0.1	46-52
Alluvium	1×10^{-4}	53
Lacustrine	5×10^{-5}	53,55-57
Till[1]	1×10^{-5}	47-52
Merthyr Mawr		
The blown sand	10	42-45
Till[1]	1×10^{-4}	42-45

1 vertical connection, not explicit model zone

In previous supplementary calculations (WynThomasGordonLewis, 2004) a water balance for the groundwater system at Kenfig pool estimated the vertical hydraulic conductivity of lacustrine deposits to be 10^{-4} m/day.

3.4 Storage

Storage parameters were assigned based on geology type (and other conceptual controls, such as confined and unconfined conditions) and further refined throughout the calibration process. The final calibrated storage values are shown on Figure 3.3 and summarised in Table 3.11 below. Calibrated values were typically well within expected ranges for these types of lithologies (see discussion below).

Table 3.11 Calibrated storage values

Zone	Storage	Zone	Storage	Zone	Storage	Zone	Storage
1	1.00×10^{-1}	16	1.23×10^{-2}	31	2.22×10^{-2}	46	2.00×10^{-1}
2	1.23×10^{-2}	17	1.23×10^{-2}	32	2.00×10^{-3}	47	2.00×10^{-1}
3	2.50×10^{-3}	18	1.23×10^{-2}	33	2.00×10^{-4}	48	5.00×10^{-4}
4	2.50×10^{-3}	19	1.23×10^{-2}	34	5.00×10^{-2}	49	5.00×10^{-4}
5	1.23×10^{-2}	20	2.50×10^{-3}	35	1.00×10^{-2}	50	5.00×10^{-4}
6	1.23×10^{-2}	21	1.23×10^{-2}	36	5.00×10^{-2}	51	5.00×10^{-4}
7	1.00×10^{-1}	22	1.23×10^{-2}	37	6.00×10^{-3}	52	5.00×10^{-4}
8	1.23×10^{-2}	23	2.50×10^{-3}	38	3.00×10^{-3}	53	1.00×10^{0}
9	1.23×10^{-2}	24	2.22×10^{-2}	39	5.00×10^{-2}	54	4.00×10^{-1}
10	2.50×10^{-3}	25	2.22×10^{-2}	40	2.00×10^{-2}	55	4.00×10^{-1}
11	2.50×10^{-3}	26	1.23×10^{-2}	41	5.00×10^{-2}	56	4.00×10^{-1}
12	1.00×10^{-1}	27	5.00×10^{-2}	42	3.00×10^{-1}	57	4.00×10^{-1}
13	1.23×10^{-2}	28	2.22×10^{-2}	43	3.00×10^{-1}	-	
14	1.23×10^{-2}	29	1.00×10^{-2}	44	2.50×10^{-1}	-	
15	1.23×10^{-2}	30	2.22×10^{-2}	45	2.50×10^{-1}	-	

Values of storage assigned to the unconfined Carboniferous Limestone varied between 2.0×10^{-3} 5.0×10^{-2}. Higher values of storage (0.1) were assigned to some Carboniferous Limestone zones (Zones 1, 7, 12) to account for additional storage in lagoons and pools. The lowest value of storage (2.0×10^{-4}) was assigned to the confined Carboniferous Limestone at Merthyr Mawr (Zone 33). Note that parameterisation of the confined Carboniferous Limestone at Merthyr Mawr causes some numerical issues, with lower values of storage causing model instability.

Storage values between 0.25 and 0.3 were used for the blown sand at Merthyr Mawr, whereas values of 0.4 were needed to represent the observed groundwater level fluctuations at Kenfig. The value at Kenfig represents the upper value of the expected range although it is not clear how much additional storage from the dune slacks may contribute to this figure.

3.5 Additional Storage

Three additional storage areas have been implemented in the calibrated model (summarised below in Table 3.12). Zone 1 represents the settlement lagoon associated with Cornelly quarry. Zone 42 and Zone 43 represent the pools and dune slacks to the south of the spring discharge at Burrows Well. Fractional areas (with respect to the zone area) and base elevations have been estimated from available survey data and groundwater levels. All bodies represent open water and a storage value of 1.0 is used.

Table 3.12 Additional storage areas

Zone	Elevation (mAOD)	Fractional area (-)	Storage (-)	Description
1	42	0.1	1.0	Lagoon
42	12	0.03	1.0	Upper Pool
43	8	0.07	1.0	Lower Pool

These additional storage areas were included where the existence of substantial surface water bodies are clearly apparent and may influence model results. Features such as dune slacks and other smaller surface water features are not explicitly represented in the model.

3.6 Boundary Conditions

3.6.1 Discharge

There are a number of licensed abstractions in the model area (Table 3.13). Discrete abstractions have been used to represent these pumping at their daily licensed values.

Table 3.13 Abstractions in the model area

Licence	X	Y	Description	Abs. (m^3/day)	Zone
21/58/51/0030	282240	180790	General Agriculture	14.6	23
21/58/33/0007	285640	178830	General Agriculture	22.7	29
21/58/51/0028	279850	183200	Commercial and Public Services	415.9	36
21/58/51/0010	279790	183480	Commercial and Public Services	1636.6	36
21/58/33/0004	282230	178120	General Agriculture	9.3	41
21/58/33/0006	282020	178550	General Agriculture	6.8	41

3.6.2 Springs

Spring boundary conditions are set at the observed spring elevations. The main springs that need to be simulated are those at New Mill Farm and Burrows Well, which are at elevations 7.9 mAOD and 13.0 mAOD respectively. Water discharging at Burrows Well is controlled via 'boundary re-direction' detailed in Section 3.6.4 below.

3.6.3 Drains

Kenfig Pool (Zone 53) has an average water level of around 10.3 mAOD which fluctuates by ±0.3 m in response to climatic conditions (Appendix K of Appendix 7.1). The pool is reported to be around 3.0 m deep and at high water levels overflows to the south west (Zone 55).

Kenfig pool is simulated as a distinct zone with a storage of 1.0 and an initial head of 10.4 mAOD. The base of the pool is effectively undefined, but a drain boundary condition is applied at 10.5 mAOD. Water overtopping this elevation is controlled via 'boundary re-direction' detailed in Section 3.6.4 below.

3.6.4 Boundary re-direction

Table 3.14 summarises the boundary re-direction implemented in the calibrated model.

Table 3.14 Boundary re-direction

Zone		Re-direction				Boundary
From	To	Area (m^2)	Fraction	Logic	Volume (m^3)	
32	42	163480	-	1	70654	Spring
32	43	371755	-	1	1000000	Spring
53	55	971716	1.0	0	0.0	Drain

Burrows Well

Redirection from Burrows Well (Zone 32) uses a logical process that best describes the conceptual understanding at this location. The logical process works in combination with the additional storage assigned to the upper pool (Zone 42) and lower pool (Zone 43) summarised in Table 3.12.

Within any given timestep the model accounts for the amount of storage in the upper pool and the quantity of spring flow available for re-direction. If the additional storage in Zone 42 exceeds 70654 m^3, any remaining spring flow is redirected to additional storage in Zone 43.

The maximum storage volume assigned to zone 32 is calculated from:

$$V_j = (S_{a,j} f_j A_j + S_j (1 - f_j) A_j). d_j$$

where V_j is additional storage volume (m^3),

$S_{a,j}$ and S_j are the additional and normal zone storage values respectively (-),

A_j is the zone area (m^2),

f_j is the fractional area of additional storage (-),

d_j is the additional storage depth (m),

The area of the upper pool (Zone42) is estimated to be 5262 m^2. Assuming the depth of the pool is approximately 1.4m this gives a total additional storage volume of water 70654 m^3. Pool volume in Zone 43 set to a sufficiently high value such to ensure all remaining spring flow can be re-directed and the water balance within the model is conserved.

Kenfig Pool

Redirection from Kenfig Pool (Zone 53) assumes that all water overtopping is discharged to Zone 55. .

3.7 Assessment of Calibration

In the following sections, the results of groundwater model are presented in terms of simulated groundwater heads, spring flows and water balances, and compared with observed data, where available.

3.7.1 Groundwater levels

A comparison between simulated and observed groundwater levels across the model area, are shown in Illustration 3.7-Illustration 3.11 (grouped spatially within model areas). These figures present the comparison of simulated groundwater heads at the nodal point of each cell and the corresponding observed data.

General acceptance criteria for a suitable representation of the simulations groundwater level timeseries are as follows:

1. A good representation of seasonal and long term trends should be achieved.
2. The ability of the model to replicate absolute observed groundwater levels is somewhat subjective (given that observation boreholes are not always located near to the cell node point), but groundwater levels simulated by the model are defined as good when within 5 m of the observed heads.

These criteria have been used to assess the simulation of groundwater level at the target locations listed in Table 3.1. ‘Average’ groundwater level residuals (observed-simulated) have been calculated for each target location. The time period used to calculate the ‘average’ groundwater level is defined by the availability of observation data at each location.

Table 3.15 Groundwater residuals

Zone	BH	mean error	absolute mean error	standard deviation	Zone	BH	mean error	absolute mean error	standard deviation
1	TQ3	6.9	7.8	4.2	29	I_TUSCA	-0.4	4.6	5.7
2	ESP2	0.5	2.7	3.7	30	T[1]	-	-	-
3	TM6	-6.1	8.7	10.8	33	MM1	0.5	1.2	1.4
4	TM6	-12.4	12.7	10.5	35	P	-6.2	6.1	2.5
5	TM4	-10.8	10.8	6.6	36	O-A	0.8	0.8	0.5
8	RW107	-1.6	4.3	5.5	38	A-A	-3.5	3.6	2.0
9	RWC105	0.4	3.7	4.4	40	B-A	0.2	1.5	2.1
10	G	-9.8	10.0	6.6	41	21	2.0	2.1	1.2
11	T95/01	-5.4	8.7	9.6	42	L	1.8	1.8	0.5
12	T95/04	1.1	6.4	7.5	43	D7	1.7	1.9	1.6
14	Q	-0.2	5.9	7.2	44	L	-5.1	5.1	0.4
15	E	2.1	4.6	5.2	45	D4	-0.4	0.5	0.4
18	RWC105	1.9	6.0	6.5	46	N-C	1.2	1.4	1.1
20	G	-2.9	5.9	6.9	47	A-B	-2.0	2.1	1.6
23	17B	-2.3	5.1	6.0	48	KP	-0.5	0.6	0.5
24	EASC	-1.4	2.6	3.3	50	K1A	-0.3	0.6	0.7
25	N-A	1.0	1.2	1.1	53	KP	0.2	0.3	0.2
26	RWC100	-0.3	2.9	3.6	55	K1B	-1.1	1.2	0.6
27	RWC100	4.3	5.2	4.2	56	CC5	-0.1	0.4	0.5
28	40	4.6	4.7	2.7					

1 observed data after end of simulation period

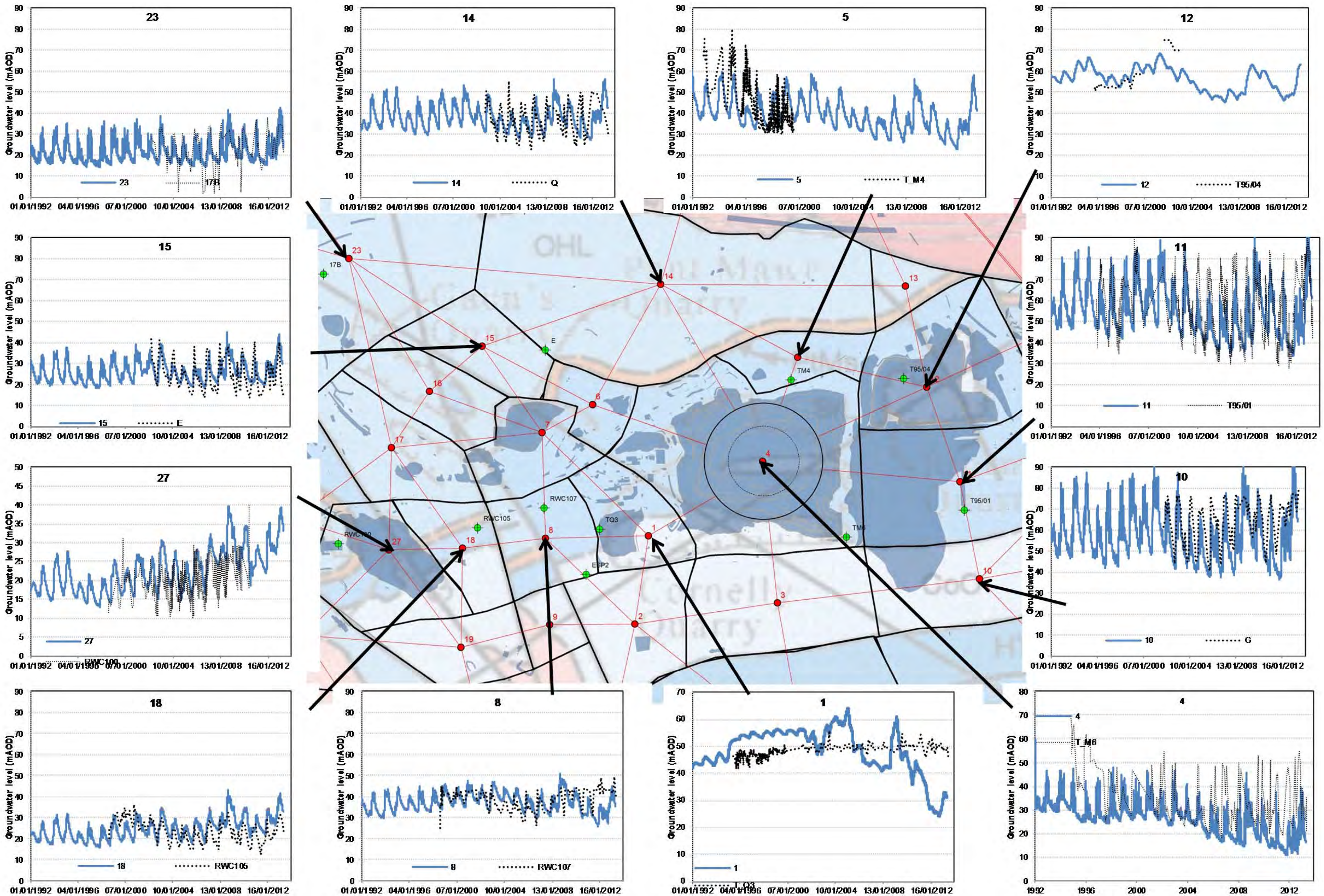


Illustration 3.7 Simulated and observed groundwater levels - Cornelly

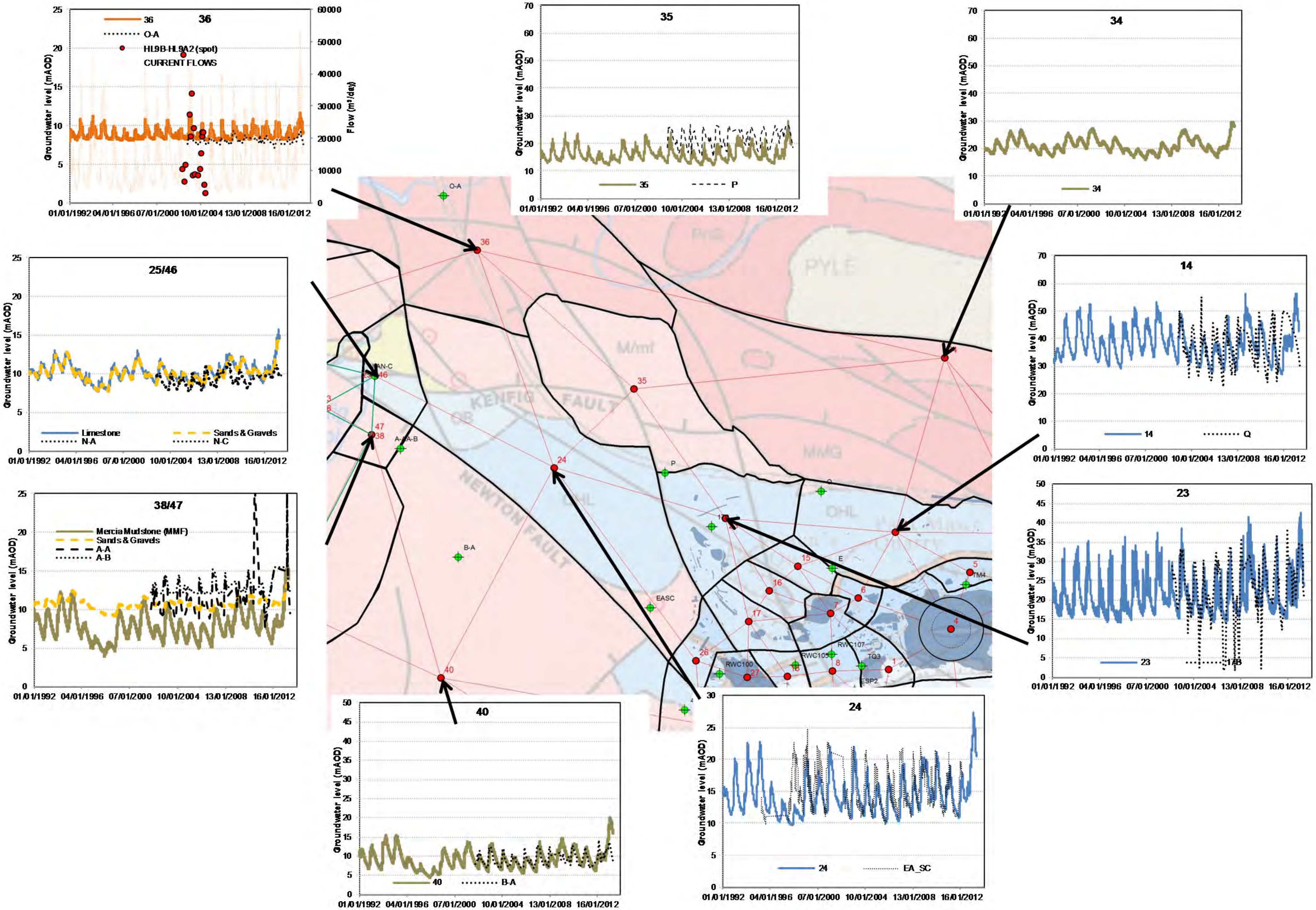


Illustration 3.8 Simulated and observed groundwater levels – N Cornelly

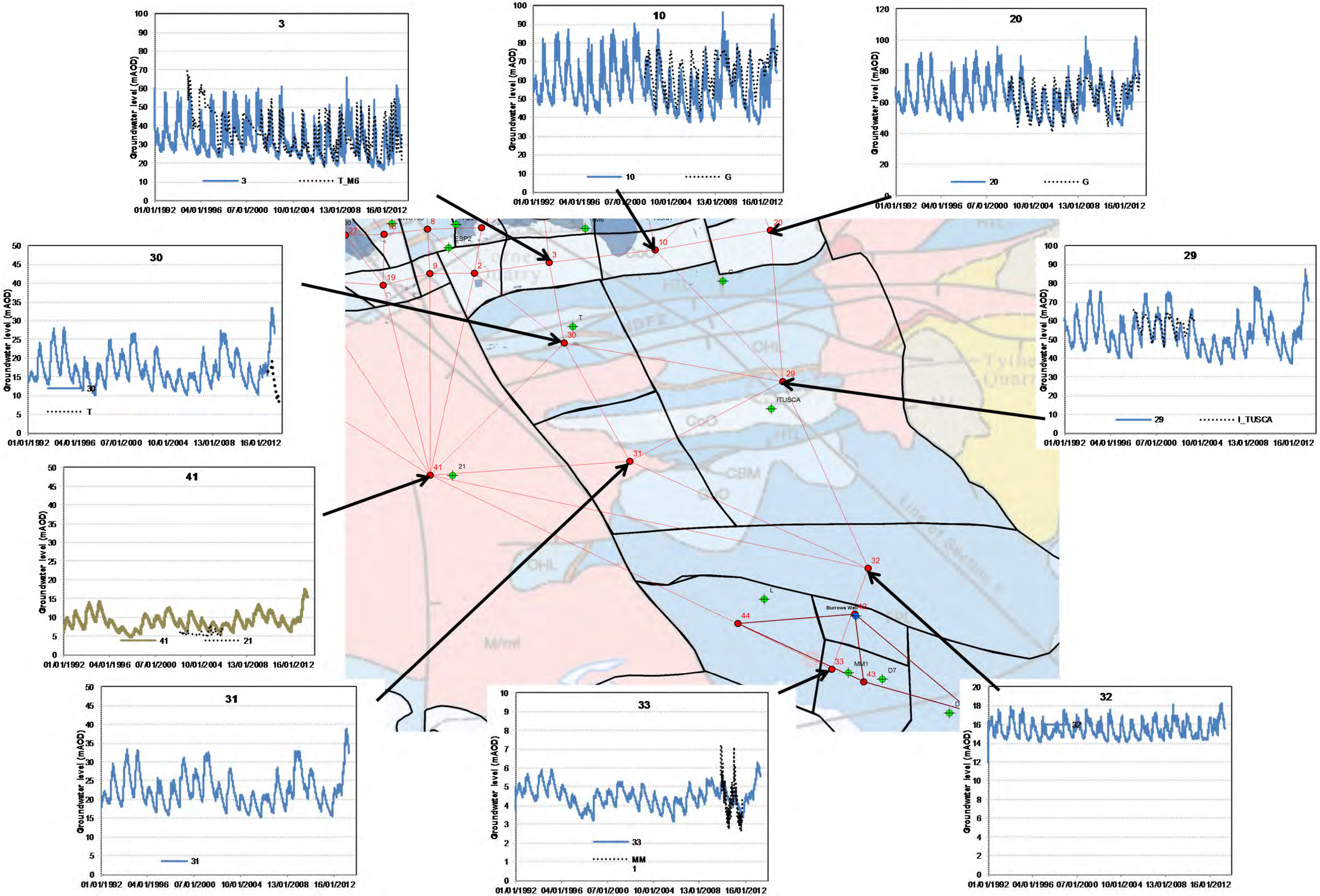


Illustration 3.9 Simulated and observed groundwater levels – Plateau

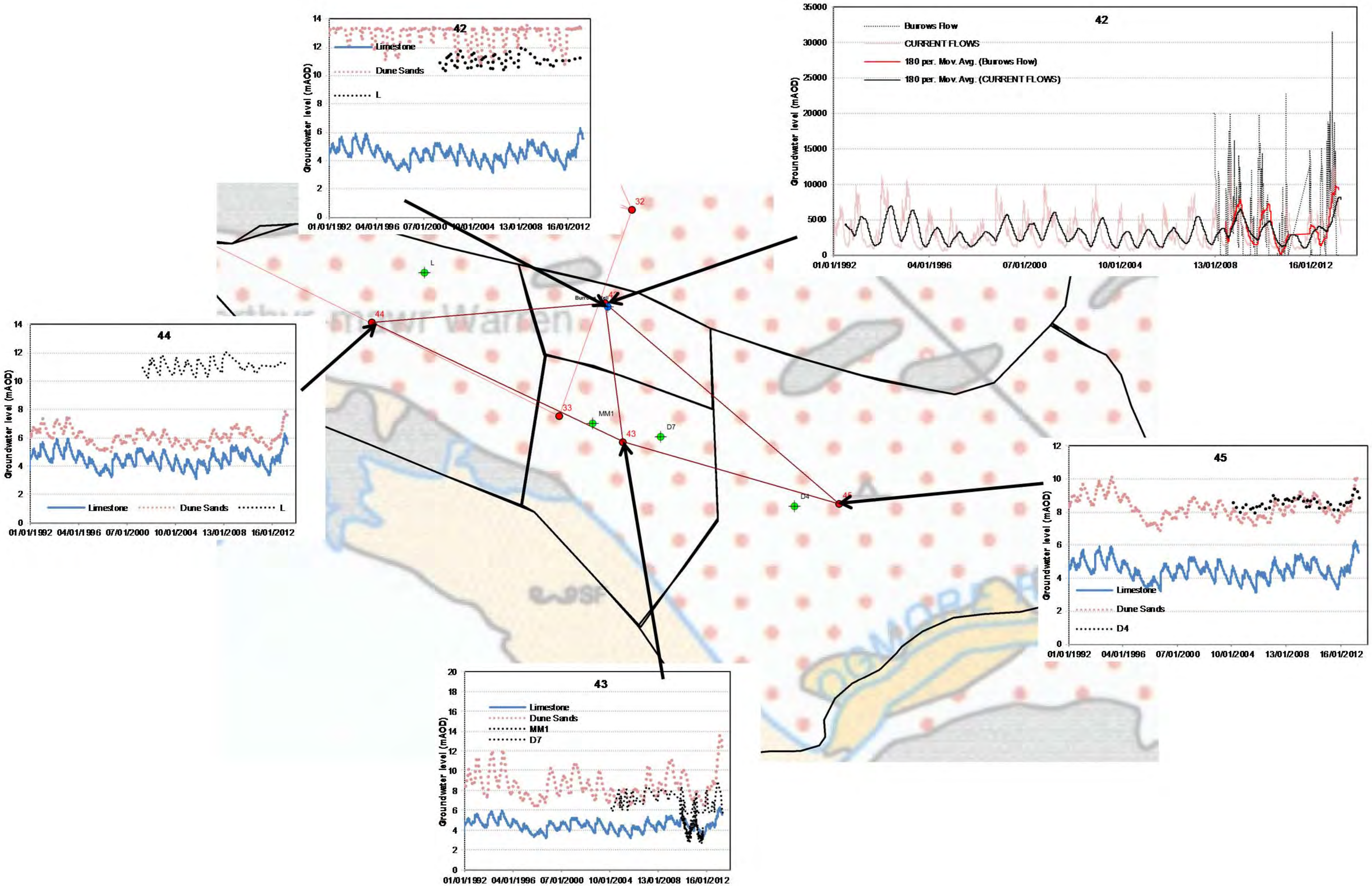


Illustration 3.10 Simulated and observed groundwater levels – Merthyr Mawr

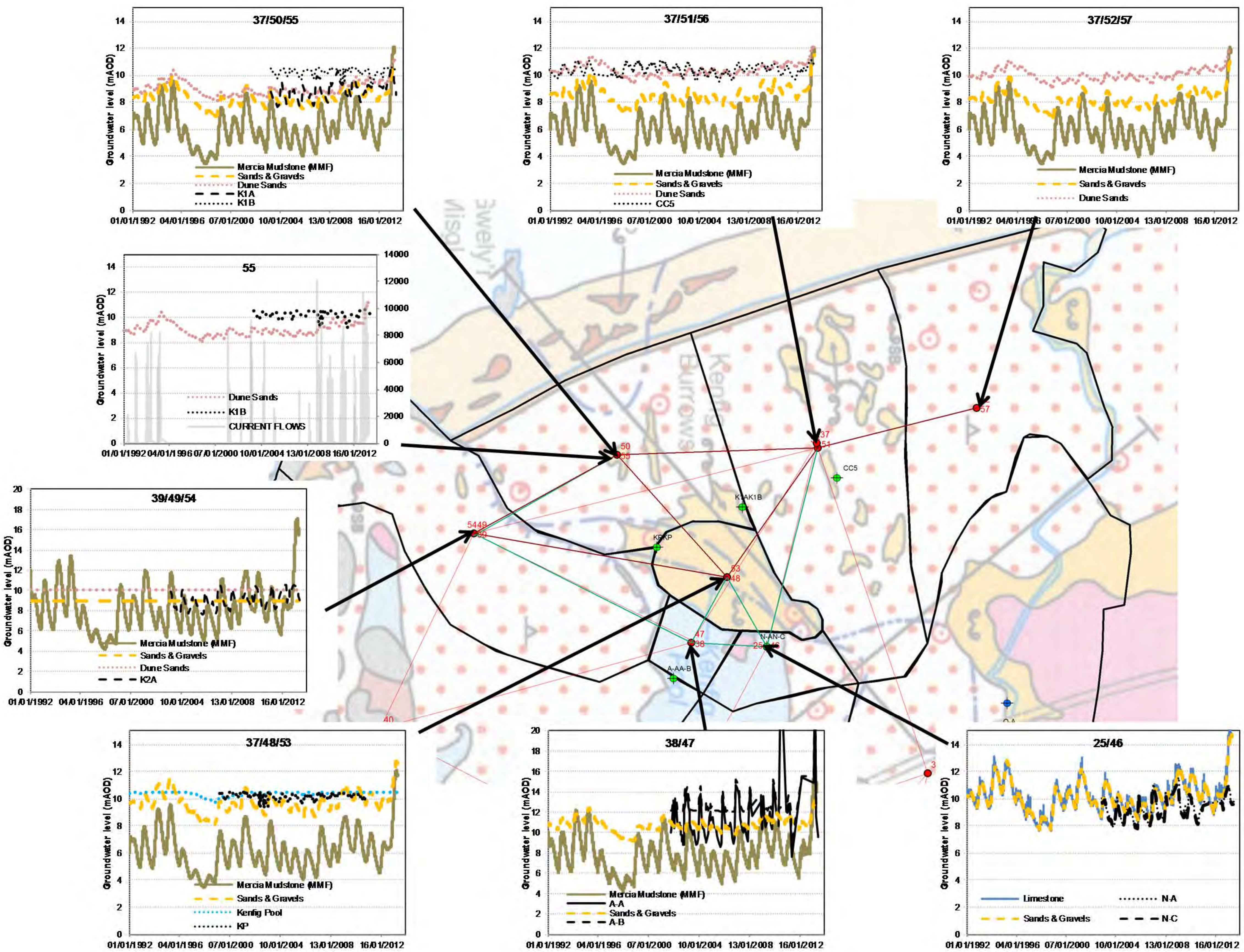


Illustration 3.11 Simulated and observed groundwater levels – Kenfig (North to right)

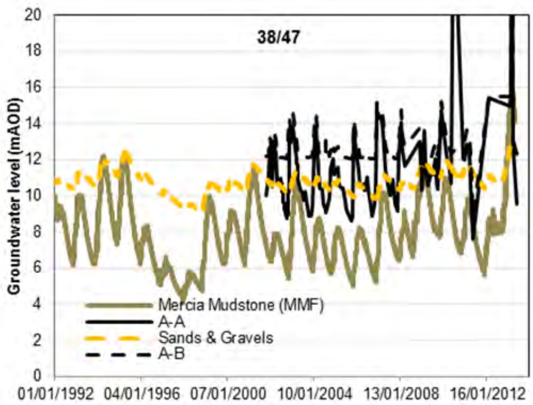
It can be seen that the model simulates the seasonal and long term groundwater level trends well. Average deviations between modelled and target heads in the superficial deposits is typically less than 2.0 m. The deviations in the simulated heads in the Carboniferous Limestone are typically 5.0 m or less. The average simulated groundwater levels are well within the total observed range and the calibration is considered acceptable. There are some obvious disparities, for example in Zone 1, where the observed groundwater level is that of the settlement lagoon, and is in all likelihood a perched groundwater level.

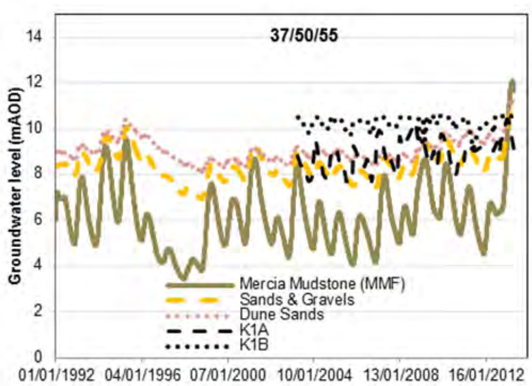
The greatest variations to the observed heads (>5.0 m) are in the vicinity of the Cornelly Quarry (Zones 3, 4, 5, 10, 11). At these locations the observation boreholes are typically at some distance from the modelled groundwater level. Given the relatively coarse zonal representation within the groundwater model and the large variation in the range in groundwater levels these absolute discrepancies are not unexpected and the observed trend is of greater significance in these locations.

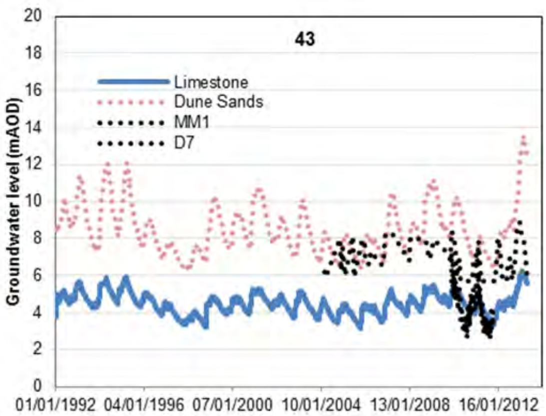
The ability of the model to simulate vertical gradients between the underlying geology and the dune systems at Kenfig and Merthyr Mawr can also be assessed. Table 3.16. compares the long term average simulated and observed groundwater gradients at multi-level monitoring locations (or those monitoring locations in the solid geology and superficial deposits located sufficiently close to allow an assessment).

Table 3.16 Vertical gradients

	Upper	Lower	i(obs)	i(mod)
Kenfig	A-B (GSG)	A-A (MMF)	0.16	0.28
Kenfig	K1B(DS)	K1A(GSG)	0.18	0.08
Merthyr Mawr	D7(DS)	MM1(CL)	0.40	0.60







The model simulates the long term groundwater level trends reasonably well, although the variation in the groundwater level in the underlying Carboniferous Limestone at Merthyr Mawr is underestimated due to model stability issues (Section 3.4). Discrepancies in the magnitudes of the vertical hydraulic gradient largely correspond with the distance between the observed and modelled groundwater levels, and their relative positions along each flow path.

3.7.2 Springs

Spring flows have been simulated by specifying an appropriate fixed head within the spring cell and deriving the flow from the model calculations. A comparison to available data at the gauging stations provides an indication of the ability of the model to reproduce observed flows.

New Mills Farm Springs

Modelled and observed flows at New Mill Farm Springs are shown on Illustration 3.12 and summarised in Table 3.17. Table 3.17 shows the long term average (LTA) observed and simulated flows over the period for which observations are available. The LTA at the New Mill Farm Springs are also shown demonstrating the variation under different recharge conditions.

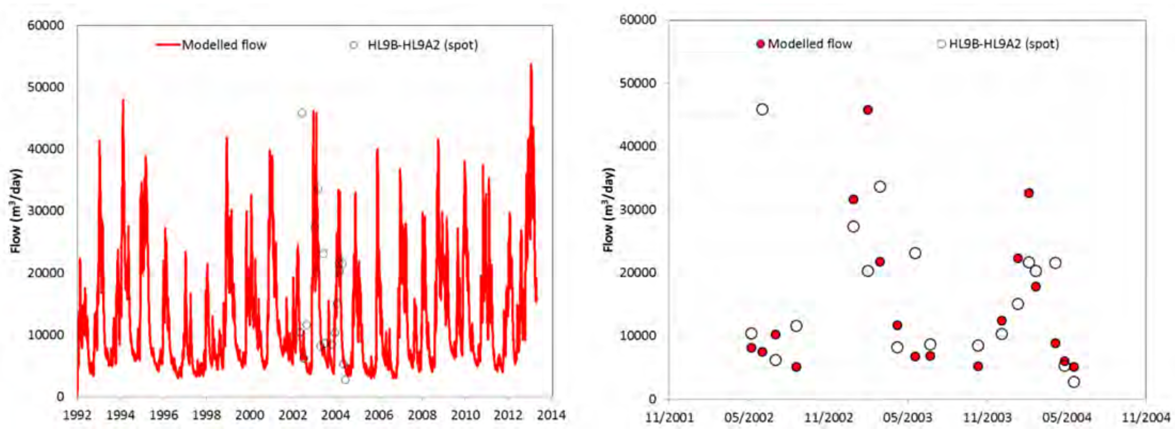


Illustration 3.12 New Mill Farm springs

Table 3.17 Observed and simulated flows at New Mill Farm Springs

Observed Flow (m^3/day)	Simulated Flow (m^3/day)	Difference[1] (%)	Comments
16735	14786	-11.7	Calibrated model
16735	17372	3.8	+15% recharge
16735	12379	-26.0	-15% recharge

1 relative to observed

Modelled flows are within 12% of the observed. Differences are relatively small given the overall uncertainty in the recharge rate (+/-15%) in addition to the relatively small number of spot gauging observations against which to compare model results. Simulated flow compares favourably with observed and together with simulated groundwater levels results are considered to provide an adequate representation of flows using current recharge estimates with the calibrated transmissivities of the various formations.

Burrows Well

Modelled and observed flows at Burrows Well are shown on

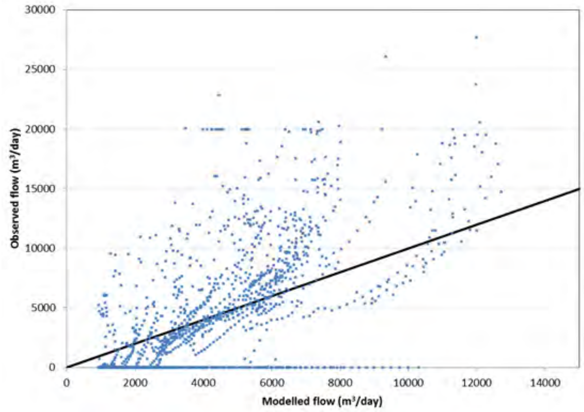


Illustration 3.13 as flow hydrographs and as a flow duration curve (flow hydrographs provide an indication of the accuracy of the model in simulating both magnitude and timing of flows; while flow duration curves assess the ability to reproduce flows under different flow conditions). Modelled versus observed flows are also shown on this figure.

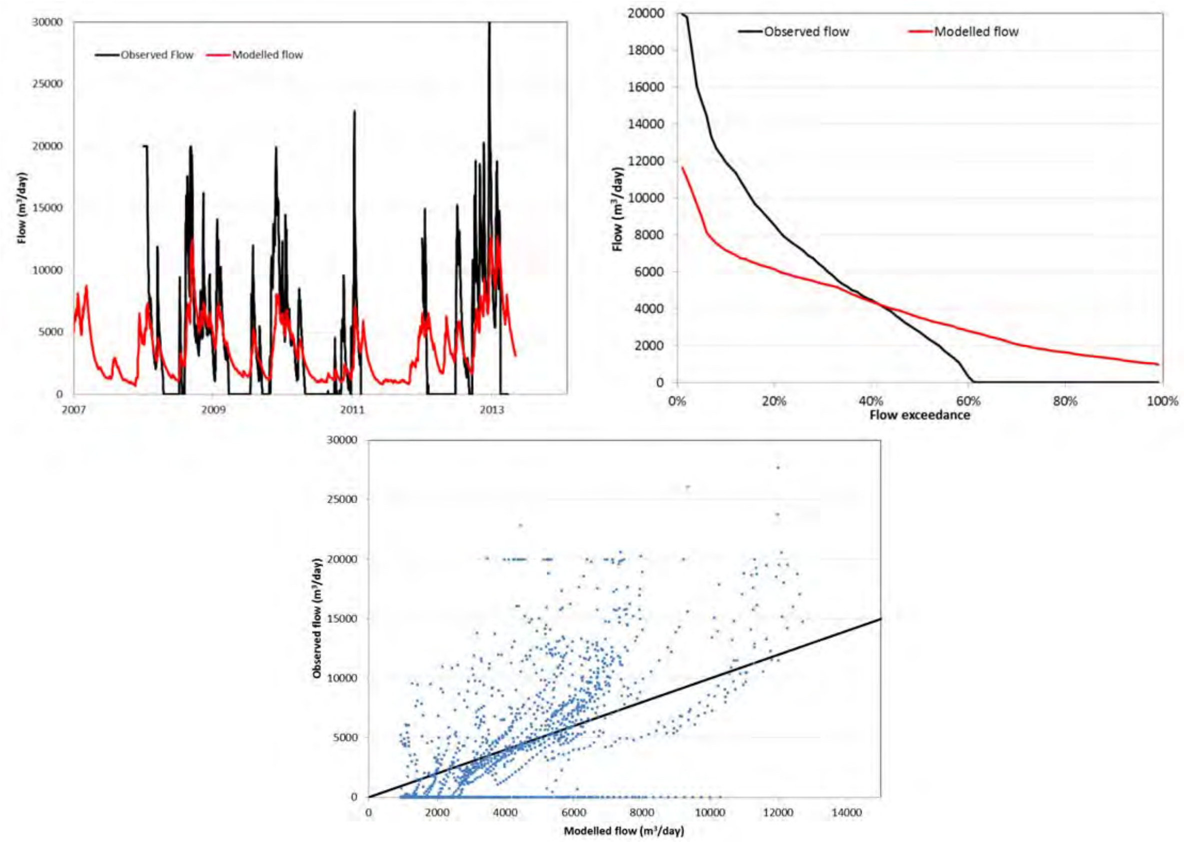


Illustration 3.13 Burrows well

Table 3.8 shows the average observed and simulated flows over the period for which observations are available. The LTA at the Burrows Well are also shown demonstrating the variation under different recharge conditions. Table 3.19 summarise key calibration statistics for average flows and Q95 flows respectively. •

Table 3.18 Observed and simulated LTA flows at Burrows Well

Observed Flow (m^3/day)	Simulated Flow (m^3/day)	Difference[1] (%)	Comments
4418	4047	-8.4	Calibrated model
4418	4685	6.0	+15% recharge
4418	3424	-22.5	-15% recharge

1 relative to observed

Table 3.19 Observed and simulated flows at Burrows Well

%	Observed (m^3/day)	Simulated	Difference
5	15,253	9,001	-41%
15	10,515	6,696	-35%
25	7,322	5,693	-22%
50	2,731	3,530	29%
75	0	1,831	-
85	0	1,444	-
95	0	1,122	-

LTA modelled flows are within 8.4% of the observed. These differences are not considered significant given the overall uncertainty in the recharge rate (+/-15%) and the subsequent variation in simulated flows. However, although the LTA flows are simulated reasonably well and the overall seasonal pattern of flows is also simulated effectively, the flow duration curve and modelled versus observed flows indicate that the model does not simulate the 'flashy' nature of Burrows Well. Simulated flows exceed observed at low flows, whereas flows are underestimated at peak flows.

Intermittent flow from the underlying Carboniferous Limestone and the discharges at Burrows Well involve the interaction between Zones 32-33 (Carboniferous Limestone), the Burrows well spring boundary, and re-direction to Zones 42-43 (Blown Sands). When groundwater levels in Zone 32 are sufficiently high, discharge occurs to Burrows Well by accessing the transmissivity above the spring elevation. Discharge to the Blown Sands from Burrows Well in turn interacts with the underlying Carboniferous Limestone in Zone 33. There is also a flow component between Zones 32 and 33 which accesses the transmissivity beneath the spring elevation, which influences groundwater levels at these locations. Difficulties in representing flows at Burrows Well largely derive from the complexity of the various transient interactions between zones at this location. Due to the low storage of the limestone, groundwater levels are significantly more variable than the sands aquifer which leads to model instability where the contrasts are large. The current parameterisation represents a compromise between a stable model and an acceptable groundwater level and flow calibration.

In general, the conclusion is that, whilst not ideal, the simulation of Burrows Well spring flow does match the transient patterns of observed spring flow reasonably well during flowing periods but does not manage to 'switch off' as rapidly as occurs in reality. Further analysis is carried out during the predictive modelling phase to determine if representing conditions closer to those observed would affect the conclusions in terms of simulated groundwater levels at Merthyr Mawr (see Section 4.6.3).

3.7.3 Pumping

Table 3.20 show results from annual monitoring data and the simulated flows over the same periods. As detailed in Section 3.1.3 calibration focussed on those periods which had complete records and where there was greater confidence in the quality of the observations.

Table 3.20 Observed and simulated flows at Cornelly quarry

	Observed Flow		Simulated Flow	
Period	Sump (m^3/day)	Offsite (m^3/day)	Sump (m^3/day)	Difference (%)
	Good data			
LTA (2001-2013)	3503[1]	-	3435	-1.9%
1 June 04 to 1 Oct 06	3382	1245	3295	2.6%
5 Aug 08 to 2 Jun 11	3735	2232	3761	-0.7%

	Poor data			
20 Jun 01 to 1 June 04	4873	1980	3559	27.0%
1 Oct 06 and 5 Aug 08	-	2281	3043	-
20 June 11 to 25 Mar 12	2969	2041	2458	17.2%

1 synthesised flow

The main inflows into Cornelly Quarry are direct recharge and groundwater inflow from the area within the cone of depression (including re-circulation from the settlement lagoon). Simulated inflows to Cornelly sump and the recirculation from the settlement lagoon are shown on Illustration 3.14.

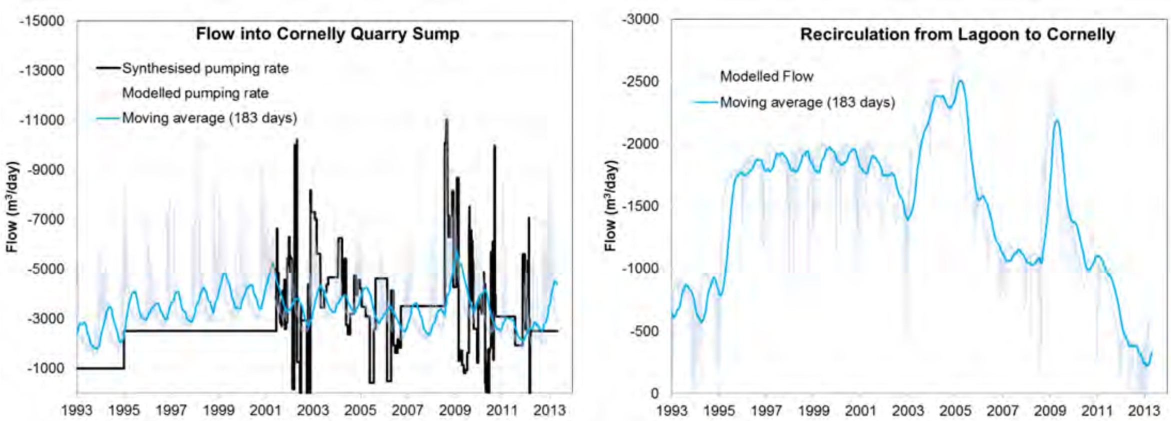


Illustration 3.14 Simulated flows at Cornelly sump

The LTA and selected data show a good agreement with the observed data and provide confidence in the model calibration. Earlier data (pre 2004) include periods of intermittent pumping when the quarry was allowed to flood. No water level measurements over this period (and less certainty in historical development depths) mean less confidence is attributed to simulated flows over this period. Records are missing between 1 Oct 2006 and 5 Aug 2008. The quality of the data post June 2011 is questionable.

Over the model calibration period re-circulation from the lagoon is typically between 1000 and 2000 m^3/day. This is broadly consistent with the difference between the sump flow and the flows pumped offsite.

3.7.4 Water balance

Model water balance

Illustration 3.15 presents the time-series water balance for each hydrogeological year (April to March) for the calibrated model. Table 3.21 summarises the model water balance over the duration of the simulation period. Average flows between zones are shown on Figure 3.4.

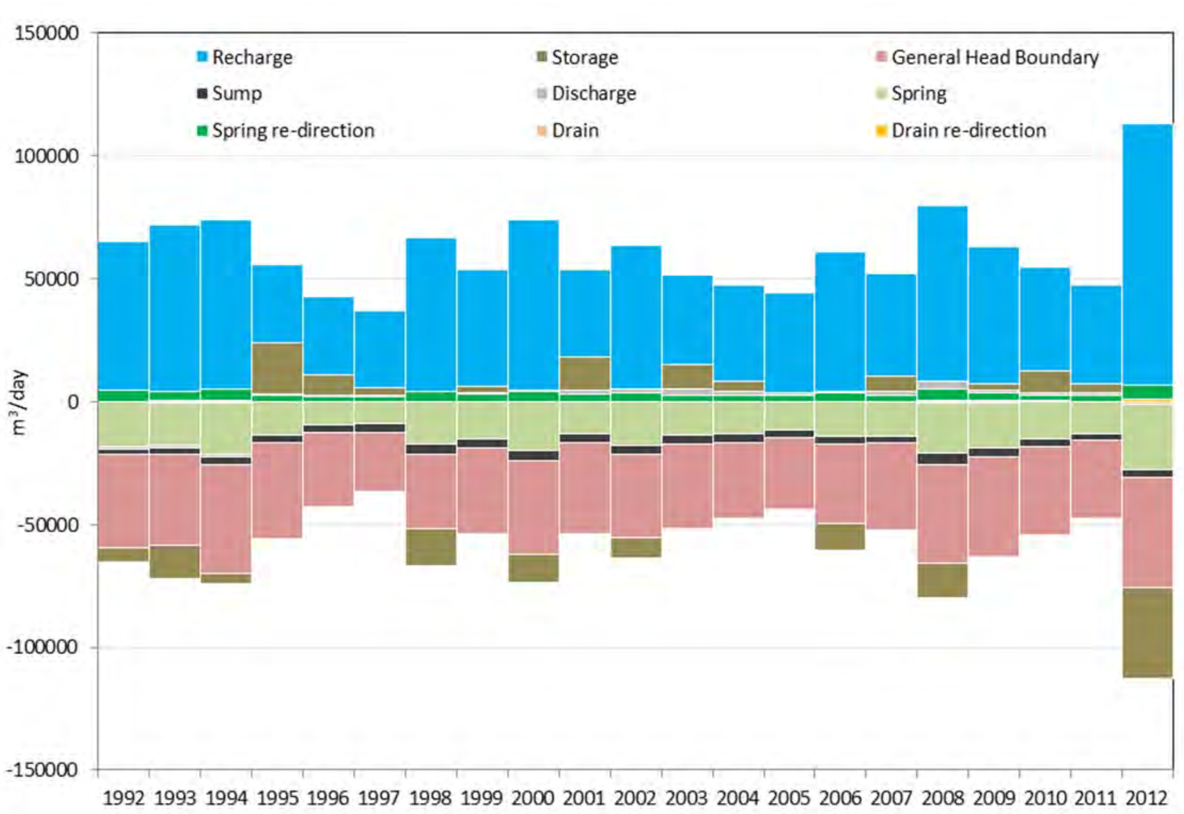


Illustration 3.15 Calibrated model water balance

Table 3.21 Model water balance over simulation period (m^3/day)

Recharge	Storage	GHB	Sump	Discharge	Spring	Drain
52,133	1,709	-35,334	-3,392	810	-15,753 (3,245)	-183 (183)

Numbers in parentheses show re-direction rates

The dominant inflow is recharge, averaging 52,000 m^3/day. A nominal inflow comprises discrete 'discharges'; the difference between consumptive abstractions and redistribution of inflow to Cornelly Quarry during historical pumping. The principal outflow is discharge to the sea via general head boundaries, which average 35,000 m^3/day, or 69% of all outflows. Spring flow (16,000 m^3/day or 31%) accounts for the remaining discharge (which comprises the discharge at New Mills Farms spring, as the flow from Burrows Well is subsequently recharged into the blown sand at Merthyr Mawr).

Kenfig water balance

Illustration 3.16 presents the time-series water balance for the Kenfig the blown sand (this excludes Kenfig Pool, other than via lateral flows and overtopping from the pool which form boundary flows to the blown sand). Table 3.22 summarises the water balance over the duration of the model period.

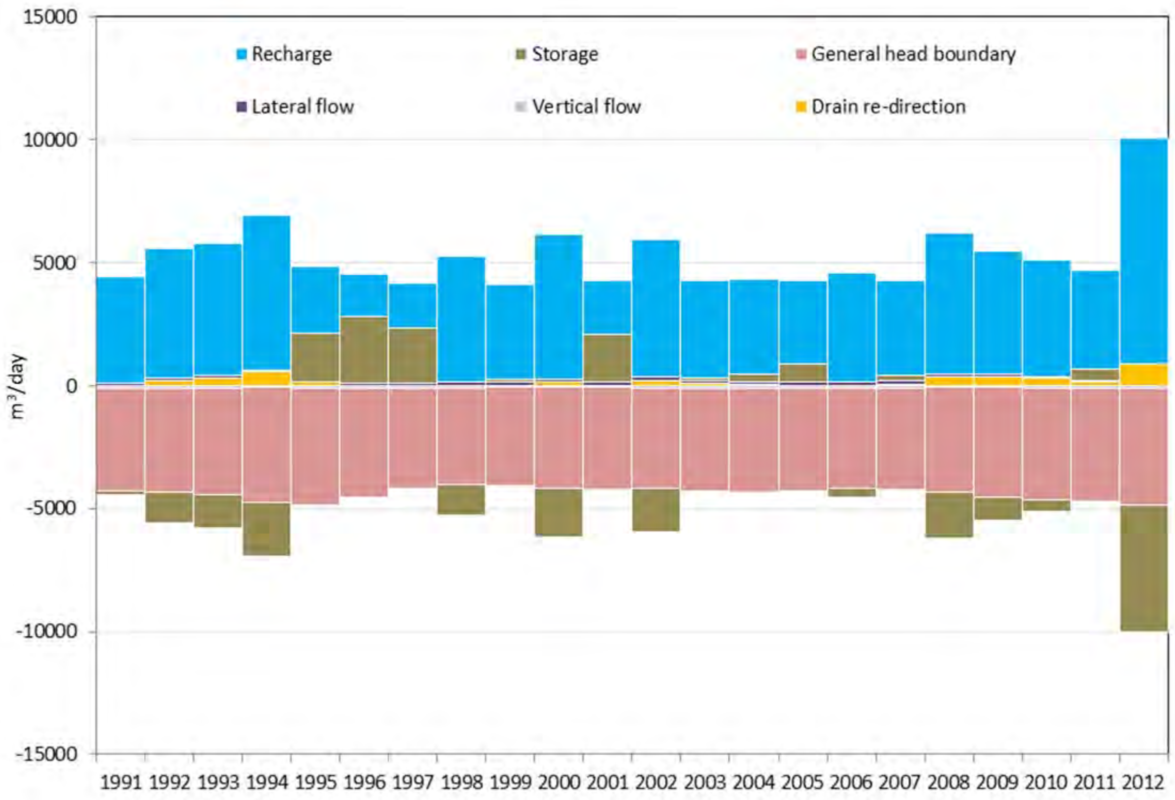


Illustration 3.16 Kenfig dune water balance

Table 3.22 Kenfig water balance over simulation period (m^3/day)

Recharge	Storage	GHB	Lateral	Vertical	Drain Re-direction
4,478	374	-4,298	104	-91	181

The dominant inflow to Kenfig blown sand system is recharge, which averages 4,500 m^3/day and amounts to approximately 94% of all inflows over the model duration (this is consistent with previous estimates (ESI,, 2004). There is a small component of lateral flow from Kenfig Pool (100 m^3/day or 2.2%). Overtopping from Kenfig pool into the blown sand also contributes a small component of inflow (180 m^3/day or 3.8%). Groundwater flow through the blown sand and discharge to the sea is the main component of outflow, with a small component of downward leakage into the underlying sands and gravels (90 m^3/day or 2.0%).

Merthyr Mawr water balance

Illustration 3.17 presents the time-series water balance for the blown sand at Merthyr Mawr. Table 3.23 summarises the water balance over the duration of the model period.

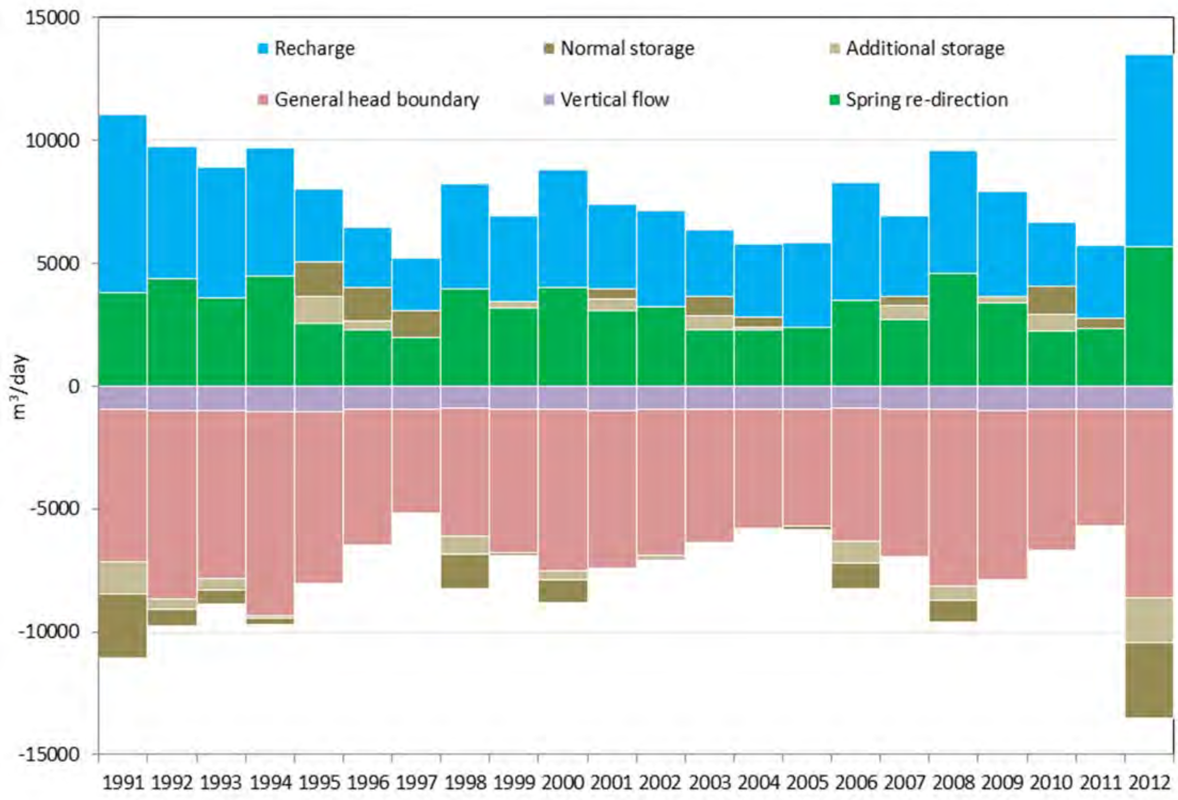


Illustration 3.17 Merthyr Mawr dune water balance

Table 3.23 Merthyr Mawr water balance over simulation period (m^3/day)

Recharge	Spring re-direction	Normal storage	Additional storage	GHB	Vertical
4,010	3,252	-120	-81	-6,101	-960

Spring flows at Burrows Well account for 3,300 m^3/day (45 %) of the total inflow to the dune system, with direct recharge contributing the remainder (4,000 m^3/day or 55 %). The principal outflow from the blown sand is discharge to the sea (6,100 m^3/day or 86%) with a significant proportion also lost via downward leakage to the underlying Carboniferous Limestone (960 m^3/day or 14%).

3.8 Model Validation

The model was validated by checking to see what effect it predicts if there was no quarry dewatering. Although there are no reliable groundwater level data for the period prior to the start of dewatering at Cornelly Quarry, anecdotally this is thought to be around 60 mAOD. The validation test shows that groundwater levels around Cornelly quarry rise from an average of 25.7 mAOD to around 52.6 mAOD over the simulated period (range 42.1-81.0 mAOD). This provides some additional confidence in the ability of the model to predict heads correctly over a wide range of conditions.

3.9 Sensitivity Analysis

A formal sensitivity analysis was carried out to investigate the level of uncertainty associated with several aspects of the model calibration. Previous phases of investigation have succeeded in clarifying many aspects of the conceptual understanding of the system, but several aspects related to the connections between the dune sand aquifers and underlying geology at Kenfig, and the conceptual representation of the dune system at Merthyr Mawr are unclear. In summary, these uncertainties include:

- The extent, thickness and hydraulic conductivity of the estuarine clay underlying the blown sand system and pool at Kenfig.
- The extent, thickness and hydraulic conductivity of the till underlying the glaciofluvial deposits at Kenfig.
- The connectivity of the glaciofluvial deposits at Kenfig to the coast.
- Lateral connection between glaciofluvial deposits and Kenfig pool (ephemeral seeps).
- Lateral connection between Kenfig pool and the blown sand.
- The thickness and hydraulic conductivity of the till underlying the blown sand system at Merthyr Mawr.
- The connectivity of the blown sand at Merthyr Mawr to the coast.
- The role of pool storage at Merthyr Mawr.

A more detailed list of the sensitivity runs is shown in Table 3.25. The sensitivity runs were designed in consultation with technical staff including detailed discussions with NRW in 2013.

3.9.1 Sensitivity results

Discussion with Natural Resources Wales had highlighted the need for sensitivity analysis in order to ensure that the model parameterisation could be justified. Where this revealed some element of model equivalence, this was then taken forward to the sensitivity analysis of predictive scenarios. Table 3.24 summarises the parameters that have been carried through to a sensitivity analysis on the predictive runs.

For each sensitivity run a comparison is made between the simulated changes in conditions and the calibrated model. A summary of the model sensitivity results due to the modifications to the conceptual model is outlined in Table 3.25.

A more detailed description of the sensitivity results are shown in Table 3.26-Table 3.31. The graphs in these tables show the difference in the simulated groundwater levels between the calibrated model and the results due to each particular variation in model parameterisation. Selected results are shown for Zone 51 (Glaciofluvial deposits) and Zone 56 (Blown Sand) at Kenfig. At Merthyr Mawr model results are shown for Zone 33 (Carboniferous Limestone) and Zone 45 (Blown Sand).

Table 3.24 Sensitivity runs in the predictive phase

Zones	Prediction	Sensitivity	Parameter		Unit	Calibrated	Sensitivity
42	SENS1	17.2	V	Pool storage	m^3	5262	10524
42	SENS2	17	V	Pool storage	m^3	5262	2631
48-53	SENS3	4.1	K	Estuarine Clay	m/d	$1.33x10^{-5}$	$2.00x10^{-5}$
46-53	SENS4	12.2	T	Alluvium	m^2/d	9.54	6.93
47-53	SENS5	11.2	T	Alluvium	m^2/d	$1.20x10^{1}$	8.87
53,55-57	SENS6	13.1	T	Alluvium	m^2/d	$3.55x10^{1}$	$2.69x10^{1}$
47-38	SENS7	9.1	K	Till	m/d	$1.62x10^{-4}$	$2.25x10^{-4}$
all	SENS8	n/a	R+T			-	+ 15%
all	SENS9	n/a	R+T			-	-15%

V pool storage; K bulk vertical hydraulic conductivity; T bulk transmissivity; R recharge

Table 3.25 Summary of model sensitivity runs

Run	Area	Zone	Parameter	Unit	Calibrated	Parameter range	Comment
1	Kenfig	46-53	Till	m/d	1.0×10^{-5}	K_v inc. $1.6\times10^{-4} – 6.0\times10^{-4}$	An increase in bulk vertical hydraulic conductivity of the till improves the connection between the GFD and underlying solid geology, allowing groundwater to drain downwards. Groundwater levels decrease in all zones with the exception of the underlying solid geology. The blown sand experience a drop of up to 10cm over the modelled parameter range.
2	Kenfig	50-52	Till coastal	m^2/d	5.0×10^{-2}	T inc./dec. 7.0×10^{-3} – 1.0×10^{-2}	Model calibration is extremely sensitive to the lateral connection which controls the discharge between the GFD and the coast. In the calibrated model till is assumed to limit this connection at the seaward boundary. Increasing the bulk transmissivity allows more water to leave the model from the GFD. Groundwater levels are significantly reduced in the GFD, which in turn increase the downward leakage from the overlying the blown sand. Conversely, a reduction in till transmissivity produces a groundwater level increase in the effected zones. A low transmissivity connection is required to maintain adequate model calibration.
3	Kenfig	46-53	Till	m/d	1.0×10^{-5}	K_v dec. 1.3×10^{-4} – 1.6×10^{-4}	A decrease in the bulk hydraulic conductivity of the till causes increased groundwater levels in all cells above the till and a reduction in groundwater levels in the underlying solid geology. An increase of 10cm is simulated within the blown sand for the maximum decrease in vertical connectivity.
4	Kenfig	46-53	Estuarine Clay	m/d	5.0×10^{-5}	K inc. 4.0×10^{-5} – 1.3×10^{-4}	The low K lacustrine layer beneath the blown sand is necessary to keep the dune sand aquifer perched. Increasing the bulk vertical hydraulic conductivity causes water to drain from the perched aquifer and increase groundwater levels in all underlying layers.
5	Kenfig	46-53	Estuarine Clay	m/d	5.0×10^{-5}	K dec. 2.0×10^{-5} – 3.0×10^{-5}	The low K lacustrine layer beneath the blown sand is necessary to keep the dune sand aquifer perched. Decreasing the bulk vertical hydraulic conductivity reduces groundwater levels in underlying zones, as groundwater is retained within the blown sand and downward leakage is reduced.
6	Kenfig	57	Estuarine Clay	m/d	5.0×10^{-5}	K inc. $3.0\times10^{-5} – 1.3\times10^{-4}$	Increasing the connectivity between the northern dunes and the GFD causes effects as described in Run 4, but more localised. Groundwater levels in the blown sand drop by several cm for the maximum increase in parameter values.
7	Kenfig Pool	53	Estuarine Clay	m/d	5.0×10^{-5}	K inc. $1.3\times10^{-5} – 1.3\times10^{-4}$	Increasing bulk hydraulic conductivity beneath the pool causes a decrease in pool and dune sand groundwater levels. A subsequent increase in groundwater levels in the underlying GFD and solid geology is simulated due to increased downward leakage, although changes are typically less than 4cm.
8	Kenfig Pool	53	Estuarine Clay	m/d	5.0×10^{-5}	K dec. $1.3\times10^{-5} – 1.2\times10^{-5}$	Decreasing bulk hydraulic conductivity beneath the pool causes an increase in pool land the blown sand groundwater levels. A subsequent decrease in groundwater levels in underlying GFD and solid geology is simulated due to decreased downward leakage, although changes are typically less than 4cm.
9	Kenfig	38	Till	m^2/d	2.0×10^{-5}	K inc./dec. 1.3×10^{-4} – 6.0×10^{-4}	Increasing bulk hydraulic conductivity of the till causes groundwater levels in the GFD to decrease as more groundwater drains into the underlying MMMF, where groundwater levels subsequently increase. The opposite effects are simulated for a bulk with decreased till vertical hydraulic conductivity. All simulated changes in groundwater levels are less than 10 cm.
10	Kenfig	25	Till	m/d	1.2×10^{-1}	K dec. $1.6\times10^{-5} – 1.2\times10^{-1}$	Decreasing the vertical connection between the GFD and CL causes increase groundwater levels within the blown sand and the GFDs. Changes in groundwater levels are typically large (up to 1.5m) in all zones.
11	Kenfig	47	Alluvium	m^2/d	5.0×10^{-1}	T inc./dec. 8.9×10^{0} - 2.7×10^{1}	Increasing the transmissivity (lateral seeps) between the GFDs (Zone 47) and Kenfig pool (Zone 53) produces model instability at high parameter values (>27m^2/day). Long term trends show a decrease in groundwater levels in the GFDs. A decrease in transmissivity produces the opposite effect in all cells. All changes are relatively small (<15cm). Kenfig pool shows little change (+/- 1cm).
12	Kenfig	46	Alluvium	m^2/d	5.0×10^{-1}	T inc./dec. $6.9\times10^{0} – 2.4\times10^{1}$	Increasing the transmissivity (lateral seeps) between the GFDs (Zone 46) and Kenfig pool (Zone 53) produces model instability at high parameter values (>24m^2/day). Long term trends show a decrease in groundwater levels in the GFDs and the blown sand (<5cm). A decrease in transmissivity produces the opposite effect in all cells. All changes are relatively small (<15cm). Kenfig pool shows little change (+/- 1cm).
13	Kenfig	55-56	Alluvium	m^2/d	5.0×10^{-1}	T inc. $3.6\times10^{1} – 2.7\times10^{1}$	Increasing the transmissivity from Kenfig Pool to the blown sand produce peaks/troughs during 1998/1999 at Kenfig Pool, GFDs and underlying solid geology. The blown sand show a modest decrease in groundwater levels. Zone 55 (which receives overtopping water from Kenfig Pool) shows a decrease in groundwater levels. Changes are typically small (<5cm) in all zones.
14	Kenfig	55-56	Alluvium	m^2/d	5.0×10^{-1}	T dec. $3.2\times10^{1} – 4.1\times10^{1}$	Decreasing the transmissivity from Kenfig Pool to the blown sand produces peaks/troughs during 1998/1999 at Kenfig Pool, GFDs and underlying solid geology. The blown sand show a modest increase in groundwater levels. Zone 55 which receives overtopping water from Kenfig Pool shows an increase in groundwater levels. Changes are typically small (<5cm) in all zones.
15	Kenfig	55-57	Initial heads	m	-	Initial head inc./dec. ±1	An increase and decrease in initial heads in the blown sand caused up to a 10cm change in groundwater levels in the GFD. Groundwater levels returned to their previous values over the simulation period.
16	Merthyr Mawr	42-45	Till	m/d	7.0×10^{-4}	K inc./dec. 4.0×10^{-4} – 1.3×10^{-3}	Groundwater levels in the blown sand are very sensitive to the bulk hydraulic conductivity of the till. A ±0.5m change in thickness (an increase or decrease in bulk conductivity) produces a decrease/increase of up to 1.0m in dune sand groundwater levels. The model failed when the thickness of the till was reduced to less than 0.4m (bulk hydraulic conductivity >1.3×10^{-3})
17	Merthyr Mawr	42/43	Pool storage	m^3	5262 1000000	Volume inc./dec. 2631 – 5262 13879 - 41637	Increasing and decreasing the pool storage at Merthyr Mawr by 50% changed groundwater levels by up to 4.5m. Mass balance errors occurred where less storage was available than spring discharge requiring an arbitrarily large value to be assigned to the lower pool. Variation of the top pool parameters alone was less sensitive to change.
18	Merthyr Mawr	43-45	Sand	m/d	20	T inc./dec. 17 – 23	The model is very sensitive to the depth dependent transmissivity of the lateral connection between the blown sand and the coast. Increasing the hydraulic conductivity (transmissivity) allows more water to leave the model, decreasing groundwater levels in all zones (and vice versa). A 15% change in the hydraulic conductivity produces change up to 0.5m in the sands and underlying limestone.

GFD: glaciofluvial deposits; MMMF Mercia mudstone marginal facies; CL Carboniferous limestone

Table 3.26 Sensitivity analyses results (Runs 1-3)

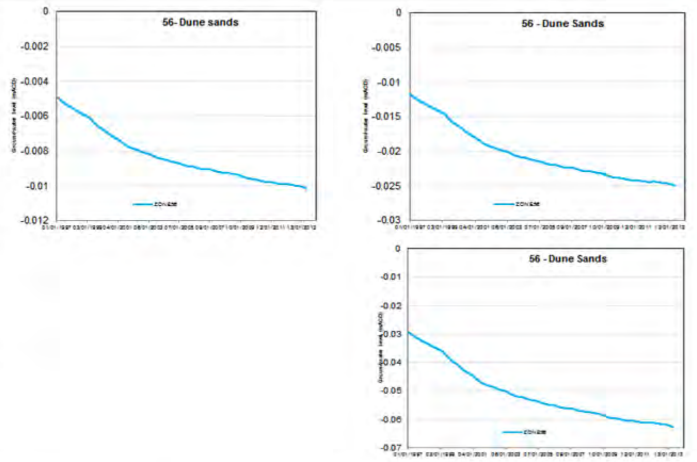
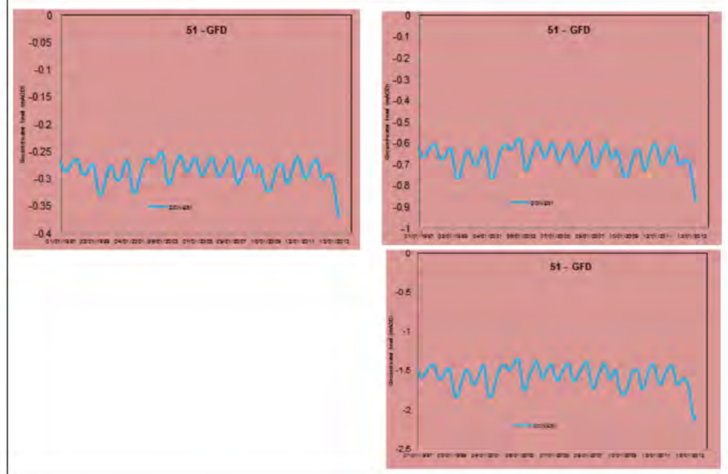
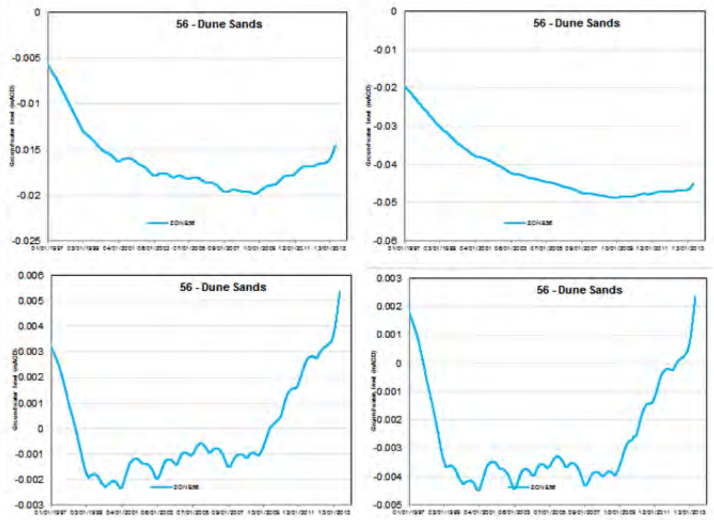
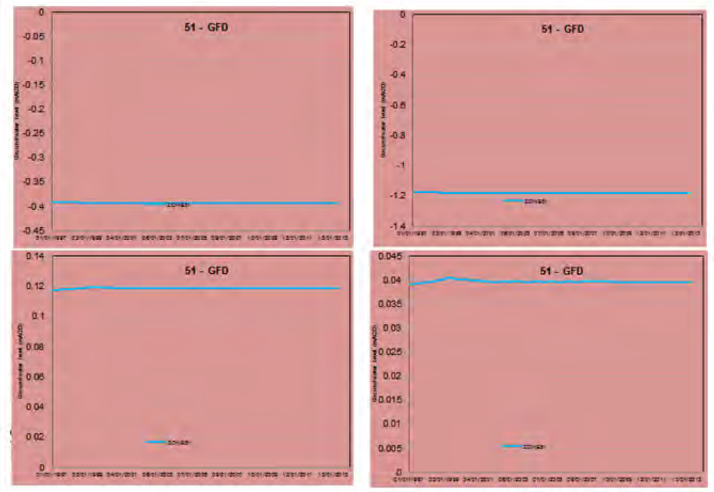
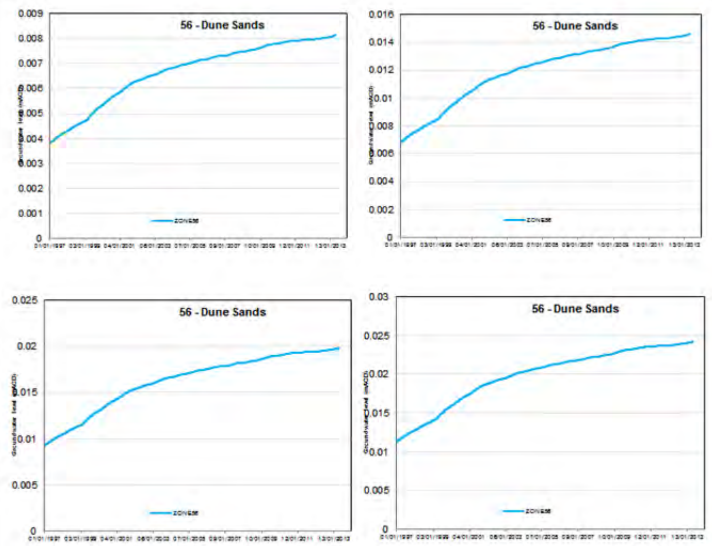
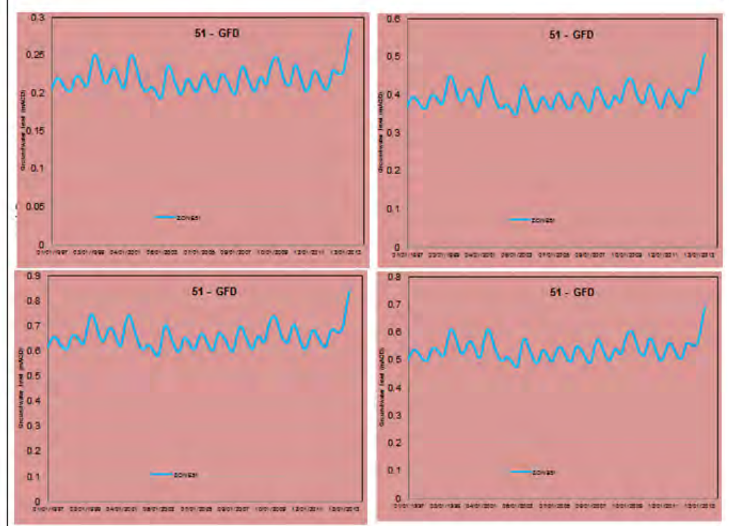
Number	Hydraulic Conductivity (m/d)	Layer Thickness (m)	Transmissivity (m2/d)	Second area Transmissivity (m2/d)	Dune Sands (Graphs in numerical order clockwise from top left)	Glaciofluvial Deposits/Limestone (Graphs in numerical order clockwise from top left)
Calibration	0.0001	8	1.62E-04			
1	**0.0001**	**6**	**1.83E-04**	-		
1.1	**0.0001**	**4**	2.25E-04	-		
1.2	**0.0001**	**1**	5.98E-04	-		
Calibration	-	8	0.01 (lateral)	0.00016 (vertical)		
2		**8**	**2.00E-02**	**1.60E-04**		
2.1		**8**	**4.00E-02**	**1.60E-04**		
2.2		**8**	**9.00E-03**	**1.60E-04**		
2.3		**8**	**7.00E-03**	**1.60E-04**		
Calibration	0.0001	8	1.62E-04			
3	**0.0001**	**10**	**1.50E-04**	-		
3.1	**0.0001**	**12**	**1.42E-04**	-		
3.2	**0.0001**	**14**	**1.36E-04**	-		
3.3	**0.0001**	**16**	**1.31E-04**	-		

Table 3.27 Sensitivity analyses results (Runs 4-6)

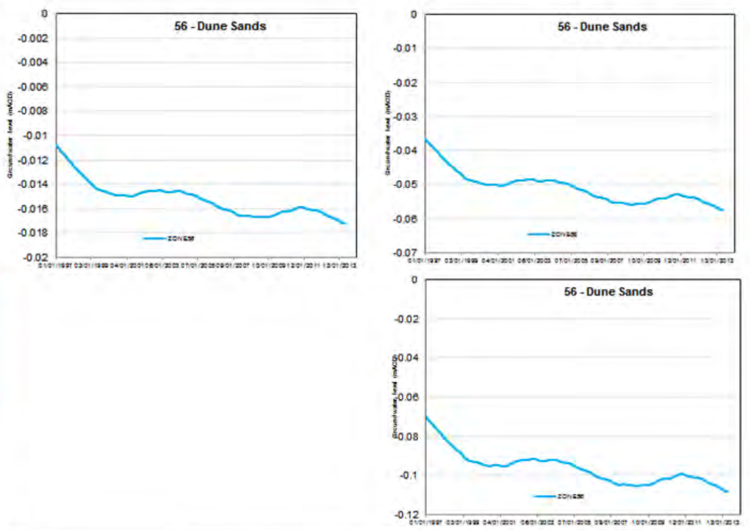
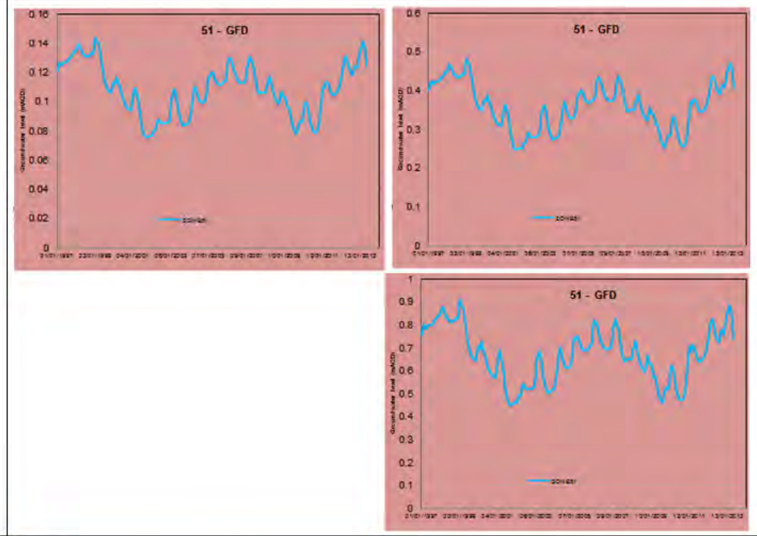
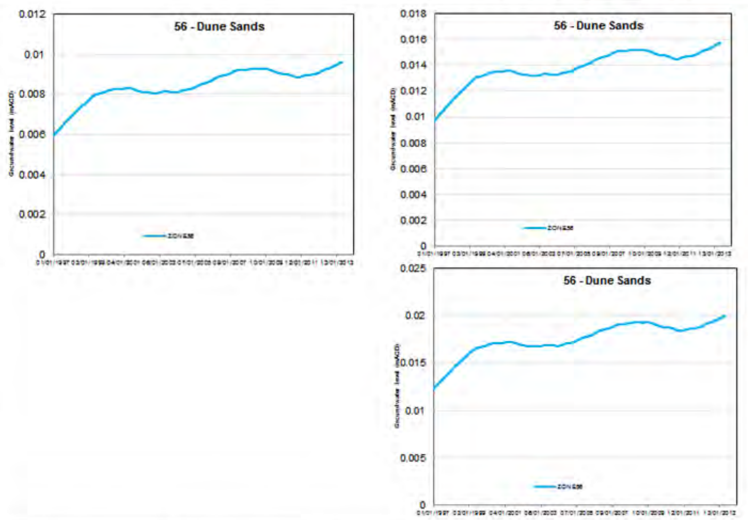
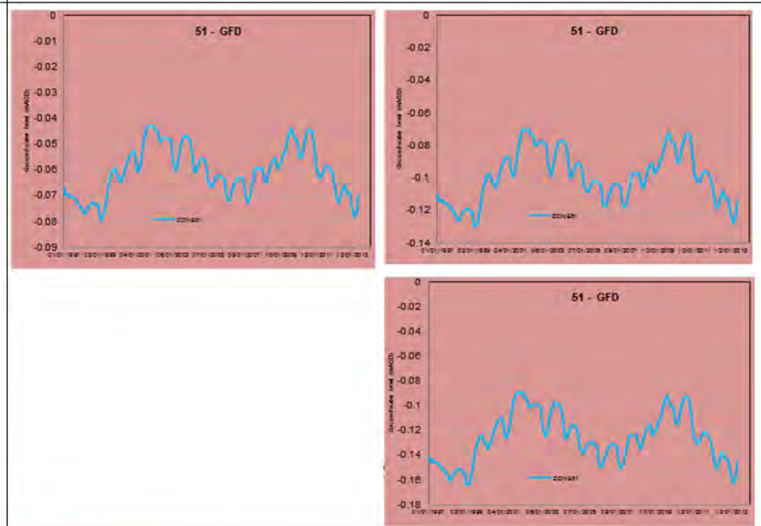
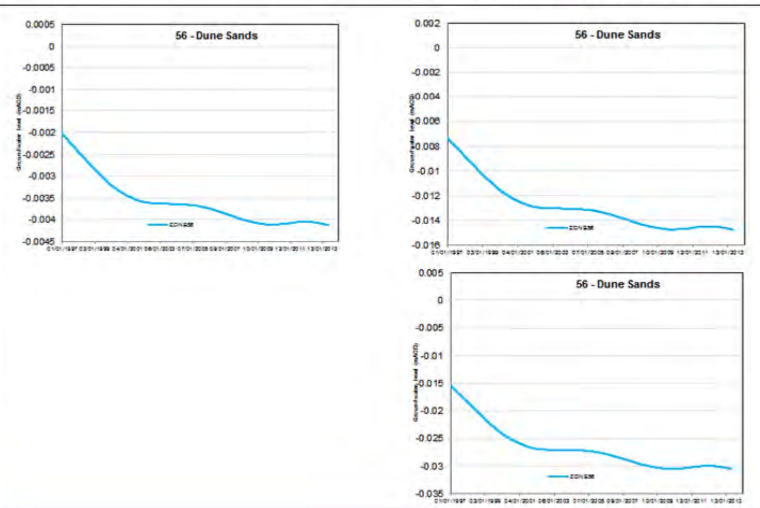
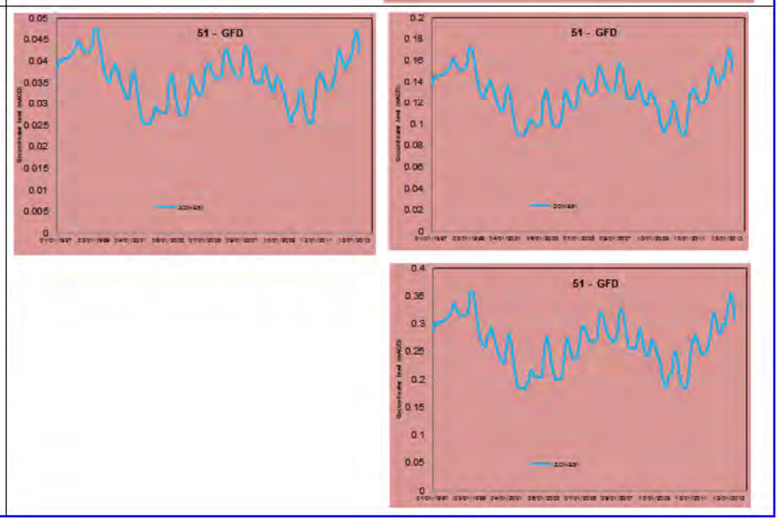
Number	Hydraulic Conductivity (m/d)	Layer Thickness (m)	Transmissivity (m2/d)	Second area Transmissivity (m2/d)	Dune Sands (Graphs in numerical order clockwise from top left)	Glaciofluvial Deposits/Limestone (Graphs in numerical order clockwise from top left)
Calibration	0.00001	3	Under Pool T 1.33E-05	Under Sands T 3.00E-05		
4	0.00001	2	1.50E-05	4.00E-05		
4.1	0.00001	1	2.00E-05	7.00E-05		
4.2	0.00001	0.5	3.00E-05	1.30E-04		
Calibration	0.00001	3	Under Pool T 1.33E-05	Under Sands T 3.00E-05		
5	0.00001	4	1.25E-05	2.50E-05		
5.1	0.00001	5	1.20E-05	2.20E-05		
5.2	0.00001	6	1.17E-05	2.00E-05		
Calibration	0.00001	3	3.00E-05			
6	0.00001	2	4.00E-05	-		
6.1	0.00001	1	7.00E-05	-		
6.2	0.00001	0.5	1.30E-04	-		

Table 3.28 Sensitivity analyses results (Runs 7-9)

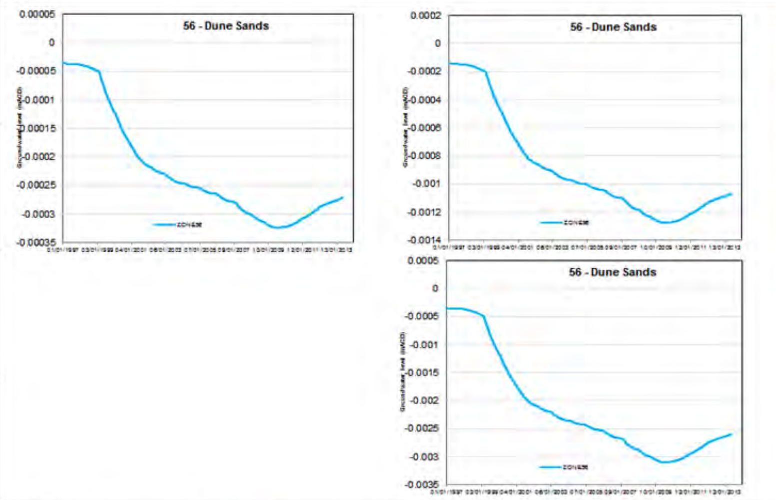
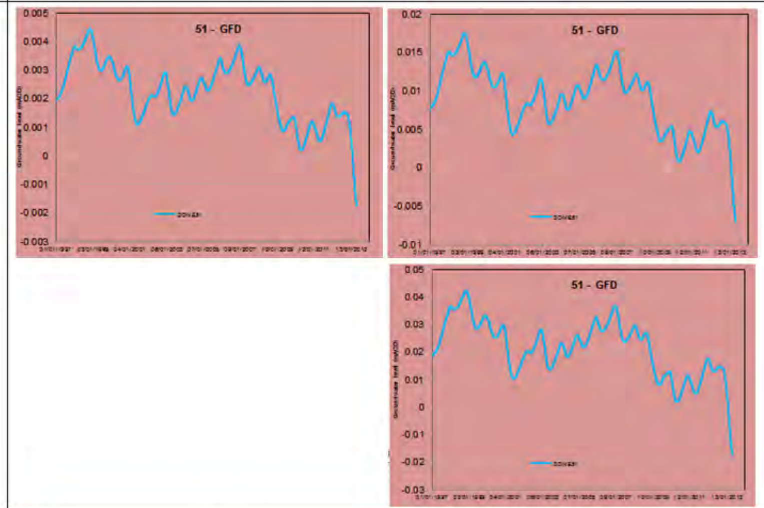
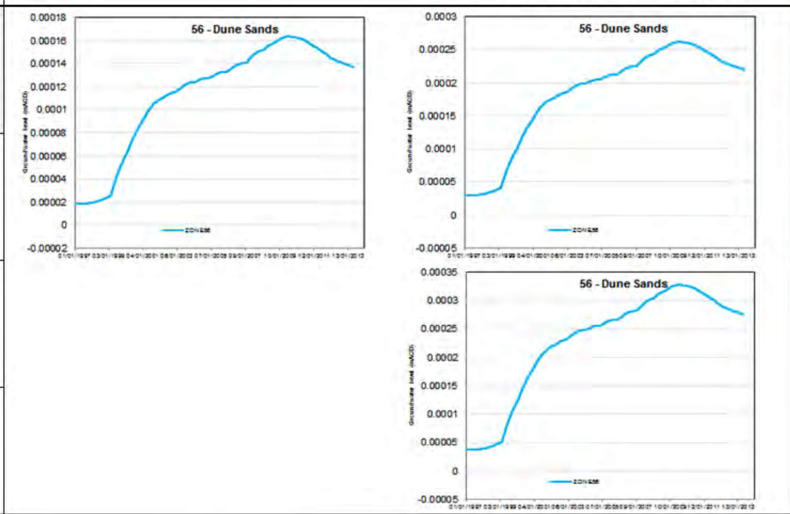
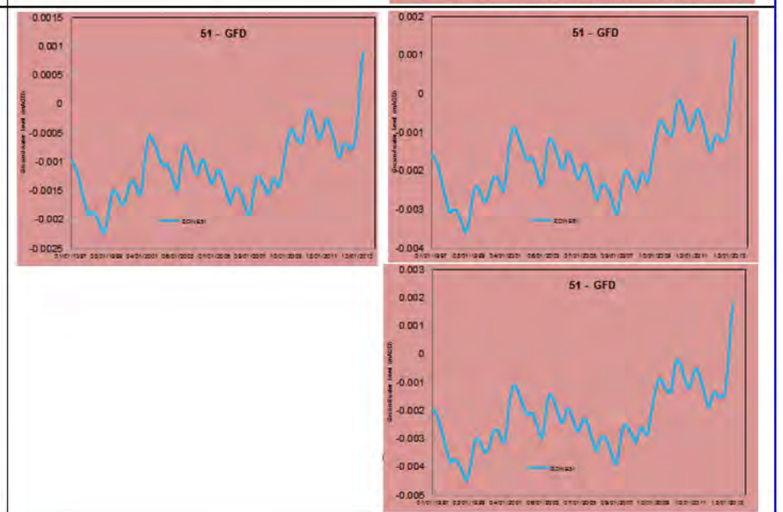
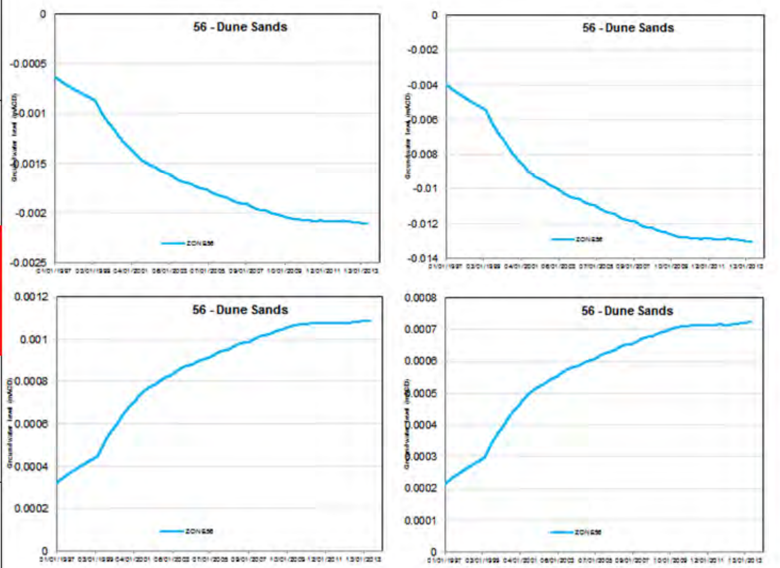
Number	Hydraulic Conductivity (m/d)	Layer Thickness (m)	Transmissivity (m2/d)	Second area Transmissivity (m2/d)	Dune Sands (Graphs in numerical order clockwise from top left)	Glaciofluvial Deposits/Limestone (Graphs in numerical order clockwise from top left)
Calibration	0.00001	3	1.33E-05	-		
7	0.00001	2	4.00E-05	-		
7.1	0.00001	1	7.00E-05	-		
7.2	0.00001	0.5	1.30E-04	-		
Calibration	0.00001	3	1.33E-05	-		
8	0.00001	4	1.25E-05	-		
8.1	0.00001	5	1.20E-05	-		
8.2	0.00001	6	1.17E-05	-		
Calibration	0.0001	8	1.62E-04	-		
9	0.0001	4	2.25E-04	-		
9.1	0.0001	1	5.98E-04			
9.2	0.0001	12	1.42E-04	-		
9.3	0.0001	16	1.31E-04	-		

Table 3.29 Sensitivity analyses results (Runs 10-12)

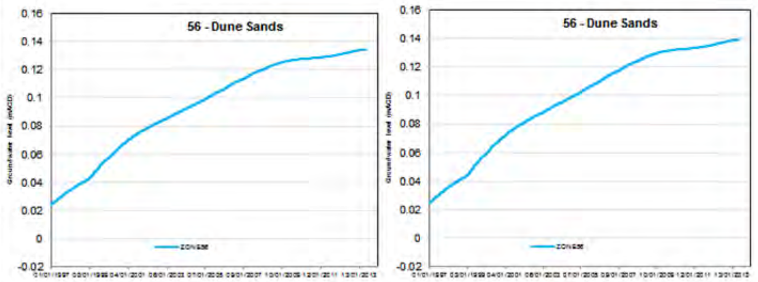
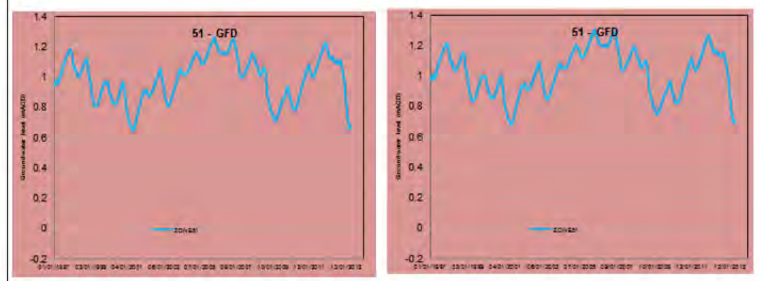
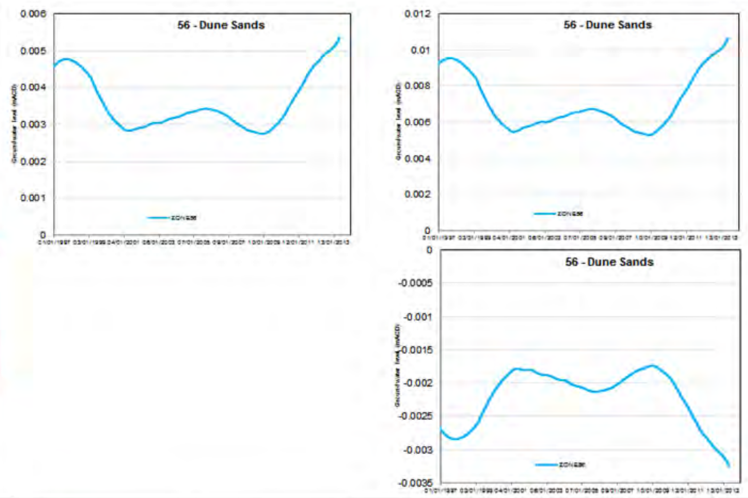
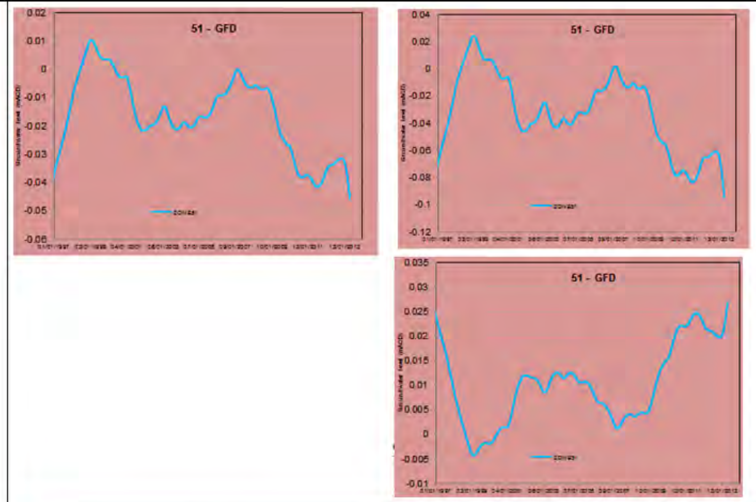
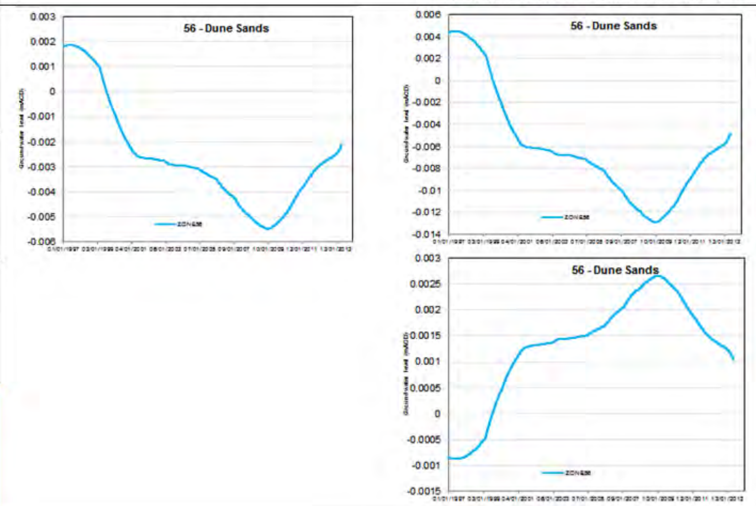
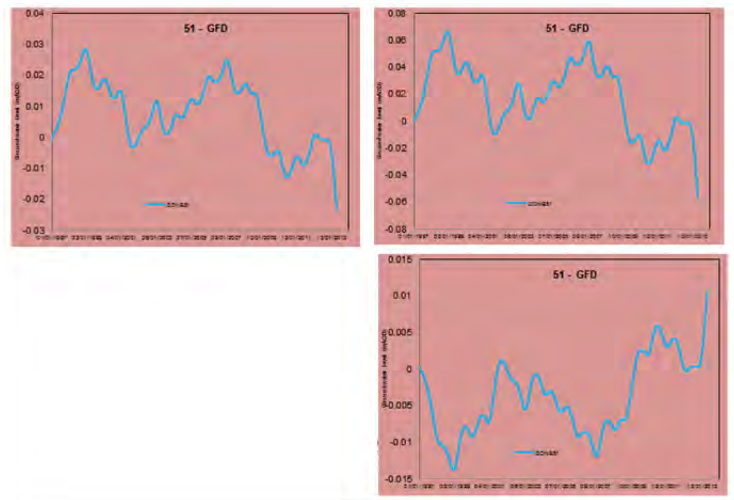
Number	Hydraulic Conductivity (m/d)	Layer Thickness (m)	Transmissivity (m2/d)	Second area Transmissivity (m2/d)	Dune Sands (Graphs in numerical order clockwise from top left)	Glaciofluvial Deposits/Limestone (Graphs in numerical order clockwise from top left)
Calibration	0.0001 (till)	0	1.19E-01	-		
10	0.0001	1	6.00E-05			
10.1	0.0001	8	1.62E-05			
Calibration	0.1	1	1.20E+01			
11	0.1	0.5	1.84E+01	-		
11.1	0.1	0.2	2.72E+01	-		
11.2	1.00E-01	1.5	8.87E+00	-		
Calibration	0.1	1	9.54E+00			
12	0.1	0.5	1.54E+01	-		
12.1	0.1	0.2	2.44E+01	-		
12.2	0.1	1.5	6.93E+00	-		

Table 3.30 Sensitivity analyses results (Runs 13-15)

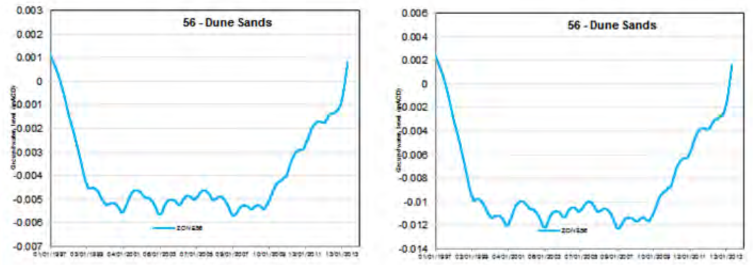
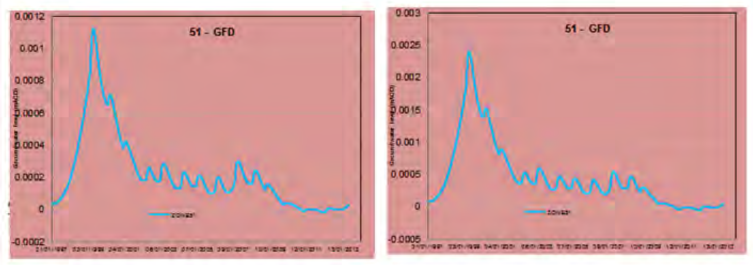
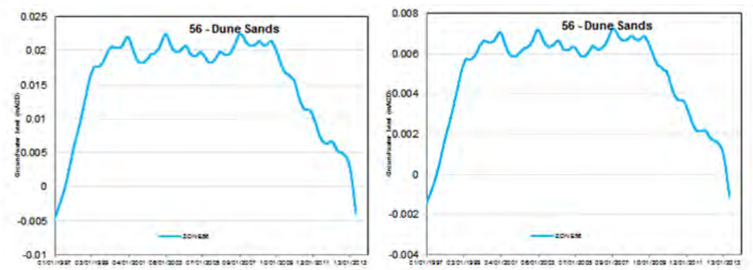
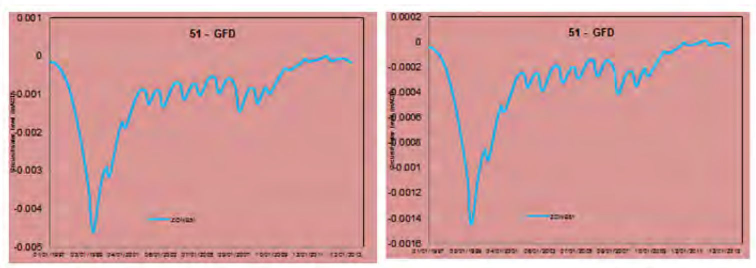
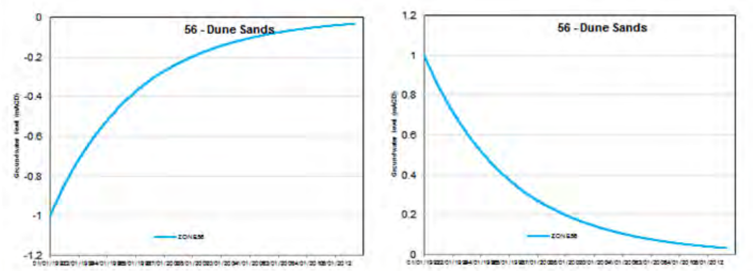
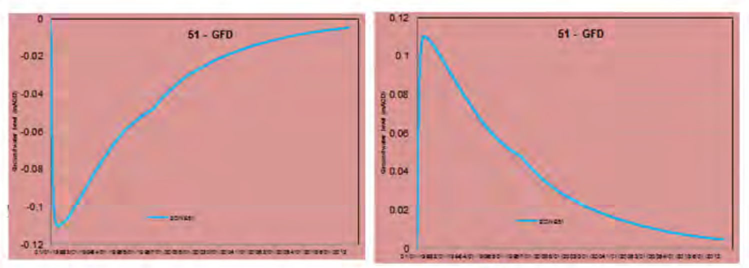
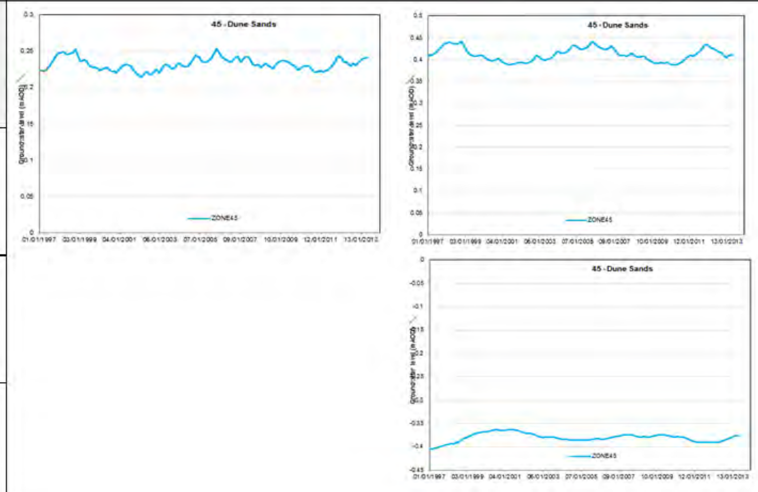
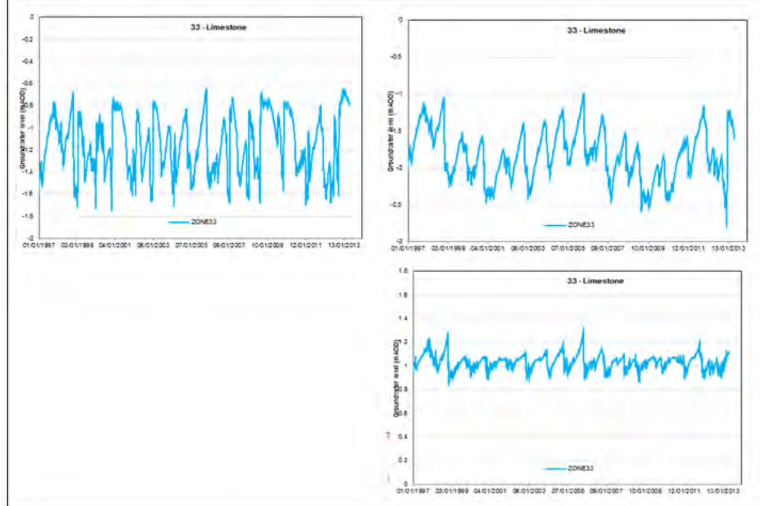
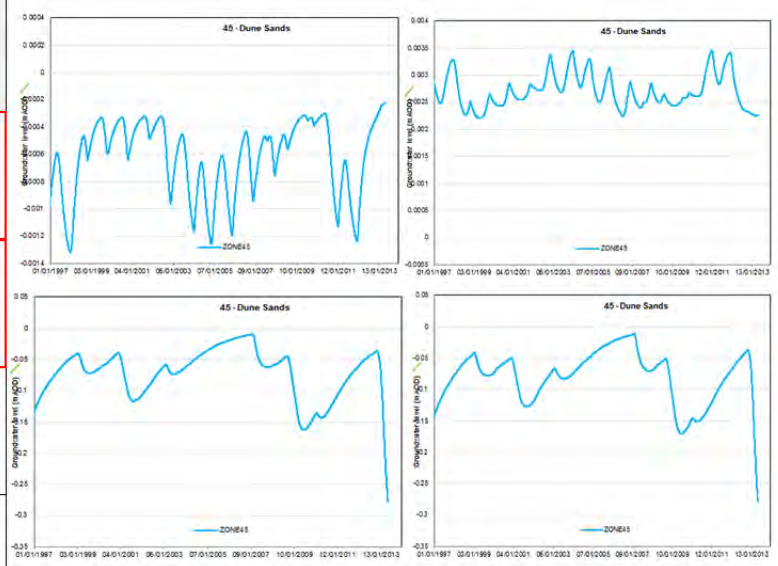
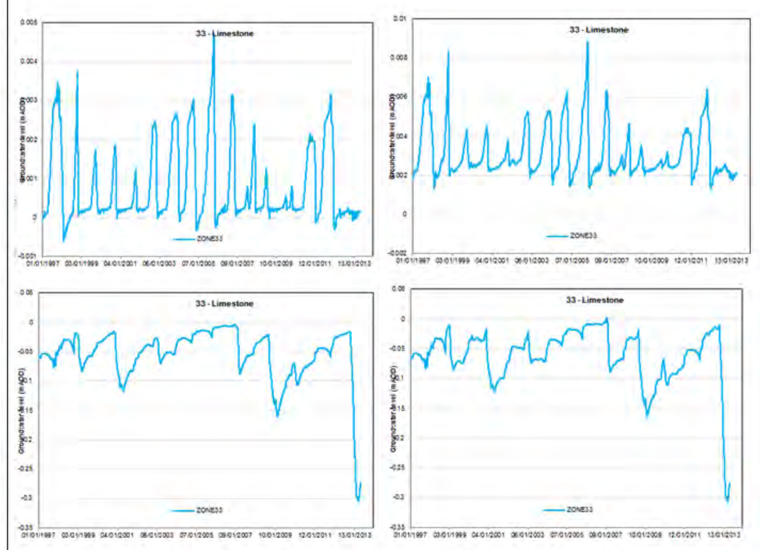
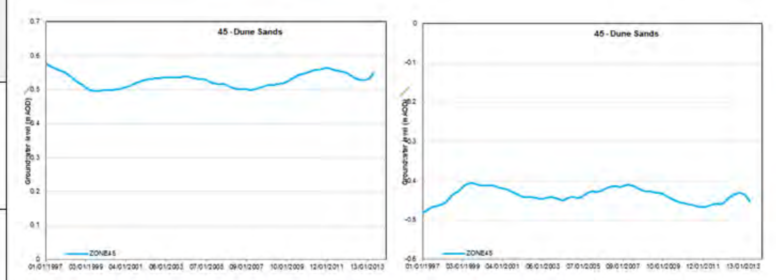
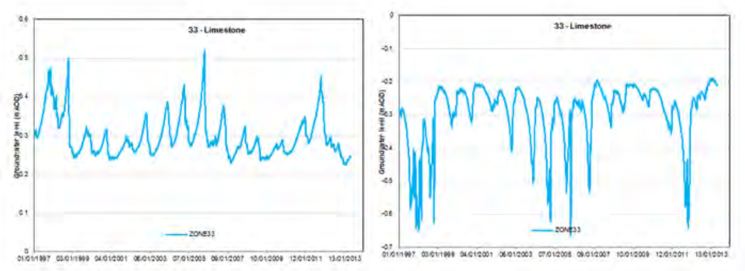
Number	Hydraulic Conductivity (m/d)	Layer Thickness (m)	Transmissivity (m2/d)	Second area Transmissivity (m2/d)	Dune Sands (Graphs in numerical order clockwise from top left)	Glaciofluvial Deposits/Limestone (Graphs in numerical order clockwise from top left)
Calibration	0.1	1	3.55E+01			
13	0.1	1.2	3.15E+01	-		
13.1	0.1	1.5	2.69E+01	-		
Calibration	0.1	1	3.55E+01			
14	0.1	0.5	5.24E+01	-		
14.1	0.1	0.8	4.08E+01	-		
Calibration	Heads 10mAOD					
15	9					
15.1	11					

Table 3.31 Sensitivity analyses results (Runs 16-18)

Number	Hydraulic Conductivity (m/d)	Layer Thickness (m)	Transmissivity (m2/d)	Second area Transmissivity (m2/d)	Dune Sands (Graphs in numerical order clockwise from top left)	Glaciofluvial Deposits/Limestone (Graphs in numerical order clockwise from top left)
Calibration	0.0001	1	7.00E-04			
16	0.0001	1.5	5.00E-04			
16.1	0.0001	2	4.00E-04			
16.2	0.0001	0.5	1.30E-03			
Calibration	5262m2 (cell 42)	27758m2 (cell 43)				
17	2631	27758				
17.2	10524	27758				
17.3	5262	13879				
17.4	5262	41637				
Calibration	Heads 20mAOD	-	-			
18	17					
18.1	23					

4 MODEL PREDICTIVE SCENARIOS

Having derived an acceptable model calibration, the model provides a tool that allows theoretical effects of quarrying activities to be assessed. The model can be used to estimate the difference between groundwater levels and flows for a baseline condition with those levels derived for any relevant quarrying scenario (i.e. the model predictions).

The model set up for the baseline and predictive scenarios are described further in the following sections. Detailed results of the predictive scenarios are described in Appendix 7.4.

4.1 Initial model set-up

The climate sequence and initial conditions uses in the baseline and predictive scenarios are shown schematically on Illustration 4.1 below.

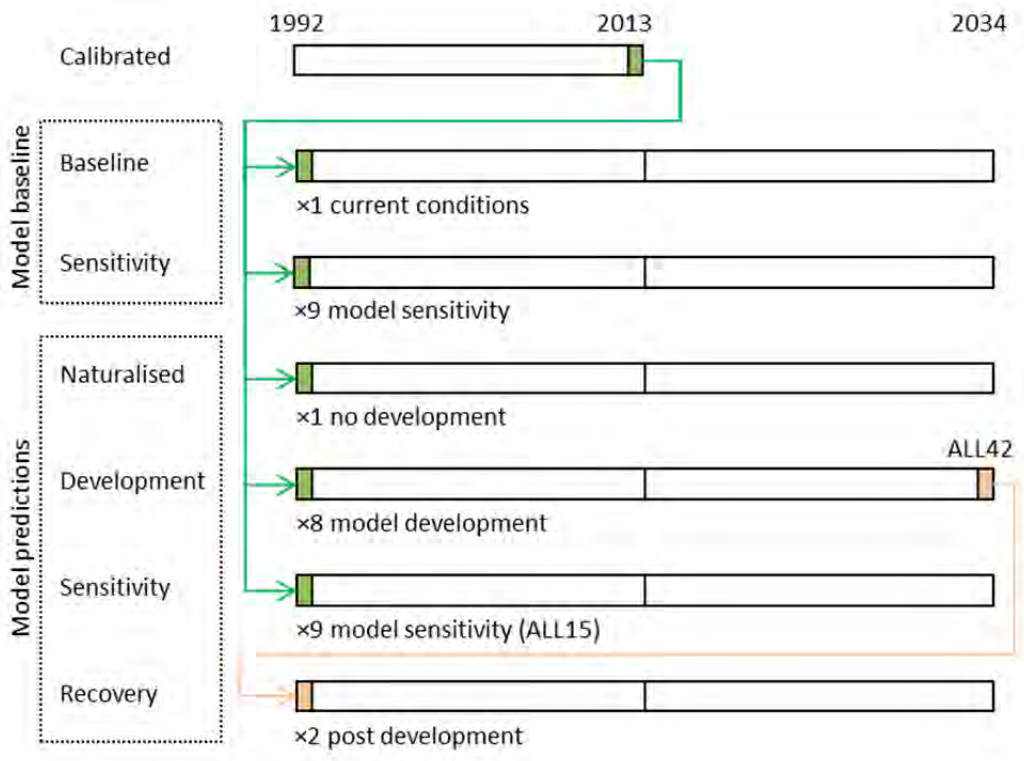


Illustration 4.1 Model baseline and predictive runs

4.1.1 Climate sequence

A future climate sequence for the baseline and predictive scenarios has been constructed from the 21 year climate sequence (1992-2013) used in the calibrated model. In order to extend the climate sequence to cover the full development period (42 years), the 21 year historical sequence has been repeated twice.

4.1.2 Initial conditions

The final heads (1 Jan 2013) from the calibrated model are used to define the initial conditions for the baseline simulation which covers the full 42 year development period. Predictive naturalised and development scenarios have the same climatic sequence and starting heads as the baseline model against which they are to be compared. The recovery model uses the final heads (1 Jan 2034) at the end of development period to see what effect it predicts following quarry development. An equivalent baseline model can be constructed for each set of model parameters brought forward from the formal sensitivity analyses and their predictive runs similarly defined.

4.2 Model Baseline

The model baseline represents the current stage of quarry development against which future development runs can be compared. Cornelly is actively dewatering and the current development depth is constant throughout the simulation at -3 mAOD. It is assumed that all groundwater entering Cornelly quarry sump (Zone 4) is pumped to Grove (Zone 27). Grove and Gaens are not actively dewatering.

4.3 Naturalised run

The naturalised run is a theoretical estimate of what conditions might have been in the absence of any quarry development. Model parameterisation is identical to the calibrated model with the exception that Cornelly sump is deactivated in Zone 4. It does not include the effects of quarry storage.

4.4 Development runs

The groundwater model has been used to carry out predictive simulations for eight development scenarios. The development of the quarries is considered at two future stages;

1) at the end of the 15 year ROMP cycle, and;

2) development at 42 years.

These development stages are undertaken for each quarry in isolation, with two further runs considering the combined development of the three quarries. The development scenarios can be summarised as follows:

- 15 and 42 year development at Cornelly (CN15, CN42)
- 15 and 42 year development at Grove (GR15, GR42)
- 15 and 42 year development at Gaens (GA15, GA42)
- 15 and 42 year development combined (ALL15 and ALL42).

For each development run the sump level for the active quarries at the given stage are set at the appropriate development depths (see Table 4.3). 'No dewatering' indicates that the sump in the respective quarry is set to inactive. The disposal location for Cornelly quarry (Zone 4) operating in isolation is to Grove (Zone 27). Grove in isolation pumps to the railway cuttings (Zone 26) and Gaens (Zone 16) in isolation discharges to the sink holes north-west of the quarry (Zone 23). For the combined development scenarios the discharge location from Grove and Gaens remain the same, whereas Cornelly pumps to Pant Mawr (Zone 7).

4.5 Recovery runs

Recovery modelling was undertaken to simulate effects following the maximum development of all three quarries (i.e. end of run ALL42). Recovery is simulated by ceasing abstraction from the sumps and adding additional storage capacity into the relevant zones to represent open water as the quarry refills (see Table 4.1).

Table 4.1 Additional storage areas in recovery runs

Zone	Elevation (mAOD)	Fractional area (-)	Storage (-)	Description
4	-75.0	0.64	1.0	Cornelly
16	-20.0	0.42	1.0	Gaens
27	-15.0	0.33	1.0	Grove

The additional storage capacity was introduced as discussed in Section 2.8. Quarry areas, as a fraction of each zone, were estimated from development plans.

Initial conditions used in all zones (other than the quarries) are groundwater levels from the end of the combined development run ALL42. Note that the radial flow approximation used to simulate quarry pumping cannot work in reverse (no sump level is defined). As such, inflows to the quarry zones are determined conventionally and would be significantly overestimated if the initial head in the quarry zone were set at the maximum development depths. An iterative approach was adopted to gradually increase the starting heads in each quarry zone to match the radial inflows at the end of the development run ALL42. Initial heads used in the recovery runs in comparison to the final heads from run ALL42 are summarised in Table 4.2.

Table 4.2 Initial quarry heads in recovery runs

Zone	All42 (mAOD)	Recovery (mAOD)	Description
4	-75.0	-10.0	Cornelly
16	-20.0	0.0	Gaens
27	-15.0	0.0	Grove

Two separate recovery models were developed:

1) no mitigation measures are in place, and

2) mitigation with some residual pumping for the initial 10 years of recovery.

- 50% Cornelly pumping rate to the railway springs (1496 m^3/day)
- 50% Grove pumping rate to the railway springs (819 m^3/day)

Additional runs to optimise the mitigation have not been carried out as the final quarry configuration is not yet clear.

4.6 Sensitivity runs

4.6.1 Conceptual and parameter uncertainty

Following the formal sensitivity analysis (Section 3.9), the parameters that were not fully constrained by the model calibration were carried through to the predictive runs. A new baseline scenario is developed for each of these sensitivity runs for the given model parameterisation. The predictive sensitivity runs are all based on the 15 year development run for the combined quarry development (ALL15).

The sensitivity of the simulated changes to model parameterisation (i.e. the difference between the sensitivity run and its sensitivity baseline compared with the difference between the ALL15 run and the main baseline run) are subsequently assessed.

4.6.2 Model equivalence

In addition to conceptual and parameter uncertainty, there remains a level of uncertainty due to model equivalence regarding the calibrated values for recharge and transmissivity. Recharge and transmissivity are influential model parameters and an approach is required to fully examine the likely range to which transmissivity has been constrained. .

An agreed upon approach has been to undertake two sensitivity runs with an increase and decrease in recharge throughout the model by 15% (this is the largest change in recharge relative to the best estimate that is considered to be credible). To ensure that groundwater heads are maintained at their approximate calibration position, the transmissivity was also increased and decreased by 15% throughout the respective models. This therefore provides sensitivity analysis with the highest and lowest transmissivity broadly consistent with the current conceptual model.

4.6.3 Burrows Well

A further sensitivity analysis was undertaken to investigate the adequacy of the model representation at Burrows Well (see Section 3.7.2).

For the calibrated model, the simulated flows were compared to the observed flows at Burrows Well and a fourth order polynomial fitted to the data (see Illustration 4.2).

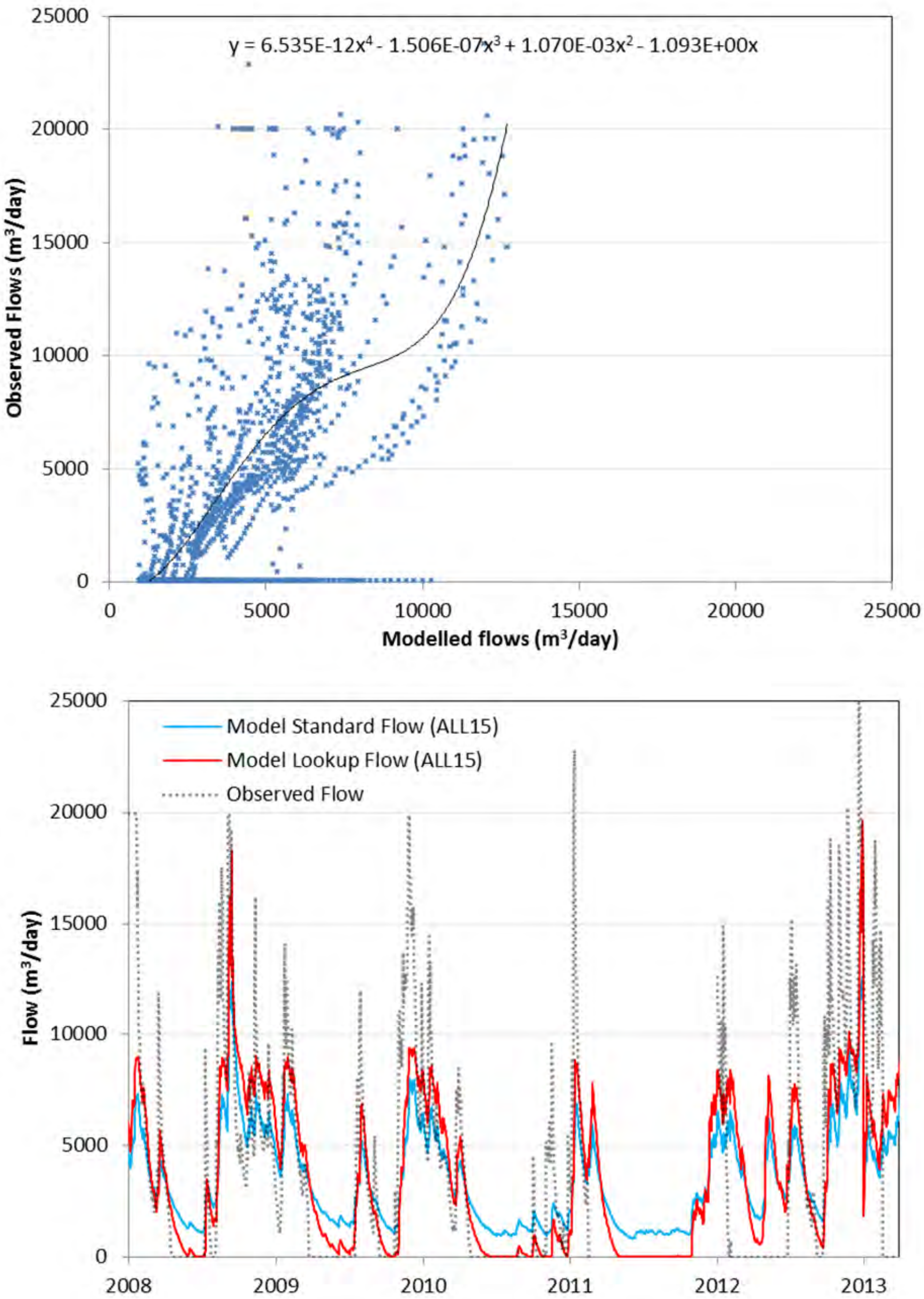


Illustration 4.2 Modelled vs Observed for Burrows Well flows lookup function

The polynomial then is used as a lookup function to transform the simulated flows at Burrows well under revised versions of the Baseline and ALL15 development runs into a data sequence that is more consistent to the observed values. That is, the model value (x) is replaced with the transformed value (y) used subsequently as the discharge at Burrow Well (note that the function is truncated where it crosses zero on the y-axis; modelled flows below 1300 m^3/day are transformed to 'no flows').

Although this potentially creates an overall imbalance in the model water balance (i.e. where water is added or subtracted according to the lookup function), the principle concern is with the relative changes in simulated water levels downstream in the Blown Sands at Merthyr Mawr. In this way an assessment can be made as to whether the relative changes between Baseline and Development runs using an improved representation of flows from Burrows Well are more or less than those simulated using the standard representation.

Whilst the results of the standard predictive run sensitivity analysis are presented in Appendix 7.4, it is more appropriate to discuss this specific issue here in terms of overall model credibility.

Illustration 4.3 shows the effect of transforming Burrows Well flows on the predicted change in water levels in the Blown Sand cells at Merthyr Mawr under the All15 development scenario (i.e. v. Baseline).

The average post development difference in water levels between the calibrated model and the sensitivity run with the Burrows Well function is set out in Table 4.3. This shows that using the Burrows Well flow function increases the simulated effect of the proposed development (i.e. All15 v. Baseline) by between 13 and 17%. This is considered to be small relative to the uncertainties in the whole assessment process and suggests that, whilst the calibration of flows at Burrows Well is not ideal, this is unlikely to affect the overall conclusions of the assessment. This constrained level of uncertainty has been taken forward into the overall assessment.

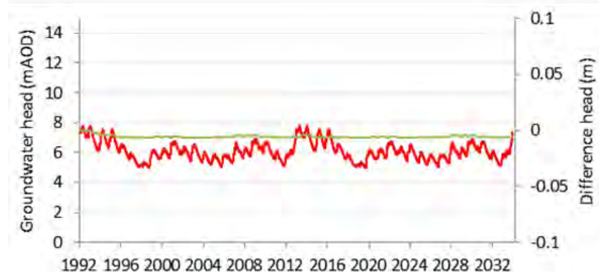
	Calibrated Model	**With Burrows Well Function**
44		
45		

Illustration 4.3 Effect of using Burrows Well flow function on simulated post development change in water levels

Cell	Calibrated Model	With Burrows Well Function	% difference
44	-0.0058	-0.0068	17%
45	-0.0093	-0.0105	13%

Table 4.3 Model prediction runs

Run	Description	Run Type	Stage (year)	Development depth (mAOD)			Starting Heads	Disposal locations
				Cornelly	Grove	Gaens		
1	Baseline	Baseline		-3	no dewatering	no dewatering	1st Jan 2013 CA	Cornelly ⇔ Grove
2	CN15	Development	15	-30	no dewatering	no dewatering	1st Jan 2013 CA	Cornelly ⇔ Grove
3	CN42	Development	42	-75	no dewatering	no dewatering	1st Jan 2013 CA	Cornelly ⇔ Grove
4	GR15	Development	15	-3	-15	no dewatering	1st Jan 2013 CA	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting
5	GR42	Development	42	-3	-15	no dewatering	1st Jan 2013 CA	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting
6	GA15	Development	15	-3	no dewatering	0	1st Jan 2013 CA	Cornelly ⇔ Grove : Gaens ⇔NW
7	GA42	Development	42	-3	no dewatering	-20	1st Jan 2013 CA	Cornelly ⇔ Grove : Gaens ⇔NW
8	ALL15	Development	15	-30	-15	0	1st Jan 2013 CA	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
9	ALL42	Development	42	-75	-15	-20	1st Jan 2013 CA	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
10	Combined recovery	Recovery	-	-	-	-	1st Jan 2034 ALL42	-
11	SENS1	Sensitivity	-	-30	-15	0	1st Jan 2013 S1	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
12	SENS2	Sensitivity	-	-30	-15	0	1st Jan 2013 S2	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
13	SENS3	Sensitivity	-	-30	-15	0	1st Jan 2013 S3	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
14	SENS4	Sensitivity	-	-30	-15	0	1st Jan 2013 S4	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
15	SENS5	Sensitivity	-	-30	-15	0	1st Jan 2013 S5	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
16	SENS6	Sensitivity	-	-30	-15	0	1st Jan 2013 S6	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
17	SENS7	Sensitivity	-	-30	-15	0	1st Jan 2013 S7	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
18	SENS8	Sensitivity	-	-30	-15	0	1st Jan 2013 S8	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW
19	SENS9	Sensitivity	-	-30	-15	0	1st Jan 2013 S9	Cornelly ⇔ Pant Mawr : Grove ⇔Railway Cutting : Gaens ⇔NW

5 REFERENCES

ESI, 2003 6227R5 Cornelly Group of Quarries: Conceptual Model of the Local Hydrogeology.

ESI, 2004 6227R6 Cornelly Group of Quarries: Hydrogeological Impact Assessment for Cornelly Quarry and Combined Quarries

Jones, P. S., 1993 Ecological and hydrological studies of dune slack vegetation at Kenfig NNR. Unpubl. PhD thesis. University College, Cardiff

Schlumberger Water Services (SWS), 2010 Refining river basin planning through targeted investigations on selected welsh groundwater dependent terrestrial ecosystems (GWDTES)

WynThomasGordonLewis, 2004. Environment Act 1995: Review of Mineral Planning permissions Cornelly Quarry.

FIGURES

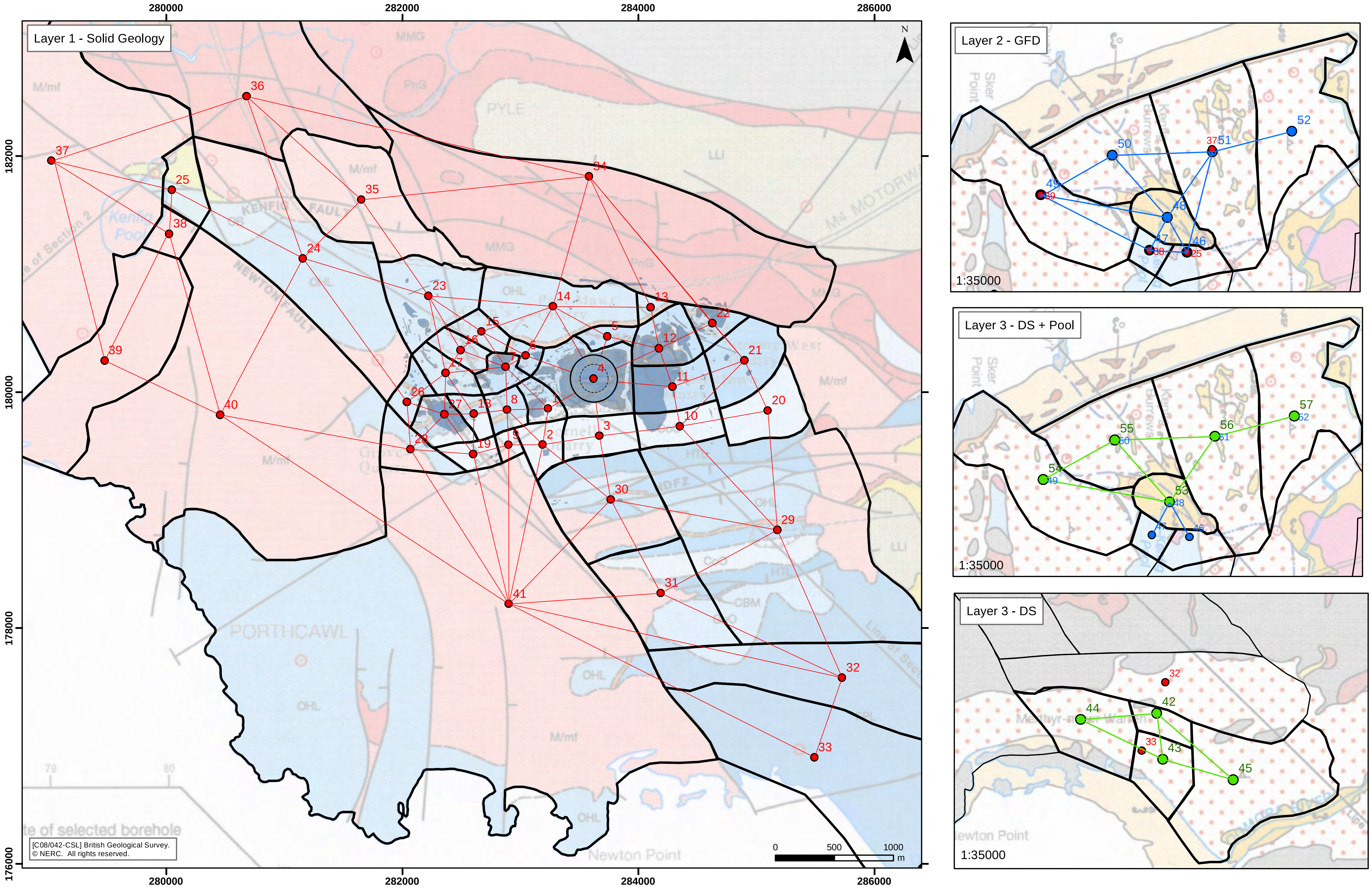


Figure 2.1
Model zones and connections

Date	Drawn
Jan 2014	SRA
Scale	Checked
1:30,000	BCH
Original	Revision
A3	1

File Reference
O:\6227_Cornelly\reports\R17 EIA\Appendix 7.3 Groundwater Modelling Report\Figures\Figure 2.1 Model zones & connections.mxd

esi Environment Specialists

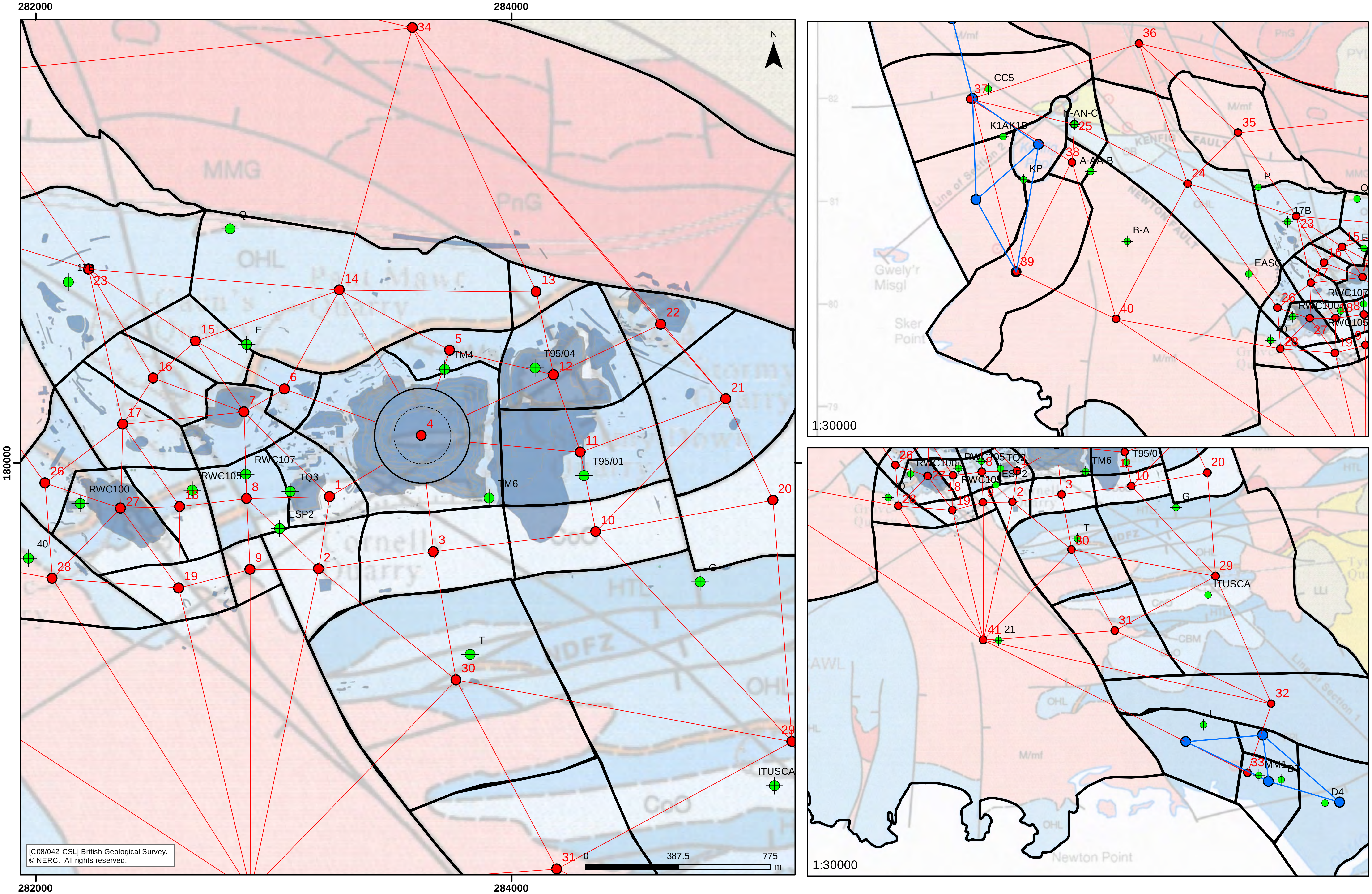


Figure 3.1
Locations of calibration boreholes

Date	Drawn
Jan 2014	SRA
Scale	Checked
1:15,000	BCH
Original	Revision
A3	1

File Reference
O:\6227_Cornelly\reports\R17 EIA\Appendix 7.3 Groundwater Modelling Report\Figures\Figure 3.1 Calibration BH Locations.mxd

esi Environment Specialists

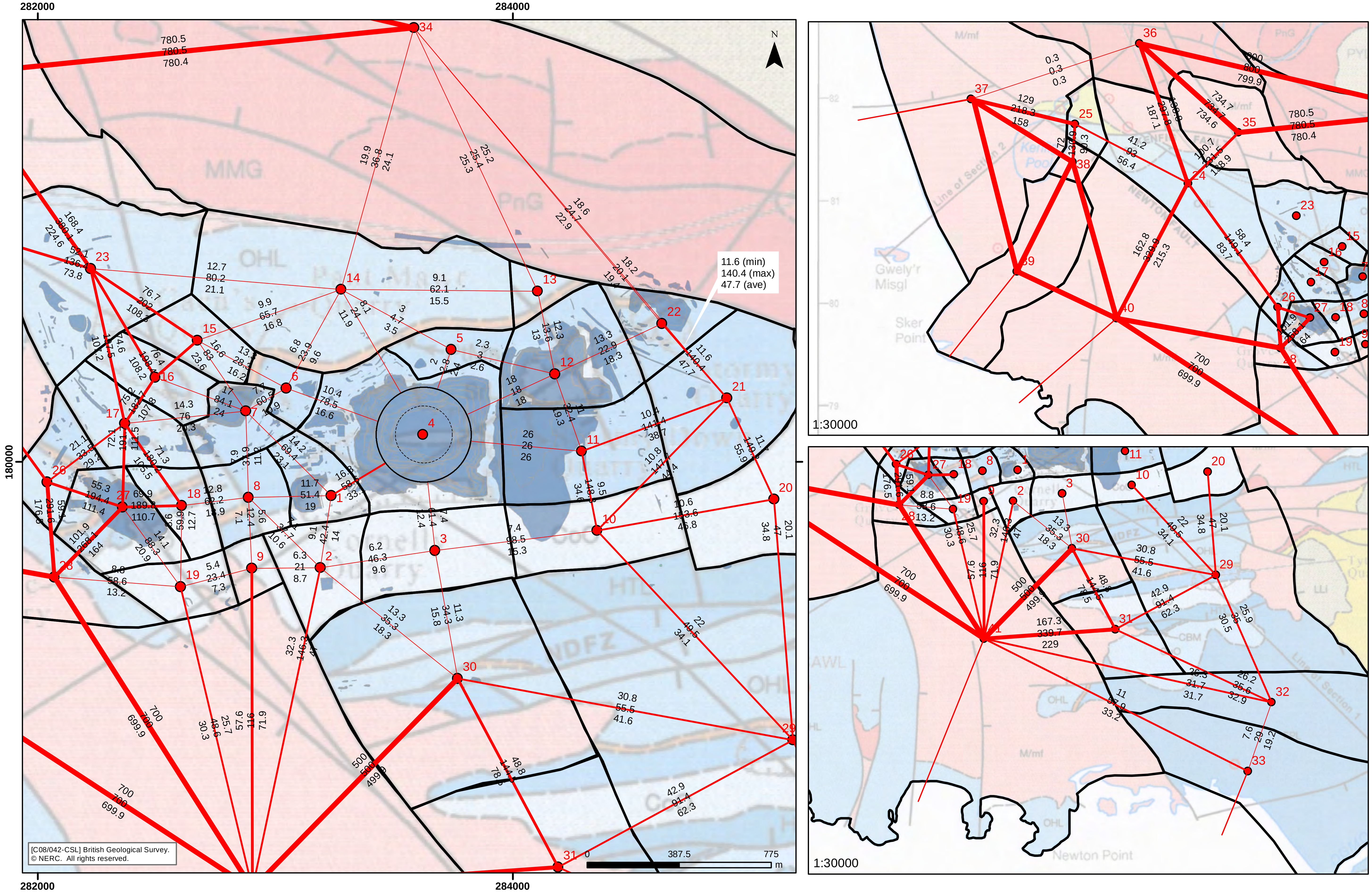


Figure 3.2
Solid geology calibrated transmissivity values

Date	Drawn
Jan 2014	SRA
Scale	Checked
1:15,000	BCH
Original	Revision
A3	1

File Reference
O:\6227_Cornelly\reports\R17 EIA\Appendix 7.3 Groundwater Modelling Report\Figures\Figure 3.2 Calibration Solid Geology T.mxd

Environment Specialists

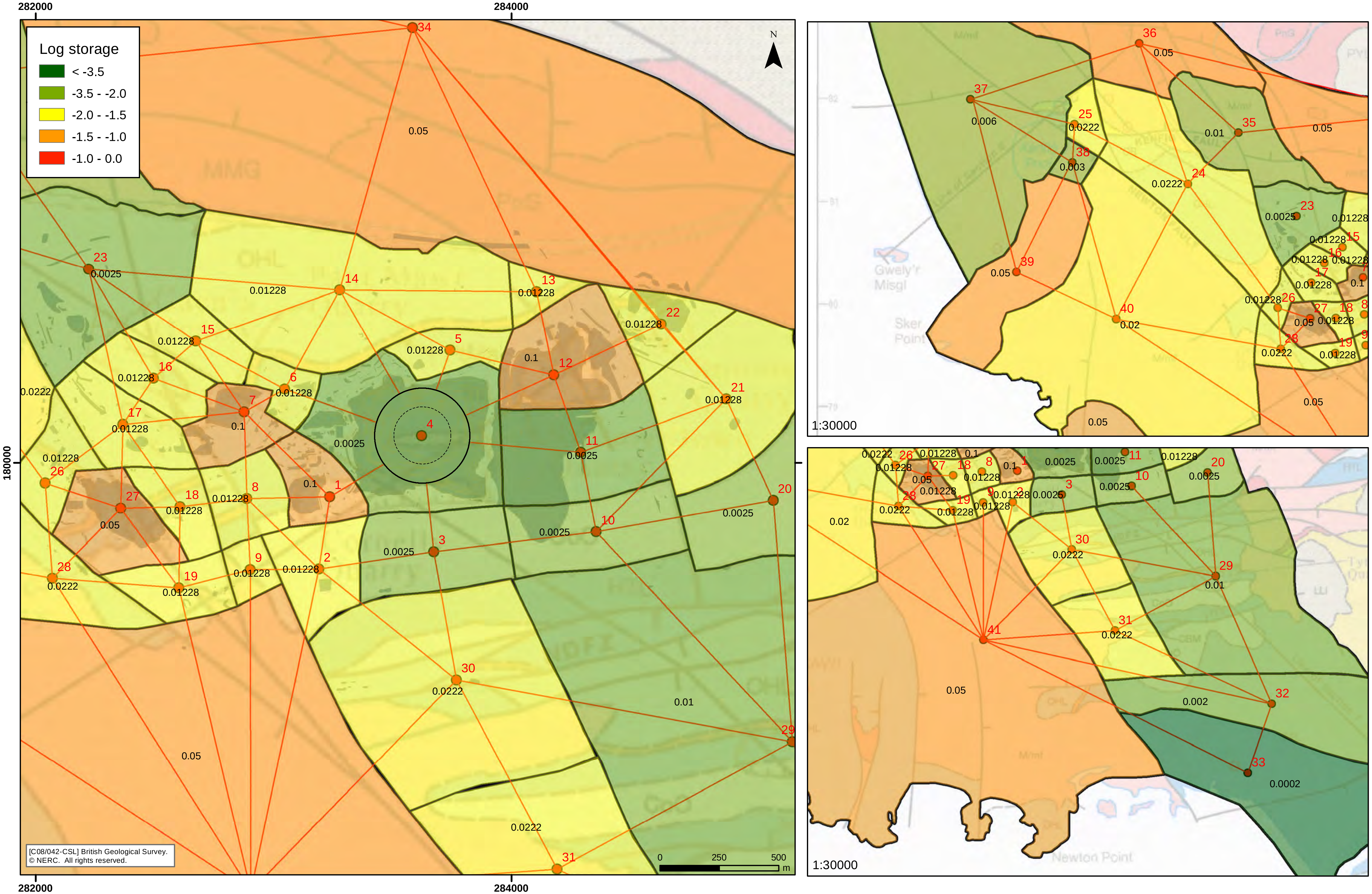


Figure 3.3
Solid geology calibrated storage values

Date	Drawn
Jan 2014	SRA
Scale 1:15,000	Checked BCH
Original A3	Revision 1

File Reference
O:\6227_Cornelly\reports\R17 EIA\Appendix 7.3 Groundwater Modelling Report\Figures\Figure 3.3 Calibration Solid Geology S.mxd

Environment Specialists

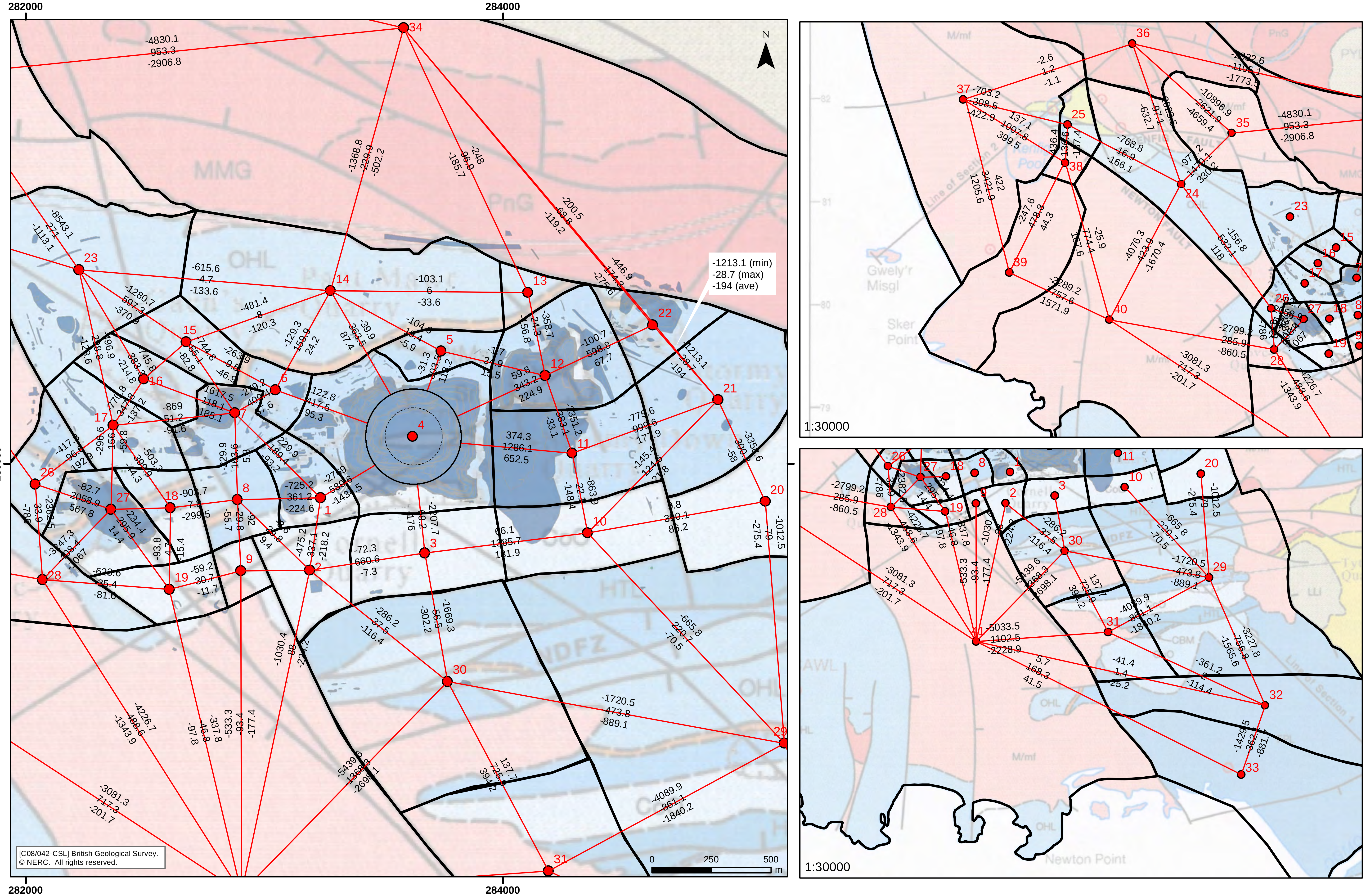


Figure 3.4
Solid geology lateral groundwater flows

Flows direction assumes Zone From < Zone To
+ve values indicate inflow
-ve values indicate outflow

Date	Drawn
Jan 2014	SRA
Scale	Checked
1:15,000	BCH
Original	Revision
A3	1

File Reference
O:\6227_Cornelly\reports\R17 EIA\Appendix 7.3 Groundwater Modelling Report\Figures\Figure 3.4 Calibration Solid Geology Q.mxd

Environment Specialists

APPENDIX F

Summary of Hydrogeological ES for Cornelly Quarry (SLR, 2014)

Appendix F Summary of Results of Hydrogeological ES for Cornelly Quarry

F.1 Conceptual Model

A comprehensive, updated conceptual model is presented in Appendix 7.1 of the Environmental Statement for Cornelly Quarry (SLR, 2014) and summarised in this section.

The Cornelly Group of quarries work Carboniferous Limestone that forms part of a wider, inter-connected aquifer system extending over an area of around 25 km^2 (see Figure 6.1 of Appendix 7.1). This is bounded by the River Kenfig to the north, the River Ogmore to the south, by various faults to the north east and by the coast to the south and west.

The Carboniferous Limestone forms the main, karstic aquifer in this area but is overlain by permeable, layered and possibly karstic, Triassic strata to the west and south. The Blown Sands at Kenfig and Merthyr Mawr form minor aquifers that have a degree of connection with the underlying Carboniferous/Triassic aquifers.

Groundwater discharge from the limestone aquifer occurs as follows:

- Along the ~10 km of coastline that forms the western and southern boundaries of the area. This accounts for around 70% of the total discharge;
- At the large springs at New Mill Farm;
- Within the Blown Sand dunes at Kenfig and in Kenfig Pool;
- At the large spring at Burrows Well;
- Pumping from Cornelly Quarry (and occasionally from Grove and Gaens Quarries). This water is all re-circulated back into the limestone and is therefore not lost to the system.

The following sections describe the conceptual model of some of the key parts of this system in more detail.

<u>Cornelly Group of Quarries</u>

Over a period of ~30 years groundwater levels at Cornelly have been reduced by a total of around 60 m over an area of around 0.5 km^2. Average inflows to the quarry sump are only ~3,500 m^3/d and the off-site pumping rate is only around 2,000 m^3/d - equivalent to a catchment area of less than 1 km^2.

The low transmissivity of the aquifer in this area is due to a combination of stratigraphical, structural and erosion/dissolution processes.

The present phase of karst development/re-activation in the limestone at Cornelly extends down about 40 m from the surface. The dewatered saturated zone appears to be characterised by diffuse fracture flow rather than a karst conduit network. This suggests that there is a low probability of the further deepening of Cornelly quarry encountering significant zones of enhanced permeability at depth.

The extent of active karst in Gaens and Grove quarries is less clear as these quarries are smaller and have not been worked to such depths.

Groundwater gradients to the west of the Newton Fault are generally flatter than to the east, implying a much lower transmissivity in the latter area.

<u>New Mill Springs</u>

New Mill Springs form an important discharge point for the northern part of the Carboniferous Limestone/Triassic aquifer system. The total gain in the River Kenfig in this area is consistent with a catchment area of 8.8 km^2.

Kenfig Pool and Dunes

The groundwater system at Kenfig comprises three aquifers: the Blown Sand dunes, and the underlying glaciofluvial gravels and Carboniferous/Triassic aquifers.

The eastern boundary of the saturated Blown Sand aquifer follows the eastern boundary of Kenfig Pool northwards to the remains of Kenfig castle and south west out to Sker point. A laterally extensive low permeability estuarine clay layer below the sands limits the hydraulic connection between the sands and the underlying aquifers.

Groundwater flows from a groundwater high north west of Kenfig Pool westwards towards the coast, north to the River Kenfig and south east to Kenfig Pool. Groundwater level and hydrochemical data imply that recharge from rainfall over the site provides the great majority of flow in the system.

The underlying gravels form a minor, confined aquifer. Groundwater level trends are similar (albeit subdued) compared to the underlying Triassic strata suggesting a degree of connection. Fluctuations are much larger than within the Blown Sands and the hydraulic gradient is downwards except in very wet periods. This indicates that these two aquifers are not well connected. Comparison of gravels groundwater levels with Kenfig Pool levels implies that this aquifer system discharges towards the coast rather than upwards through the sands.

Merthyr Mawr

There are two distinct hydrogeological units at Merthyr Mawr – the Blown Sand superficial deposits at surface and the underlying Carboniferous Limestone. A degree of hydraulic separation between the two units is provided by a clay layer which appears to be present across the majority of the site and is typically more than 0.5 m thick.

A step in the underlying limestone separates the Blown Sand deposits into two topographic levels: an area at lower elevation, within which the dune slacks form, adjacent to the sea and an area at higher elevation further inland which is considered to be largely dry.

Limestone water levels are generally below those in the sand, however, due to a higher degree of fluctuation there are times when the limestone aquifer water levels are higher than the sand levels and the gradients are reversed. Burrows Well spring discharges during periods of high limestone groundwater level

In the area to the south of Burrows Well, water levels are affected by the discharge of limestone groundwater levels into the Blown sands which causes large areas to pond, possibly on a shallow clay layer in this area (SWS, 2010). When the spring stops flowing, these water levels drop rapidly by three or more metres (e.g. piezometer D7) i.e. the groundwater system in this area is not typical of dune slacks more generally.

There are three main inputs to the groundwater system in the sands: direct recharge, runoff from less permeable catchments to the north east and intermittent flow from the underlying Carboniferous Limestone that discharges at Burrows Well. Groundwater flow in the limestone and Blown Sand aquifer is southwards towards the sea.

Water Balance

The following conclusions regarding water balance have been drawn from the work carried out:

- Almost all of the flow in the Blown Sands at Kenfig is sourced from direct rainfall (2% from surface water inflow). This flow leaves the system by a mixture of groundwater flow and overland flow via the slacks with a very small component of downwards leakage into the underlying sands and gravels.

- New Mill Farm springs appears to account for all of the water recharging to the Carboniferous Limestone and Triassic marginal facies aquifers in the northern part of the study area.
- The diffuse nature of coastal outflows around Porthcawl mean that the water balance is not as good.
- 45% of the total inflow to the Blown Sand system comes from Burrows Well discharge with the remainder being sourced by direct recharge. The majority flows to the sea; around 14% leaks downwards to the underlying limestone.

F.2 Summary of Results of Impact Assessment

This section contains a summary of the results of the hydrogeological impact assessment for Cornelly Quarry (SLR, 2014 Chapter 7). This is provided to assist cross reference between the WMP and the ES. For further detail on the approach used etc., the original report should be used.

F.2.1 Approach

The assessment is based on the standard *source-pathway-receptor* approach and is sub-divided into a number of steps:

1. Identification of receptors
2. Identification of pathways
3. Quantification of effects
4. Assessment of significance/impact

A number of critical thresholds have been set to screen out those effects which may be significant from those that aren't:

- Licensed groundwater abstraction boreholes - predicted groundwater level reduction in excess of 0.5 m
- Shallow wells - predicted groundwater level reduction in excess of 0.25 m.
- Ponds (excluding Kenfig Pool and any dune slacks in Kenfig Pool and Dunes and Merthyr Mawr SAC) - predicted groundwater level reduction in excess of 0.1 m.
- Spring flows - derogation of flow in excess of 10% of mean long term flows.

Degree of impact is assessed through consideration of the degree of effect and the importance of the receptor as summarised in the table below:

		Receptor Value		
		Low	**Medium**	**High**
Degree of effect	**Negligible**	Negligible	Negligible	Negligible
	Low	Minor	Minor	Moderate
	Medium	Minor	Moderate	Major
	High	Moderate	Major	Major

For reporting purposes effects/impacts are presented in four separate categories A to D as shown in the following section.

F.3.2 Results

(A) General effects on groundwater levels and flows – this is taken to include the assessment of the potential impacts on the water resources of the Swansea Southern Carboniferous Limestone groundwater (Water Framework Directive) body;

Quarry development generally results in decreased groundwater levels in the immediate vicinity of the quarries but these effects dissipate quickly with distance from the quarry. Recovery results in temporary decreases away from the quarry as water fills storage within the quarry voids. In some areas recovered levels are slightly higher and in other areas they are slightly lower due to the removal of the effects of quarry dewatering discharge.

Impacts are **Negligible** for individual development, combined development, and recovery conditions

(B) Potential effects on water levels in the dune sands at Kenfig Pool and Dunes SSSI and the Merthyr Mawr SSSI

Water levels rise slightly at Kenfig in the Cornelly-only development scenario but fall when all quarries are combined and during recovery. Stabilised recovered levels remain lower than current. The largest change in water levels at Kenfig is seen during recovery with a temporary drop of up 12 cm in the dunes to the east of Kenfig Pool. Planned Mitigation Measures reduce this below the 10 cm critical threshold. Changes in other dune cells and for other scenarios are not more than 1 cm. Hydrogeological impact is **Negligible**.

Water levels at Merthyr Mawr decline under all development scenarios and during the initial stages of recovery. Stabilised recovered levels and flows remain higher than current. The largest changes in level and flow at Merthyr Mawr are seen during recovery. Representative Blown Sand aquifer cells at Merthyr Mawr show no more than 3.5 cm reduction under all scenarios. Flows at Burrows Well do not exceed 5% peak reduction under all scenarios. Hydrogeological impact is **Negligible**.

(C) Potential effects on water levels and flows at other receptors

The largest changes in level and flows are seen during recovery.

Drawdowns in excess of the critical threshold are seen at:

- Ty Tanglwyst Farm pond (Loc. 17)
- Ty Tanglwyst Farm well (Loc. 17a)
- Ty Talbot Farm, Nottage (Loc. 18b)
- Wilderness Pond (Loc. 20)
- The well at White Wheat (Loc. 21)
- Pwll y Waun pond (Loc. 23)
- The well at Home Wood (Loc. 33)
- The pond at location 34 (Loc. 34)
- Royal Porthcawl Golf Club well (Loc. 36A & 36B)
- Grove Golf Club well (Loc. 40)
- Tynycaeau (Loc. 61)
- Pyle & Kenfig Golf Course (Loc. 65)

Of these, hydrogeological conditions mean that only Grove Golf club has **Moderate adverse** impact with the remainder considered **Minor adverse**.

Effects at springs vary depending on location and scenario. At New Mill Farm springs the greatest reductions in flow are seen during recovery. Short term flows initially exceed 10% reduction but flows increase over the recovery period. Impacts at springs are either **Negligible** or **Minor adverse** under all scenarios.

(D) Other potential effects

There is a relative increase in flows toward Cornelly Quarry from Stormy West landfill under all scenarios but the magnitude of flows is small. At Tythegston flows are always away from the quarries.

There are no ground stability effects.

Flows toward the coast are most reduced under in the recovery run where a maximum reduction of just under 9% is predicted.

APPENDIX G

Outline Engineering Measures to Control any Sudden Inflow of Water to the Quarry

www.preene.com

19 March 2015

Reference: 14-143.102A.V1
Prepared by Dr M Preene

TECHNICAL NOTE
CORNELLY QUARRY – REVIEW OF GROUNDWATER CONTROL OPTIONS

Preene Groundwater Consulting Limited (PGC) has been instructed by ESI to summarize the options for controlling groundwater inflows in the event of encountering a fissure at depth. This Technical Note summarises this study.

1. The Proposed Works

Cornelly Quarry ('the Quarry') is an existing hard rock quarry exploiting the Carboniferous Limestone. The base of the Quarry is currently at approximately -3 mOD (approximately 100 m below surface), and is to be deepened in stages to -15 mOD, -30 mOD and -75 mOD. The Quarry currently requires dewatering by groundwater pumping from an in-pit sump, and this requirement is expected to increase as the quarry is deepened.

2. Hydrogeological Setting

The Quarry is sunk into the Carboniferous Limestone, the upper horizons of which are affected by paleokarst features of enhanced permeability, predominantly extending down to 40 m below surface. The description of the paleokarst features indicate that they may comprise dilated joints, breccia bodies or irregular pipes and voids. The paleokarst features are described as typically being filled with sediments of low permeability silts and clays. It is indicated that the proposed quarry development will be below the paleokarst zone, and the probability of encountering a significant permeable feature is low. Nevertheless, the Quarry requires a groundwater control contingency plan for such an event.

Predicted water inflow rates to the developed Quarry are indicated to be of the order of 3,000 to 4,000 m^3/d (35 to 46 l/s) with 50 to 60 % of this pumped off-site and the remainder re-circulated in other parts of the Quarry pit.

3. Groundwater Control Options

It is likely that a discrete permeable feature will be encountered in one of two ways. It may be exposed in the newly blasted face as the quarry is extended horizontally at a given level. Effectively, the Quarry would work laterally into the feature, in which case the flow from the permeable feature will probably be easy to identify quickly. Alternatively, the permeable feature may be encountered in the floor of the zone where the first deepening of a new stage of the Quarry is made. In these circumstances the Quarry will work down onto the feature, and while increased groundwater inflows will be observed, it may not immediately be obvious that a discrete permeable feature has been encountered. In either case, it is clear that all groundwater control options (including those based on grouting) will require some groundwater pumping, at least as temporary measure.

Groundwater control options at the Quarry fall into three main types:

1. *Accept the water into the Quarry pit and remove by in-pit pumping*. Conceptually this is the simplest solution, and simply involves allowing the water to flow from the feature, and directing it by drainage channels to a local sump from where it is pumped away. This appears feasible in practice because the current inflows are not very large, and

because further water entry into the pit is unlikely to cause geotechnical problems. The negative aspects of this approach are that the water disposal route has to accept significantly increased flow rates, and the larger groundwater inflows may cause greater external hydrogeological impacts.

2. *Intercept the water prior to entering the pit*. In theory, if the orientation and extent is known for a permeable feature exposed in the Quarry it may be possible to drill into the feature before it enters the pit and attempt to seal it with grout. However, in reality the uncertainties and access problems in a developing quarry rule out this option.
3. *Blocking of pathways to prevent water from entering the pit.* Where the feature is exposed in the Quarry, measures can be taken to seal or block the feature and exclude the water from the pit. The technical challenges are that any seal must be able to hold back significant groundwater pressure, and must be extensive enough to prevent water 'short-circuiting' around the seal and emerging nearby in the pit. A practical challenge is to locate the seal where it will survive for some time, and not quickly be destroyed by further blasting and pit expansion.

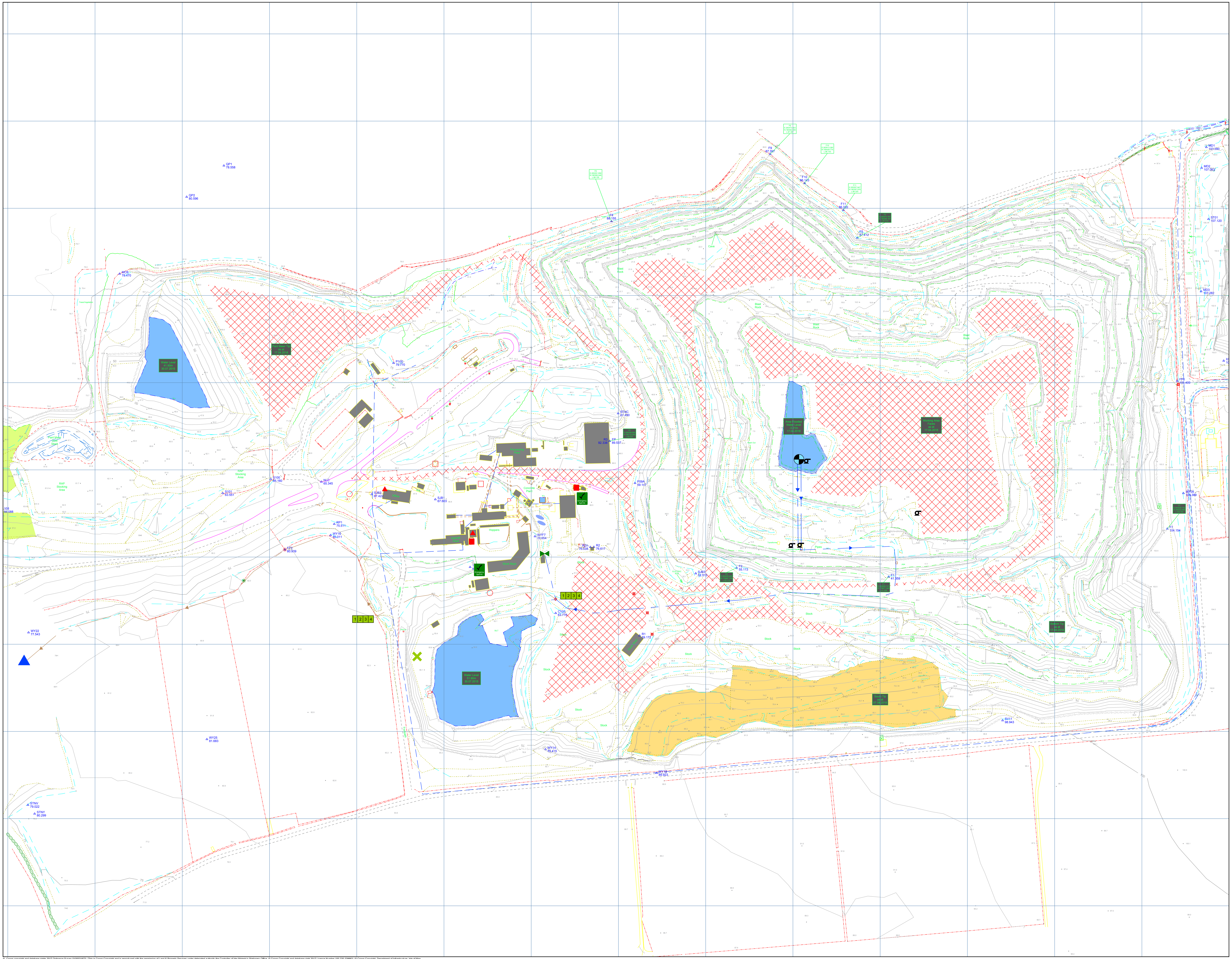
4. Preferred Groundwater Control Option

The preferred groundwater control solution to deal with a discrete permeable feature is to pump the groundwater inflow, on a temporary basis, and then, when pit geometry allows, seal the feature to exclude the groundwater. Outline stages of work are:

1. When a permeable feature is encountered, deploy temporary sump pumps to handle the inflow. Water to be pumped through a V-notch weir tank and flow rate measured daily during the works to determine if flow rate is constant or increasing/decreasing. Feature to be inspected to assess type, orientation, effective opening, etc.
2. Assess geometry of feature to determine where it will intercept a pit face or floor that will not be affected by blasting or pit development. Prepare a plan to seal the feature at that location (see outline steps below).
3. At the seal location, clean out as much sediment from the feature as is safely accessible (e.g. by scouring with jetting lance or narrow excavator bucket). Set minimum of two steel relief pipes in the feature, protruding into the Quarry void. Ideally the relief pipes should be 150 mm diameter if the feature is large enough to accommodate them. Relief pipes to terminate in a valve and flange.
4. Seal around the relief pipes using aquareactive polyurethane grout. This material reacts with the water to form a foamed void filler to seal around the pipes. Water will continue to flow from the feature through the relief pipes, so the grout is not subject to high water pressures.
5. Construct a reinforced concrete headwall across the exposed feature to give structural support to the relief pipes. The headwall will need to extend sideways out to sound rock, and may need to the bolted to the rock face. During construction water is allowed to flow through the relief pipes.
6. Once the concrete headwall is cured the relief pipes are closed off by the valves. A pressure sensor should be fitted to one of the relief pipes and the rise in groundwater pressures monitored following closing of the valves. An inspection should be made of the rock around the headwall to identify any zones where water is leaking, and if necessary these can be sealed with polyurethane grout.
7. Once the feature is sealed at the headwall, it can either be left full of water, or it can be backfilled with a cement-based void filling grout by pressure grouting through the relief well valves, with lower volume secondary injection of polyurethane grout if required.

Appendix E

Water management drawing



Legend

Site Transfer Water (Clean)
- Water body
- Pipe (below ground)
- Pipe (above ground)
- Ditch
- Water tank
- Pit (eg rainfall collection)
- Ground seepage
- Discharge point

Natural Water (Clean)
- Water body
- Ditch
- Sensitive receptor
- Abstraction point
- Water course (with flow direction)

- Silt pond (active)
- Pipe (below ground)
- Pipe (above ground)
- Ditch
- Water tank
- Pit
- Wet extraction

- Fuel / oil storage capacity
- Septic tank (dischargeable)
- Chemicals
- Plant, exposed quarry floor & haulage routes
- Mobile fueling / workshop
- Cesspit (sealed)
- Wheelwash

- Emergency spill kit
- Valve
- Oil boom / interceptor
- Bunding

- Piezometer
- Inspection point
- Sampling point (water)
- Gauge board
- Flow meter
- Flume or weir

- Pump (with capacity)
- Reed beds
- Flocculent station
- Extent of Tarmac Interest

Activity type:
Authorisation number:
Source/Receptor:
Permit Details/Limits:

Improvement Actions

Improvement location number (see accompanying document for more details & photographs)
Title of improvement
Urgency of improvement
Urgency : Low
Urgency : Medium
Urgency : High
Soil and seed exterior slopes - access road to new excavation
Area : 1,250m²
Soil / seed banks to improve external appearance and minimise run off to nearby burn
Date: 12/12/2016
Quantity required
Further description
Quarry Manager to sign & date once complete

TARMAC
A CRH COMPANY

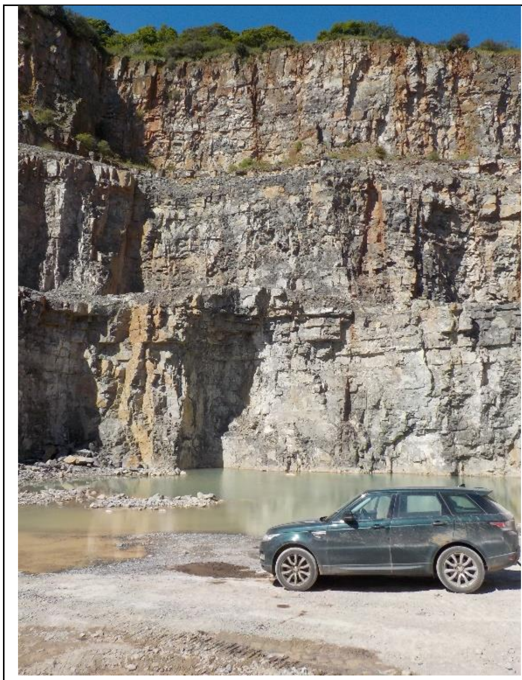
Site Name:
C112 - CORNELLY QUARRY

Drawing Name:
Site Water Management Plan
(Based on 17.04.18 Survey)

Drawn By:	Scale @ A0:
KRE	1:1333
Date:	**Drawing Number:**
03/09/2018	TBC

Appendix F

Photographs

	
Sump	Sump pump (22kW)
	
Meter 1 (out of sump)	Meter 2 (out of sump)

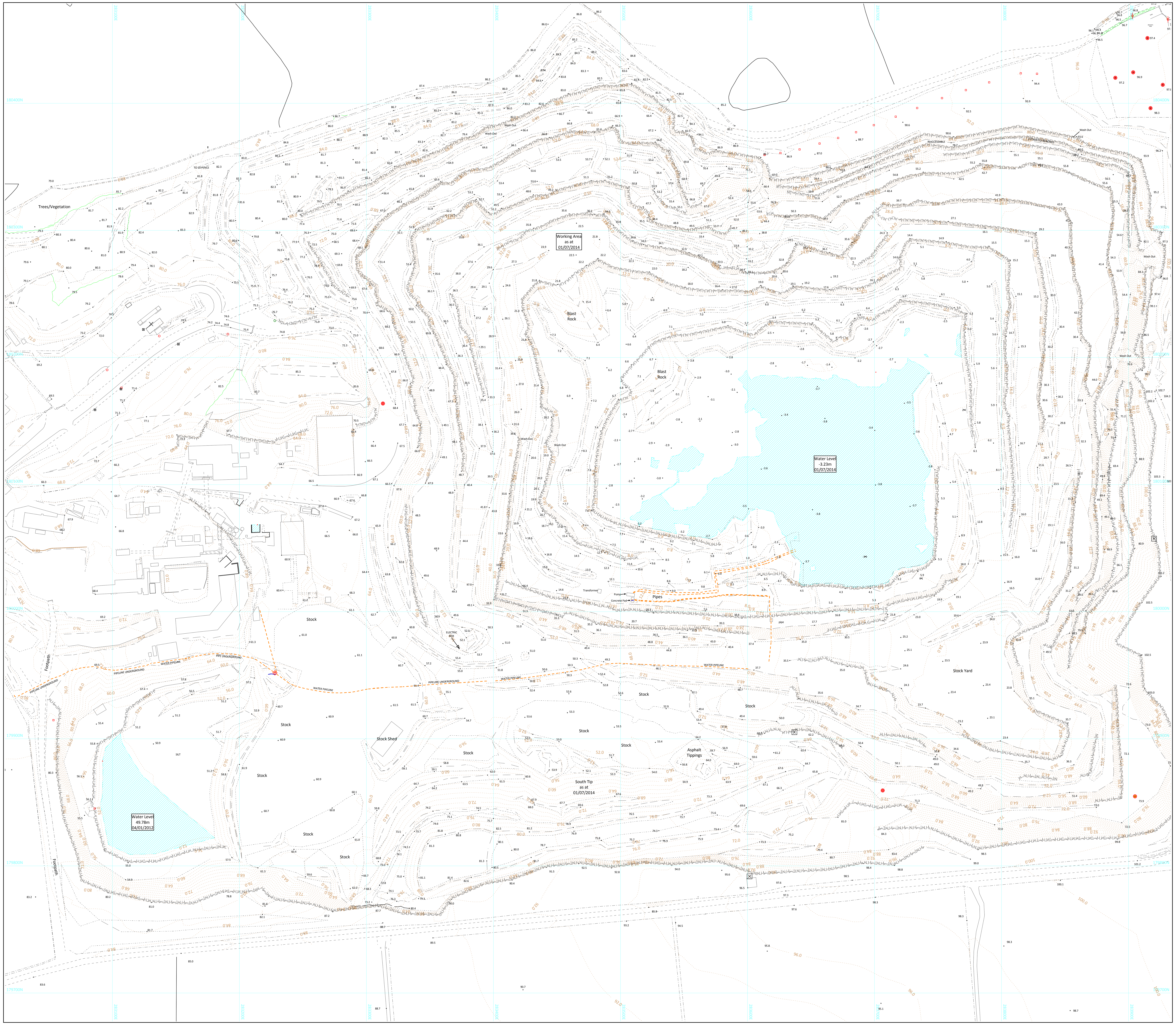
	
Meters 1 & 2 (out of sump)	
	
Processing area	Surface booster Pump (100kW)
	
Two pipes become one, out of quarry void	Meter 3 (post processing area)

Appendix G

Dewatering calculations worksheet (Electronic appendix)

Appendix H

2014 Topographical survey



Site Name:

Drawing Name:

2014-07-01

Drawn By:

Scale:

1 : 1500

Date:

17/07/2014

Drawing No:

N

LAFARGE TARMAC