Technical note

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ATKINS

Project:	Glan Llyn – Monks Ditch	**To:**	Andrea Nelmes - Rodgers Leask
Subject:	Hydraulic modelling – impact assessment of pumped surface water discharge into the Monks Ditch	**From:**	Mike Vaughan
Date:	03 August 2016	**cc:**	

1. Introduction

1.1. Context

This technical note provides an update on that issued on 14 July 2016 (5111373-ATK-GEN-ZZ-CO-H-0004_P02). This follows discussions with Natural Resources Wales and the agreement that additional information and detail was required to demonstrate that a surface water drainage strategy based on pumping from the Glan Llyn Development into Monk's Ditch, when conditions permit, was acceptable.

The drainage concept requires a balance between a pumped discharge into the Monks Ditch, on-site surface water storage, the impact on Monks Ditch, and the implementation of mitigatory works.

This note describes the hydraulic modelling undertaken to inform the discussions. The note does not address the design, permitting, or planning issues surrounding the implementation of a control system.

1.2. Background

The proposed development at Glan Llyn occupies a brownfield site on the former Corus steelworks at Llanwern. The proposed (revised) surface water drainage strategy for the site relies on a pumped discharge to the Monks Ditch, a Main River under the control of Natural Resources Wales.

It is intended that the surface water runoff from the development is treated and attenuated / stored on site, in a series of reens, ponds and lakes. The number and size of these features, means that the site affords a large volume of storage. However, an eventual discharge to the Monks Ditch will be required to maintain the storage and evacuate excess water. Given the ground levels in the vicinity, the discharge is to be pumped into the Monks Ditch: the pumped discharges would be up to a rate of 750l/s, with 500l/s from the west (residential) site and 250l/s from the east (commercial) site.

This note describes the approach and findings from a study to evaluate the impact of the Glan Llyn pumped surface water on flood risk along the Monks Ditch.

This discharge will be 'new' water, with previous runoff from the operational steelworks site having been intercepted, collected and pumped to the Severn Estuary via the steelwork's own pumping system.

1.3. Approach

1.3.1. Caldicot Levels model

The early assessment, using a large and complicated 1D-2D hydraulic model of the Caldicot Levels, demonstrated the interaction of waters across the wider area. That modelling reinforced the assessment that the Monks Ditch cannot be considered in isolation and that the movement of surface water to and from the levels is more complicated than a 1D model alone could represent. However, the work did identify that a pumped discharge into the Monks Ditch, from Glan Llyn, would need to be managed to ensure flood risk across the levels would not be increased.

That work was not able to provide sufficient detail on the conveyance of water along the Monks Ditch, nor define the impact the proposed scheme might have on the various features along that watercourse, being of a resolution developed for the wider Caldicot Levels and not a local assessment with specific representation of the Monks Ditch.

1.3.2. Previous 1D only model

To address the need for detail on the Monks Ditch, a new 1D-2D model of the watercourse was developed. This was undertaken using FloodModeller, creating a detailed 1D model of the watercourse and structures, and supplementing it with a basic 2D domain. In this way, the assessment would pick up the detail on the watercourse, account for the passage of water across the levels, yet avoid the complications arising from having too much detail in that area.

At the time of the previous note (5111373-ATK-GEN-ZZ-CO-H-0004_P02) the model was simulated in 1D only. However, being 1D only and not including any floodplain representation, the model is restricted to calculating water levels within the confines of the channel. In reality, the Monks Ditch is a perched channel, embanked above the natural levels of the surrounding fields.

As a result, the model over-predicted water levels during periods of high flow when the reality would be a spill of water into the floodplain. The 1D only model was unable to make an assessment of this loss of water from the channel, and hence makes its predictions based on the high flows and channel dimensions only.

This had limitations and it was advised in that note to ignore the absolute peak values reported. This was aimed at any water level predicted higher than the point when water would be lost from the system – i.e. when the Monks Ditch channel is overtopped. Water levels predicted in channel, where no water would be lost from the channel, are still considered to be relevant. Hence, the context of the trigger levels remains valid.

This limitation was assumed to have little impact on the timing and duration of threshold exceedence, and, for Glan Llyn the period that the surface water pumps would be operated. However, the full 1D-2D model was not operational at the time and the evidence to demonstrate that was not available.

1.3.3. New 1D-2D model

The linked 1D-2D model in Flood Modeller is now operational and is reported on in this note. A location plan is shown in the appendix to this note. This uses a simple 2D domain based on a merged grid of 1m and 2m resolution LiDAR. The model simulations use a 50m cell size to speed up processing time – a scale justified given that specific and detailed results across the floodplain are not required for this assessment.

2. Hydrology

The hydrological analysis was based on rainfall hyetographs into the 2D domain, and fluvial inflows to represent flow contribution from the upper catchments into the Monks Ditch and those passing water into the 2D domain. The FEH Statistical method was used to evaluate all the inflows to the system, with the ReFH not being appropriate given the permeable nature of the catchments. The ReFH calculations were used to generate the hydrograph shape, being scaled to match the peak flows from the FEH Statistical method.

The Monks Ditch itself, at the northern boundary of the steelworks site, has a catchment area of approximately 20km^2 with an annual average rainfall of 990mm.

Rainfall return periods of 1 in 100 year plus climate change and 1 in 1000 year were assessed in accordance with TAN15. A 20% allowance on flow was included for climate change, with a 30% increase in the rainfall depth. Note that there is no requirement under Welsh Government rules for consideration of climate change on the 1 in 100 year event. A 1 in 5 year storm was tested to provide a pseudo-validation of the model under a magnitude of event likely to have been observed in the recent past.

A 12 hour critical duration was established for the Caldicot Levels from previous work, but later tested by applying a 24 hours storm duration and then back-to-back storms.

With more focus on the Monks Ditch, the summer penning conditions were deemed the worst-case in deriving the period of time that a pumped drainage system could operate, (with water levels across the Caldicot Levels held higher in the summer, and thus less freeboard to bank level). As such summer storm events were used.

The Monks Ditch catchment draining from the north was found to generate a median flow of 3.4m^3/s (summer storm) with a corresponding site rainfall of 34.08mm. The 100 year event was predicted to cause some 11.1m^3/s from the upstream catchment and some 92.86mm rainfall on the site. Applying the 20% flow allowance for climate change gives 13.3m^3/s for future flows. The 1 in 1000 year estimate was 21.8m^3/s with 158.01mm of rainfall across the site.

A baseflow value of 0.3m^3/s was applied, being taken directly from the ReFH results. This baseflow estimate may be high, given the permeable nature of the catchment. However, as part of the testing the baseflow was applied to represent a dry weather flow.

A mean high water spring (MHWS) based tidal boundary at the tidal outfall was also included in the model, with a 2008 MHWS of 6.5m AOD used for Monks Ditch. Sea level rise of 1.094m was applied when considering the condition in the year 2116 (in 100 years' time from the present day), giving a tide level of 7.59m AOD. For modelling purposes, the tide has been 'dried out' at -0.5m AOD, rather than taking water levels below the invert of the channel at the downstream boundary.

3. Hydraulic Modelling

3.1. Baseline

3.1.1. Model build

1D model

A 1D FloodModeller representation was developed for the Monks Ditch covering the 6.1km reach between the tidal outfall at Goldcliff and Llanwern village.

The 1D model was developed using survey of the watercourse at various locations, and interpolating cross sections in between, supplementing the bank levels using LiDAR data. LiDAR was also used to generate cross sections upstream of the mainline railway near Llanwern village. Topographic survey of the Monks Ditch through Glan Llyn was taken by Hawk Group in March 2015 and applied to the model (dwg E.S.31).

Details of the system outfalls were provided by Natural Resources Wales in 2015. However these were not added to the model, as the initial testing indicated that Monks ditch was not receiving water from the floodplain and as such the calculation of how much water was not necessary. Similarly, the direct rainfall and inflows to the floodplain were not included.

Hawk Group were commissioned to undertake a survey of the Monks Ditch channel structures. This was undertaken in June 2016. The information was used to add the various bridges, sluices and culverts into the model.

As-built record drawings were obtained from Tata to describe the bridges and siphons present within the Llanwern steelworks boundary. These drawings date from the 1950's and the dimensions and levels converted to metric for this present study.

Record drawings and data were also obtained from Network Rail for the mainline railway crossing. This was added to the model near its upstream boundary.

2D model

The 2D domain was extracted from LiDAR data of the area, using a composite grid from several flights over the recent years (such is the extent of the domain that a single dataset was insufficient).

The domain covers the land between the coastline, the River Usk, and the mainline railway to the north.

The domain was split into two parts to reflect the east and west banks off the Monks Ditch. A 50m cell size was used in the model. This was intended sufficient to allow movement and storage of water across the Levels, yet minimise computational time. This combined 1D-2D model is reported on herein.

3.1.2. Simulations

Simulations were undertaken for the 1 in 100 year plus Climate Change (+CC), and for the 1 in 1000 year, 12 hour duration storms (summer profile). Model simulations were made by routing rainfall and flows against the MHWS tide.

The model was simulated in 1D-2D. Note that if any impact of the scheme could be restricted to the in-bank environment then the 2D domain would become obsolete. This lends itself to consideration of the lower order flood events less than 1 in 5 years.

3.1.3. Validation

The 1 in 5 year storm was tested to provide a pseudo-validation of the model for an event that likely to have been observed in the recent past.

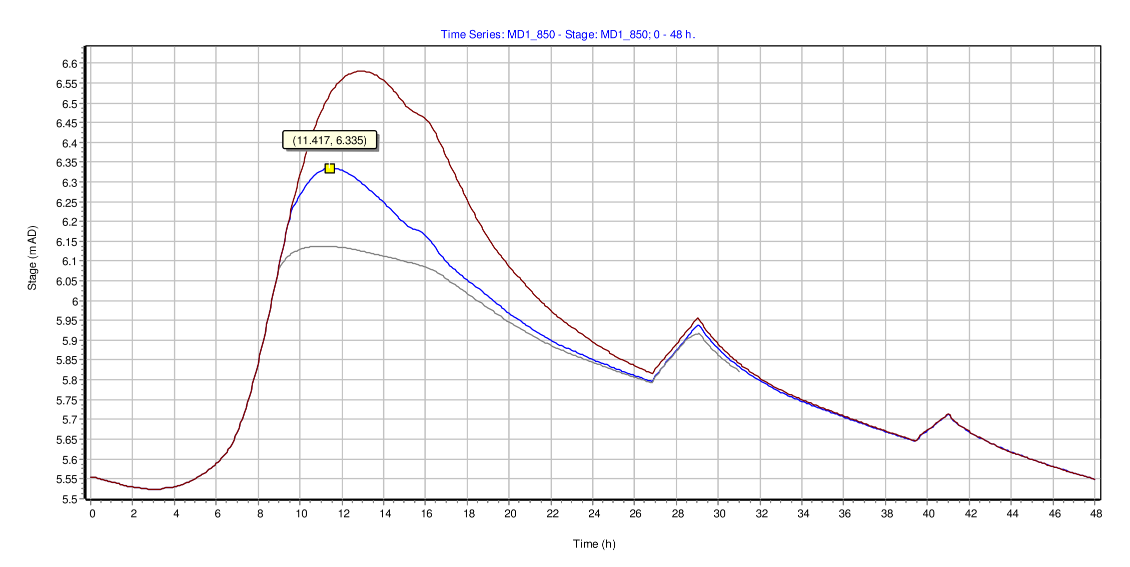
The model is not being used to define a flood level for a particular return period flood event. It is being used to determine the impact of the proposed Glan Llyn surface water drainage on the local flood risk and thus it is the change in flood level between pre and post project simulations that are important.

The simulation of a 1 in 5 year, 12 hour storm was undertaken using both the ADI and FAST solvers in Flood Modeller.

The results show that water levels alongside the stop board controls at Monks Croft Reen rise to 6.3m AOD, being sufficient to flood Broad Street Common road, which is substantiated by Natural Resources Wales. The FAST model gives a lower prediction at 6.14m AOD. However, both the 1D-2D peak-stage results are significantly lower than the former 1D only model, which predicted 6.58m AOD for the same event. This indicates the effect of the spill of water from the Monks Ditch into the surrounding fields.

In terms of timing and durations, the results show that water levels are predicted to rise above the notional trigger level of 5.82m AOD for 23 hours and 52 minutes. This is similar to the 1D only model, which predicted 23 hours and 35 minutes.

Figure 1 – Comparison of 1D and 2D model



Blue line = 1D-2D ADI model   Grey line = 1D-2D FAST model   red line = 1D only model

As expected, the attenuation of water caused by losses into the floodplain nominally increases the stage-duration data for the in-bank levels. However, this is not significant and will have only minor impacts on the proposals made in the previous note.

The 1D-2D model was also tested removing the inflows applied to the 2D domain, and the direct rainfall. The results on stage for Monks Ditch are identical, confirming that the condition of the floodplain has no impact on water levels in the Monks Ditch.

To simplify computation, all further tests have now been undertaken/repeated using the 1D-2D model with ADI solver, but omitting the directly applied flows and rainfall to the 2D domains.

3.2. With-project

The 'with project' model contains the proposed pumping stations for the Glan Llyn site. These provide two discharges into the Monks Ditch: from the west serving the residential development site discharging up to 500l/s; and from the East serving the commercial site, outfalling 250l/s. Hence a combined discharge of 750l/s was included in the with-project model.

The two pumps were included to provide a discharge into the Monks Ditch. They do not remove water from a representation of the development site, but instead form a flow boundary to the system. The pumped discharges were represented as inflows directly linked to the 1D network at two locations on the Monks Ditch (OS NGR 336673 187238; and 336778, 186933).

The model has been used to gain an appreciation of the fluvial hydraulics of the Monks Ditch and how the proposed pumped drainage system could impact on the flood risk situation in the locality.

3.2.1. Constant pumping scheme

To test the impact of the pumping and evaluate the need for any restriction on discharge, two abstraction (ABS) units were added to the model:

- Resi_pump residential pumped discharge 500l/s
- Busi_pump commercial pumped discharge 250l/s

The abstraction units represent the pumped inputs, adding water into the Monks Ditch based on a specified time series of inputs. The discharges were first simulated as a constant discharge. Hence the pumps remain on at all times and issue the 750l/s constant discharge into the Monks Ditch, regardless of conditions.

The constant pumping model was simulated for the dry weather flow (baseflow), and 5 year events.

Simulation of the dry weather scenario was also tested for a 24 hour simulation.

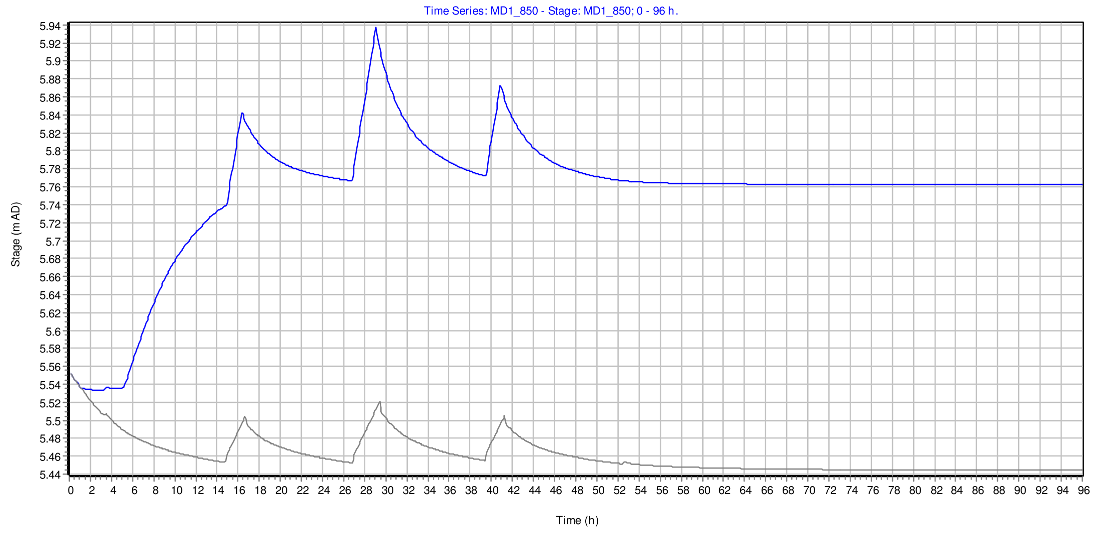
Results

Results for the dry weather flow indicate the impact of adding the new 750l/s into the Monks Ditch from Glan Llyn. Water levels were predicted to rise from 5.445m AOD to 5.763m AOD near the Whitson electricity substation, taken at the stop boards placed at the offtake into Monks Croft Reen. This is an increase of 318mm during periods not influenced by the tide.

The level on the stop boards preventing the discharge of water into Monks Croft Reen is at 5.82m AOD. Water levels in Monks Ditch above this level will spill into a culvert through the left bank of the watercourse and into the other system. This has been taken as a trigger threshold for comparison within the results.

The chart below further indicates that the higher spring tides enhance the rise, and during the peak tide modelled here, 6.50m AOD, water levels in the Monks Ditch rise from 5.52m AOD to 5.938m AOD, an increase of 418mm.

Figure 2 – stage hydrograph of dry weather flow at Monks Croft Reen boards



Blue line = with fixed pumped discharge Grey line = baseline conditions

The results of the fixed pumping confirm that unregulated pumped discharge from Glan Llyn could increase water levels in the Monks Ditch. This could be offset by lowering the main water level control sluice (Natural Resources Wales reference C32) at the Mireland Link Reen – so maintaining water levels in the Monks Ditch to the baseline when pumping.

However, it is also evident that during flood events, the Monks Ditch should not receive additional water until such a time that it can cope with it. This would require implementation of a controlled pumping regime, where the discharges are stopped during times of flood, over even during the higher tides. The chart in Figure 2 shows that the detriment caused during dry weather flow increases during the higher spring tides, and that a constant pumped discharge at such time, during dry weather flows, will trigger the discharge of water into Monks Croft Reen near the electricity substation (at 5.82m AOD). This result demonstrates that water levels in Monks Ditch are sensitive to tide level.

The results of the fixed pumping demonstrate that unregulated pumped discharge from Glan Llyn would increase out of bank water levels in the Monks Ditch if additional controls were not implemented. Further simulations were then undertaken to demonstrate that if the pumps were only operated when certain conditions permit, that any impact on flooding could be negated.

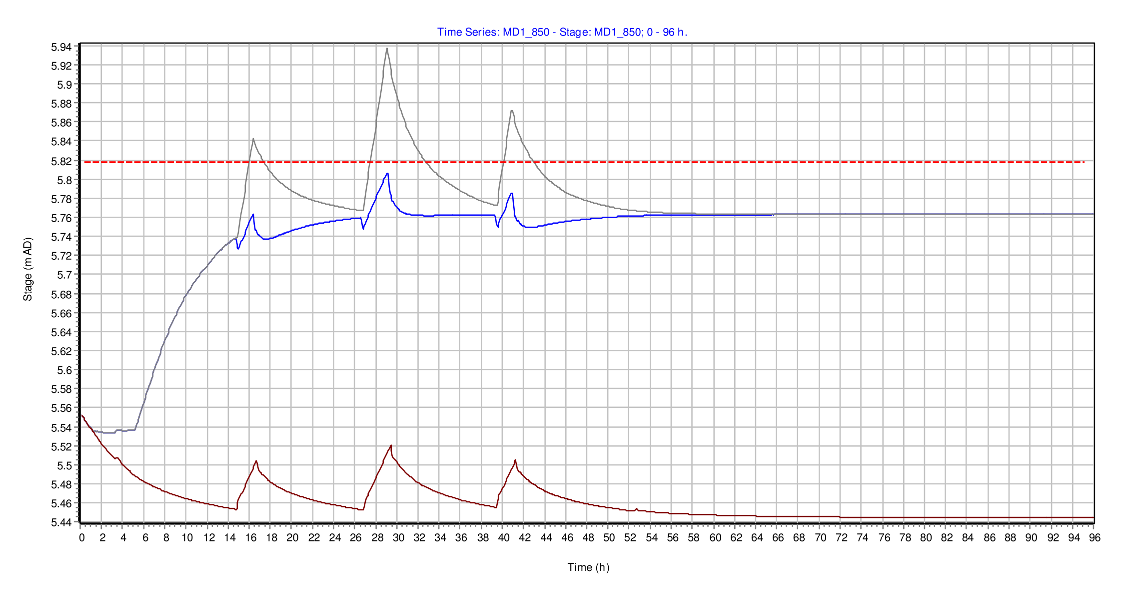
3.2.2. Tidal control

As the tide was predicted to impact water levels when above 6.0m AOD, a tidal control was added.

The abstraction units were modified to include control RULES specifying the discharges to be switched off during high tide and on for lower tides. The form of pump control (be it manual or electronic) is irrelevant here, but the key point is that a trigger level is dictating when the pumps are used.

A tide trigger level of 5.5m AOD was found capable of preventing the dry weather flow from rising above the Monks Croft Reen stop boards. This is indicated in Figure 3 below.

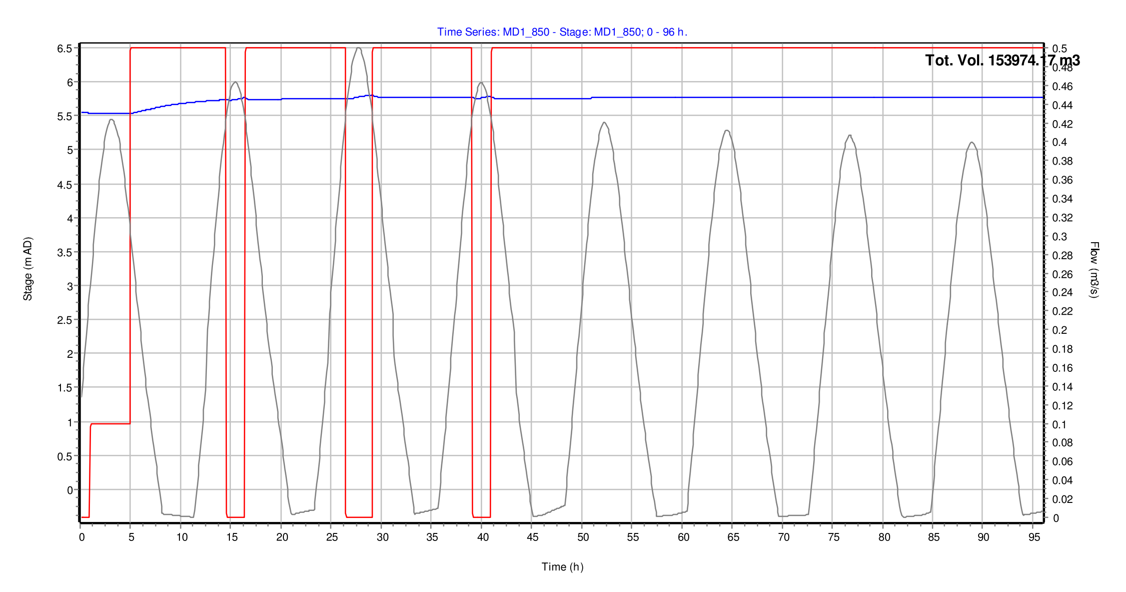
Figure 3 – stage hydrograph of dry weather flow at Monks Croft Reen boards



Blue line = tidally controlled discharge
Brown line = baseline conditions
Grey line = with fixed pumped discharge
Red line = Monks Croft threshold level

Figure 4, below, shows how the logically controlled pumped discharge from the residential site operated during the course of this dry weather event. The pumps were switched off during the high tide, and the discharge from Glan Llyn reverted to 0m^3/s. Once the tide receded beyond 5.5m AOD, the pumps switched back on again and the discharge resumes to 0.5m^3/s.

Figure 4 – stage and discharge hydrograph of dry weather flow at Monks Croft Reen boards



Blue line = water levels at Monks Croft Reen boards
Red line = discharge from residential pumps
Grey line = tide levels at outfall

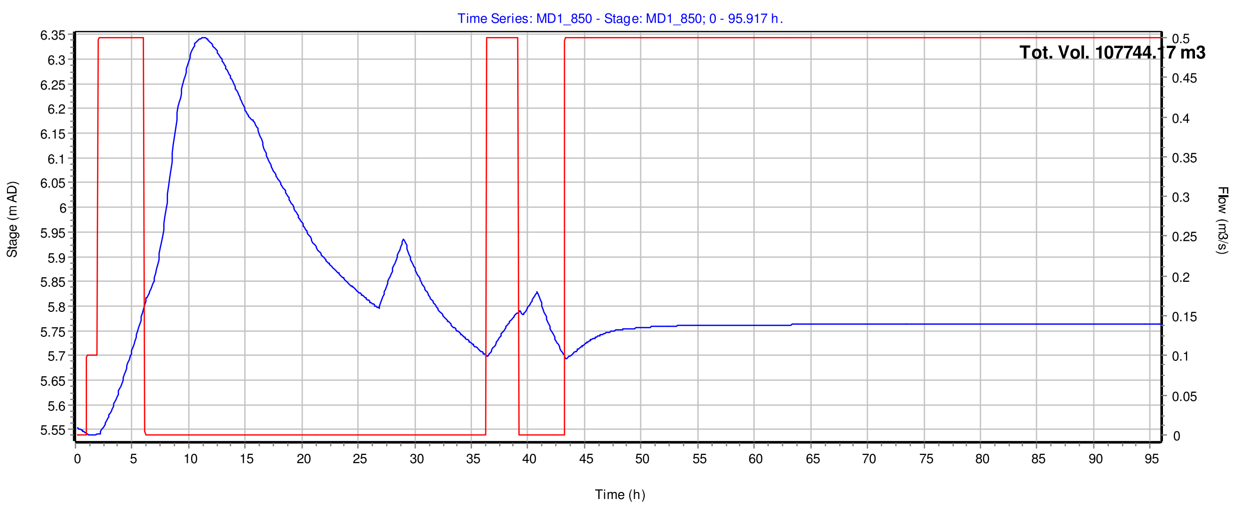
During this dry weather test, the pumps are unable to operate for a maximum period of 2 hours and 50 minutes.

3.2.3. Water level control

A second water level control was added to the abstraction units to switch off the discharges when water levels at the Monks Croft Reen stop boards exceed a nominal 5.80m AOD, and switches them back on when water levels there recede to a nominal 5.7m AOD. This is in relation to the stop board level of 5.82m AOD.

Figure 5 below indicates the water level response under those rules. Here the pumps remain switched off for a constant 30 hours, followed closely by a second period of 4 hours effected by the tide. Once the water levels recede, the pumps remain on.

Figure 5 – stage and discharge hydrograph of 1 in 5 year flow at Monks Croft Reen boards with fully controlled discharge



Blue line = water levels at Monks Croft Reen boards

Red line = discharge from residential pumps

The results show that the water level controlled discharge reduces the impact of the scheme. The detriment predicted at the peak of the flood (8mm) is a function of the pumped discharge taking up storage in the Monks Ditch before the flood event.

4. Monks Ditch sluice C32

The results of the controlled and fixed pumping demonstrate that a pumped discharge from Glan Llyn will increase water levels in the Monks Ditch. This is a result of additional (new) water being added to the watercourse, so increasing water levels by some 300mm. Furthermore, the result show that during prolonged periods of rainfall, existing water levels in Monks Ditch may remain elevated and prevent the use of the pumps at Glan Llyn (although up to a point, that water can be retained on the development site). A pumped discharge could be assisted by opening Natural Resources Wales' sluice C32 near the Mireland Link Reen, as would be undertaken today in order to evacuate flood waters from the Caldicot Levels.

By lowering the main water level control sluice (Natural Resources Wales reference C32) near the Mireland Link Reen – water levels in the Monks Ditch could be encouraged back to the baseline conditions and reduce the period of time when pumping was prevented.

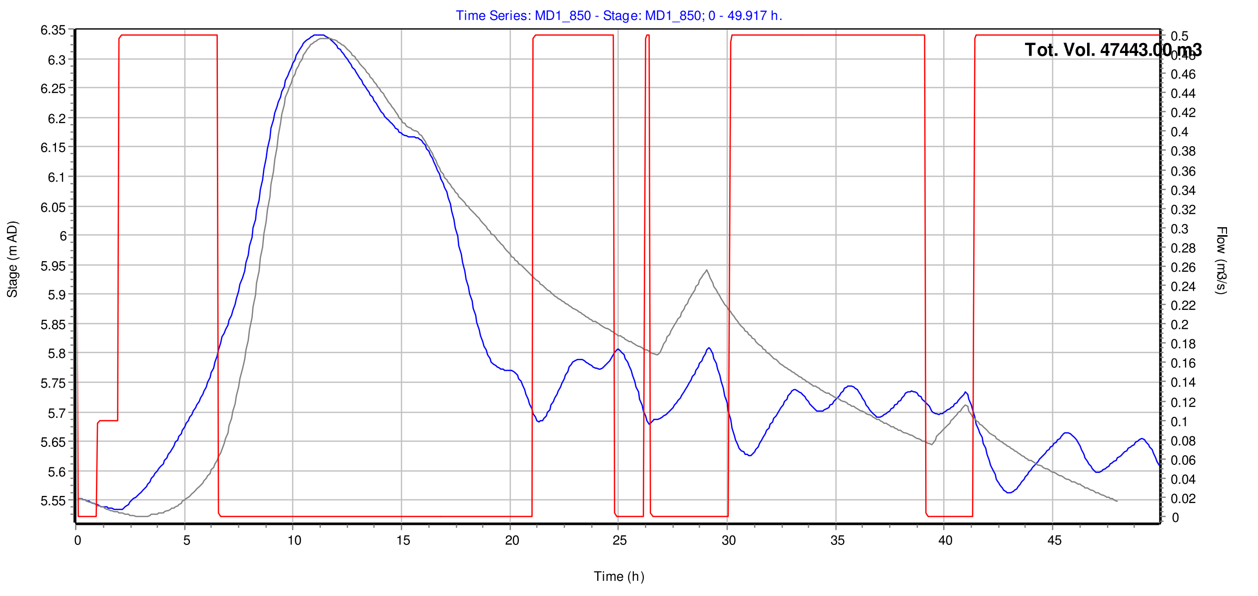
The above results show a dry weather increase in water levels of 318mm. Hence the gates would need to be dropped (or raised) by a similar amount to retain the status quo.

Sluice C32 is presently manually operated by Natural Resources Wales. If the option of using sluice C32, to increase the opportunity to pump from Glan Llyn, was pursued, then automation of the structure, to raise, or lower, one of the leaves in the twin leave sluice would be required.

Tests were then undertaken with the hydraulic model by adding control RULES to the modelled sluice to simulate an automated control. The RULES were set to open sluice C32 when water levels at Monks Croft Reen stop boards were greater than a nominal 6.0m AOD, and close the sluice when they recede below a nominal 5.45m AOD. As before, a 1 in 5 year event, 12 hour storm was used.

The results demonstrate that water levels in the Monks Ditch could be lowered to accept the Glan Llyn pumped discharges by opening or closing the sluice. In this test the pumps were inoperable over a longest period of 14 hours and 20 minutes and a combined 19 hours, saving almost 10 hours in comparison with the water level only control (30 hours).

Figure 6 – impact of automated sluice C32 refined control on water levels



Grey line = water levels at Monks Croft Reen boards under baseline conditions
Blue line = water levels at Monks Croft Reen boards with automated sluice C32
Red line = discharge from residential pumps

Use could be made of the C32 sluice, alone, to regulate water levels in Monks Ditch when Glan Llyn was discharging. However, as the work has indicated a tidal signal at the Monks Croft Reen stop boards caused by the tidelock and use of the sluice would not be able to prevent that. Furthermore, the water levels at the trigger location are enhanced by a fluvial component and use of the sluice would not prevent that.

5. Discussion

5.1. Volume for discharge

The discharges modelled here take no account of the finite volume of water to be released from the Glan Llyn site but instead assume an infinite volume of water for evacuation. Whilst the various charts show an extended period of time where water levels in the Monks Ditch remain consistently raised above the baseline levels, the volume to be discharged is in fact finite. As such, the pumps will not need to run indefinitely, and will switch off once water levels inside the development site are drawn down to acceptable levels.

Previous calculations undertaken by Rodgers Leask for the Glan Llyn drainage system indicate that a maximum design volume of 180,537m^3 is required to be discharged (1 in 100 year event with allowance for climate change). At a constant pump rate of 0.75m^3/s, this would take some 67 hours.

5.2. Recession limb

Clearly the period of time in which the Monks Ditch remains high has a direct consequence on the ability to pump water from Glan Llyn. Where water levels in the Monks Ditch remain high for a prolonged period of time, the site would, under these rules, be unable to discharge.

It should be noted that the ReFH model does not generate predicted flow data beyond the time where the rapid response hydrograph recedes to zero, leaving only the longer term baseflow component. For the 12 hour storm, this is predicted to occur at 22 hours. The simulations undertaken above assumed, arbitrarily, that the full hydrograph recession takes until 48 hours, whereupon the total flow in the watercourse returns to match that which is started with at 0 hours.

Simulations were undertaken to test the sensitivity of the results to the recession limb of the hydrograph.

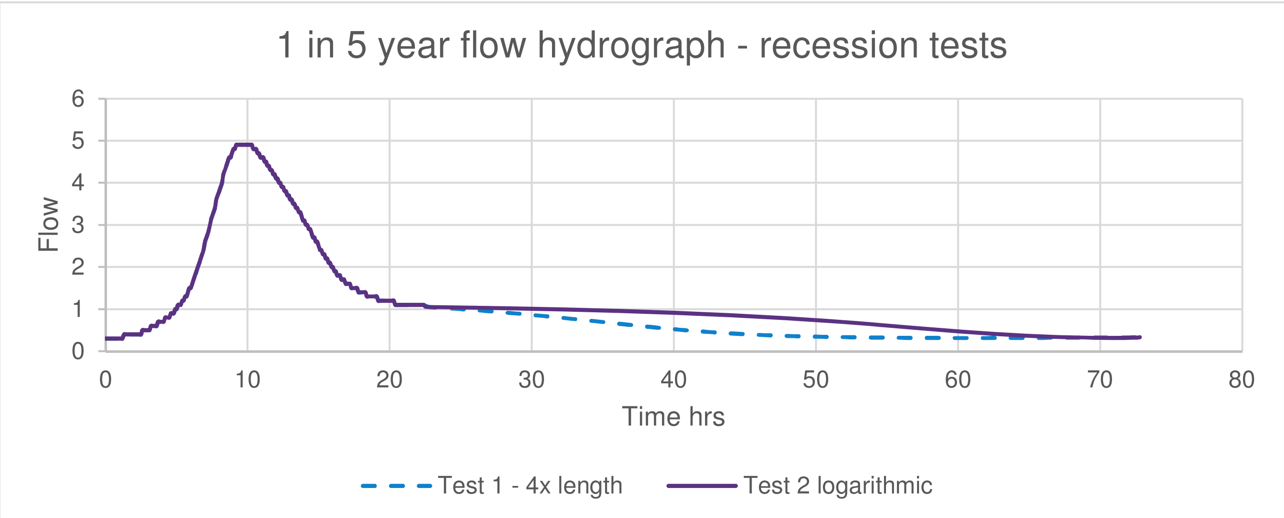
5.2.1. Test 1 – 4x recession period

The baseflow was predicted to peak at 16 hours, a baseflow recession taking four-times this at a further 64 hours, bringing the total hydrograph response to 72 hours, was tested. The ReFH baseflow was extended and mirrored about the peak and added to the flow-time boundary.

5.2.2. Test 2 – logarithmic recession

The baseflow was also tested by extending the length of time it remained elevated to 72 hours as above, but also by using a more exponential decay at in the final hours.

Figure 7 – flow hydrograph for different recession tests.

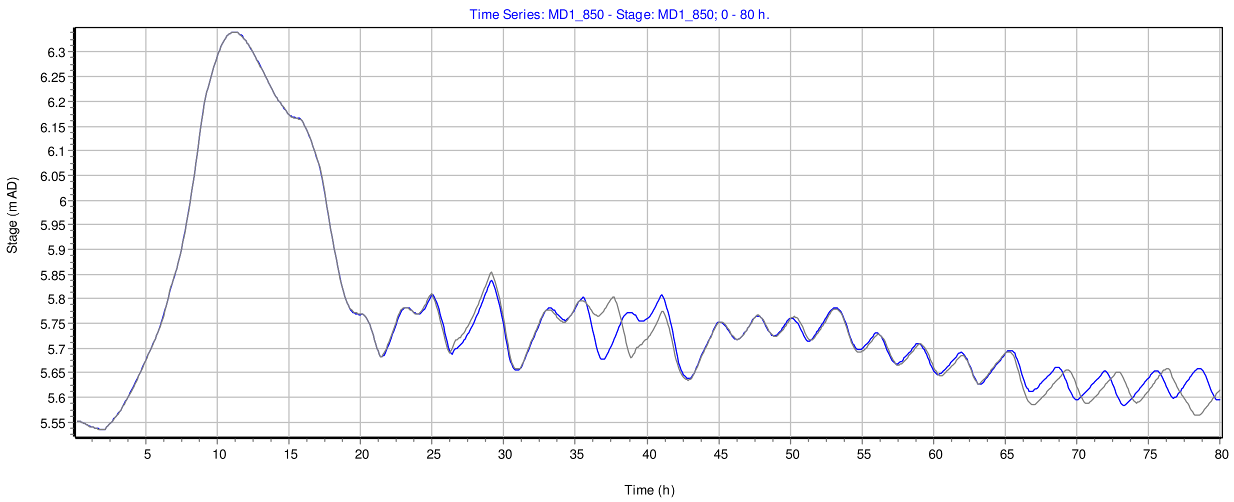


5.2.3. Results of recession limb tests

The results show that the assumed recession and 4x recession are almost identical, indicating that the model is insensitive to the small variation in flows at the bottom of the hydrograph.

Where the recession was elevated for a longer period of time in the logarithmic test, the results show little impact. Similarly there was little impact on the period of pump operation.

Figure 8 – Stage hydrograph for different recession tests.



Grey line = water levels at Monks Croft Reen boards with logarithmic recession
Blue line = water levels at Monks Croft Reen boards with 4x recession limb

6. Sequential storms

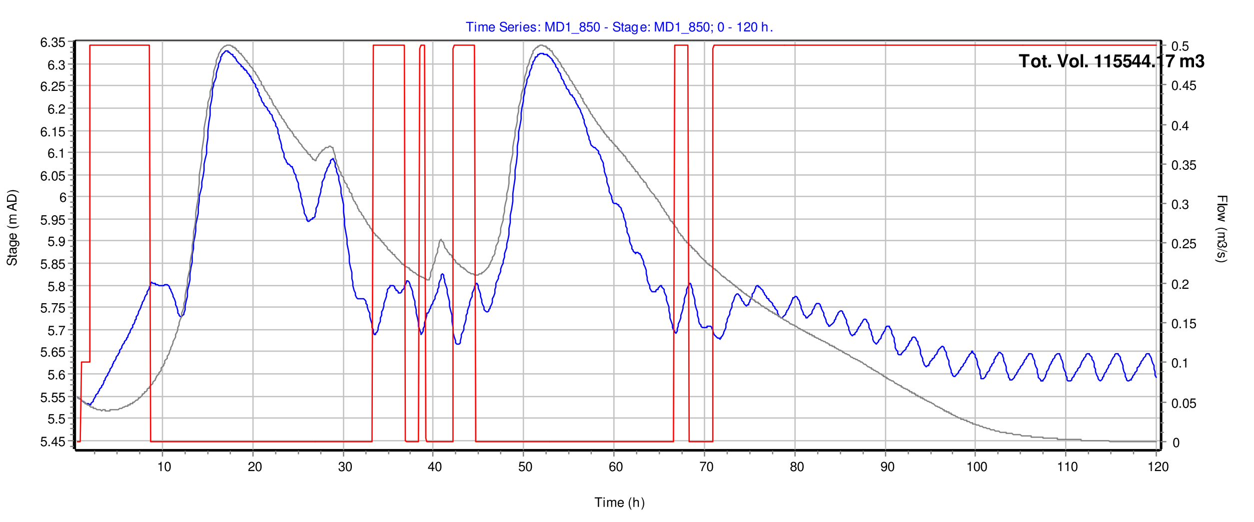
6.1. Back to back storms

Previous considerations had suggested the need to be resilient to sequential ('conveyor belt') storms. To test the impact of this, a back-to-back 1 in 5 year 24 hour summer flood was simulated in the model. Each is generated from 54.52mm of rainfall over 24 hours (total 109.04mm), precipitating 233,346m^3 onto the 214ha Glan Llyn site. This is a greater rainfall depth than the 1 in 100 year storm (~88mm).

In reality, the 142ha of permeable area will actually supply less water into storage – a value of 180,437m^3 has been derived for the 1 in 100 year storm with climate change by the drainage strategy.

The results, indicated on the charts below, show that water levels in the Monks Ditch would remain elevated for a long period of time, and that under the RULES implemented above, the pumps would be switched off for 24 hours 35 minutes in a single period, followed by a second period of 21 hours and 50 minutes.

Figure 9 – stage hydrograph of back to back 1 in 5 year 24hour storms at Monks Croft Reen boards with fully controlled discharge



Blue line = water levels at Monks Croft Reen boards
Red line = discharge from residential pumps
Grey line = Baseline water levels at Monks Croft Reen boards

The site masterplan includes for sufficient (250,650m^3) on-site surface water storage which can accommodate this prolonged rainfall. A further 148,350m^3 storage is also available on-site although reserved for tidal breach compensation. However, that could be opened for use on agreement from Natural Resources Wales.

It is clear that the Monks Ditch will recede, at some point, to water levels that can accept a pumped discharge. The uncertainty remains in how long that would be, and will depend on the rainfall.

Tests were next made using observed rainfall data, supplied by Natural Resources Wales.

6.2. Historic events

The full 15-minute rainfall record for the Natural Resources Wales gauge at Nash was obtained (2001 to present day). This large dataset was inspected to identify notable events. Two periods were identified and applied through the ReFH model as above.

These events were then simulated in the with-project model to evaluate the performance of the system and ability to discharge.

6.2.1. Winter 2015-2016

The recent winter was identified as having a specific period of wet weather, whereby a notable flood storage area at Cowbridge (near Cardiff) had impounded.

Rainfall data was obtained for the Collister Pill rainfall gauge and the event identified from 9 January 2016 over 60 hours duration. The rainfall was applied into a ReFH model to derive the contributing flows to the Monks Ditch. A scaling factor of 84% (based on the FEH Statistical results) was applied as with the design flows (derived following previous detailed hydrological analysis of the catchment). A peak flow of 6.6m^3/s was derived.

The standard tide curve was applied to the model. No observed tide data was sought and as such these results are indicative only of how Monks Ditch might have performed. However, the tests here are considering the pattern of rainfall and its impact on the ability to pump from Glan Llyn.

Figure 10 – January 2016 rainfall

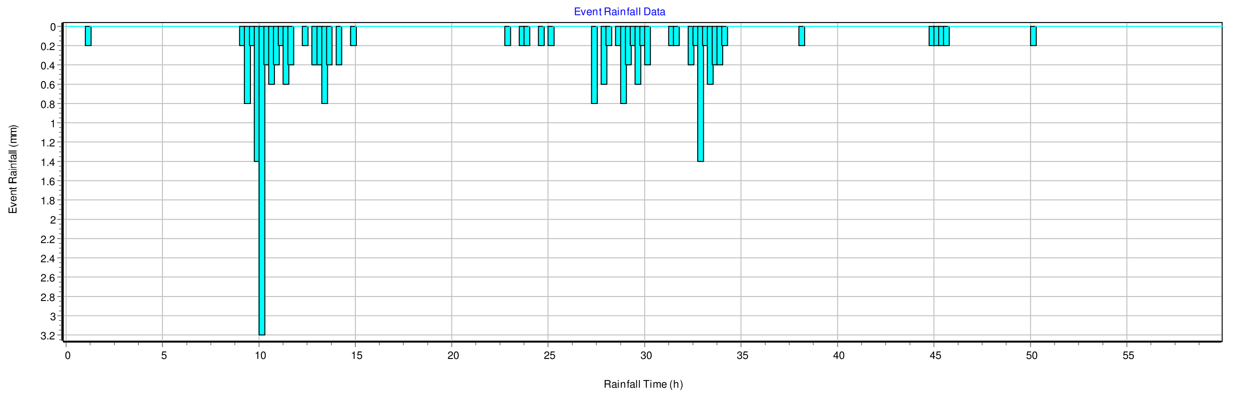
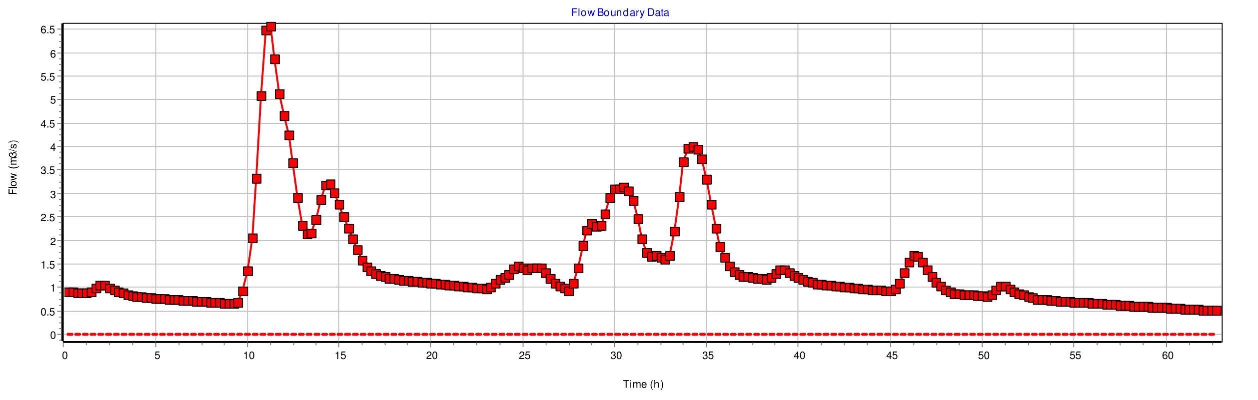
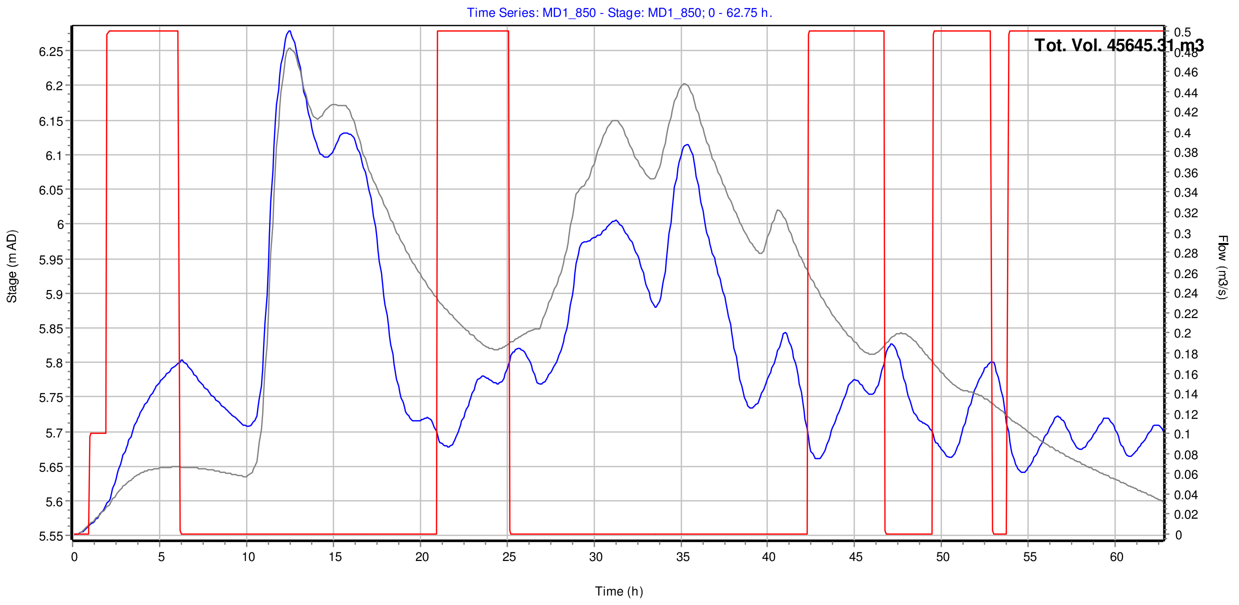


Figure 11 – Flows derived for January 2016



The results, shown in Figure 12, indicate that the proposed pumps would be switched off for 2 long periods over this event, being some 15 hours followed by a further 17 hours. The 4 hour interim period would be suitable for pumping and could evacuate 10,800m^3 in that time.

Figure 12 – stage hydrograph of January 2016 at Monks Croft Reen boards with fully controlled discharge



Blue line = water levels at Monks Croft Reen boards
Red line = discharge from residential pumps
Grey line = water levels at Monks Croft Reen boards under baseline conditions

6.2.2. Winter 2013-2014

This was found to provide perhaps the longest period of prolonged rainfall in the entire record. A period of some 83 days was used between 12 December 2013 and 5 March 2014, giving 535.8mm of rain over 2128 hours of data to simulate. A peak flow of 21m^3/s was determined for this rainfall.

Figure 13 – Rainfall record for Winter 2013-14

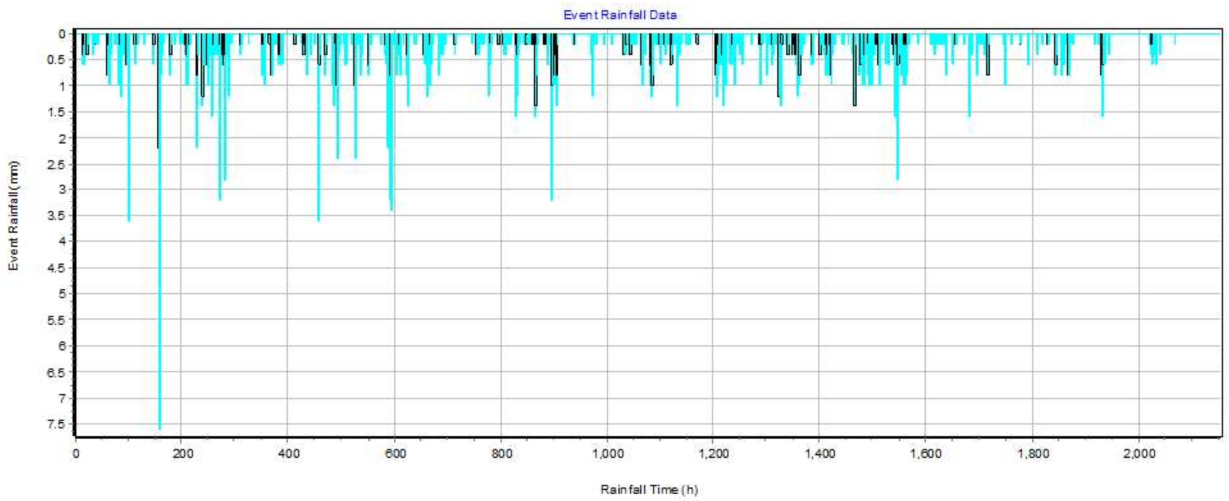
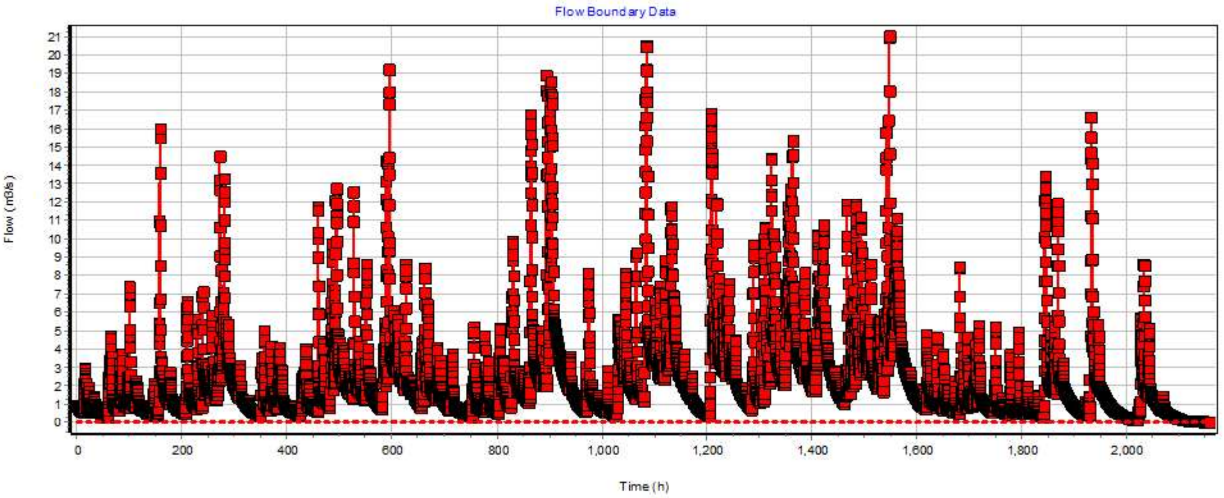


Figure 14 – ReFH predicted flows for Winter 2013-14



The hydraulic model became unstable at 1434 hours (just under 60 days). Time constraints on publishing this note meant that we were unable to stabilise the model and simulate the full period.

The results (Figure 15) indicate that the development would have been unable to discharge for numerous discrete periods. Up to 1000 hours of simulation, the pumps would be inoperable for longer periods of 86 hours, 119 hours and 174 hours (see bullets below).

Over the longest period of time the pumps would be switched off (828 hours to 1002 hours) some 53.2mm of rain would have fallen. Across the 142ha of impermeable site, this would have generated 75,544m^3 runoff. This would be stored within the provided 250,650m^3 on-site storage.

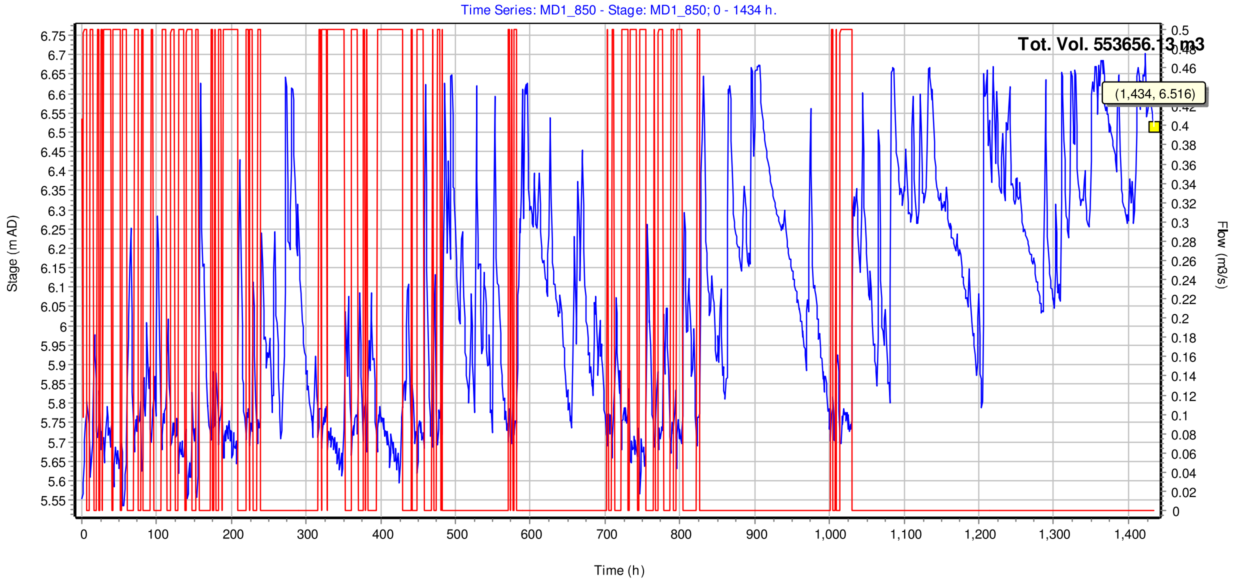
- t = 483 hours to 569 hours =86 hours 32.8mm rainfall 46,576m^3 runoff
- t = 582 hours to 701 hours =119 hours 41.2mm rainfall 58,504m^3 runoff
- t = 828 hours to 1002 hours =174 hours 53.2mm rainfall 75,544m^3 runoff

Whilst the pumps appear to be inoperable for long periods of time the volume of water accrued on the site appears manageable.

The results after 1000 hours are subject to the instability in the model. The prediction is for the pumps to be switched off for that entire period onwards where 130.2mm of rain fell in the subsequent 396 hours of simulation. That amounts to 184,884m^3 to be stored within Glan Llyn which can be accommodated by the site layout.

Over the 1430 hours of simulation the model predicted a total volume of discharge of 553,656m^3, against a rainfall of 429.6mm, or 610,032m^3 precipitated. The difference here being 56,376m^3 which would remain in storage. A review of how the water balance works is provided in Section 6.3.

Figure 15 – stage hydrograph of Winter 2013-14 at Monks Croft Reen boards with fully controlled discharge



Blue line = water levels at Monks Croft Reen boards

Red line = discharge from residential pumps

Further work will be needed to define the pumping regime, trigger levels and thresholds, and how the sluice C32 is operated but such is subject to detailed design and assessment. For example, the current assessment only allows for the C32 sluice to be opened up to 1m, but this could be opened further to help evacuate water from the Monks Ditch.

The results are open to error but give some confidence that the proposed system can be made to perform in these conditions.

6.2.3. August 2006

This was found to provide the most intense period of rainfall, with the 2 days between 17 August 2006 and 19 August 2006 giving some 69mm rainfall. A peak flow of 23m^3/s was determined for this rainfall.

Figure 16 – Rainfall record for August 2006

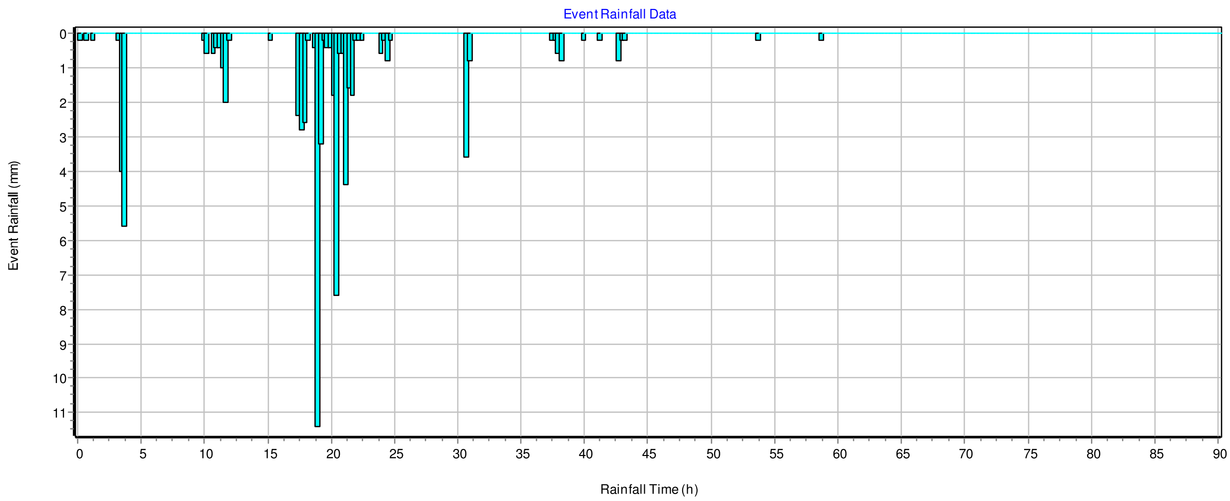
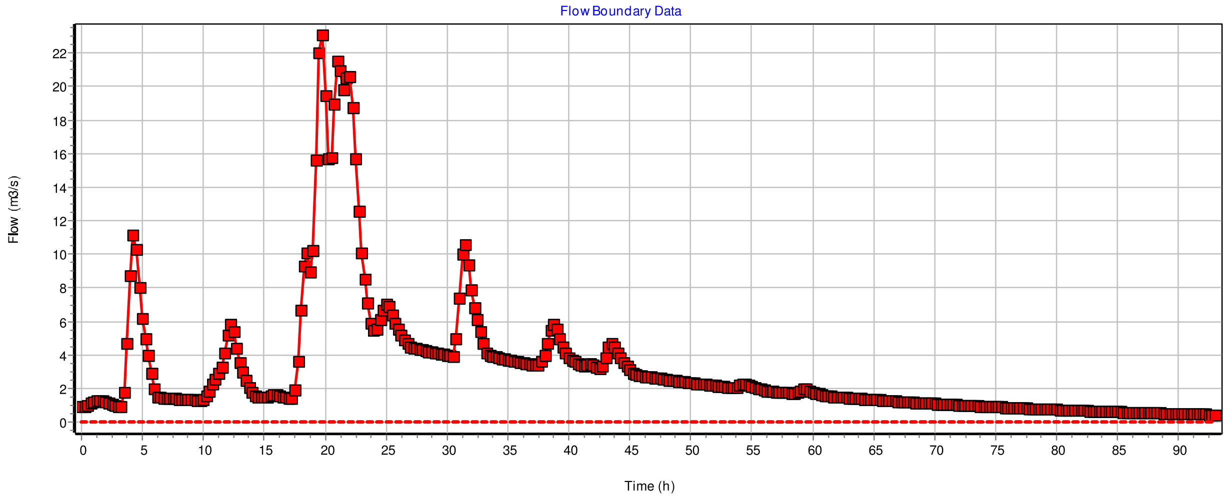


Figure 17 – ReFH predicted flows for August 2006

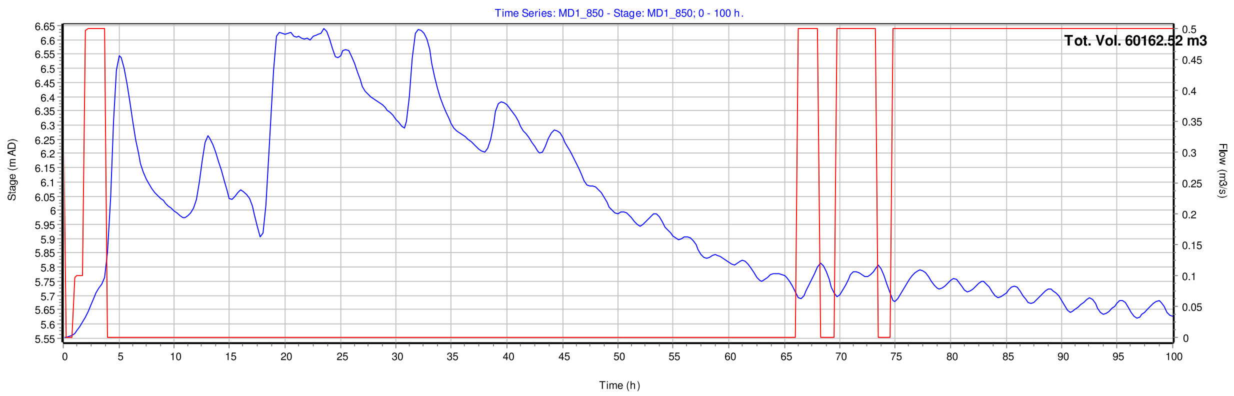


The results (Figure 18) indicate that the development would be unable to discharge for 62 hours during this event. At time 75 hours, the river levels recede and the pumps are switched on. These then stay on for the next 25 hours until the end of the simulation, and would be capable of discharging some 67,500m^3 in that time.

Over the period of time the pumped would be switched off (4 hours to 66 hours) some 58.6mm of rain would have fallen. Across the 142ha of impermeable site, this would have generated 83,212m^3 runoff. This would be stored within the provided 250,650m^3 on-site storage.

Hence the August 2006 event could be managed by the controlled system.

Figure 18 – stage hydrograph of August 2006 at Monks Croft Reen boards with fully controlled discharge

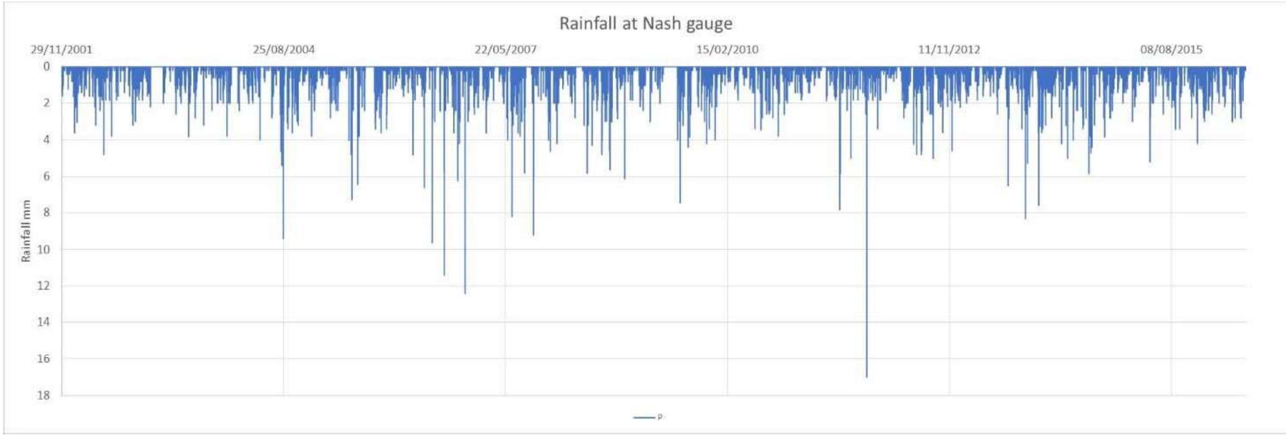


Blue line = water levels at Monks Croft Reen boards
Red line = discharge from residential pumps

6.3. Rainfall record analysis

The full period of record for the Nash gauge was considered and analysed to evaluate how the system may perform over a long term period. The record lasts 16 years from 29 November 2001 to present day.

Figure 19 – Rainfall record for Nash



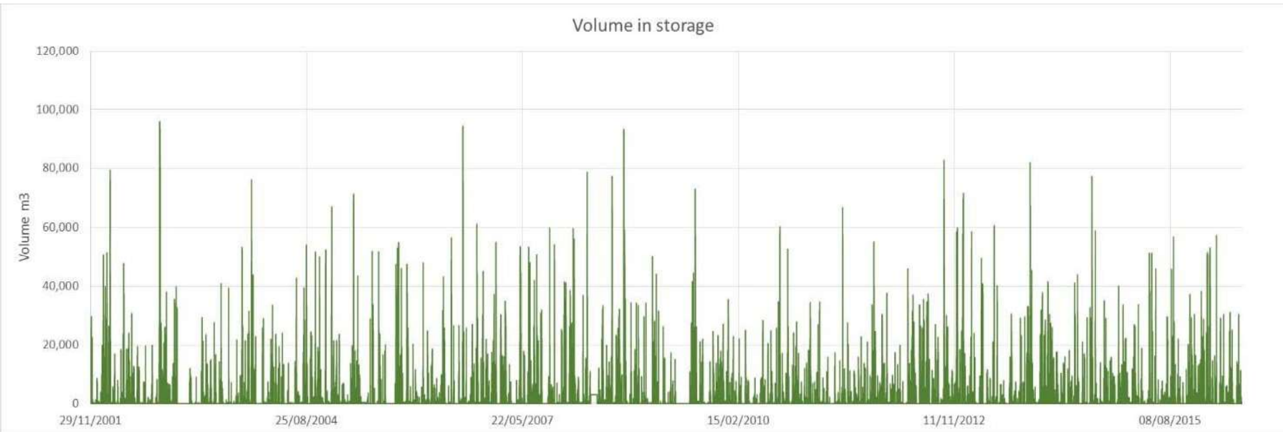
6.3.1. Water balance

An assessment was made to consider a water balance for the site, evaluating over time (for each 15 minute time step) the volume of rainfall falling on the site and the discharge from the pumps into the Monks Ditch.

In this simplistic assessment, it was assumed that no discharge from Glan Llyn would be made when it was raining, and that 750l/s would be pumped out when it was not raining (regardless of river conditions). An impermeable site area of 214ha was used.

The assessment indicates that the maximum volume held in storage, at any one time, would have been 95,921m^3 (in comparison to the 250,650m^3 available). Whilst a simplistic assessment, this indicates the system is robust when considering rainfall.

Figure 20 – Volume of water in storage under control discharge scheme



Seven separate occasions were calculated to generate a storage requirement of over 80,000m^3. It is noted that the maximum of 95,921m^3 is approximately half the drainage requirement for the 1 in 100 year storm with climate change. This suggests that events over the last 20 years have been far less severe than the design event.

The average storage requirement over this period was determined to be 1,627m^3, with this being exceeded some 2,584 times in the record.

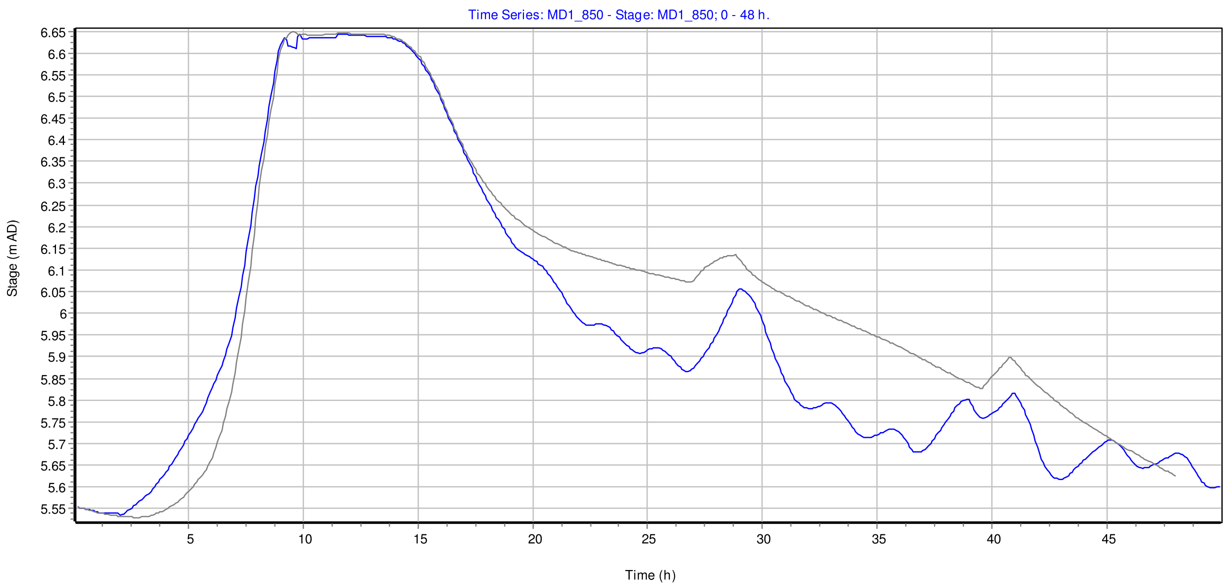
Over the 16 years there were some 7,703 separate occasions when the storage was not empty covering 75,926 data points (each of 15 minutes). There were 512,053 data points. There were 436,127 data points where the storage was 0m^3, amounting to over 12 years total time: this indicates that the storage would be empty (available) 85% of the time.

7. Extreme events

The model was tested with the 1 in 100 year, 1 in 100 year with climate change allowance and 1 in 1000 year floods. Both baseline, and pump & sluice control option, were tested. The charts showing the impact of the sluice and pump control system on water levels for these three events are shown below.

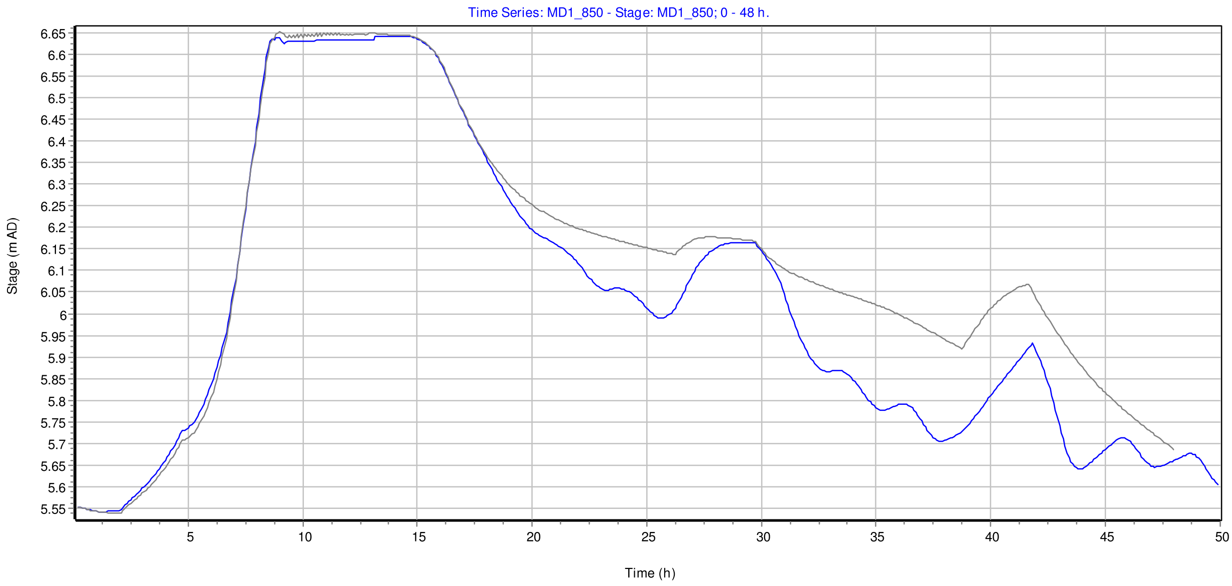
Whilst the charts suggest similar peak water levels, as high lows are being passed onto the floodplain, the focus of these is on the change from the baseline to the with-project stage. In all cases the proposed controlled discharge scheme, with operational control of sluice C32, reduces water levels in the Monks Ditch.

Figure 21 – stage hydrograph for 1 in 100 year event



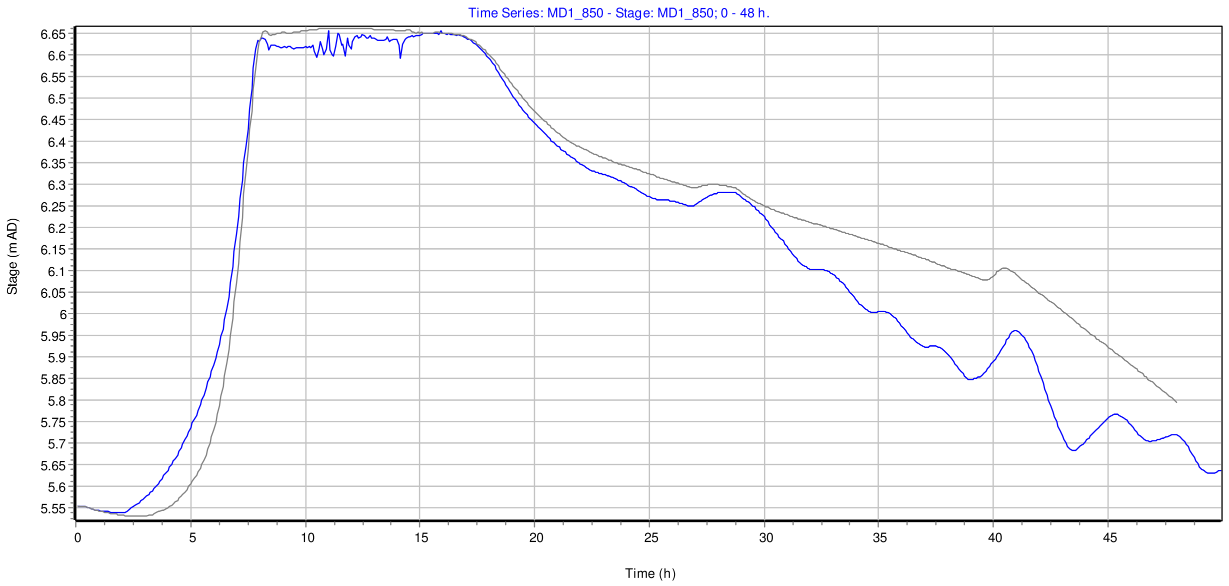
Grey line = baseline conditions
Blue line = with pump and sluice control

Figure 22 – stage hydrograph for 1 in 100 year event with climate change (and sea level rise)



Grey line = baseline conditions
Blue line = with pump and sluice control

Figure 23 – stage hydrograph for 1 in 1000 year event

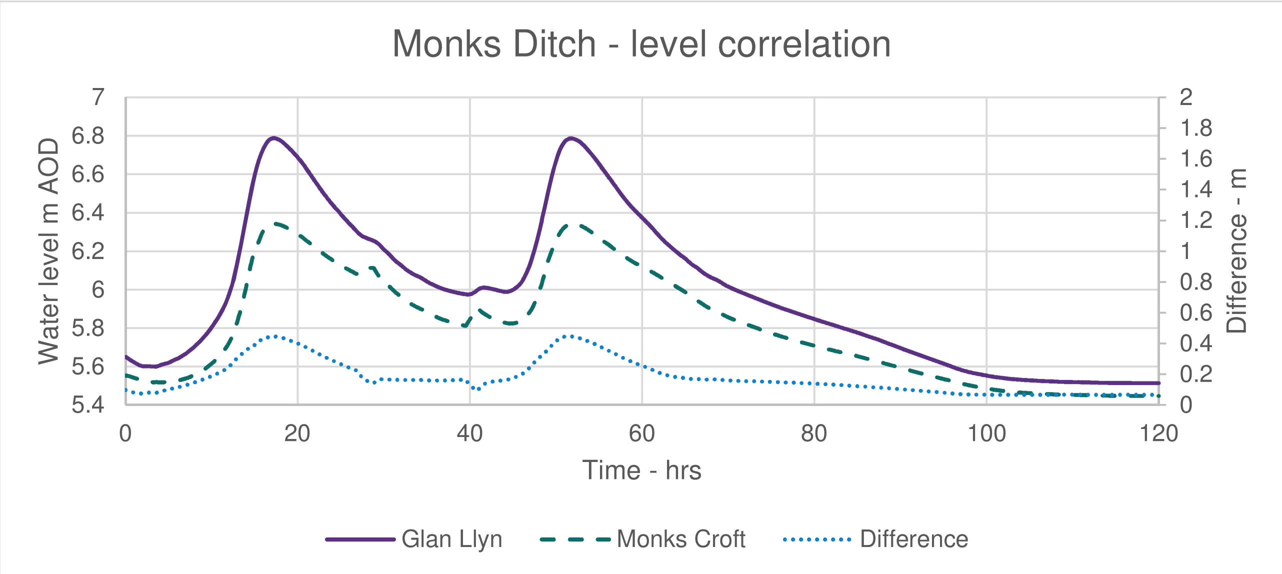


Grey line = baseline conditions
Blue line = with pump and sluice control

8. Site control

The above work looked at controlling the surface water pumps using water levels triggers off site. This provided the best form of control given the constraints in terms of flood risk. Consideration was also made to using only controls adjacent to the site – i.e. in the Monks Ditch through Glan Llyn.

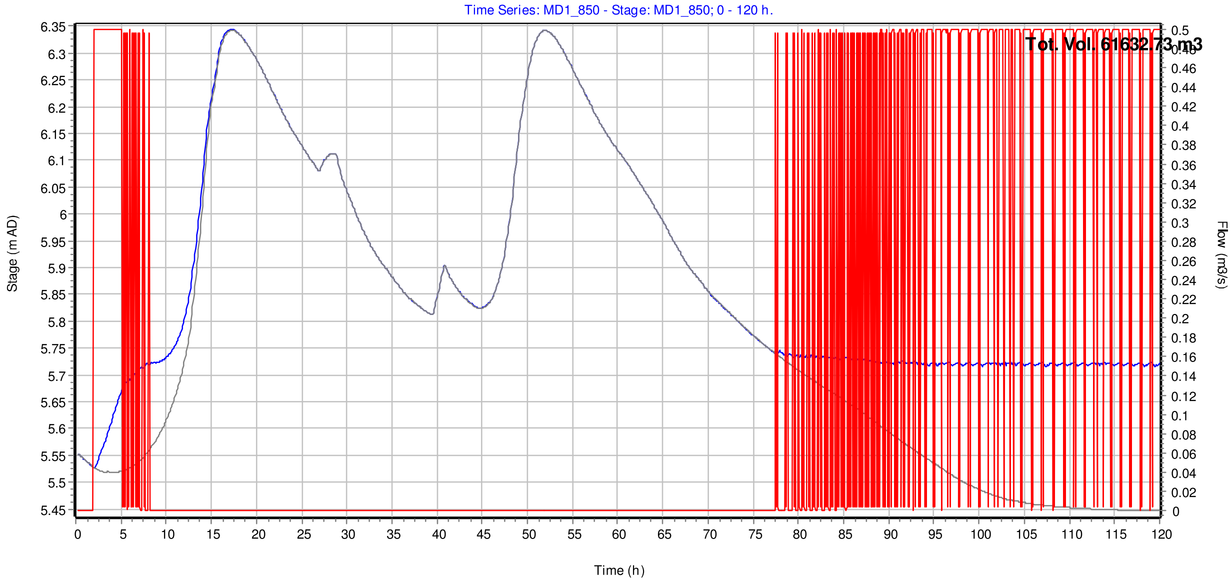
The modelling indicates the correlation between the site and the critical trigger point at Monks Croft Reen, by the Whitson electricity sub station. The results, presented in the chart below, show a varying difference in water level between the two locations with an average difference of 178mm, with a maximum difference of 447mm and minimum difference of 65mm.



Should the decision be made to control discharges from Glan Llyn based on this local water level alone, the system would have to be precautionary to ensure no detriment was caused downstream. As such, if the pumped discharge was automatically switched off when water levels in the Monks Ditch, alongside Glan Llyn, were at 5.885m AOD, we could be confident that water levels at Monks Croft Reen were below 5.82m AOD, being the critical threshold at that location. Given the variable correlation, it may be that levels at Monks Croft Reen were actually well below the threshold at 5.438m AOD (5.885m – 0.447m), and that the pumps could actually remain on.

The hydraulic model was applied to test this logical control, using back-to-back 1 in 5 year 24 storms.

The result of the model tests indicate that water levels could be managed at Monks Croft Reen through this approach. However, the pumps would be switched off for some 69 hours during a single period of the event, which is longer than the total 46 hours (two periods of 24hr + 22hr) for the remote water level with remote sluice control option.



Blue line = water levels at Monks Croft Reen boards
Grey line = baseline water levels at Monks Croft Reen boards
Red line = discharge from residential pumps

8.1. Efficiency of control options

The back-to-back 1 in 5 year 24 hour storms provides 109.01mm of rainfall onto the 214ha site. This is a total rainfall volume of 233,346m^3. The 142ha of impermeable area supplies a lesser volume to the storage areas via the drainage network. A simple adjustment here suggests something of the order of 154,837m^3. It is clear that the site is physically able to store these volumes, with 250,650m^3 being designed into the masterplan.

The table below indicates the length of time, from the start of the same event, for the drainage system to be able to discharge a certain volume of water into the Monks Ditch. It assumes that once the pumps operate at the end of the event that they remain on until the water is discharged.

Here 154,837m^3 could be discharged in 114 hours with the remote water level and sluice control, but up to 143 hours for the local level control. This is an extra 29 hours.

Table 1 – Time to discharge a given volume (hours)

Scheme	40,000m^3	60,000m^3	80,000m^3	154,837m^3	233,346m^3
Water level control	92.50	99.92	107.33	135.00	164.00
Water level and sluice control	71.42	78.83	86.25	114.00	143.00
Site correlation control	97.25	106.00	114.67	143.00	172.00

The 29 hours of pumping (between t=114 hours and t=143 hours), at 750l/s, equates to a volume of 79,344m^3 that could then be pumped from the system if required.

Thus a site based control could be implemented, but the draw backs are the risk of having to hold more water on site (not being able to pump) and thus increased chance of follow on event when storage is unavailable. Remote controls, and remote use of Sluice C32, lessen this risk.

9. Implementation

The concept of the controlled pumped discharge will require construction of several assets, some outside of the Glan Llyn site:

- Water level gauge and telemetry trigger at the Monks Croft Reen stop boards;
- Tide level and inland gauge with telemetry at the tidal outfall near Goldcliff;
- Optional automated C32 Mireland sluice control; and
- Control system with on site (Glan Llyn) pumping station and pumps.

An added complication arises at Mireland Link Reen. At this location manually operated stop logs (Natural Resources Wales reference C43) are used to feed water into the Mireland Reen system. Any discharges from Glan Llyn would pass extra water into Mireland Pill Reen when their stop boards were lowered, and could lead to flooding at Whitson and Portland.

As a result, the scheme would need to include for a new automated tilting weir in series with the existing Mireland Link Reen stop boards. This is not optional, and would be required to prevent flooding in Whitson and Portland. This new tilting weir would need to be:

- raised during any pumped discharge from Glan Llyn, with an override facility for Natural Resources Wales to be able to pass water into the Mireland system;
- lowered when the pumps were stopped, such that the Natural Resources Wales stop board then retain control of the feed water; and
- telemetered to the pumping station on Glan Llyn.

It should be noted that the testing has only considered a discharge of 750l/s, or 0l/s. In practice, the pumps could be controlled with variable discharge up to the maximum. In this sense, the pumps could be brought to site to match the growing development, reaching the maximum capacity on completion of the work. Alternatively, the pumps could be installed to provide the long term capacity, yet run at lower speeds in the short term whilst the site is partially developed.

A higher discharge rate may be achievable, so evacuating the Glan Llyn system quicker, by refining the control RULES tested in the modelling. However, recall that any water pumped into the Monks Ditch is ‘new’ water and that this might need to be offset elsewhere.

Whilst consideration could be given to implementing this in a staged approach, the gauges, telemetry, and C43 tilting weir will be required from the outset. Only the capacity of the on-site pumping station could be phased over time in conjunction with the development. An interim manual system is unlikely to be suitable.

It may be possible to use water levels in the Monks Ditch adjacent to the Glan Llyn site as a simple trigger, by correlating with water levels at Monks Croft Reen: however, there is no fixed correlation between water levels by Glan Llyn and at Monks Croft Reen, with a weaker tidal signal and less attenuated flood response at the site. This will limit the efficiency of a simple system which would therefore have to operate on a precautionary basis – leaving the site pumps off when at all in doubt. However, implementation would be simpler, and at a lower cost.

All matters for implementation will require permitting, agreements, and approvals from Natural Resources Wales. This will require consultation with Natural Resources Wales over the operation of any control system and the modification of any of their existing assets. These changes are not something that Natural Resources Wales can be expected to undertake themselves, although works to Mireland sluice C32 could be implemented in partnership to provide mutual benefit.

10. Conclusion

In conclusion the results of the assessment indicate that the revised surface water drainage strategy for the Glan Llyn development can be implemented with a regulated pumped discharge which would manage the flood risk in the Monks Ditch.

The work has demonstrated that:

1. A new discharge of 750l/s would add some 300mm to water levels in Monks Ditch.
2. By controlling when the pumps discharge into the Monks Ditch (using a combination of tide level and threshold trigger level at the Monks Croft Reen stop boards), and closing Mireland Link Reen, that increases in water level can be accommodated in-bank and without spilling water into the Caldicot Levels.
3. By operating Natural Resources Wales sluice C32, that water levels in Monks Ditch can be further controlled to increase the period of time, during adverse weather, when the pumps could be operated.

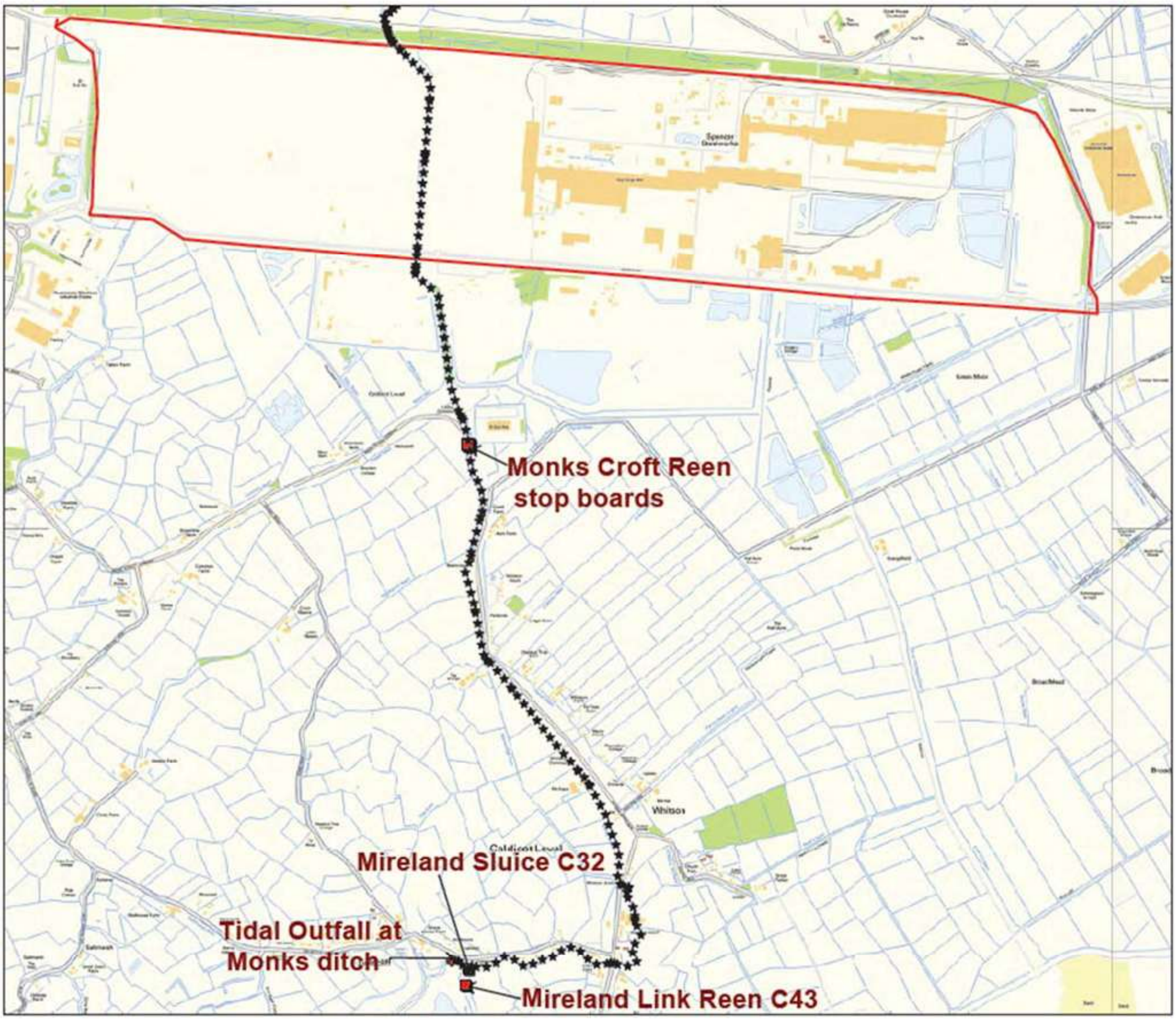
There are clearly many variants and options for a logical control system looking after the pumping and water level regime. These would need to be developed in conjunction with Natural Resources Wales and their Drainage District. However, the work undertaken as described in this technical note confirms the technical capability of this solution and proves that such a system can work.

The storage provided by the site affords acceptable consequences with respect to flood risk being able to store sufficient water whilst the proposed pumping system is switched off during adverse weather. The controlled pumped discharge into Monks Ditch provides acceptable consequences along that watercourse, and it can be managed/modified over time. It is noted that there are numerous flood risk receptors along the watercourse, not least the various conurbations at Whitson.

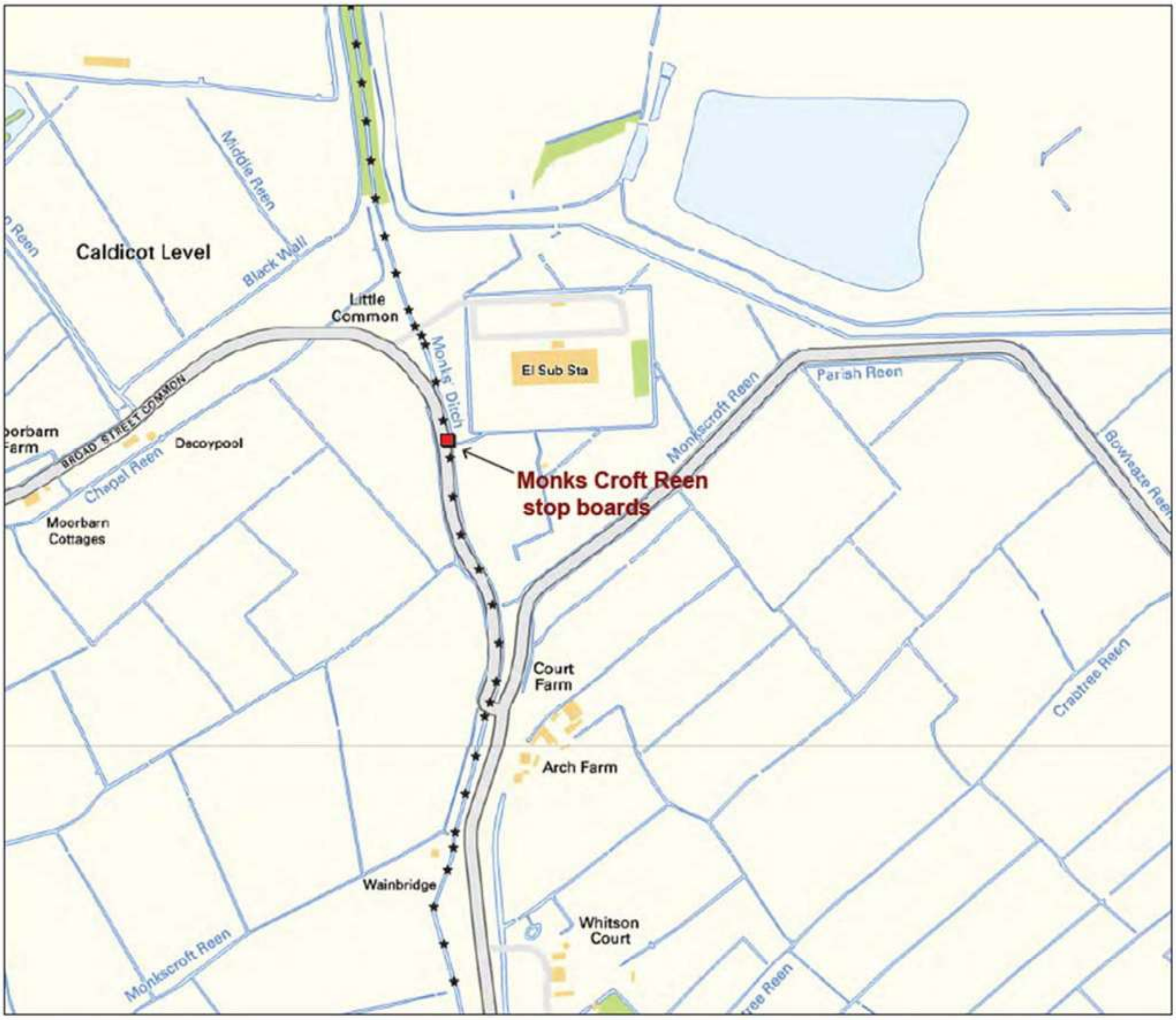
It is concluded that the proposed pumped drainage system for the Glan Llyn is suitable for the site and can be implemented without detriment to the water level management system of the Monks Ditch and Caldicot Levels.

Appendix – Location plans

Model nodes and key locations



Monks Croft Reen stop board – threshold trigger location



Tidal boundary – structures