NEWPORT STEAM REFORMING PLANT

Documentation in support of an Environmental Permit Application

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1 Non technical summary

This document is presented in support of an application for an environmental permit under the Environmental Permitting (England and Wales) (Amendment) Regulations 2013 (SI 2013 No 390). The permit application relates to the proposed installation of a hydrogen plant to be located on part of an existing site operated by Solutia UK Limited in Newport.

The overall site is owned and managed by Solutia UK Limited who manufacture a range of chemicals. Solutia are currently installing a Therminol 3 plant to produce heat transfer fluids for use in solar panels and power stations. This plant has a substantial requirement for hydrogen, which it is intended will be supplied by the proposed hydrogen plant avoiding the need for tankered deliveries.

The operation of the hydrogen plant and its immediate area will be the responsibility of BOC Group Limited. The plant is intended to primarily supply the Solutia Therminol 3 process, although there is also a prospect of commercial sales from tanker filling. The tanker station facility also provides a back up supply, via tanker deliveries from BOC's Margam site, for the Solutia operations should the hydrogen plant not be operational.

The selected process for hydrogen production is steam methane reforming, which is considered to represent best available technique for this particular application. The natural gas feedstock is available via the Wales & West utilities network from the Regional Transmission System.

The plant intended for installation is an existing process which has been operational at the Roche Vitamins (UK) Limited site at Dalry. The plant has been operated at this site on a similar basis to the intended operation at Newport for over ten years. The plant has become available due to a reduction in demand at the site. The plant has been decommissioned and is currently undergoing inspection and refurbishment prior to relocation to Newport. It is anticipated that installation at Newport will commence in early 2014 and will be complete around July 2014.

The experience of operation at the Dalry site provides a wealth of pertinent information for this application and is referred to throughout in order to demonstrate environmental impact.

The process generates relatively small quantities of solid and liquid wastes and also emits gaseous species to air. The typical solid waste is generally office and maintenance items which are managed within the existing site disposal system for recovery and recycling where possible. Occasionally there will be a need to dispose of spent catalyst or sorbent. These activities are undertaken by specialist contractors. In accordance with industry standards these materials are treated and recovered where possible, with disposal to landfill being a last resort. Small, but regular quantities of used lubricating oil are generated and are removed from site, treated and recovered by a specialist contractor. A continuous stream of boiler blow down is produced and routed to the existing site water treatment facility. The amount is negligible in comparison to the overall site water treatment burden. Emissions to air are via high level release points and are minimised as far as possible by process control and abatement measures. The environmental impact of these emissions has been assessed to be low.

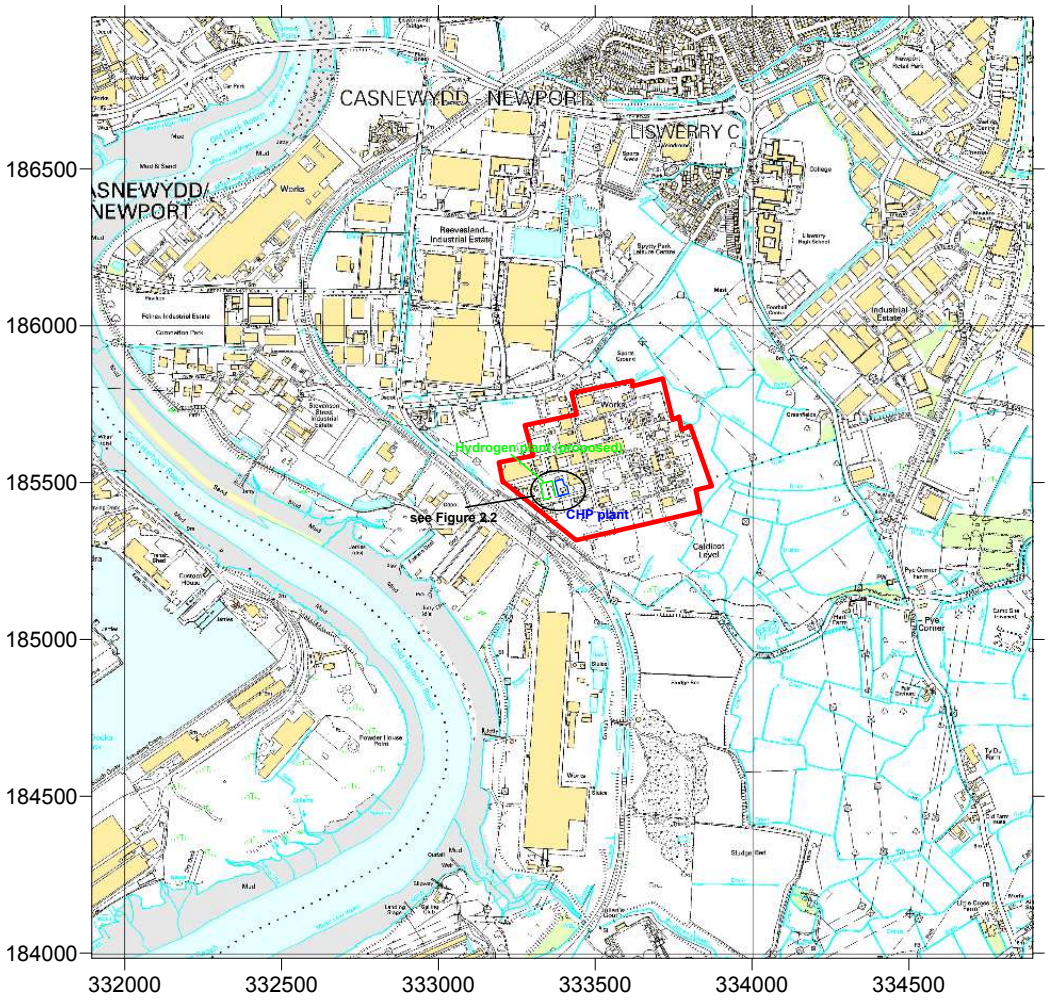
The following document provided details on the process and its operation and management and assesses the associated environmental risk and discusses how the process meets the requirement for compliance with best available technique.

2 Installation overview

2.1 Solutia site location

The Solutia UK Limited, Newport site is situated on the Caldicot level, which comprises a flat expanse of mainly agricultural land with some industrial and retail developments approximately 3.5 km south east of Newport city centre. The site occupies 128 hectares, 41 of which are used for chemical manufacturing operations. The area forms part of the flood plain of the lower river Usk and Severn estuary, the western boundary lying approximately 400m from the river Usk as shown in Figure 2.1. The site is at an elevation of approximately 7m above ordnance datum (AOD). The approximate National Grid Reference is 333560 185576.

Figure 2.1 Solutia UK Limited site location



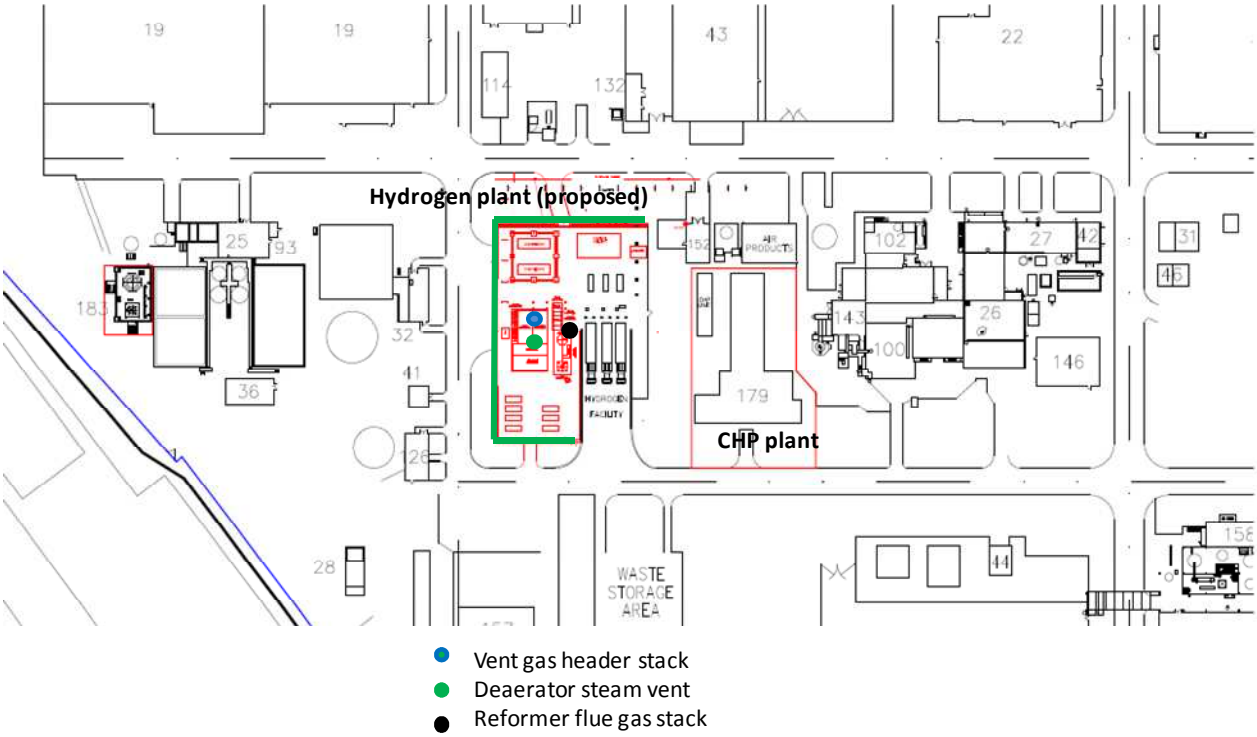
The site is located within 10km of a several potentially sensitive sites. Sites of special scientific interest (SSSIs) comprising the Gwent Levels are within 1 km to the west with various other SSSIs such as the Newport Wetlands and Severn Estuary within 5 km to the south. The general habitat is discussed in more detail in 14.2

There are several industrial developments around the site boundary with the closest being around 200 m to the south west. The nearest residential properties are around 500 m to the east on Nash Road at Greenfields. There is an estate of about 150 homes at a distance of around 800 m to the north east of the proposed site on Traston Road/Nash Road.

2.2 Proposed hydrogen plant location

The proposed location of the hydrogen plant is close to the western edge of the site boundary near to the existing combined heat and power (CHP) plant as shown in Figure 2.2. This provides further separation from both the nearest commercial building and closest residential housing.

Figure 2.2 Location of hydrogen plant



The proposed plant will occupy a relatively small part of the overall site and will have a relatively low visual profile. The three stacks serving the plant are summarised in Table 2.1. It may been seen that the highest stack is around 16 m which is around a third of that of the existing CHP plant stack (40 m).

Table 2.1 Hydrogen plant release point conditions

Discharge	Stack diameter (m)	Stack height (m)	National grid reference
Reformer flue gas	0.4	10.5	333343 185472
Deaerator steam vent	0.05	8.2	333341 185479
Vent gas header	0.15	16.2	333347 185482

3 Application overview

This document is presented in support of an application for an environmental permit under the Environmental Permitting (England and Wales) (Amendment) Regulations 2013 (SI 2013 No 390). The permit application relates to the proposed installation of a hydrogen plant to be located on part of an existing site operated by Solutia UK Limited in Newport.

The overall aim of the document is to assess the environmental impact risk of the process as specified in horizontal guidance note H1 and to demonstrate how the process and its management meets the requirements for best available technique as discussed in sector guidance note EPR 4.03. It also provides the mandatory site condition report application and accompanying detailed baseline assessment in accordance with horizontal guidance note H5.1

Sections 4 to 13 follow the general headings in EPR 4.03 and describe the process, its management and potential impact on the environment. These sections are heavily influenced by the historical data and experience available from 10 years' plant operation at the Dalry site. As such it is possible to present clear evidence to demonstrate many of the points made and conclusions drawn.

In Section 14 the releases to air are assessed to determine their significance, largely in respect of air quality standard attainment. This is particularly important here as the site is located relatively close to a number of sensitive receptors and as such it is necessary to demonstrate the level of risk associated with the releases to air.

Section 15 is a summary of the environmental risk assessment undertaken following the format in H1.

Section 16 follows the format of EPR 4.03 to demonstrate how the proposed plant complies with the requirements for best available technique.

The general arrangement of this document is summarised in Table 3.1 showing how the environmental risk assessment and BAT assessment references the information within this document.

In sections 15 and 16 the specified requirements of risk and compliance with BAT are tested against the process operating characteristics and management systems proposed in order to determine level of risk and compliance with BAT. For each of headings specified in H1 and EPR 4.03 a conclusion is made regarding how the plant compares with the general indicators for risk and indicative BAT. In this case it is concluded that environmental impact risk is generally low to insignificant and BAT requirements are met. There are therefore no improvements recommended. However the process operation and management system has been developed through continuous refinements based on experience both at Dalry and at similar plants elsewhere. It is expected that this will continue during operation at Newport to ensure that best practice is applied to ensure effective operation and management of the plant.

The Site condition report application is presented in Section 17 and references the detailed baseline Phase 2 site condition report which is provided in Section 18. This provides an assessment of the condition of the site prior to installation and may be used as a reference point at the time of permit surrender to determine any site deterioration and required remediation due to the permitted activity.

Table 3.1 Arrangement of assessment

Section heading		Environmental Risk Assessment	BAT Assessment
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4.2	Process selection		16.2.1, 16.2.4
4.3	Process optimisation		16.2.1, 16.2.5
4.4	The steam methane reforming process		
4.5	Main process flows		
4.6	Operating and maintenance		16.2.3
4.7	Process control system		16.2.6
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5	**Releases and environmental impact**		
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5.2	Point source releases to land and water	15.2	16.3.2, 16.3.3
5.3	Fugitive emission to air	15.1.3	16.3.4
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5.6	Noise	15.1.2	16.3.6
6	**Process management**	15.1	16.1.1
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6.2	Plant management at Newport		
6.3	Environmental management at Newport		
7	**Efficient use of raw materials and water**		16.1.4, 16.2.3
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8	**Avoidance, recovery and disposal of waste**		16.1.5, 16.2.7, 16.2.2
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8.3	General waste		
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9	**Energy use and efficiency**		16.1.3
9.1	Energy consumption		
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11.2	Measures to reduce risk		
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12	Decommissioning and site restoration		16.2.1
12.1	Decommissioning		
12.2	Site restoration		
13	**Emissions inventory**		
13.1	Point source emissions to air	15.3	16.2.6
13.2	Compliance with limit and benchmark values		16.3.7
14	**Impact assessment**		
14.1	Policy context and assessment criteria		
14.2	Local area and sensitive receptors		
14.3	H1 assessment of releases to air	15.3	
14.4	H1 assessment of photochemical ozone creation		
14.5	H1 assessment of global warming potential	15.5	

4 Description of installation

4.1 Introduction

Hydrogen is produced using the method of natural gas steam reforming. In the process, natural gas is desulphurised and then passed through a reformer, where at high temperature in the presence of a catalyst, hydrogen and carbon monoxide are formed. The stream then flows through a shift converter where the carbon monoxide is oxidised to carbon dioxide and more hydrogen is formed. The gas is then cooled, principally by heat exchangers, which pre-heat the natural gas entering the reformer or raise steam. The gas then passes through a pressure swing adsorption (PSA) unit, which removes the carbon dioxide and carbon monoxide to give a pure hydrogen stream. The resulting side stream of carbon monoxide, carbon dioxide and some hydrogen is used as fuel in the reformer furnace.

The product from the process is hydrogen with a small amount of impurities. Table 4.1 summaries the contractual impurity tolerances and typical plant performance.

Table 4.1 Product impurities

Species	ppmv (Contractual)	ppmv (Typical)
Methane (CH_4)	2.0	< 0.5
Carbon Monoxide (CO) and Carbon Dioxide (CO_2)	2.0	< 0.5
Oxygen	5.0	< 1.0
Nitrogen (N_2)	80.0	< 20
Water (H_2O)	8.0	< 0.5

The plant arrangement selected for this application is considered to provide the most effective means of producing hydrogen for this particular application bearing in mind the available processes and their various arrangements. Evaluation of the options for this application and the subsequent process optimisation is described in sections 4.2 and 4.3.

4.2 Process selection

BREF[1] recognises several alternative routes to hydrogen production which could be considered:

- Steam reforming of light hydrocarbons such as naphtha
- Partial oxidation of heavier hydrocarbons
- Coal gasification
- By-product of processes for other chemicals or refinery processes

On a smaller scale, processes that are feasible are:

- Electrolysis of water
- Methanol disassociation
- Ammonia disassociation

This section examines the alternative processes.

4.2.1 Steam reforming of light hydrocarbons

The steam reforming process is capable of converting many hydrocarbon liquids and gases to synthesis gas by techniques similar to the proposed process for Newport. Essentially the hydrocarbon is desulphurised, heated to typically 800-870°C and reacted with steam in the presence of a suitable catalyst: Based on a naptha feedstock the overall reaction is:

$$C_nH_{(2n+2)} + 2n\ H_2O \rightarrow CO_2 + (3n+1)H_2$$

In practice the reforming process is a two stage equilibrium process, the first stage being formation of carbon monoxide along with hydrogen and the subsequent water gas shift reaction to convert the carbon monoxide to carbon dioxide, producing a further mole of hydrogen per mole of carbon monoxide reacted:

$$CO + H_2O \rightarrow CO_2 + H_2$$

The methane steam reforming process produces 0.25 moles of carbon dioxide per mole of hydrogen generated. As the hydrocarbon chain length increases the ratio of CO_2 to H_2 approaches 0.33 (ethane reforming 0.29 and C_6 "naphtha" 0.32). In terms of environmental considerations therefore the reforming of methane is preferred to using higher molecular weight hydrocarbons. Additionally, use of liquid hydrocarbon feed stocks is likely to increase the complexity of the facility (requiring storage tanks, pumping arrangements etc) and hence the capital cost. Naphtha is generally a more expensive feedstock than natural gas.

4.2.2 Partial oxidation

The partial oxidation of hydrocarbons using steam and oxygen is established process technology and is used commercially. The process route may be used for converting a wide range of hydrocarbons, from methane through to heavy industrial fuels to produce synthesis gas.

The partial oxidation of natural gas is potentially economically competitive with natural gas steam reforming where high carbon monoxide to hydrogen ratios and high synthesis gas pressures are desired. The oxidation process also allows for feed stock flexibility, as heavier hydrocarbons may be utilised.

The partial oxidation of methane would generally be governed by the reactions.

Partial oxidation $CH_4 + \frac{1}{2}O_2 \rightarrow CO + 2H_2$

Shift conversion $CO + H_2O \rightarrow CO_2 + H_2$

Overall $CH_4 + H_2O + \frac{1}{2}O_2 \rightarrow CO_2 + 3\ H_2$

In principal this would give a ratio of 0.33 moles of carbon dioxide per mole of hydrogen produced. For hydrogen production, the carbon dioxide would subsequently be released to atmosphere. The process is more likely to be suitable to methanol synthesis than hydrogen. Additionally more energy is required when compared with reforming and a supply of oxygen is required.

Whilst this route may be used with a variety of feedstocks, including residual oils, it tends to be used only where there is a surplus of residual oils and a shortage of hydrogen.

The process also suffers from the general increase in sulphur levels, typical of heavier hydrocarbons compared with natural gases or light naphtha.

In consequence there is increased potential for release of pollutants to the environment, including:

- Carbon (soot)
- Sulphur compounds
- Sour water streams
- Reduced energy efficiency

4.2.3 Coal gasification

It is also feasible to produce synthesis gas and hence hydrogen from coal via the coal gasification route. Modern techniques are derived from the town gas process and coal gasification is a well established technology.

The technology is of particular interest where natural gas and oil are scarce but coal is abundant. A major proponent of coal gasification and gasification technology in general is SASOL in South Africa where it plays a major part in the production of synthetic gasoline and intermediates for the chemical industry.

There are however, major environmental issues associated with coal gasification. The more obvious environmental aspects are:

- Coal handling
- Ash
- Particulates
- Sulphur compounds
- Energy requirements

Putting in effective environmental controls to mitigate these pollutants results in the process being uneconomic in situations where other feedstocks are readily available.

4.2.4 Electrolysis of water

The least costly and most abundant raw material for the production of hydrogen is water. However, electrolysis, although simple in concept, is generally the most expensive route to hydrogen. The technique is primarily used on a small scale for low hydrogen demand situations where low cost electricity is readily available e.g. hydroelectric schemes

The main problem is that under the prevailing conditions, the power used to generate hydrogen is 3 to 5 times more expensive than fossil fuel derived energy. Additionally the predominant source of electricity in most industrial countries, including the UK, is fossil fuel. In consequence, whilst the process is clean at point of use, there are environmental disadvantages on the generation side.

The electrolytic process is considered not to be a commercially or environmentally viable option for this application.

4.2.5 Methanol dissociation

The commercial production of methanol is via the steam reforming process with conversion of the synthesis gas to methanol.

It is feasible to reconvert the methanol to hydrogen.

There is however no advantage either economically or environmentally in producing hydrogen via this route as additional processing and re-reforming stages would be required. Additional flue gas would be generated. There would be a need to deliver, store and handle methanol, which would require extra environmental safeguards to minimise environmental impacts.

The one advantage to this process route to hydrogen may be where small quantities of hydrogen are required, particularly in discrete/remote locations.

4.2.6 Ammonia dissociation

This process involves the splitting of ammonia into a mixture of hydrogen and nitrogen via an endothermic reaction using a nickel-based catalyst.

As with the methanol route, the main commercial route to ammonia is via steam reforming of hydrocarbons, particularly natural gas, to produce synthesis gas. The hydrogen is separated from the synthesis gas and subsequently reacted with nitrogen, abstracted from air.

There is again no commercial or environmental advantage of this route. The environmental disadvantages stem from the adverse environmental properties of ammonia, particularly associated with transport, handling and storage. Extensive precautions would be necessary for safety and environmental reasons.

4.2.7 Selection of natural gas steam reforming

The selection of the steam reforming of natural gas entails the most efficient use of natural gas and has the least adverse impact on the environment. The releases to air, water and land are minimised. In particular, there are no significant liquid hydrocarbon inventories or releases. Under normal circumstances the only releases to the atmosphere arise from the de-aerator vent and the reformer flue gas.

Table 4.2 summarises the indicative carbon dioxide releases from the processes considered.

Table 4.2 Performance of hydrogen production processes

Process	CO_2 to H_2 molar ratio	Fuel Ratio (molar)	Total CO_2 emitted mol/ mol H_2 produced
Natural gas reforming	0.25	0.277	0.567
Naphtha reforming	0.32	0.285	0.605
Partial oxidation	0.33	0.3	0.63
Coal gasification	0.53	0.3	0.83
Electrolysis	0	0.772	0.772

It is considered, in line with the general conclusions of the draft BREF[1], that natural gas steam reforming is the most environmentally effective hydrogen production process for this particular application.

4.3 Process optimisation

The key steps governing the optimisation of the selected process for the Newport hydrogen plant are:

- Natural gas steam reforming stage
- Selection of a single stage high temperature water gas shift reaction
- Use of pressure swing adsorber system (PSA) to recover a high purity hydrogen stream.

The process design is optimised for this combination of process steps, based on initial optimisation and subsequent refinement during 10 years' operation at Dalry.

4.3.1 Steam reforming

Natural gas is used both as feedstock and as fuel to the reforming furnace. The total utilisation of natural gas establishes the carbon dioxide burden for the reforming process. Carbon dioxide is generated directly by firing of natural gas or by the rejection of the carbon element in the reaction process.

The use of PSA to recover hydrogen at a high purity requires purge gas to regenerate the adsorption bed. Around 15% of the synthesis gas is used in purging. Optimisation involves use of the PSA tail gas as the primary fuel for the reformers, reducing significantly the natural gas fuel demand.

4.3.2 Shift conversion

Two types of conversion process are generally considered:

- High temperature (HT)
- Low temperature (LT) shift reactions

Different catalysts are required for these reactions, as summarised in Table 4.3.

Table 4.3 General properties of shift conversion catalysts

Active Components	Temperature Range (ºC)	Comments
HT- Iron oxide (chromium promoted)	340-600	Sulphur resistant
LT- Copper Zinc	175-260	Easily poisoned with sulphur Damaged by condensate Expensive

With the development of PSA technology modern plants can rarely justify the inclusion of a low temperature shift stage. The superior performance of promoted HT shift catalysts is realised from:

- Increased CO conversion
- Lower temperature operation
- Lower steam ratio
- Longer catalyst life

It should be noted that some concerns exist with shift catalysts. Methanation reactions may occur, resulting in methanol formation. Under certain situations, the Fischer Tropsch (FT) reaction involving higher saturated and unsaturated hydrocarbons may also occur. The methanol reaction is more likely in the LT process due to the specific nature of the catalyst. The FT reaction is less likely in the HT process.

The two-stage shift process was considered essential when the older hydrogen recovery methods were employed. The carbon dioxide was scrubbed out using hot potassium carbonate or proprietary amine solvents providing a hydrogen purity of around 98.2% and the residual carbon monoxide and carbon dioxide required conversion to methane by reheating to 315ºC in the presence of a methanation catalyst.

The proposed hydrogen plant has therefore been designed with a single stage of high temperature carbon monoxide shift catalyst that reduces the carbon monoxide concentration in the synthesis gas to 3.9 mol % (dry). This residual carbon monoxide is subsequently removed from synthesis gas in the PSA hydrogen purification stage and is recycled as furnace fuel in the off-gas.

The plant could have been designed to achieve a lower residual carbon monoxide content (typically 0.4 mol % dry), by the inclusion of a second low temperature stage of carbon monoxide shift. A two stage (HT+LT) shift system would increase the conversion in the synthesis to give approximately 3.8% more hydrogen for the same quantity of feed gas than a single HT shift. However the loss of the heating value of the additional carbon monoxide converted, which would otherwise have contributed to the fuel, has to be compensated for by burning extra natural gas in the furnace.

The overall affect is that for the same hydrogen product rate, the total natural gas consumption is reduced by less than 1% of that required for a single stage shift design. On the equipment side, the reformer furnace would be slightly smaller and there would be the extra LT shift vessel, which requires a start up heater and circuit. The LT shift copper based catalyst is expensive and sensitive to the presence of trace poisons in the gas.

Consequently it is considered that the selection of the single stage HT shift process is optimum for the configuration involving PSA recovery.

4.3.3 **Pressure swing adsorption**

The PSA process is used in virtually all situations where high purity hydrogen (>99%) is required.

The process works on the principal that hydrogen has a weak affinity for adsorption, whereas larger molecules such as carbon monoxide, nitrogen, carbon dioxide, methane, water and light hydrocarbons are easily adsorbed. They may therefore be efficiently separated from the hydrogen.

Hydrogen recovery is temperature dependent. The lower the inlet temperature the higher the hydrogen recovery. The optimum inlet temperature is in the range 10-30ºC. In consequence air-cooling needs to be supplemented by trim cooling using cooling water as a medium. Where ultra-high purity hydrogen is required, it may be necessary to include a water chilling stage to cool the synthesis gas to below about 15°C. This is not a requirement for the hydrogen purity necessary for the proposed Newport installation.

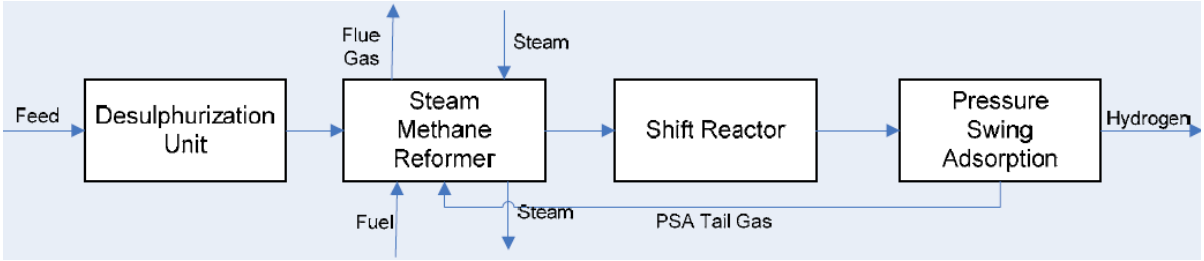
Regeneration of the adsorption bed requires depressurisation, followed by a hydrogen purge. Whilst yield of hydrogen is apparently low (typically 80-85%), the tail gas is used to reduce natural gas fuel firing by up to 90%. In consequence on a total natural gas consumed basis (fuel plus feed) recovery levels are acceptable.

It is considered that the use of PSA for this particular application and plant arrangement is effective.

4.4 The steam methane reforming process

The steam methane reforming process can be used industrially to produce hydrogen, carbon monoxide and their mixtures. Depending on the quantities of the desired products, the elements of the process can be adapted. The steam methane reforming process for production of hydrogen essentially consists of four stages as shown in Figure 4.1.

Figure 4.1 Hydrogen production by steam methane reforming



The process uses a light hydrocarbon feedstock such as natural gas or naphtha. The feedstock generally requires desulphurisation as the catalysts used in the steam methane reformer and the shift reactor are extremely vulnerable to sulphur poisoning. For natural gas reforming to produce hydrogen the principal chemical reactions involved are:

Methane reforming $CH_4 + H_2O \rightarrow CO + 3H_2$

Shift reaction $CO + H_2O \rightarrow CO_2 + H_2$

Overall reaction $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$

The reforming reaction is highly endothermic and is thermodynamically favoured by high temperature. This is undertaken using a specially formulated nickel catalyst in tubes in the radiant zone of the reforming furnace. After cooling carbon monoxide, formed as a co-product during reforming, is reacted with steam in the shift converter to produce carbon dioxide and additional hydrogen. The crude hydrogen stream is then cooled further to reduce the moisture content of the gas before being purified using pressure swing adsorption.

4.5 Main process flows

The above general procedure is used in the proposed hydrogen generation process at Solutia, Newport. The detailed description of how this process is specifically applied in this case is described below and illustrated in Figure 4.2. Tables 4.6 to 4.12 describe the material flows through the system based on the plant design conditions.

4.5.1 Feed gas supply and desulphurisation

Natural gas is supplied from the Wales and West utilities network from the Regional Transmission System and available locally via the CHP plant supply system.

A portion of the gas from this supply flows into the reformer fuel system. The remainder of the gas flows to the feed heater. Prior to entering the feed heater it is mixed with hydrogen recycled from the product compressor. The gas flows to the feed heater where the temperature is increased to 390°C and then to the hydrodesulphuriser. The hydrodesulphurisation step is necessary as sulphur can poison the nickel catalyst within the reformer. If sulphur were to enter the reformer it would be

adsorbed on the nickel catalyst as a surface sulphide and would interfere with the steam reforming reaction. The loss of activity can lead to carbon deposition and subsequent overheating of the reformer tubes, which may result in tube failure.

In the hydrodesulphuriser, sulphur removal is carried out in two stages.

The first stage is uses a sulphided cobalt-molybdenum (CoMo) bed with an excess of hydrogen. Unsaturated hydrocarbons in the feed gas react with recycled hydrogen. The rate of hydrogenation increases with temperature. Under normal process conditions all sulphur compounds will react with the hydrogen catalytically to form hydrogen sulphide. The second stage contains a bed of granules of high porosity zinc oxide. Zinc oxide reacts almost completely with hydrogen sulphide to form zinc sulphide:

$$ZnO + H_2S \rightarrow ZnS + H_2O$$

The concentration of hydrogen sulphide in the gas leaving the bed is reduced to less than 0.02 ppm. Zinc oxide is consumed during the process and is not regenerable. The bed must therefore be discharged and replaced when it is exhausted. Zinc oxide absorbent is the preferred treatment in the reforming process, due to its reliability and performance compared with other methods. No hydrogen sulphide has yet been detected during routine monitoring over the period of plant operation at the Dalry site.

4.5.2 **Steam reforming**

After desulphurisation of the natural gas, it is mixed with superheated, high pressure steam at around 550ºC at the mixing tee. This heated natural gas/steam mixture is cracked endothermically when it passes through the reformer tubes.

The reformer unit comprises a gas-fired furnace operating at around 900-1100ºC containing tubes filled with a nickel catalyst. The furnace operating temperature varies depending on plant loading. The reactions occurring in the reformer are:

Gasification	$C_nH_m + {}_nH_2O \rightarrow {}_nCO + (n + \frac{m}{2})H_2$
Hydrocracking	$C_nH_m + (2n - \frac{m}{2})H_2 \rightarrow {}_nCH_4$
Shirt	$CO + H_2O \leftrightarrow CO_2 + H_2$
Reforming/Methanation	$CH_4 + H_2O \leftrightarrow CO + 3H_2$

The gasification and hydrocracking reactions are irreversible and go to completion, whereas the other reactions are reversible and will reach an equilibrium. The gasification and reforming reactions are endothermic whilst the other reactions are exothermic. The methanation reaction is highly exothermic and reaction conditions need to be set carefully in order to avoid reaction runaway. Overall the reforming reactions are endothermic.

The energy, which is required for the endothermic reaction, is generated by means of a burner. Both natural gas and vent gases from the PSA unit are used as fuel in the reformer furnace providing a maximum total net thermal input of 2.7MW. The reformer furnace temperature is controlled by a low-NO_x burner (LNB) management system. The flue gases exiting the reformer furnace are continuously monitored for, and controlled by, oxygen content with low and high alarms to indicate adverse conditions.

The large volumes of high temperature flue gases leaving the radiant section are utilised to preheat the reactants, generate and superheat steam, preheat the feed gas and preheat combustion air in the convection section of the reformer.

As the reformer uses air preheat there is too much resistance in the reformer to be able to use natural or induced draught flow only. Therefore the reformer has both a forced draught (FD) fan, and an

induced draught (ID) fan. The air pre-heater is an integral part of the process from an efficiency standpoint as it recovers waste heat from the reformer flue gas, reducing the fuel gas consumption of the reformer. The air enters the FD fan and passes through the air pre-heater which is heated up to approximately 427ºC by the hot flue gas. The preheated air is then ducted to the reformer burners as combustion air. The design basis for the reformer is to use 10% excess air for normal operation, though currently operating in excess of this to facilitate steam export to the HT Shift vessel to promote reaction rates.

The ID fan is used to achieve a slight negative pressure in the reformer and to discharge the flue gas from the air pre-heater at around 150ºC. Corrosion is avoided on the cold end of the air pre-heater by a manual bypass, allowing the metal temperature to be kept above the dew point of the flue gas.

The cracked gas, which leaves the reformer tubes at approximately 820-860°C and 15.5 bar(g), and consists of methane, carbon dioxide, carbon monoxide and approximately 75% hydrogen, flows to the reformer effluent steam generator where it is cooled down to 377°C by counter current flow heat exchange with boiler feed water and then passes through the HT CO shift converter.

4.5.3 Shift conversion

Shift conversion occurs in the shift reactor over an iron/chromium catalyst where a major part of the carbon monoxide in the gas from the reformer is converted exothermically to hydrogen and carbon dioxide:

$$CO + H_2O \rightarrow CO_2 + H_2$$

The gas stream leaves the shift converter at around 375^{o}C and contains about 75% hydrogen and smaller amounts of methane and carbon dioxide.

The gas stream then passes through:

the feed heater where it is cooled to 377°C
the shift effluent steam generator where it is cooled to 216°C
the product air cooler where it is cooled to 169°C.

The gas flows through the process trim cooler where it is cooled down to 25°C . The heat recovered is used to generate steam and to preheat boiler feed water.

The resulting condensate is separated from the converted gas in the cold condensate drum. Water collected in the condensate drum is re-used as part of the boiler water feed to the various process steam generator units.

4.5.4 Pressure swing adsorption

This condensate free gas at a pressure of around 15 bar (g) is subsequently cleaned in a four-bed adsorber operating on the pressure swing adsorption basis. Each bed is packed with activated carbon and a molecular sieve material supported on a bed of alumina.

During normal operation, one adsorber is always switched to adsorption, while the three others are in de-sorption and re-pressurisation phases. De-sorption of the captured impurities is carried out at low pressure of around 0.2 bar(g).

Waste gases from the desorption process comprising hydrogen, carbon dioxide, carbon monoxide and nitrogen are fed to a vent gas drum. The gas from the vent gas drum is subsequently used to provide up to 90% of the fuel requirement for the burner system in the reformer furnace.
The product hydrogen has a purity of 99.99% by volume with a pressure of 14 bar(g) and a temperature of 25°C (15°C). This is fed to a three stage glycol-cooled hydrogen compressor. The composition of the gas stream is continuously monitored for moisture and carbon monoxide content.

The compressed hydrogen stream at around 230 bar is then exported to the customer's hydrogen storage or to a trailer filling facility for merchant demands.

4.5.5 Purge gas

The vent gas, which gathers during the regeneration of the pressure swing adsorption plant, passes to the vent gas drum. This vessel pressure cycles from 0.2 bar to around 1.0 bar during the process, ensuring that the vent gases fully mix to provide a consistent fuel composition. The vent gas flows to the burners of the reformer furnace under flow control to be used as fuel. Flow control is used to eliminate fluctuations due to the pressure changes.

With only natural gas as the fuel for the reformer burner, plant capacity would only be approximately 60%.

4.5.6 Furnace flue gas

The flue gas generated by the burners at 1010°C is used for:

- heating of the steam in the steam superheater. In here it is cooled to 650°C.
- generation of saturated steam in the flue gas steam generator. In here it is cooled to 250°C.
- Heating of combustion air in the pre-heater where it is cooled to 150°C by exchange with ambient air

A portion of the flue gas from the steam superheater bypasses the flue gas steam generator in order to maintain the flue gas inlet temperature of the combustion air pre-heater

The cooled gas finally passed through the ID fan and is vented to atmosphere.

4.5.7 Boiler feed water

Process condensate is produced from unreacted steam in the synthesis gas and is collected in the cold condensate vessel. It is then fed to the deaerator, where carbon dioxide and other contaminants are partially stripped out of the contaminated water. The steam used for deaeration is regulated high pressure steam from the steam drum.

From the de-aerator boiler feed water (BFW) is picked up with a pressure of approximately 0.3 bar(g) and a temperature of around 100°C and flows to the boiler water pump. Here the pressure is increased to 22 bar(g).

The boiler feed water passes through the steam drum and into the common shell of the steam generators. Make up water (approximately 594 kg/h) is also supplied to the plant and is controlled by the de-aerator level controller. It flows to the de-aerator stripping column.

4.5.8 Steam system

The plant produces steam via waste heat recovery from the reformer flue gas as well as the synthesis gas from the reformer outlet. From the steam drum, water circulates to the flue gas steam generator, and reformer effluent steam generator, by gravity and is pumped (using the boiler water circulation pumps) through the convection section steam generation coils. Steam and circulating boiler water pass back to the steam drum. The steam used for process purposes is then superheated in the superheater coil before being injected into the process gas stream before the reformer. Non superheated steam is used in the de-aerator to strip out non-condensibles and excess steam is exported to the shift reactor to promote the reaction.

Blow down from the steam drum is continually sent to the blow down drum. Blow down is necessary to maintain the quality of the steam. Regular analysis (once per day during start-up and once per

week at normal operation) is made from blow down condensate at the sample cooler. Table 4.4 summarises the properties measured and the acceptance criteria.

Table 4.4 Blow down analysis and acceptance criteria

Property	Acceptance criteria
pH	<9
Conductivity	20μΩ
Iron as Fe	<1 mg/l
Silica as SiO_2	1-5 mg/l

There is a continuous vent of steam from the de-aerator. This vent is contaminated with some carbon dioxide, carbon monoxide, methanol, ammonia and hydrogen.

4.6 Operating and maintenance

The plant will be largely unmanned and operated remotely from the European Operations Centre (EOC) in BOC's Brinsworth, Sheffield office. Routine tasks and start-up/shutdown procedures are performed locally via dedicated Facilities Engineers and Operations Support Technicians based at BOC's Margam site.

Plant loading is adjusted based on daily communications with the customer and BOC's central planning department for the merchant market. Typically this would be once per day, but could be adjusted at any time due to a sudden change in demand.

BOC operates the plant continuously to obtain maximum efficiencies, requiring shutdowns for pre-planned maintenance only (to ensure system integrity), or unforeseen equipment failures.

The design life of the plant catalysts and adsorbent have been based on the plant operating continuous campaigns at 100% output and 3 years between maintenance turnarounds. The individual catalyst design lives are summarised in Table 4.5.

Table 4.5 Catalyst specification

Service	Active Ingredient of Catalyst	Quantity (m^3)	Expected Life (years)
Hydrotreating	CoMo	0.24	5
Desulphurisation	ZnO	0.24	2
Reforming	Ni	0.73	5
Shift Conversion	FeCr	0.8	5

PSA adsorbents will last through the life of the plant as demonstrated during operation at Dalry. The design life of the reformer catalyst tubes and convection coils is 100,000 hours (11.4 years) in continuous operation.

The maintenance shutdown is expected to be 21 consecutive days every two or three years. During normal operation instrument readings are regularly checked and samples of gas are taken and analysed, to confirm correct operation of the catalysts. The state of each of the catalysts is checked as follows:

Sulphur absorber

at monthly intervals the gas is sampled after the absorption and tested for sulphur content. The catalyst is guaranteed to remove the sulphur to a level lower than 0.1 ppm to prevent poisoning of the reformer catalyst. The primary indication of deterioration in sulphur removal is bed operating temperature, as it will be necessary to increase bed temperature towards the end-of-run in order to maintain removal efficiency.

Reformer catalyst

periodically gas samples will be taken and a component mass balance carried out. The approach to equilibrium temperature and the methane conversion will be calculated and compared to the manufacturer's curves. Methane is periodically monitored in the outlet gases.

Shift catalyst

periodically gas samples will be taken upstream and downstream and a component mass balance carried out. The carbon monoxide conversion and the equilibrium temperature will be calculated and compared to the manufacturer's curves. Although the catalyst is designed to last 5 years, it will be checked after 3 years.

PSA adsorbent

the hydrogen gas will be sampled and checked for impurities to confirm compliance with contracted hydrogen purity. Any breakthrough of carbon monoxide, which would indicate a problem with the PSA adsorbent, would be noticed.

General maintenance of compressors and pumps will be carried out to an agreed maintenance schedule. Vessels will generally be inspected during the 3-year shutdown. Vessels containing catalysts, with a longer life than the three years, however, will be inspected during the catalyst change out.

Special precautions will need to be taken when removing catalyst from vessels, particularly for pyrophoric catalysts. Sulphur removal catalysts and the shift converter catalyst will be discharged under nitrogen positive pressure by vacuum extraction from the top manway or for the sulphur absorber it may be discharged through the dump nozzle. Water hoses will be on hand to quench the catalyst if required. The reforming catalyst will be discharged by vacuum extraction from the top flange. The Reformer will be purged with nitrogen with the catalyst above 200ºC to minimise the risk of producing nickel carbonyl ($Ni(CO)_4$), a toxic and odourless gas.

Detailed Operating and Maintenance procedures are contained in the Operating Manual and Integrated Management Systems and Standards (IMSS).

The general operating and maintenance and philosophy described above has been applied successfully to this plant whilst operating at the Dalry site. The maintenance periods and catalyst lifetimes are confirmed based on this previous operational experience.

4.7 Process control system

The hydrogen plant is designed to operate on a continuous basis with the minimum level of manning commensurate with maintaining a safe plant. A multi-variable control system is used to help with the efficient running of the plant

The multi-variable controller adjusts the following operation parameters simultaneously:

- natural gas feed rate
- process steam feed to reformer
- reformer firing
- reformer forced draft fan

Key controlled variables are extremely reliably maintained within control limits:

- steam to carbon ratio
- steam reformer outlet temperature
- reformer furnace draughts

- flue gas oxygen content
- methane slip from the reformer
- steam pressure

In accordance with the aim of the plant design and operating philosophy, the plant will normally be unmanned receiving only routine visits from the Newport-based operational staff for log taking, routine maintenance and abnormal operating conditions. During and after the commissioning phases the plant will be manned. Transfer of control to BOC's European Operation's Centre will only be made once reliable operating conditions have been established and maintained and competencies of operational staff confirmed.

Overall responsibility for plant operation will be retained by the Margam site, but the plant will monitored and controlled remotely via BOC's EOC at Brinsworth, Yorkshire. From the EOC the plant is controlled with exactly the same functionality as on site, but by operators who have a broader knowledge and experience of operating similar plants. Thereby the EOC allows operation of a number of plants to a common standard, or Best Operating Practice, which inherently provides more efficient operations. Close communication between the EOC and local operators is essential for safe and effective operations to continue, and this is achieved via daily contact, common electronic logbooks and Service Level Agreements for each plant.

A typical day/week in the operation of the plant would involve at least two verbal communications between the local and remote staff, with control normally retained at the EOC unless specific local actions are required. The EOC will change plant load settings 3 – 5 times per week and resolve most of the operational issues remotely. The local operator may be called out once in this week to respond to a fault that cannot be rectified remotely, e.g. trailer filling trip, in addition to the normal visits to site, of around five times per week. Any issues that result in a local operator call-out are logged and subsequently if these issues require maintenance or engineering support, they are logged by the EOC within BOC's Maintenance Management system.

Prior to handover all of EOC's staff will have visited the plant on at least one occasion, to receive training on local specifics and seeing firsthand the layout of the plant. Some key competency information will be tested, e.g. contract supply limits, shutdown procedures and alarm handling, before full theory training is obtained via BOC's IMSS system (as it is for the local operators). Competency checks are duly made and recorded to ensure that the EOC operators have sufficient knowledge and ability to perform their role.

This mode of operation has worked successfully during operation of this plant at Dalry.

4.8 Abnormal operating conditions

4.8.1 Protection during start up and shutdown

Protection is provided during start-up and shutdown of the burner. The sequencing of burner start-up is automatic with operator intervention required to ensure set points are input such that interlocks are satisfied before the burner can be started. Shutdown of the burner is automatic if certain process conditions are not maintained. Additionally, there are clear procedures and guidelines for the operators to follow in the event that a start-up or shutdown is required.

4.8.2 Operating failure scenarios

Protection has been provided in the event of control or equipment failure. Each vessel and plant item is protected from over pressure. All relief valves connect into the vent header and are discharged to atmosphere through the process vent. The relief valves and vent have been sized for worst case emergency relief conditions.

As process relief streams vent to the atmosphere, there are potential environmental impacts. The primary vents of environmental concern are described below:

- If the Regulator on the gas inlet line to the burner fails, then the natural gas in the line will be vented to atmosphere through the high level vent. A flow alarm will be generated and the problem will immediately be investigated. A standby regulator can be utilised to prevent a plant shutdown. This event is unlikely to occur more than once in the life of the plant.

- If the PSA unit has tripped and blocked in, then the upstream pressure control valve will open and the raw hydrogen product will be discharged through the high level vent. Again the plant will be shut down following shut down procedures. This is likely to occur approximately once a year. Venting may occur for up to three hours.

- There is also a relief valve before the main process equipment items that will lift and thus protect the reformer if any blockage further down the line occurs. This will discharge gas through the process gas vent. This event is unlikely to occur more than once in the life of the plant.

4.8.3 Reformer furnace flue gas control

The reformer furnace flue gas temperature and composition is controlled via a fuel air ratio controller. This constantly looks at the fuel flows into the furnace and adjusts the air flow automatically to ensure complete combustion and the desired set point of oxygen in the flue. The oxygen has a separate controller that feeds a bias into this loop and alarms when levels reach too low or too high a setting. This control strategy works well as it allows the furnace to operate consistently without any step changes in temperature whilst maintaining consistent oxygen levels.

In the event of abnormal conditions, the operator is advised of this via the alarm settings and can troubleshoot likely causes to ensure the situation is recovered. Normally situations can be recovered within a 30 minute period, without adversely affecting plant operation and ensuring emissions do not deteriorate further. If this control loop was to have the functionality to trip the process then very little trouble shooting could be achieved and increased volumes of venting would occur to effect a plant shutdown and start-up, along with the associated problems of thermal stress in the plant and equipment.

4.8.4 Vent gas header fires

Under normal circumstances a small amount of hydrogen is regularly vented from the vent gas header due to the operation of blow down valves on the hydrogen compressor every 30 minutes.

A number of instances have occurred at Dalry whereby the vent gas header emissions have ignited due to ambient weather conditions. After two such occasions it was decided that a warning system should be installed to highlight the problem immediately, along with a procedure to purge the header with a larger volume of nitrogen to extinguish the flame. The stack is designed to intermittently cope with these fires,

This improvement, coupled with lower plant venting rates has helped reduce the frequency of occurrence significantly.

Figure 4.2 Process flowchart

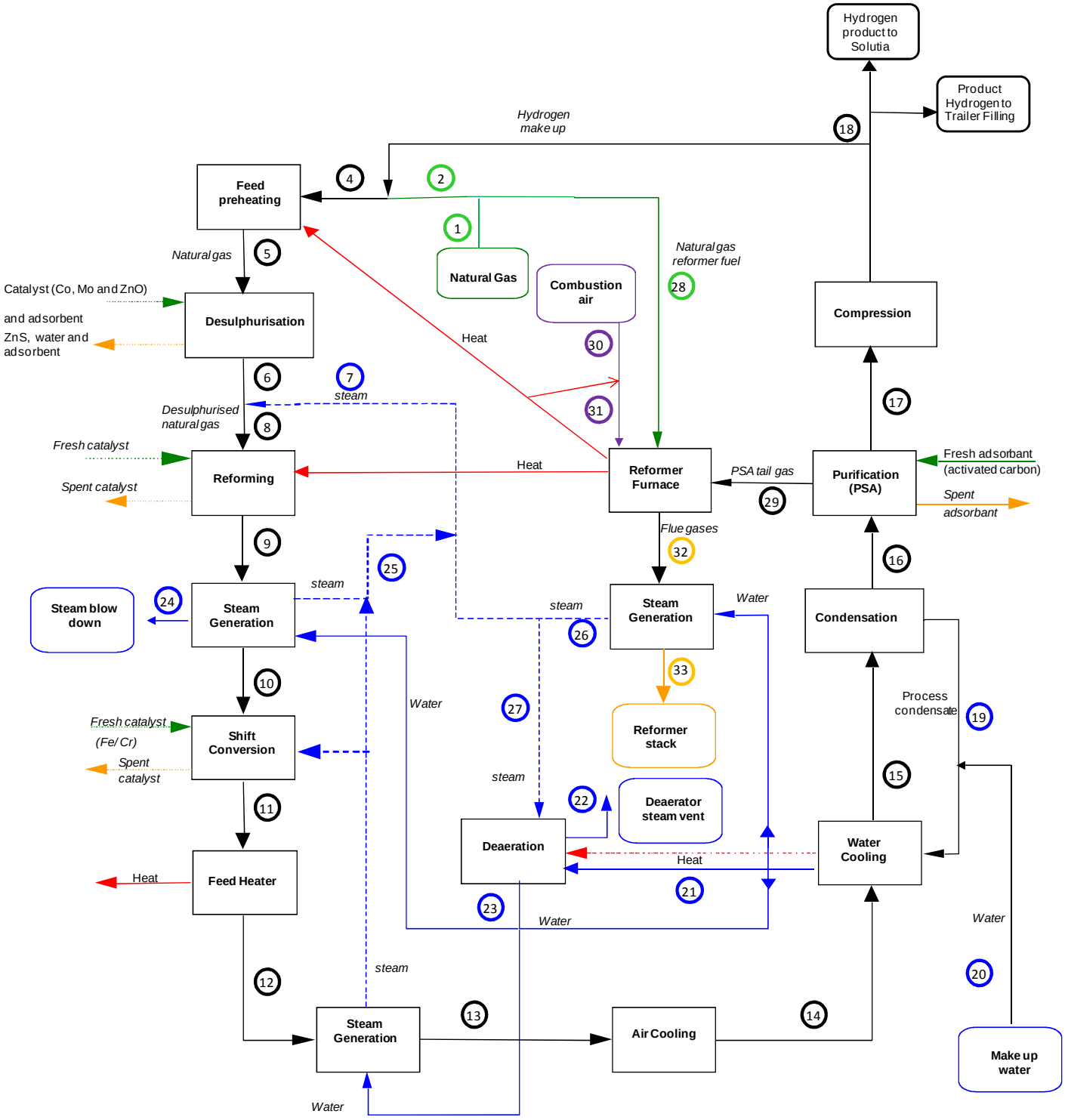


Table 4.6 Design process material flows – Input streams

Stream No.	**1**	**3**	**20**	**30**
Stream Description	**Total Natural Gas**	**Recycle H_2**	**Treated Water Makeup**	**Combustion air**
Composition, kg mols/h				
Methane	16.229			
Carbon dioxide	0.388			
Carbon monoxide				
Hydrogen		0.340		
Nitrogen	0.969			73.847
Oxygen				19.882
Argon				0.947
Ethane	1.163			
Propane	0.388			
n-Butane	0.194			
n-Pentane				
n-Hexane	0.058			
Total dry, kg mols/h	19.389	0.340		94.676
Water Vapour				1.385
Water Liquid			32.965	
Ethylene Glycol				
Total wet, kg mols/h	19.389	0.340	32.965	96.061
Flow				
kg/h	373	1	594	2,768
NCMH	435	8		2,153
m^3/h			0.59	
Temperature, °C	16	38	16	21
Pressure, barg	18.6	18.6	4.0	

Table 4.7 Design process material flows – Output streams

Stream No.	**18**	**22**	**33**
Stream Description	**H_2 product**	**Deaerator Vent**	**Reformer flue gas to Stack**
Composition, kg			
Methane			
Carbon dioxide			21.231
Carbon monoxide			
Hydrogen	44.593		
Nitrogen			74.816
Oxygen			1.807
Argon			0.947
Ethane			
Propane			
n-Butane			
n-Pentane			
n-Hexane			
Total dry, kg mols/h	44.593		98.802
Water Vapour		1.659	26.980
Water Liquid			
Ethylene Glycol			
Total wet, kg mols/h	44.593	1.659	125.782
Flow			
kg/h	90	30	3,612
NCMH	1,000	37	2,820
m^3/h			
Temperature, °C	38	108	212
Pressure, barg	207.0	0.3	

Table 4.8 Design process material flows – Process streams

Stream No.	**2**	**4**	**5**	**6**	**8**	**9**
Stream Description	**Feed stock natural gas**	**Feed preheater Inlet**	**Heated natural gas + H_2**	**Desulpd natural gas**	**Reformer feed**	**Reformer exit**
Composition, kg mols/h						
Methane	14.239	14.239	14.239	14.239	14.239	2.326
Carbon dioxide	0.340	0.340	0.340	0.340	0.340	6.879
Carbon monoxide						9.424
Hydrogen		0.340	0.340	0.340	0.340	52.299
Nitrogen	0.851	0.851	0.851	0.851	0.851	0.851
Oxygen						
Argon						
Ethane	1.021	1.021	1.021	1.021	1.021	
Propane	0.340	0.340	0.340	0.340	0.340	
n-Butane	0.170	0.170	0.170	0.170	0.170	
n-Pentane						
n-Hexane	0.051	0.051	0.051	0.051	0.051	
Total dry, kg mols/h	17.012	17.352	17.352	17.352	17.352	71.779
Water Vapour					65.200	42.698
Water Liquid						
Ethylene Glycol						
Total wet, kg mols/h	17.012	17.352	17.352	17.352	82.552	114.477
Flow						
kg/h	327	328	328	328	1,502	1,502
NCMH	381	389	389	389	1,851	2,566
m^3/h						
Temperature, °C	16	16	399	371	538	843
Pressure, barg	18.6	18.6	18.5	16.9	16.9	15.5

Table 4.9 Design process material flows – Process streams

Stream No.	10	11	12	13	14	15
Stream Description	**Shift inlet**	**Shift exit**	**Preheater exit**	**Shift steam gen exit**	**Process air cooler**	**Process trim cooler**
Composition, kg mols/h						
Methane	2.326	2.326	2.326	2.326	2.326	2.326
Carbon dioxide	6.879	13.702	13.702	13.702	13.702	13.702
Carbon monoxide	9.424	2.600	2.600	2.600	2.600	2.600
Hydrogen	52.299	59.123	59.123	59.123	59.123	59.123
Nitrogen	0.851	0.851	0.851	0.851	0.851	0.851
Oxygen						
Argon						
Ethane						
Propane						
n-Butane						
n-Pentane						
n-Hexane						
Total dry, kg mols/h	71.779	78.602	78.602	78.602	78.602	78.602
Water Vapour	46.913	40.090	40.090	40.090	0.670	0.329
Water Liquid					39.419	39.761
Ethylene Glycol						
Total wet, kg mols/h	118.692	118.691	118.691	118.691	118.691	118.691
Flow						
kg/h	1,578	1,578	1,578	1,578	1,578	1,578
NCMH	2,661	2,661	2,661	2,661	1,777	1,769
m^3/h					0.72	0.72
Temperature, °C	357	421	342	232	52	38
Pressure, barg	15.4	15.2	15.1	15.0	14.8	14.7

Table 4.10 Design process material flows – Process streams

Stream No.	16	17	12	13	31	32
Stream Description	**PSA feed**	**PSA H_2 product**	**Fuel natural gas to reformer**	**PSA offgas**	**Heated combustion air**	**Flue gas to steam heater**
Composition, kg mols/h						
Methane	2.326		1.990	2.326		
Carbon dioxide	13.702		0.048	13.702		21.231
Carbon monoxide	2.600			2.600		
Hydrogen	59.123	44.933		14.189		
Nitrogen	0.851		0.119	0.851	73.847	74.816
Oxygen					19.882	1.807
Argon					0.947	0.947
Ethane			0.143			
Propane			0.048			
n-Butane			0.024			
n-Pentane						
n-Hexane			0.007			
Total dry, kg mols/h	78.602	44.933	2.377	33.668	94.676	98.802
Water Vapour	0.329			0.329	1.385	26.980
Water Liquid						
Ethylene Glycol						
Total wet, kg mols/h	78.931	44.933	2.377	33.997	96.061	125.782
Flow						
kg/h	862	91	46	772	2,768	3,612
NCMH	1,769	1,007	53	762	2,153	2,820
m^3/h						
Temperature, °C	38	38	7	38	427	954
Pressure, barg	14.7	13.9	2.8	0.2		

Table 4.11 Design process material flows – Glycol circuit

Stream No.	**34**	**35**	**36**	**37**
Stream Description	**Glycol supply to Compressor**	**Ethylene glycol to air cooler**	**Ethylene glycol to drum**	**Ethylene glycol to pump**
Composition, kg				
Methane				
Carbon dioxide				
Carbon monoxide				
Hydrogen				
Nitrogen				
Oxygen				
Argon				
Ethane				
Propane				
n-Butane				
n-Pentane				
n-Hexane				
Total dry, kg mols/h				
Water Vapour				
Water Liquid	466.602	466.602	466.602	466.602
Ethylene Glycol	123.615	123.615	123.615	123.615
Total wet, kg mols/h	466.602	466.602	466.602	466.602
Flow				
kg/h	16,812	16,812	16,812	16,812
NCMH				
m^3/h	15.52	15.52	15.52	15.52
Temperature, °C	46	53	46	46
Pressure, barg	2.8	2.4	2.1	0.3

Table 4.12 Design process material flows – Steam and water system

Stream No.	7	19	21	23	24	25	26	27
Stream Description	**Process Steam**	**Cold Proc Cond**	**Heated Water to Deaerator**	**Deaeratd Water**	**Steam System Blowdn**	**Total Steam Make**	**Excess Steam**	**Steam to DA**
Composition, kg mols/h								
Methane								
Carbon dioxide								
Carbon monoxide								
Hydrogen								
Nitrogen								
Oxygen								
Argon								
Ethane								
Propane								
n-Butane								
n-Pentane								
n-Hexane								
Total dry, kg mols/h								
Water Vapour	65.200					79.328	4.214	9.914
Water Liquid		39.761	72.726	80.947	1.619			
Ethylene Glycol								
Total wet, kg mols/h	65.200	39.761	72.726	80.947	1.619	79.328	4.214	9.914
Flow								
kg/h	1,175	716	1,310	1,458	29	1,429	76	179
NCMH	1,462					1,778	94	222
m^3/h		0.72	1.32	1.53	0.03			
Temperature, °C	212	38	44	108	212	212	212	212
Pressure, barg	18.6	14.7	2.1	0.3	18.6	18.6	18.6	18.6

5 Releases and environmental impact

Releases from the proposed installation are discussed in the following sections:

5.1 Point source releases to air
5.2 Points source releases to water and land
5.3 Fugitive releases to air
5.4 Fugitive releases to water and land
5.5 Odour
5.6 Noise

This plant has been operating for over 10 years at Dalry. The historical information available on these releases from past operation is considered to be representative of the intended operation when the plant is relocated to Newport. In the following sections this historical information is employed to quantify likely releases and to assess impact following installation of the plant at Newport.

5.1 Point source releases to air

There are three point source releases to air:

- Flue gases from the reformer stack
- Steam venting from the deaerator vent
- Releases from the vent gas header stack

Releases at the reformer stack and deaerator stack are continuous, whilst the vent gas header stack has an intermittent release, the frequency and composition of which will be dependent on plant operation and plant failure events.

5.1.1 Reformer stack releases

The reformer furnace is largely fired with waste gases from the vent gas drum with some natural gas (see 4.3.3). The resulting flue gases are eventually discharged to atmosphere via the reformer stack. Based on commissioning trials and subsequent testing during early operation at Dalry the releases from the process at varying loads as in Table 5.1 have been established. These release factors have been used to determine release inventories for submission to SEPA as part of BOC's statutory obligations for plant operation at Dalry.

Table 5.1 Reformer stack mass releases

Parameter		Full load	50% load	35% load
Nitrogen oxides	$kgNO_2/h$	0.14	0.09	0.09
Sulphur dioxide	kg/h	0.003	0.003	0.003
Volatile organic compounds	kgC/h	0.003	0.002	0.0014
Carbon monoxide	kg/h	0.006	0.006	0.004
Carbon dioxide	kg/h	1110	752	511

It is expected that when fully operational at Newport, the plant will operate at an average load of around 35-40% for the first year rising. This will equate to the approximate annual releases summarised in Table 5.2. These are considered to be below the reporting threshold in the Environment Agency's Pollution Inventory for Part A(1) processes. Plant load is expected to rise to around 80% in two years when planned Solutia developments come on line

Table 5.2 Estimated annual releases from the Reformer stack

Parameter		Annual release (kg)
Nitrogen oxides	$kgNO_2$	800
Sulphur dioxide	kg	26
Volatile organic compounds	kgC	16
Carbon monoxide	kgCO	53
Carbon dioxide	$kgCO_2$	6600000

The local environmental impact of these releases is considered further section 15.

The corresponding flue gas concentrations are presented in Table 5.3. The balance is essentially oxygen (c. 12% and nitrogen 70%).

Table 5.3 Reformer stack gas composition

Parameter		Full load	50% load	35% load
Nitrogen oxides	$mgNO_2/m^3$	51	46	62
Sulphur dioxide	mg/m^3	1	1	1
Volatile organic compounds	mgC/m^3	1	1	1
Carbon monoxide	mg/m^3	1	1	1
Carbon dioxide	%	20.1	19.2	18.5

Concentrations are expressed at reference conditions of Standard Temperature (0^oC) and Pressure (1.013b) (STP) in a dry gas containing 3% by volume oxygen.

Current emission limit values (ELVs) for operation at Dalry are shown in Table 5.4. These are broadly in line with BAT achievable emission limits (see 16.3.1) and were met during the most recent periodic compliance monitoring in October 2012. The emissions characteristics established during commissioning (Table 5.3) indicate that these ELVs are expected to be met with a reasonable amount of headroom at all operating loads. In addition the visible emission assessment criterion is also met.

Table 5.4 Reformer stack gas emission limit values

Parameter		Emission limit value (ELV) (STP, dry gas basis, 3% oxygen)
Nitrogen oxides	$mgNO_2/m^3$	140
Carbon monoxide	mg/m^3	25

Visible emissions, in accordance with BS 2742:1969, should not exceed Ringelmann shade 1.

5.1.1.1 Reformer stack monitoring requirements

At its current location the reformer stack release is subject to an annual periodic monitoring requirement for:

Sulphur dioxide
Nitrogen oxides
Volatile organic compounds
Carbon monoxide
Carbon dioxide

At its proposed location it would be expected that at least a similar level of periodic monitoring would be required.

To facilitate this monitoring the reformer stack will be equipped with sampling facilities which comply with the requirements of Environment Agency Technical Guidance Note M1 for this scope of testing.

Appropriately accredited contractors will be engaged to conduct the required testing in accordance with the MCERTs performance standard.

5.1.2 De aerator steam vent

The deaerator steam vent provides a continuous release which comprises over 94% steam. Table 5.5 summarises the general composition of the release.

Table 5.5 Deaerator steam vent release composition

Parameter	Mass release (kg/h)	Concentration (%)
Water vapour	29	94.4
Carbon dioxide	1.7	5.5
Nitrogen	0.0021	0.007
Carbon monoxide	0.0012	0.004
Methane	3.4×10^{-6}	0.00001
Hydrogen	0.0015	0.005

This release is not considered significant in terms of environmental impact and currently is not subject to any release limits. Whilst the steam plume may be occasionally visible this is not considered significant in view of other visible plumes in an around the proposed location.

5.1.3 Vent gas header stack

Releases from the vent gas header will occur on an intermittent basis during certain plant operations. The composition of the release will vary depending on circumstances. The main release scenarios are:

Hydrogen balancing	Hydrogen will be vented during plant load changes. Around 400 kg of hydrogen is vented during each occurrence and this is generally expected at a weekly frequency. The release is predominantly hydrogen (89-96% depending on load) with a balance of nitrogen.
Synthesis gas venting	Synthesis gas and hydrogen will be vented once during start up of the plant.
PSA blockage	If there is a blockage of the PSA unit there will be a release of largely carbon dioxide. It is expected that a blockage will occur around once per year.
Gas regulator failure	On failure of the gas regulator there will be a release of methane of around 20 tonnes per episode. This is expected to occur once in the lifetime of the plant.

Table 5.6 summarises the likely releases from the vent gas header stack for the various release scenarios. It may be noted that there are no releases of nitrogen oxides associated with the vent gas header. The most significant emissions come about through the two major failure scenarios (PSA blockage and gas regulator failure) which are expected to occur infrequently.

Table 5.6 Estimated annual average mass releases from the vent gas header

Vent scenario	Components	Annual average mass release (kg)
Hydrogen balancing	Hydrogen	21000
Synthesis gas venting on start up	Hydrogen	61
	Carbon monoxide	52
	Carbon dioxide	40
	Methane	0.3
PSA blockage	Hydrogen	13000
	Carbon monoxide	10000
	Carbon dioxide	65000
	Methane	7000
Gas regulator failure	Methane	1300

5.1.3.1 Vent gas header stack monitoring requirements

At its current location the vent gas header stack release is subject to an annual periodic monitoring requirement for:

Nitrogen oxides
Volatile organic compounds
Carbon monoxide

There is however, no ELV specified for these parameters.

Sampling is not undertaken in full accordance with the requirements of the MCERTs performance standard due to safety considerations. The potential for high concentrations of hydrogen and methane at the sampling location makes it unsuitable for conventional monitoring. Grab sampling with subsequent analysis is more appropriate.

To facilitate this monitoring the vent gas stack suitable grab sampling point will be installed such that sampling may be undertaken in a safe manner if required. It is unlikely that sampling at this position will be in full accordance with the MCERTs performance standard.

5.2 Point source releases to water and land

Four releases to water and land have been identified:

Boiler feed water blow down
Storm water
Domestic sewage
General waste

5.2.1 Boiler feed water blow down

Boiler feed water blow down rate will be dependent on plant loading and boiler feed water quality. Plant design indicates an average rate of 29 kg/h. The blow down will be at a pH of around 11 and will contain chemicals for the treatment of corrosion and may also contain trace amounts of methanol and ammonia.

Boiler feed water blow down will routed to the current site treatment system. The rate of blow down associated with the hydrogen plant is considered insignificant in comparison to the overall site throughput.

5.2.2 Storm water

The plant offers few sources of contamination for storm water. Most areas will have an impenetrable surface. All chemicals will be stored in tanks with integral bunds, so no ground contamination can occur in case of spillage. Around pumps and compressors, where lubrication systems could result in small spillages of lube oil, measures will be taken to prevent rainwater washing off the contamination to ground. The machines are set on concrete foundations and areas deemed susceptible to oil drips will be protected by drip trays.

During current decommissioning operations at Dalry, the final site condition inspection following over 10 years' operation indicated some minor oil staining on the concrete base which was not considered significant by the Regulator.

5.2.3 Domestic sewage

BOC operations following plant installation will use existing site welfare facilities. There will be no additional facilities requiring sewage disposal for this installation.

5.2.4 General wastes

The production of general wastes resulting from office and maintenance activities will be minimised by adherence to existing BOC and Solutia site housekeeping policies. All general wastes generated will be disposed of by Solutia using existing disposal routes. There will be no significant increase in general waste as a result of this installation and no requirement for additional special disposal routes.

There will from time to time be a requirement for a change out of catalyst resulting in special disposal or recycling. This is undertaken infrequently and is discussed in detail in sections 7 and 8.

5.3 Fugitive emissions to air

The primary components of fugitive emissions to air associated with the hydrogen plant are:

Organic compounds
Dust

5.3.1 Organic compounds

Within the system containment (piping and vessels) there is a considerable inventory of gases gaseous hydrocarbons.

The principal streams are:

- Natural gas feed - mainly methane with some ethane, propane, butane and higher hydrocarbons

- Synthesis gas - a mixture of carbon monoxide and hydrogen with carbon dioxide and methane
- Hydrogen product - high purity hydrogen

Leaks from these lines are avoided by appropriate design of the piping and subsequent inspection. All piping and vessels are constructed of materials meeting the required standards for this type of plant. 100% radiography is specified for all lines in hydrogen service and alloy materials. All other process service is subject to 10% radiography.

As part of the decommissioning and subsequent installation process all piping and vessels will be subject to a comprehensive programme of inspection and general refurbishment/replacement.

It is considered unlikely that there will be significant releases of fugitive emissions from the system containment during the operation of the hydrogen plant.

There is no liquid inventory of volatile hydrocarbons within the hydrogen plant and hence no release of volatile organic compounds is anticipated.

There is a small inventory of lubricating oil for the compressor units. This organic mixture has a high boiling point and is therefore unlikely to give rise to volatile organic compound releases. In the event of a release, any oil spill will be captured in a bund.

5.3.2 Dust

Dust creation and generation of pollutants will be minimised by implementation of effective design and operating practices. Experience from operation at Dalry has indicated no significant fugitive dust releases from around the plant.

5.4 Fugitive emissions to water and land

The hydrogen plant has no associated sub-surface piping systems

There is negligible liquid inventory within the hydrogen plant process area and most areas including those beneath equipment, vessels and pipe racks will be paved with concrete. The remaining areas are level and covered with gravel.

Annual audits of the site will be conducted and will include inspection of impervious surfaces and kerbs to ensure their integrity. Operating and maintenance staff will be given adequate training to ensure that during routine housekeeping patrols they will also assess the state of any impervious surfaces and containment kerbs. Any observed damage will be reported via the BOC management system for remedial action.

During current decommissioning operations at Dalry, the final site condition inspection following over 10 years' operation indicated some minor oil staining on the concrete base which was not considered significant by the Regulator.

5.5 Odour

In hydrogen production from steam reforming there are two main sources of odour:

Sulphur dioxide from the reformer flue gas
Mercaptans present in natural gas feedstock

The reformer flue gas is expected to have a sulphur dioxide content of around 1 mg/m^3 (Table 5.3), although measurements at the Dalry site in October 2012[a1] indicated a higher concentration of around 28 mg/m^3. The concentration of mercaptans present in natural gas for industrial use is expected to be around 160 μg/m^3. The release points for both sulphur dioxide and mercaptans in natural gas are at

high level (reformer stack vent gas header stack respectively) and as such any release will be subject to significant dilution upon dispersion.

The United States Environmental Protection Agency (US EPA) SCREEN 3 model has been used to estimate the likely ground level concentration (1.5 m) of these releases at distances from the point of release. This model is a screening model which generally represents a worst case estimation of dispersion for the purposes of identifying significant impact for subsequent more detailed assessment. Estimated maximum ground level concentrations have then been compared with odour threshold values for sulphur dioxide and mercaptans to determine significance and potential for nuisance. The results of the assessment are summarised in Table 5.7

Table 5.7 Summary of results of odour dispersion screening analysis

Components		Sulphur dioxide[1]	Mercaptans[2]
Odour threshold (OT)[3,4]	µg/m^3	300	0.5
Release concentration	µg/m^3	28000	160
Release rate	g/s	0.015	0.000007
Maximum ground level concentration	%OT	1.0	0.6
Distance from release point of maximum	m	71	78
Ground level concentration at 200 m	%OT	0.8	0.4
Ground level concentration at 500 m	%OT	0.5	0.2

1 Based on measured releases and flue gas conditions at the reformer stack in October 2012[4].
2 Based on a release from the vent gas header stack of 155 Nm^3/h natural gas.
3 Odour thresholds for sulphur dioxide is lower end of range suggested[2].
4 Odour threshold for mercaptans is assumed to be that for methyl mercaptan[3].

Based on the release characteristics considered, the assessment indicates that ground level concentrations of both sulphur dioxide and mercaptans are at most no more than 1% of the odour threshold. The maximum predicted concentration occurs within the site boundary. Concentrations at the nearest commercial building (200m) and nearest significant residential area (500 m) are lower still and at a level which is very unlikely to cause any nuisance.

Experience during operation at Dalry is that there is no perceptible odour in the vicinity of the hydrogen plant and no complaints have been made since installation which have been attributable to hydrogen plant operations.

5.6 Noise

The main sources of persistent noise within the hydrogen plant are the plant fans and compressor pump. The vent gas header stack is a source of intermittent noise during venting episodes. A hydrogen plant noise survey was undertaken during operation at Dalry in 2003 and the results are summarised in Table 5.8. It is not expected that there will be any significant departures from these measurements when the plant is installed at the Newport site.

Table 5.8 Hydrogen plant noise survey at Dalry – 2003

Source	Sound power level (dB(A))	Characteristics	Hours of operation	Contribution to overall site noise
Vent gas header stack	Not measured	Intermittent Pop/Bang	30 second frequency for 1-2 hours per year	High
Plant fans	70	Continuous high pitched whirr	24 hours/day 365 days/year	Low
Compressor pump	70	Continuous low frequency whirr with impulse	24 hours/day 365 days/year	Low

The hydrogen plant is considered to apply current BAT to noise levels with equipment being used which have comparatively low noise levels.

The existing Newport site has been subject to regular noise surveys. The site survey in 2000 indicated noise levels ranging between 53-94 dB(A) at the various production units. An assessment in March 2012 considering noise impact at sensitive receptors to the north and north east of the site concluded that complaints attributable to existing site sources were unlikely.

The persistent noise sources associated with the hydrogen plant are considered to make a relatively low contribution to the overall site noise. Based on simple distance attenuation methodology it would be expected that the persistent noise associated with the hydrogen plant would reduce to below 30 dB(A) at the site boundary (i.e. at a distance of about 150 m. It is therefore considered that these sources of noise are insignificant.

The most significant noise contribution is likely to result from vent gas header stack emergency venting episodes. Typically during emergency venting there will be a pop at around 30 second intervals for a period of between 1 and 2 hours. Occurrences are likely to be infrequent with an average of one episode per year, although this is likely to have a high contribution to the overall site noise. Due to its nature it has not been possible to quantify the noise during a venting episode. Experience at Dalry has indicated that there have been no noise complaints attributable to hydrogen plant operation.

6 Process management

6.1 Introduction

BOC Group Limited operates Linde Integrated Management Systems and Standards (LiMSS) for all its operational sites. This is designed to be a management and technical tool to assist business units in implementing the BOC Group's policies including those related to Environmental Management and Community Protection.

The IMSS contains operating, maintenance and HSE instructions for management, engineers, supervisors and operating staff along with the Group's environmental protection policy and standards. It also includes an information database on hydrogen production. The IMSS provides a "hands on" training and instructional tool for all BOC and support staff. Competency testing is undertaken to ensure staff with the most appropriate skills are allocated to all jobs. The system undergoes continual review and development.

The IMSS provides the basis for control and audit of the environmental protection performance of individual business units. It is intended to provide firm guidance for each business unit, but allows flexibility to tailor implementation plans to suit local situations, including legislative differences, culture, local environmental and business practices.

BOC maintain environmental management systems in accordance with ISO 14001 at several of its UK sites.

IMSS provides a comprehensive management system that will ensure the safe and effective management of the proposed hydrogen plant at Newport.

BOC's hydrogen plant Environmental Management System (EMS) will be an integral part of the Integrated Management System applied to the Newport installation and will be structured to ensure:

- The key environmental impacts identified in the EPR application are recognised and addressed during operations
- Operations Management set environmental objectives and targets to ensure continual improvement to the environmental performance of the hydrogen plant
- Regular monitoring, audit and appropriate reporting of environmental performance to BOC Group, Environment Agency and where appropriate the local community
- Clear allocation of responsibilities for the EMS, achievement of improvements to environmental performance and in particular ensuring compliance with the EPR permit.

Responsibility for implementation of the Environmental Management System on the proposed hydrogen plant, for compliance with all environmental requirements and liaison with the Environment Agency lies with the Plant Manager for the neighbouring Margam facility.

6.2 Plant management at Newport

As with all other hydrogen plant operated by BOC, specific instructions for operation of the plant at Newport will be available in the form of an operating manual. These will be similar to those currently existing for operation of the plant at Dalry and will include the following elements.

HYDSMR01	Hydrogen general
HYDSMR03	Hazards and safeguards
HYDSMR27	Compressed hydrogen trailer filling
HYDSMR29	Hydrogen product storage and back-up
HYDSMR02	Hydrogen SMR plant operations
HYDSMR05	Feed pre-treatment system
HYDSMR06	Process steam system
HYDSMR07	Reformer mixed feed system
HYDSMR10	Carbon monoxide shift reaction
HYDSMR19	Boiler feed water management
HYDSMR13	Hydrogen purification
HYDSMR16	Reformer furnace system
HYDSMR17	Burner management system
HYDSMR18	Flue gas heat recovery system
HYDSMR22	Utilities
HYDSMR23	Environment and waste management

Topics mandated in the instructions include:-

Unit operating instructions
Waste disposal and recovery
Quality control
Plant optimisation and control
Maintenance
Emergency procedures
Condition monitoring
Management and administration
Design basis and information
Commissioning

The proposed hydrogen plant at Newport is designed to operate on a continuous basis with the minimum level of manning commensurate with maintaining a safe plant. A multi-variable control system is used to help with the efficient running of the plant as discussed in section 4.7. Plant loading is adjusted based on daily communications with Solutia and BOC's central planning department for the merchant market. Typically this would be once per day, but could be adjusted at any time due to a sudden change in demand. BOC operates the plant continuously to obtain maximum efficiencies, requiring shutdowns for pre-planned maintenance only (to ensure system integrity), or unforeseen equipment failures.

During and after the commissioning phases the plant will be manned until reliable operating conditions have been established and maintained and competencies of the operations staff confirmed.

Overall responsibility for plant operation is retained by Margam site, but the plant is monitored and controlled remotely via BOC's Remote Operation's Centre (EOC) at Brinsworth, Yorkshire. From the EOC the plant is controlled with exactly the same functionality as on site, but by operators who have a broader knowledge and experience of operating similar plants. Thereby the EOC allows operation of a number of plants to a common standard, or best operating practice, which inherently provides more efficient operations. Close communication between the EOC and local operators is essential for safe and effective operations to continue, and this is achieved via daily contact, common electronic logbooks and service level agreements for each plant.

Typically daily operation of the plant would involve at least two verbal communications between the local and remote staff, with control normally retained at the EOC unless specific local actions are required. The EOC will change plant load settings 3 to 5 times per week and resolve most of the operational issues remotely. The local operator may be called out once in this week to respond to a fault that cannot be rectified remotely, e.g. trailer filling trip, in addition to the normal visits to site, of around five times per week. Any issues that result in a local operator call-out are logged and subsequently if these issues require maintenance or engineering support they are logged by the EOC within BOC's Maintenance Management system.

EOC had been in operation for more than 10 years and is a key element of BOC's global operating model to enhance efficiency and reliability at all of its plants.

The Margam Plant Production Manager will have overall responsibility for all activities at the Newport hydrogen plant, including health, safety and environmental aspects. Direct responsibility is exercised by the Facilities Manager.

The Facilities Manager is responsible for managing effectively all aspects of production and maintenance (both plant and people).

6.3 Environmental management at Newport

The management of environmental issues at the Newport site will be undertaken as described in Table 6.1.

Table 6.1 Environmental management system for the Newport site

Requirement	Control Method
Environmental Performance	
Environmental impact	IMSS 22: Environmental Management
Objectives and measurable goals for environmental performance	SHEQ Plan
Improvement programme	IMSS
Monitoring on a regular basis of the overall environmental performance of the installation	Management monitoring. Bi- Annual Operation and Engineering Audit.
Feedback from the monitoring to the setting of the targets with a commitment to regularly improve the targets where appropriate	O&E Audit category listing, i.e. improvement notices.
Regular audit both internal and Independent	Audit programme including LRQA, O&E. Mgt Review, Integrated Audit, Quality and Env Audit.
Reporting of Environmental Performance	
Annual report to Environment Agency	Facilities Manager, IMS-9, SAP
Public environmental statement	Public reception notice boards. Website information www.boc.com
Monitoring and control systems	Facilities Manager
To ensure that the installation functions as intended	Facilities Manager
To detect faults and unintended operations	Facilities Manager and Audits
To detect slow changes in plant performance to trigger preventative maintenance	IMS-08, SAP look, listen & feel tasks
Statement of skills and competencies required for each job	IMS-10, IMS 18, Audits, Operating support centre.

Requirement	Control Method
Training and Competency	
Awareness of the regulatory implications of the Permit for the activity and their work activities	IMS-21
Awareness of all potential environmental effects from the operation under normal and abnormal circumstances	IMSS Operating Procedure for plant, HYDSMR 23
Prevention of accidental emissions and action to be taken when accident emissions occur	IMS-23, IMS-29
Implementation and maintenance of training records for operational staff	IMS-18
Have staff assigned to both technical and managerial posts sufficient qualifications, training and experience for their roles	IMSS Competency Training (IMS-18) Job Descriptions Training records
Preventative maintenance programmes Corrective action to environmental complaints	IMSS Maintenance Staff, SAP Maintenance System, SAP defect System
Environmental Business Management	
The control of process change design and review of new facilities, engineering and other capital projects	CEPM (6 Stage Process)
Capital approval	Project Proposal Procedure
The allocation of resources	Business Production Manager
Planning and scheduling	Annual Budget Process
Incorporation of environmental aspects into normal operating procedures	IMSS Operating Instructions
Purchasing policy	IMS-06, Technical Purchasing Policy
Accounting for environmental costs against the process involved rather than as overheads	Group Environmental Survey Annual Environmental Performance Review (IMS-22-10)
Operating control	
Selection of raw materials	Procurement Team IMS-07
Water efficiency	NALCO monthly report to Facilities Manager
Waste minimisation	IMS-23
Control of point and fugitive emissions	Plant monitoring OSC, Facilities Manager, Master Management Procedure, IMS 22-10
Waste management	IMSS Contractors, HYDSMR23, Veolia.
Energy	Daily Performance, Monitoring, IMS-22-14
Noise and vibration	RCM & conditions based monitoring IMS 22-13
Monitoring	OSC, Facilities Manager. Brinsworth CBM Review, IMS-09

6.4 Environmental performance indicators

A range of key performance indicators are defined in procedure HYDSMR14-02 and targets set for the proposed operation at Newport in a similar manner to other BOC operations. These indicators will report on both the SHEQ and economic management of the operation.

Key performance indicators are recorded at weekly or monthly intervals as appropriate and reported to the BOC Group at monthly intervals. Under normal circumstances these will be subject to a high level review at 6 monthly intervals. The Margam Plant Manager will have overall responsibility for plant performance and will, along with the local control team and wider Group resources, be continually seeking to enhance performance in these key areas.

The primary environmental performance indicators for this plant are summarised in Table 6.2.

Table 6.2 Environmental performance indicators

KPI	Description
Thermal efficiency coefficient	This is a measure of how efficiently the plant uses thermal energy. The plant takes in thermal energy in the form of fuel and feed gas and discharges thermal energy in the form of hydrogen and steam. Through the plant process some thermal energy is lost to the flue gas, to cooling systems and to heat leak. By comparing the useful thermal energy exiting the plant to the useful thermal energy entering the plant we calculate the percentage of useful thermal energy preserved throughout the plant process. The coefficient is calculated as follows: $\frac{\text{Hydrogen Higher Heating Value (HHV)} \times \text{Hydrogen Produced}}{\text{HHV of feedstock and fuel} \times \text{feedstock and fuel used} - \text{heating value of exported steam (from steam tables)}} \times 100\%$
Vent losses	This is a measure of how closely hydrogen production matches demand and is calculated as follows: $1 - \left[\frac{\text{Total hydrogen supplied to customer}}{\text{Total hydrogen produced}}\right] \times 100\%$
Plant utilisation	This is a measure of how well the total installed capacity of the hydrogen plant is being utilised and is calculated as follows: $\frac{\text{Total hydrogen produced}}{\text{Rated capacity of the plant}} \times 100\%$
Supply Availability	This is a measure of how much the customer is kept supplied and is calculated as follows: $\frac{\text{Hrs of H2 supply to the customer}}{\text{(Hrs in the month - lack of demand hrs)}} \times 100\%$
Plant Availability	This is a measure of how much the plant is on stream as a percentage of the time the plant is required to be on stream and is calculated as follows: $\frac{\text{Hrs of H2 supply from the plant to the customer}}{\text{(Hrs in the month - lack of demand hrs)}} \times 100\%$
Supply Reliability	This is a measure of how much supply on stream time is attributable to reliable performance of the overall supply system and is calculated as follows: $\frac{\text{Hrs of H2 supply to the customer}}{\text{(Hrs in the month} - \text{Hrs of external downtime)}} \times 100\%$
Plant Reliability	This is a measure of how much plant on-stream time is attributable to reliable performance and is calculated as follows: $\frac{\text{Hrs of H2 supply from the plant to the customer}}{\text{(Hrs in the month} - \text{Hrs of external downtime)}} \times 100\%$
Interruptions	This is a measure of how often hydrogen supply to the customer is interrupted. A running total of externally and internally caused supply interruptions should be reported.

In addition to the above it is anticipated that there will be a requirement (currently on an annual basis at Dalry) for periodic monitoring of emissions to air from the reformer stack and confirmation of compliance with emission limit values which will form part of the BOC management report and the annual report to the Environment Agency. It is also expected that, as part of the larger site, the operations will be subject to periodic environmental audits (noise etc.).

7 Efficient use of raw materials and water

7.1 Selection of raw materials

The primary raw material in the proposed hydrogen plant is the natural gas feed stock. The reasoning behind the selection of steam reforming as the process and natural gas as the feedstock is discussed in section 4.2. Essentially the preferred raw material for hydrogen production is the one with the highest hydrogen to carbon ratio as this will result in the lowest waste production (i.e. carbon dioxide). Methane produces 0.25 moles of carbon dioxide per mole of hydrogen produced and produces the least waste in comparison to the alternatives. Natural gas comprises greater than 85% methane and is the most suitable readily available alternative. The selection of the natural gas reforming process will therefore largely determine many of the raw materials necessary for the process (e.g. catalysts, adsorbents etc.). The catalysts and adsorbents in the process are selected as the most suitable for the most efficient performance of the plant

The chemicals used in the treatment of boiler feed water are also an important raw material. The management of boiler feed water treatment and material selection is sub contracted to NALCO. It is their responsibility to select the most appropriate chemicals for treatment of the boiler feed water and to manage their storage and use and are expected to use industry best practice. All chemicals are added on safety grounds and operational grounds to ensure effective boiler operation.

The catalysts and adsorbents in the process were selected as the most suitable for the most efficient performance of the plant.

7.2 Raw material inventory

Table 7.1 summarises the expected plant inventory of raw materials. The primary materials used in the process are:

- Natural gas
- Catalysts and adsorbents
- Chemicals for boiler feed water treatment
- Lubrication oil
- Water

The acquisition of all raw materials follows the purchasing procedures and approved supplier requirements of BOC's IMSS. This ensures the suitability and quality of all purchased materials.

The plant control system has facilities for providing trend analysis for major parameters including:

- reformer efficiency
- operating costs
- incident reporting

The hydrogen plant management will be required to report performance data including the costs, effectiveness and environmental impact of all raw materials and additives used in the process throughout the operation of the hydrogen plant> these are part of the environmental performance indicators which are reported on a national basis monthly and subject to a six month review (see 6.4).

Table 7.1 Raw material plant inventory

Material	Components	Plant inventory	Annual usage[1]
Natural gas	84%+ methane	-	267 t
Oxygen scavenger	10% amine	Maximum 300 l	500 l
Corrosion inhibiter	22% sodium polyphosphate	Maximum 300 l	150 l
	aqueous polymer		
	phosphate solution		
pH control	30% sodium hydroxide	Maximum 300 l	105 l
Hydrogenation catalyst	cobalt oxide	0.24 m^3	Change every 10 years
	molybdenum oxide		
Absorber	zinc oxide	0.24 m^3	0.12 m^3
Reformer catalyst	nickel oxide	0.73 m^3	0.15 m^3
Shift catalyst	ferric oxide	0.80 m^3	Change every 5 years
	chromium oxide		
	copper oxide		
PSA adsorbent	zeolite	25 m^3	Good for lifetime of plant
	alumina		
	activated carbon		
Lubrication oil	mineral oil	50 l	1095 l
Hydrogen	Hydrogen	0.5 t	-
Water	Water	-	216 t

1. Annual usage based on continuous operation at 100% load design condition.

7.2.1 Natural gas

Natural gas will be supplied from the Wales and West Utilities network from the Regional Transmission system.

7.2.2 Catalysts, adsorbents and absorbents

Catalysts, adsorbents and absorbents are used in the following process operations:

Desulphurisation – hydrogenation
Desulphurisation – absorption of hydrogen sulphide
Reforming - cracking
Shift conversion
Pressure swing adsorption

It is possible to make confident predictions as to the expected lifetime of these materials as there is ample experience from the plant operation at Dalry. On re-installation at Newport all catalysts, adsorbent and absorbents will be fresh and therefore expected to at least meet the performance and service life summarised in Table 7.1.

7.2.2.1 Desulphurisation

Desulphurisation of the natural gas feed stock is a two-stage process featuring hydrogenation of organic sulphur compounds to form hydrogen sulphide followed by absorption of hydrogen sulphide on a zinc oxide bed. Both catalyst beds are situated in a single vessel. The organic sulphur level in the gas is very low.

The hydrogenation catalyst consists of cobalt oxide (CoO) and molybdenum oxide (MoO_3) on an alumina base. The plant inventory is around 0.24 m^3 and, despite a guarantee life of 5 years, experience at Dalry indicates that the catalyst will have an effective lifetime of 10 years. Zinc oxide (ZnO) will be used to absorb the hydrogen sulphide in the gas stream. The volume will be around 0.24m^3. The design life of the catalyst is around 2 years (at a total sulphur content of 5.1 ppm). If sulphur levels of incoming gas are less than this then catalyst life will be extended.

These materials have been selected on the basis of their proven effectiveness in providing very low levels of sulphur (c. 0.1 ppm) for the reformer feed gas. This performance is generally considered to be superior to available alternatives.

7.2.2.2 Reforming

The reforming reaction uses a nickel oxide catalyst. The plant inventory is around 0.73m^3 with a design lifetime of about 5 years. This catalyst can be poisoned by sulphur, as such it is important to have good desulphurisation performance. Nickel oxide is an established industry standard for reforming.

7.2.2.3 Shift conversion

The shift conversion, which operates at high temperature, reacts carbon monoxide with steam to form hydrogen and carbon dioxide. This undertaken over a catalyst of ferric oxide (Fe_2O_3) with some chromium oxide (Cr_2O_3) and copper oxide (CuO). The plant inventory is around 0.8m^3 with an expected life time of 5 years. The catalyst proposed is accepted industry standard.

7.2.2.4 Pressure swing conversion

In pressure swing adsorption, the gas from the shift converter which contains hydrogen, carbon dioxide, carbon monoxide and nitrogen is separated by adsorption of the impurities on to a bed of zeolite with alumina and activated carbon. This results in the production of a highly pure hydrogen stream and a tail gas stream on desorption which is returned to the reformer furnace as fuel. The adsorbent would be expected to be effective for the lifetime of the plant. The adsorbent represents current industry best practice.

7.2.3 **Boiler feed water chemicals**

The selection of the boiler feed water chemicals is the responsibility of NALCO. During operation at Darly the hydrogen plant used proprietary NALCO chemicals. The oxygen scavenger employed is the most effective chemical in terms of levels of dosage. Phosphate/polymer is used to comply with the British Standard for scale inhibition should any hardness get through the demineralisation process and to aid in dispersion of iron and silica. Caustic is added, again to comply with the British Standard for alkalinity to protect the boiler.

NALCO is a recognised market leader in the treatment of boiler water and management of water systems. The products employed at any one time are understood to represent standard industry practice and to effectively meet the specific requirements of the hydrogen plant system.

7.2.4 **Lubrication oil**

The hydrogen compressor has a requirement for lubrication oil of around 3 l/day. This will be sourced from an approved supplier to the manufacturer's specification.

7.3 **Material delivery, storage and handling**

The procedures that will be employed to manage delivery, storage and handling will be aimed at minimising the site inventory of materials and receiving, storing and handling in the most appropriate manner to avoid accidental release. Storage facilities will be designed to contain accidental releases and minimise the risk of subsequent contamination.

7.3.1 Hydrogen

In the event that imports are required to maintain supply to Solutia UK Limited (e.g. during plant shutdown/maintenance), hydrogen would be supplied via trailers nominally from BOC's nearest alternative supply source at Margam. There will be three trailer-filling bays on site.

7.3.2 Instrument air and nitrogen

Instrument air and nitrogen will be provided from the existing Solutia UK Limited site facilities A continuous supply of 200 Nm^3/h (7 barg with a dew point of $–40^oC$) of instrument nitrogen is required for the hydrogen plant instruments.

The instrument air system is clean, dry air supplied from a fully automatic regenerative (pressure swing) type air dryer. In the event of instrument air failure there is a nitrogen backup system to supply instrument air. Design instrument air consumption 50 Nm^3/h (5.0 bar(g)).

7.3.3 Lubrication oil

The site storage capacity for the hydrogen compressor lubricating oil will be around 50 litres. This will be stored in two 25 l containers in a 30 l capacity bunded area. Oil usage is around 3 l/d. The oil storage area will be located close to the compressor and will have an impermeable surface to prevent seepage of any drips/spills into the ground. The compressor area will be covered to reduce the potential for contamination of rainwater and hence minimise the volume of contaminated water for disposal. In the event of an oil spillage, absorbent material will be used in the first instance. Used material will be collected in a sealed box and disposed of via existing site disposal routes for oily waste.

Used oil from the compressor will be transferred back into empty oil drums and stored in a separate bunded area. This is then sent to an approved specialist contractor for treatment and recovery . Based on experience at Dalry it is estimated that there will be a need to remove one 25 l container every two weeks.

7.3.4 Catalysts, adsorbents and absorbents

There will be no on site storage of either fresh or spent catalyst. BOC has selected vendors on the basis of their handling procedures and treatment capabilities.

The vendor will both load and unload the catalyst in accordance with its procedures which will have been reviewed and approved by BOC. Fresh catalyst will be brought on to the hydrogen plant area in sealed containers. This will either be reusable steel drums lined with polythene or, for the reformer catalysts, in pre-packed socks sized to suit the tube dimensions. Catalyst loading will be undertaken by qualified competent vendor staff under the overall supervision of the BOC Facility Manager.

Unloading of spent catalysts will be undertaken at plant shutdowns. This will also be by the vendor's qualified staff. Particular attention will be paid to the catalysts, which could form potentially pyrophorric compounds. Such catalysts will be discharged under a nitrogen blanket into containers, which will be sealed as soon as they are full.

All spent catalysts are to be returned to the vendor for re-processing. BOC will regularly review performance to ensure that catalyst handling is effective and in compliance with its environmental policies.

7.3.5 Boiler feed water chemicals

All chemicals will be stored in tanks with integral corrosion resistant bunds within a separate building which is kept locked at all times. The floor and bunds are impenetrable to the liquid chemicals. The storage tanks will have a capacity of 325 l with a fill level of 300 l. The design capacity of the tank bunding will be around 333 l per tank. Each tank sits within its own bunded area occupying approximately 200 litres of the bund capacity. The tanks have a low-level alarm, but no high level alarm. NALCO fills the storage tanks when necessary. The chemicals are manually transferred from a 200 l drum into the storage tank via a pumped fill, supervised at all times under the control of BOC personnel. Each storage tank is permanently connected to a pump, which is used to transfer the required dosage of chemicals into the deaerator. Both BOC and NALCO have responsibility for clearing up and disposing of any spillage which may occur.

7.4 Waste minimisation

There are four main waste streams from the hydrogen plant

Flue gas from the reformer
Steam venting from the deaerator
Releases from the vent gas header
Boiler feed water blow down (see 7.5)

There has been significant work to either minimise these waste streams or exploit some of the properties (e.g. heat). Following experience at Dalry it is considered that all reasonable measures have been undertaken to reduce losses via these streams.

7.4.1 Deaerator steam vent

Steam vented via the deaerator is at a level where further reduction is not possible due to the need to remove non-condensibles from the water.

7.4.2 Reformer flue gas

The flue gases from the reformer have to be released, although as described in section 9, the stream is optimised both for waste heat recovery and release of combustibles (e.g. carbon monoxide). Further minimisation is likely to result in condensation difficulties and an increase in releases of nitrogen oxides respectively.

7.4.3 Vent gas header

Several options for reducing vent gas header losses have been assessed during operation at Dalry, although few have been determined to be significantly effective. The main release from the stack is hydrogen which comes about from the need to balance plant production with demand (see section 5.1.3). BOC have made improvements to the control system during operation at Dalry which has sought to better match plant load and demand through automated control so as to minimise the need for venting. Product venting is a key performance indicator which is monitored as part of the regular plant reporting procedures.

7.5 Water use

The uses of water in the hydrogen plant are:

- Process steam for the reforming reactions
- Cooling and steam raising by heat exchange

Water usage is controlled by effective management of an integrated water/steam system.

Hydrogen production by steam reforming is energy intensive and requires effective energy management to minimise energy requirements and hence raw material usage, particularly natural gas feedstock. The energy management plan is described in section 9 and a key part of this is the effective use of waste heat by heat exchange.

The following order of preference has been used for cooling:

1. Steam raising
2. Heating of feedstocks
3. Air cooling
4. Water cooling for trimming

Steam raising and feed stock heating is achieved by incorporation of extensive heat interchange systems, whereby the energy contained in the flue gas is reduced to a minimum and feedstocks and products heated to the required operating conditions.

A combination of air-cooling and water heating is necessary to reduce the temperature of the raw product to the optimum required for hydrogen separation in the PSA System.

Specific cooling systems on the plant will be a combination of air and glycol cooling. Glycol cooling is used for the hydrogen compressor. The glycol system is self-contained and is occasionally topped up with water (during shut-downs). The design circuit ethylene glycol flow rate is 16.8 t/h.

At design conditions the stream raising and heating systems result in water losses via steam venting and boiler feed water blow down of around 59 kg/h. These losses are considered to be effectively managed. The deaerator steam vent releases have been optimised (5.1.2), whilst the blow down rate is effectively managed by good boiler water treatment (7.2.3).

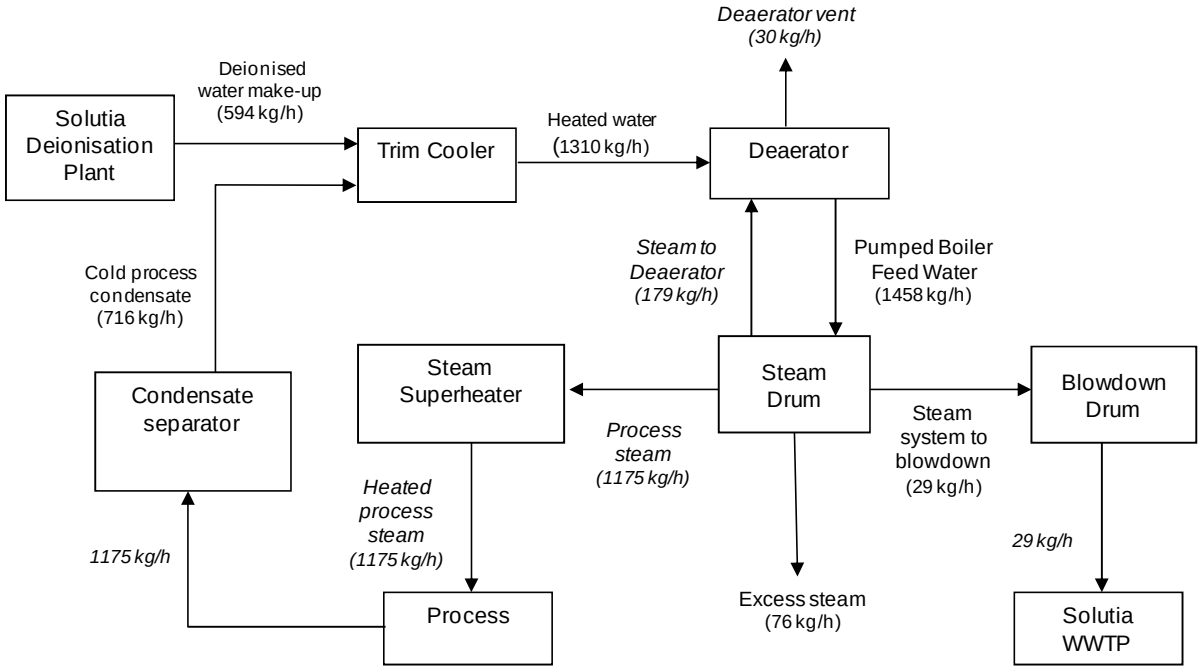
Process water usage is around 459 kg/h based at 100% load. Process condensate contains dissolved carbon dioxide as well as small amounts of methanol, organic acids and ammonia. It is recycled within the system by being fed to the deaerator, where carbon dioxide other contaminants are partially stripped out.

There is a low level of risk of surface water contamination as there are no significant liquid hydrocarbon inventories. Dosage chemicals tanks are bunded to contain any spills.

BOC does not envisage routine wash-down of equipment during plant maintenance. It may be steamed-out and nitrogen purged during shutdowns and re-starts. If fouling does occur (as in superheater tubes), then remediation will be undertaken offsite in controlled conditions.

Figure 7.1 illustrates the water/steam flows within the system. Quantities are based on operation at 100% load design conditions.

Figure 7.1 Water and Steam Flows (Design conditions -100% load)



8 Avoidance, recovery and disposal of waste

There is no intention to store waste in any significant quantity around the proposed hydrogen plant. General wastes associated with maintenance will be limited and handled within the existing Solutia UK Limited site waste management system. Wastes arising from process operations will be intermittent and well developed procedures will be in place to ensure such wastes are handled effectively and the most appropriate environmental option selected for their treatment, recycling or disposal.

8.1 Solid process wastes

During normal operation the only solid wastes from the plant will be spent catalysts and/or adsorbents and maintenance wastes, such as bearings and seals from pumps.

BOC has selected a catalyst supplier who is also contracted to recover catalysts (see 7.3.4). Spent catalysts will be removed from the site in sealed containers by the approved supplier or a designated specialist contractor in accordance with the approved procedures for handling and disposal of spent catalyst. The pyrophoric catalysts will be removed under a blanket of nitrogen and taken by sealed container to the vendor's manufacturing facility. The frequency of discharge depends on the specific catalyst and ranges from 3 to 6 years (see Table 4.3). All catalysts are returned to the manufacturing site for recovery and subsequent re-generation. The removal agreement applies to the following catalysts and absorbents:

- Desulphurisation catalyst and zinc oxide absorbent
- Reformer promoted and active catalysts
- High temperature shift catalyst

Catalyst movements will be recorded in accordance with BOC procedures; transfer notices and receipts will be required to ensure the catalyst is returned. The catalyst vendor will also be required to provide an audit trail to authorised waste disposal contractors for any material which cannot be re-used.

Other operating wastes, in particular, PSA adsorbent will be disposed of to authorised landfill, as inert waste. Removal of PSA wastes will be in enclosed containers sealed from ingress of moisture. PSA waste is likely to be produced only at the end of the operating life of the hydrogen plant. This type of waste will not be stored on site, but removed after emptying each vessel by an authorised waste disposal contractor under the supervision of the relevant vendor.

8.2 Liquid process wastes

There are no significant quantities of hydrocarbon wastes as the reforming process occurs in the gaseous phase process, i.e. there is no liquid inventory. There is a very low inventory of lubricating oil (0.12 m^3) in the hydrogen compressor sump. Disposal of this material will be required, following a plant shut-down and maintenance programme.

Used oil from the compressor is transferred back into the original empty oil drums and stored in a bunded area. The used oil will be removed from site treated and recovered by a specialist company. It is expected that one 25 l container of used oil will need to be removed from site every two weeks.

There are no additional domestic sewage facilities required for this installation. Existing Solutia UK Limited site facilities will be used.

8.3 General wastes

General waste arising during normal operation (e.g. packaging, office waste) will be stored in covered containers to guard against the elements. The waste will be disposed of under the existing Solutia UK Limited site system and will be appropriately labelled and segregated to enable effective recycling.

8.4 Waste management

BOC utilises the services of licensed waste disposal contractors for all waste handling. Any wastes designated for authorised landfill will be managed in accordance with BOC procedures. Waste transfer notices will be completed and the waste will go to a licensed disposal site appropriate for the waste category. Wastes will be segregated and arrangements put in place to:

- Record the quantity and nature of the waste
- Track waste movements to the selected authorised waste management contractor and the authorised landfill.

8.5 Waste minimisation

BOC has implemented a solids waste minimisation programme for all its operating sites. However, in this cases the amount of waste generated is very low in terms of total quantities therefore there are few opportunities for waste minimisation.

As discussed it has been found possible to extend the life of selected catalysts and/or absorbents, by efficient monitoring of process parameters and effective process control. Factors that influence the life of catalysts, adsorbents and absorbents that will be monitored on a regular basis during plant operation, are summarised below.

- Level of sulphur in natural gas feed
- Sulphur absorber operating temperature
- Component balances across reformer and shift reactor
- Hydrogen purity, especially CO contaminants to assess PSA performance
- pH of BFW in deaerator
- Steam-hydrocarbon ratio in the reformer

Adoption of the above monitoring regime and appropriate control will assist in prolonging the lifetime of catalysts and sorbents and hence minimising the production of solid wastes. Experience from operation at Dalry has shown that catalyst life can be extended significantly beyond that specified by the vendor.

Extensive evaluations of the most appropriate recovery options for solid waste have already been undertaken during plant operation at Dalry. Current procedures, which are intended for implementation at Newport reflect industry best practice.

In over 10 years' operation at Dalry various audits aimed at waste minimisation have been undertaken. It is generally concluded that most waste streams are effectively managed and minimised as far as possible. Hydrogen venting is still seen as the primary waste stream and efforts continue to determine means of better responding to changes in demand to reduce the need for hydrogen venting (see section 7.4.3). This remains a key performance indicator for the plant.

9 Energy use and efficiency

The hydrogen plant energy consumption comprises primarily of:

- imported electricity
- natural gas

The PSA unit tail gas, which contains partly converted natural gas, is used as a supplementary fuel for the reformer furnace. Natural gas is used both as a fuel and process feedstock as shown in Figure 10.1. Typical plant consumption at a 35 % load is summarised in Table 10.1.

Figure 9.1 Hydrogen plant natural gas flow

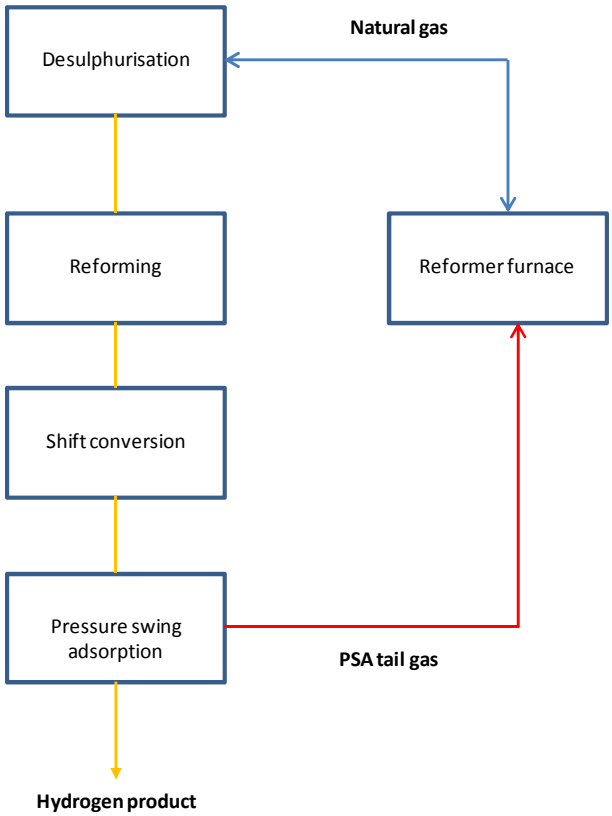


Table 9.1 Hydrogen plant natural gas consumption (design) at 35% load

Stream	Flow rate (Nm^3/h)
Total natural gas consumption	175.7
Natural gas to reformer furnace	53.2
Natural gas to process	122.5
PSA vent gas to reformer furnace	309.7
Hydrogen product	387.1

The BOC hydrogen plant will source electricity from Solutia UK Limited and will be charged according to usage and therefore this specific plant is not subject the Climate Change Levy Agreement, although other BOC operations, depending on circumstances, have an agreement in place.

9.1 Energy consumption

Current practice at the Dalry plant is to measure and report energy consumption (electricity and natural gas) on a weekly and monthly basis. The Dalry plant operated for the first six months of 2013 and the recorded energy consumption figures at an average loading of 35% are presented in Table 9.2. In addition these figures have been used as the basis for an extrapolation for the entire year. This is relevant to the proposed installation at Newport as the loading for the first year's operation is anticipated to be around 35-40%.

Table 9.2 Measured and extrapolated energy consumption - Dalry 2013

Source		January to June 2013	Extrapolated 2013[1]
Natural gas	Therms	287405	608279
Electricity	MWh	948	2006

1.Extrapolated to 8760 hours based on January to June operating period of 4139 hours.

The above energy usage is equivalent the indirect and direct carbon dioxide emissions in Table 9.3.

Table 9.3 Extrapolated carbon dioxide releases - Dalry 2013

Source	Energy consumption (GJ)	Energy consumption (MWh)	CO_2 emission factor (tCO_2e/MWh)[1]	CO_2 release (t)
Natural gas	64116	17809	0.19	3384
Electricity	7222	2006	0.40	799

1 CO_2 emission factors from H1 Annex H[5].

Natural gas is the predominant energy source comprising 90% of the total and contributing to 81% of the carbon dioxide emission.

9.2 Energy efficiency

Despite being over 10 years old the proposed hydrogen plant arrangement represents the industry standard in terms of energy efficiency[6]. Exploitation of available waste heat is integrated into the design of the plant.

The process is energy intensive and as a result there are significant opportunities to exploit in both the flue gas and product gas streams.

The flue gas from the reformer leaves the furnace at around1000^{o}C and is progressively cooled by heat exchange to the stack exhaust temperature of around 150^{o}C i.e.

Furnace exit	1000^{o}C
Heating steam in steam superheater	1000^{o}C to 650^{o}C
Saturated steam generation	650^{o}C to 250^{o}C
Pre heating of combustion air	250^{o}C to 150^{o}C

Further cooling of the flue gas prior to discharge is not considered appropriate in view of the potential for condensation and subsequent corrosion.

The product gas from the reforming stage is at around 800°C and is subsequently cooled by heat exchange as it passes through the remaining process stages:

Reformer exit	800°C
Steam production in reformer effluent steam generator	800°C to 300°C
Steam production in shift effluent steam generator	300°C to 216°C
Air cooling	216°C to 169°C
Steam production and boiler feed water preheat in trim cooler	169°C to 15°C

In addition, the PSA unit vent tail gas is used as the primary fuel for the reformer furnace. Natural gas is used as a supplementary fuel only.

Whilst other process operations at the Solutia site may have available waste heat it is not considered appropriate for integration into the current hydrogen plant arrangement for two reasons.

- The system is already well integrated and there are few further opportunities for significant exploitation of additional waste heat.
- For safety reasons the hydrogen plant is situated remote from other site process operations. Use of available waste heat over such a distance is not considered viable.

9.3 Energy monitoring and auditing

Electricity and natural gas usage figures are measured, recorded and trended every week and month. All increases in energy usage are investigated to ensure deviations are understood and resolved where necessary.

The hydrogen compressor is the main consumer of electricity (see 9.3.1) and as such it is continually monitored to ensure efficient operation. The compressor is a positive displacement, reciprocating machine and the energy requirement is reasonably consistent irrespective of the actual plant loading. Efficiency of this machine and energy usage per unit product would therefore improve with increased plant loading. Whilst the first year's operation is likely to be around 35-40% of plant load the long term aim would be to operate at higher loadings to improve efficiency.

Plant loading is the primary issue affecting the overall energy efficiency of the plant. This has been a feature of operation at Dalry, where BOC have sought to mitigate these problems by close communication to determine demand patterns and manage the plant accordingly to ensure optimum efficiency.

A weekly plant performance report is an existing requirement which includes monitoring and assessment of energy usage. This will be employed at Newport to enable the plant to be monitored and managed based on key performance indicators:

- flue gas oxygen
- plant venting rates
- Hydrogen:natural gas ratio

Reports will be reviewed by the Facility Manager and significant deviations from target values will be subject to investigation and remedial action. This management system has been applied successfully during plant operation at Dalry.

The plant will be required to produce a monthly performance report to BOC's national management demonstrating compliance with operating targets which include energy efficiency requirements.

9.4 Operation, maintenance and housekeeping

The following systems are relevant to the site's energy consumption:

- Process cooling systems

- Pumps
- Dryers
- Motors and drives
- Compressed gas systems
- Boiler
- Lubrication
- Building services

The objective is to employ energy efficient equipment and operate and manage these systems in the most energy efficient manner.

Regular maintenance activities will be managed by the SAP maintenance system as currently in place at Dalry. This system allows total integration with purchasing systems and interrogation to determine current status of planned maintenance requirements for all site equipment. The system automatically produces work orders as determined by defined frequencies for a particular maintenance task, which are then assigned and completed by the relevant personnel. This ensures that the regular maintenance tasks necessary to ensure efficient plant operation are scheduled and completed in an effective and timely manner.

9.4.1 Process cooling systems

Cooling of the flue gas, reformer effluent and process gas stream is done by exchanging heat with water in heat exchangers to produce the steam required in the process (see 9.2). The inter-stage cooling in the hydrogen compressor uses a glycol cooling system. Air cooling is used to cool the glycol, the hydrogen product and to further cool the process gas from the shift effluent generator. All cooling systems are regularly maintained in accordance with the site's Written Scheme of Examination to ensure efficient and safe operation.

9.4.2 Motors and drives

The energy significant motors and drives associated with the process are described in Table 9.4. As discussed above (9.20 the hydrogen compressor is the most electrical energy intensive device within the plant.

Table 9.4 Electrical devices

Device	kW	Motor HP	Hours of Operation
Induced draught fan	14	20	8760
Forced draught fan	4	7.5	8760
Air cooler fans (process & glycol cooling)	16	30	8760
Glycol circulation pumps	4	2 x 7.5	8760
Boiler feed water pump	9	2 x 15	8760
H_2 product compressor	160	215	8760

In addition to the above major systems there is around 35 kW of other smaller devices making a total of around 242 kW. All motors are checked and serviced in accordance with BOC's pre-planned maintenance regime and the manufacturer's instructions to ensure efficient operation.

9.4.3 Compressed gas systems

The process uses nitrogen and instrument air for utility services. The system has a low pressure indication and alarm and will be remotely monitored 24 hours a day. Any significant leak will result in a low pressure/flow alarm being activated. The procedure is then for the operator call a Facilities Engineer to the site to undertake remedial work.

Routine plant walk rounds and 'Look Listen & Feel' tasks are used to monitor the integrity of gas systems.

9.4.4 Boiler maintenance

The plant is equipped with a burner management system. The reformer has view ports located around the burner. These holes are used for inspection of the flame pattern and viewing of the reformer catalyst tubes.

An oxygen analyser is installed on the flue to monitor combustion conditions. The analyser is used to control the air/fuel ratio with 10% excess air normally be considered adequate for satisfactory combustion of the fuel. It is possible to operate the furnace at lower excess air levels. Whilst this may desirable from an efficiency point of view, the aim is to minimise carbon monoxide production. Operation at 10% excess air is known to essentially eliminate carbon monoxide in the flue gas and care is necessary at lower excess air levels to ensure this is maintained.

Whilst the burner operation is visually inspected regularly via the view ports, a full inspection and service is scheduled every two years in accordance with BOC's pre-planned maintenance regime and manufacturer's instructions. Observed problems outside of this main inspection period will be addressed as required to ensure efficient operation is maintained.

9.4.5 Lubrication

All pumps and motors require lubrication, provided by automatic lubricators. The hydrogen compressor uses oil for lubrication of the moving parts and lubrication of the process gas during compression. Oil usage for this purpose amounts to approximately 3 l per day based on current operating practice at Dalry. Operators will be required to regularly check levels and top up as appropriate. Used oil is collected and suitably stored and subsequently recycled off-site by a specialist vendor.

9.4.6 Building services

Building services are expected to account for around 14% of the total electrical energy consumption based on operating experience at Dalry. BOC's standard policy provides measures for energy management, conservation and minimisation within its buildings and offices which is unpinned by environmental awareness training. This will be applied at Newport to ensure efficient energy management of building services. Although the hydrogen plant will operate continuously, the site will be normally unmanned and as such, apart from the control room area there will be limited scope for significant improvement on the current situation at Dalry.

10 Discharges to groundwater

The Environmental Permitting Regulations 2010[7] transpose the requirements of the Groundwater Directive 1980, the Water Framework Directive 2000 and Groundwater Daughter Directive 2006.

These Directives require that inputs (discharges) of pollutants to groundwater are either prevented or limited, to avoid or control groundwater pollution. In so doing such measures should also prevent the deterioration of the chemical status of groundwater bodies and avoid (environmentally) significant and sustained upward trends in the concentration of pollutants in groundwater.

Hazardous substance is defined in Article 2(29) of the Water Framework Directive 2000 as meaning substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern. Previously List I and List II groupings of substances were defined for regulation, although these no longer apply. Substances are instead treated as either 'hazardous substances' (initially broadly equating to the former List I) or non-hazardous pollutants' (analogous to the former List II, but potentially applying to all other pollutants)

The identification of hazardous substances is the responsibility of the Environment Agency on the recommendation of the Joint Agencies Groundwater Directive Advisory Group (JAGDAG).

Table 10.1 lists the substances which are associated with the operation of the hydrogen plant and their classification status based on the latest JAGDAG listing (www.wfduk.org/stakeholders/jagdag-work-area-0).

Table 10.1 Hydrogen plant materials and classification

Material	Components	Annual usage[1]	Classification
Natural gas feed stock	84%+ methane	267 t	-
Oxygen scavenger	10% amine	500 l	-
Corrosion inhibiter	22% sodium polyphosphate	150 l	-
	aqueous polymer		-
	phosphate solution		-
pH control	30% sodium hydroxide	105	-
Hydrogenation catalyst	cobalt oxide	Change every 10 years	-
	molybdenum oxide		-
Absorber	zinc oxide	0.12 m^3	non hazardous
Reformer catalyst	nickel oxide	0.15 m^3	-
Shift catalyst	ferric oxide	Change every 5 years	-
	chromium oxide		-
	copper oxide		-
PSA adsorbent	zeolite	Good for lifetime of plant	-
	alumina		-
	activated carbon		-
Lubrication oil	mineral oil	1095 l	hazardous
Hydrogen	hydrogen	-	-
Water	water	216 t	-

Table 10.2 details substances which are already present in the soil around the intended location of the hydrogen plant at the Newport site. These are the results of a Phase 2 site condition report undertaken in 2002[8] (see section 18).

Table 10.2 Soil contaminant content – Newport site 2003

Substance	Soil content (mg/kg)	Classification
Arsenic	<1-11	-
Cadmium	<1	Hazardous
Chromium	23-109	-
Copper	1-24	-
Mercury	<1-11	Hazardous
Nickel	37-48	-
Phosphorus	383-1583	-
Lead	34-58	-
Selenium	<1	-
Zinc	84-201	Non hazardous
Solvent extractable material	245-19284	-
Acid soluble sulphide	2-2320	-
Total phenols	<0.01-34.8	Non hazardous
Total sulphate	600-2891	-
C_9-C_{28} hydrocarbons	260	-
C_{10}-C_{20} hydrocarbons	61.5	-
C_{10}-C_{26} hydrocarbons	134	-
C_{10}-C_{30} hydrocarbons	147	-
C_{12}-C_{24} hydrocarbons	23.5	-
Terpine type compounds	0.8	-
Chlorinated biphenyls	379	Hazardous
Molecular sulphur	1.3	-
Biphenyl	0.7	-
Benbzothiazole	1.4	-

The delivery storage and containment measures described in section 7.3 will be put in place to ensure that there will be no direct or indirect releases from the plant of process materials to ground water. Containment of liquid is ensured by the use of integral bunds and suitably engineered and maintained piping systems. Whilst there is quite limited handling of solid and liquid materials, appropriate working procedures, based on best practice and previous extended operating experience, will be in place.

11 Risks and consequences of accidents

11.1 Risk management

All BOC projects are subject to a project safety review (CEPM, 6 stage process) which is an ongoing procedure following a project from conception through construction, commissioning to examination of operational experience. This ensures that health and safety issues are considered during all stages of project development.

At the design stage Hazard and Operability studies (HAZOP) and Safety Integrity level (SIL) reviews are undertaken to ensure that the design and engineering of the facility is suitable to safeguard against foreseeable failure events. The HAZOP team comprises several qualified process, engineering and operations specialists who are required to analyse each plant system systematically at the direction of an experienced HAZOP leader. Failure events such as high pressure, high temperature, reaction changes, flow changes, avoidance of cross contamination and contact between incompatible substances are identified and recorded. The team evaluates the consequences of failure and determines the optimum solution to prevent it occurring.

This process was undertaken throughout the process design, development and implementation phase at Dalry. In addition, there is the benefit of over 10 years successful operational experience and risk management which will be incorporated into the operational procedures when the plant is relocated to Newport.

11.1.1 COMAH Regulations

It is anticipated that the hydrogen plant operating a Newport will not come under the Control of Major Accident Hazard (COMAH) Regulations. Whilst hydrogen is a named substance under COMAH it is estimated that the inventory (piping vessels etc.) is likely to be less a tonne which is below the specified lower quantity limit (5 tonnes). It is noted that the Solutia site is currently a COMAH top tier site. This will be confirmed with the Health and Safety Executive. Nevertheless, BOC operate several COMAH regulated sites and the well proven procedures employed at these sites in terms of design construction operation and maintenance are equally applied to non- COMAH sites. These are described in BOC's Health Safety and Environment Quality Management Procedures and are aimed at:

- Ensuring the integrity and safety of the design of the facility, by the adherence to recognised national and international design standards, codes and practices and by the implementation of stage HSE reviews throughout the design process to identify and minimise risks;
- Accident free operation and sound maintenance of the plant throughout its life.

11.2 Measures to reduce risk

BOC employ procedures to ensure that risk is minimised throughout its operations. Some of the measures to be employed on this plant to reduce the risk and consequences of accidents are described below and relate to the inherent safety aspects of the process and the measures in place to further reduce risk where it arises.

11.2.1 Material inventory

The aim during operation at Dalry was to minimise the storage of raw materials on site. As discussed in sections 7 and 10 the requirements for storage of raw materials on site is not significant. There is no requirement for storage of solid materials such as catalysts and adsorbents. The main storage requirement is for boiler feed water treatment chemicals and lubrication oils.

All chemicals will be stored in tanks with integral corrosion resistant bunds and stored within a separate building which is kept locked at all times. The floor and bunds are impenetrable to the liquid chemicals. The tanks have a low-level alarm, but no high level alarm. NALCO fills the storage tanks when necessary. The chemicals are manually transferred from a 200 litre drum into the storage tank via a pumped fill, supervised at all times under the control of BOC personnel. Each storage tank is permanently connected to a pump, which is used to transfer the required dosage of chemicals into the deaerator. Both BOC and NALCO have responsibility for clearing up and disposing of any spillage which may occur.

At any one time the maximum inventory of lubrication oil will be 50 l. The oil will be stored in 25 l capacity drums within a bunded area. Oil usage is around 3 l/day. As discussed in section 7, there is a relatively low usage of oil and measures are in place to satisfactorily handle any spills or leaks and to prevent rainwater contamination.

The plant will therefore operate with minimum inventories of hazardous or potentially hazardous substances and with secure measures in place to handle any accidental release.

There have been no notifiable releases of these chemicals during plant operations at the Dalry site.

11.2.2 Equipment

Assessments conclude that the health, safety and environmental risks for the hydrogen plant are low. The main concerns with interruptions/plant failures are related primarily with reliability to meet the 99% availability criteria.

Redundancy measures include:

- Sparing of all pumps
- Use of four fans on the air cooler duty, permitting shutdown of one for maintenance.
- Use of two independent level switches on the steam drum.

These procedures have enabled effective operation at Dalry.

11.2.3 Control systems

The control system philosophy is discussed in section 4.7.

Individual control system philosophies have been established for:

- Reformer steam to carbon ratio
- Steam drum level control
- Burner management
- Emergency shutdown system

These systems have the benefit of being refined based on significant operational experience at Dalry and will be employed at the Newport site.

11.2.4 Other measures

The installation at Newport will benefit from the operational experience at Dalry and the various general risk evaluations undertaken in support of its installation and subsequent operation.

BOC quality control procedures are implemented to ensure that raw materials in the form of feedstocks and dosage chemicals are segregated where there is a risk of incompatibility. Natural gas feed is piped from the Wales and West utilities main and is fully segregated from any other material until it enters into the process equipment. The only other primary raw material is water. Dosing chemicals are handled by qualified NALCO staff who are trained to minimise associated risks and avoid cross contamination and incompatibility.

Maintenance procedures are well defined and identify the preventative maintenance regime that will be employed to maintain the safety and integrity of the plant. Routine checks of equipment and systems will be carried out. Instrumentation is regularly calibrated in accordance with the supplier's instructions, or as defined within BOC's own standards. Maintenance schedules for every item of equipment and instrumentation are defined and as a minimum meet manufacturers' recommendations. All items of equipment are maintained on a centralised computerised schedule to provide for automatic recall of spares, checks and calibration.

11.2.5 Operating procedures

Operating procedures are defined within the Operating Manual and are described more fully in section 6. The main features of the procedures include:

- Site security is through the Solutia UK Limited main access gate which is permanently manned.
- Responsibilities of the BOC Management and Operators are clearly laid down with regard to accident management
- Permit to Work systems are in operation to ensure effectiveness of communications and control during maintenance or other engineering work
- Emergency Response Shutdown and Execution Planning
- Incident Recording and Evaluation records and reporting
- Start-up and shutdown
- Instrumentation control systems

Section 6 summarises the plant protection systems incorporated into the hydrogen plant and the primary failure scenarios.

An installation register and incidents log is maintained within the computerised management system to record all incidents, near misses, abnormal events and findings of maintenance inspections. Analysis of the entries, trend reports will be used to evaluate the need for changes to instructions or procedures. The Newport installation will benefit from this continual review of the plant process management which has resulted from over ten years of operational experience at Dalry and from other similar plants.

11.3 Emergency response procedures

An emergency plan will be developed which will involve response from the Solutia UK Limited site and the BOC Brinsworth (European Operations Centre).

The plant will contain a relatively low inventory of flammable gases in the form of hydrogen, synthesis gas and natural gas. In the event of a gas escape which subsequently ignites, the hydrocarbon liquid inventory is considered to be insufficient to continue to supply fuel to any fire. Any fires will be quickly extinguished by remote emergency activation of the natural gas feed shut off valve. Any leaks will burn out quickly. Equipment spacing is such that there is unlikely to be flame impingement on

adjacent facilities and the fire will not spread. The plant is to be sited some distance from other major process operations at the Solutia UK Limited site to avoid such problems.

The only significant liquid inventories envisaged are the boiler feed water treatment chemicals and lubrication oil. Spills of these materials have only a limited environmental risk and measures are proposed to contain these materials within the vicinity of the storage area. Storage tanks are bunded to contain any leaks from the tanks. Where there is a leak within the confines of the bund, the operator will be required to isolate the source of the leak, analyse the composition of the material and arrange for it to be hand pumped, with agreement, into the existing site effluent system. In the unlikely event that bund containment is also compromised, spill kits will be available around the storage area, to be used to prevent the spread of the spill from the concrete apron to the groundwater.

BOC operating procedures clearly detail the actions needed to respond to such events and the specific responsibilities of hydrogen plant personnel. Operating staff will be trained to respond quickly to any emergency and will be responsible for taking the initial actions necessary to prevent the spread of any incident. They are responsible for advising the Facilities Manger and the Operations Group of all incidents involving spills and fires. Back up is available from the operations support group at Brinsworth at all times. All plant information, alarms and trips will be duplicated within the Brinsworth site to ensure that incidents are recognised, understood and followed up.

The hydrogen plant operators will be responsible for informing the Facilities Manager of all incidents and action taken. The Facilities Manager is responsible for directing follow-up actions and for establishing communications routes with Solutia UK Limited and any other external bodies as necessary (Environment Agency, Health and Safety Executive, Emergency Services, Local Authority etc.). The Facilities Manager is also responsible for reporting incidents to BOC management. The reports will include analysis of the incidents with trends/recommendations for avoidance. The Facilities Manager will prepare all specified statutory reports.

12 Decommissioning and site restoration

12.1 Decommissioning

The hydrogen plant has a design life of 15 years. The design and construction of the plant is in accordance with national and international standards and good engineering practice. The plant is designed to permit scheduled maintenance and catalyst replacement shutdowns. Such shut-downs will be undertaken in a safe and controlled manner without detriment to the environment.

These planned arrangements will be used to ensure that the plant will be shut down and decontaminated without harm at the end of its useful life.

Measures include:

- Controlled de-pressurising of the plant
- Sweetening of vessels by steam out after shutting off the natural gas flow
- Controlled removal of catalysts by competent personnel under an inert atmosphere and return to catalyst vendor
- Wash-down, drain-out and cleaning of all vessels and pipe work
- Use of waste inventory to establish optimum handling and disposal arrangements for small quantities of hazardous materials (e.g. spent compressor lube oil)

Key engineering features that will assist in the safe disposal of plant and materials include;

- Use of non-hazardous mineral fibre insulation material (preformed for ease of installation and removal)
- Avoidance of underground piping and underground tanks
- Provision of vents and drains for all vessels, equipment and piping systems so that all systems may be drained completely
- Identification and use of measures to protect groundwater during dismantling of buildings and other structures

A complete review of the plant equipment and hardware will be undertaken to identify material that can be recovered, re-used elsewhere or recycled for alternative use. Only non-usable material will be treated as waste for disposal at authorised landfill sites.

As discussed the plant proposed for installation at Newport has already been operational at Dalry for some 10 years. The plant has recently undergone decommissioning and a complete inspection and refurbishment before the intended relocation to Newport. The above procedures have been implemented at Dalry during the decommissioning process. As part of the process these procedures will be reviewed in the light of experience. This will enable improvements to be made to the procedures which will eventually be employed to decommission the plant following operation at the Newport site.

12.2 Site restoration

In the context of restoration of the site to its original condition it should be recognised that:

- The current site is designated as industrial use and falls within the boundary of the Solutia UK Limited plant.

- BOC will maintain a record of any incident that could potentially cause additional contamination within the perimeter of the hydrogen plant.

The degree of site restoration will be determined at closure with consideration of the operational history and findings of the initial site condition report based on that prepared for Solutia UK Limited in 2002 (see Section 18).

The final site condition report following operation at Dalry is awaited, although visually there are no significant indications of contamination which would require substantial remedial action. There has been some minor oil staining of the concrete base, although this is not considered significant by the Regulator (SEPA). BOC's register of operation at Dalry has no recorded incidents of significant fugitive releases.

13 Emissions inventory

Emissions inventories, based on the information provided in sections 4 and 5, have been compiled for all anticipated significant point source emissions to air arising from the proposed installation, including normal and abnormal releases.

There are no process related emissions to surface water or sewer.

13.1 Point source releases to air

There are three point source releases to air:

- Flue gases from the reformer stack
- Steam venting from the deaerator vent
- Releases from the vent gas header stack

Releases at the reformer stack and deaerator stack are continuous, whilst the vent gas header stack has an intermittent release, the frequency and composition of which will be dependent on plant operation. The characteristics of these releases are discussed in section 5.1 and a full estimated inventory of releases is presented in Table 13.1.

Emissions to air have been quantified based on monitoring data obtained at the original plant commissioning at Dalry and from routine annual compliance monitoring from the reformer flue gas stack for nitrogen oxides and carbon monoxide. Emissions from both the de-aerator and vent gas header stack are based on calculations. Monitoring of emissions at these points is not required as part of the current permit requirements and in the case of the vent gas header stack representative monitoring presents significant difficulties.

Fugitive releases of volatile organic compounds and gaseous hydrocarbons from the installation are discussed in Section 5.3.1. It is considered that fugitive releases are unlikely to give rise to significant emissions and these are therefore not considered further.

13.1.1 Reformer flue gas stack

Releases from the reformer furnace flue gas stack are considered to be continuous. Mass emission rates for this release point have been established based on commissioning data and subsequent routine compliance monitoring. Most recent routine monitoring data[4] indicates spot measurements broadly in line with the established plant performance.

Peak emissions data are taken from worst case measured mass emission rates, with the plant operating at 100% load. This is considered to be a conservative estimate of typical peak emission data as the maximum plant load is approximately 65-70%. Normal emissions data is taken from worst case measured mass emission rates, with the plant operating at 50% load. This again will provide a conservative estimate as the plant will typically operate in the first instance at around 35-40% load.

13.1.2 Deaerator steam vent

Releases from the de-aerator vent are considered continuous, however no monitoring has been undertaken on this vent. Release rate data have been taken from calculated emissions data at plant commissioning, which was based on a BOC process simulation. In the absence of other data, the calculated mass emission rates are assumed to represent both peak and normal emission rates. No flow rate data is available for releases from this source.

13.1.3 Gas header vent

The vent gas header vent stack is used intermittently for venting during start-up, shut-down and emergency releases as discussed in section 5.1.3.

Monitoring was undertaken during start-up and shut-down of the plant during original commissioning at Dalry. Start-up and shut-down operations on the plant typically last one hour. Mass release rates obtained during these exercises are therefore considered to represent the peak hourly average release. Normal emissions have been calculated from peak emissions, assuming that start-up and shut-down of the plant occurs once every three years, by averaging the peak mass emission rate over three years. Flow rate data obtained during the monitoring exercise has been used to calculate peak and normal concentrations.

Release data for the other operating scenarios are based on annual release rate data, reported for 2002. These data have been calculated from the results of the commissioning trials. Flow rate data for these scenarios are not available.

PSA blockage is predicted to occur approximately once a year, resulting release of gas for up to three hours. Normal mass emission rates have been calculated from annual mass emission data, averaged over the year. Peak emissions have been calculated from annual mass emission data, averaged over three hours.

Hydrogen balancing is conducted on a weekly basis, with annual release rates reported. Normal mass emission rates have been calculated from annual mass emission data, averaged over the year. Peak emissions have been calculated from annual mass emission data, averaged over fifty two hours, assuming weekly operation for one hour.

Gas regulator failure is predicted to occur once in the lifetime of the plant (typically 15 years). The normal mass emission rate has been calculated from the mass emission estimate for this scenario averaged over 15 years. The peak mass emission rate has been calculated assuming that the release event lasts for 1 hour.

13.2 Compliance with limits and benchmark values

The reformer stack release point at Dalry (regulated by SEPA) is currently subject to the emission limit values specified in Table 5.4. Sector guidance[9] indicates benchmark values for nitrogen oxides and carbon monoxide of 100 mg/Nm^3 and 50-200 mgNO_2/Nm^3 (STP, no correction for oxygen or water vapour) respectively. The draft BREF[1] specifies guideline range for nitrogen oxides, based on the use of low NO_x burners, of 100-140 mgNO_2/Nm^3 (STP, dry 3% oxygen).

In all cases the projected normal and worst case monitored emission concentrations for carbon monoxide and nitrogen oxides are met.

Table 13.1 Emissions Inventory - Point Source Releases, Normal and Abnormal Operation

Release point	Substance	Annual release (kg)	Normal release rate (kg/h)	Peak release rate (kg/h)	Flow rate peak (Nm^3/s)	Normal emission (mg/Nm^3)	Peak emission (mg/Nm^3)
Reformer furnace flue gas stack	CO_2	6587520	752	1110	0.50	417778	616667
	NOx (as NO_2)	788.4	0.09	0.144	0.50	50	80
	SO_2	26.3	0.003	0.003	0.50	2	2
	CO	52.6	0.006	0.006	0.50	3	3
	Methane	15.8	0.0018	0.049	0.50	1	27
De-aerator vent	CO_2	14892.0	1.7	1.7	-	-	-
	CO	10.5	0.001	0.001	-	-	-
	Ammonia	trace	trace	trace	-	-	-
	Methanol	trace	trace	trace	-	-	-
	Methane	0.0	0.000	0.000	-	-	-
	H_2	13.3	0.002	0.002	-	-	-
Vent header – Start-up	H_2	20.3	0.002	61.0	0.28	2.30	60516
	CO_2	133.3	0.015	400.0	0.28	15.10	396825
	CO	17.3	0.002	52.0	0.28	1.96	51587
	Methane	0.1	0.000	0.3	0.28	0.01	298
Vent header – Shut-down	H_2	29	0.003	86.0	0.28	3.25	85317
	CO_2	0	0.000	0.4	0.28	0.02	397
	CO	0	0.000	0.0	0.28	0.00	3
	Methane	0	0.000	0.0	0.28	0.00	4
Vent header – Hydrogen balancing	H_2	21000	2.40	403.8	-	-	-
Vent header – PSA blockage	H_2	13000	1.48	4333	-	-	-
	CO_2	65000	7.42	21667	-	-	-
	CO	10000	1.14	3333	-	-	-
	Methane	7000	0.80	2333	-	-	-
Vent header – Gas regulator failure	Methane	1300	0.15	20000	-	-	-
Vent header – cumulative releases (all scenarios)	H_2	34049	3.89	-	-	-	-
	CO_2	65133	7.44	-	-	-	-
	CO	10017	1.14	-	-	-	-
	Methane	8300	0.95	-	-	-	-

See notes in 13.1.1 to 13.1.3 for calculation bases.

14 Impact assessment

The likely emissions to atmosphere from the proposed hydrogen plant are detailed in Section 13.In order to assess the impact of these emissions on the local environment, initial screening assessments have been carried out, in accordance with the Environment Agency's H1 methodology[10]. The emissions data and subsequent assessments are based on a number of assumptions as discussed in Section 13 and should therefore be considered to be indicative only.

H1 screening assessments have been conducted for the main process emissions for both normal and peak emissions based on:

- Peak emission rates during abnormal operation
- Normal emission rates

14.1 Policy context and assessment criteria

14.1.1 Context of assessment

Local Authorities are required to assess compliance with applicable air quality objectives. Where the objectives are unlikely to be met the Local Authority is required to declare an Air Quality Management Area (AQMA) and prepare proposals for remedial action to achieve the required objective.

Whilst applicable emission concentration limits may be met, it is also important to understand whether the discharges are adequately dispersed such that local air quality is not significantly affected. It is in this context that the proposed plant is being examined to determine its contribution to the current concentrations of important pollutants and therefore determine compliance with applicable air quality limit values. It is understood that there are no substantial current developments in the locality which would have a significant impact on air quality with respect to the pollutants of interest in this case.

The pollutants considered to be of interest with respect to air quality are nitrogen oxides, carbon monoxide and sulphur dioxide. Emissions of other species (methane, carbon dioxide) are discussed later with respect to their impact as greenhouse gases.

14.1.2 Legislation and guidance

The UK Air Quality Standard Regulations of 2010[11] specify air quality standards for a range of species. Those considered applicable to this development are summarised in Table 14.1.

Table 14.1 UK Air Quality Standards (AQS)

Pollutant	Basis	Concentration
Carbon monoxide (CO)	running 8 hour mean	10 mg/m^3
Nitrogen dioxide (NO_2)	1 hour mean (99.79 percentile – 18 exceedences per year)	200 µg/m^3
	annual mean	40 µg/m^3
Sulphur dioxide (SO_2)	1 hour (99.72 percentile – 24 exceedences per year)	350 µg/m^3
	24 hour (99.18 percentile – 3 exceedences per year)	125 µg/m^3

The Environment Agency's guidance note H1[10] provides a methodology for assessing the impact and determining the acceptability of emissions to atmosphere on ambient air quality. H1 provides Environmental Assessment Levels (EALs) for each pollutant such that impact may be assessed.

The EALs relevant to this development are summarised in Table 14.2. The EALs employed are based on the more stringent of the EAL, where specified, and the corresponding air quality standard.

Table 14.2 Environmental Assessment Levels

Pollutant	Long term EAL µg/m^3	Short term EAL µg/m^3
CO	-	10000
NO_2	40	200
SO_2	125	350

The contribution of the process (PC) to the ambient concentration of a given pollutant is considered insignificant if:

- the long term PC is less than 1% of the long term environmental standard
- the short term PC is less than 10% of the short term environmental standard

14.1.3 Background air quality in Newport

In considering the overall impact of an operation, such as this herein, on local air quality and compliance with limit values, it is necessary not only to consider the contribution from the source of interest, but also the existing levels of pollutants of interest.

Background air quality data for the Solutia UK Limited site area are available from DEFRA's air quality archive (http://uk-air.defra.gov.uk/data/pcm-data). The archive provides estimated background concentrations of important pollutants for 1km^2 areas for the UK. The background level of pollutants of concern for the area around Solutia UK Limited's Newport site were considered in this assessment. The values determined are those specified for a fixed point within the site boundary (333500, 185500). Table 14.3 summarises estimated background concentrations as obtained from the air quality archive.

Table 14.3 Background pollutant concentrations (2010/11)

Pollutant	Concentration (µg/m^3)
Nitrogen dioxide (annual mean)	31.8
Sulphur dioxide (annual mean)	5.0
Carbon monoxide (maximum 8 hour average)	1644

Carbon monoxide values are for 2010, whilst others relate to 2011

When considering the combination of estimated process contributions and background concentrations it should be noted that background concentrations are generally available as annual mean values and as such simple addition when considering short term air quality standards may not be appropriate. Guidance from the Environment Agency[11] suggests a simplified method for combining estimated process contributions and background concentrations. For comparison with long term standards the overall concentration is the sum of the process contribution (annual mean) and background concentration (annual mean). For comparison with short term standards the Environment Agency suggest the sum of the process contribution (hourly or daily mean) and twice the background concentration (annual mean). This methodology has been employed in this assessment.

When considering the impact of a process contribution, the existing background concentration and the headroom that this allows are significant. Table 14.4 summarises the estimated existing background concentrations around the Newport site in the context of the current air quality limit values. These values are used in the subsequent parts of this assessment to determine compliance with air quality standards.

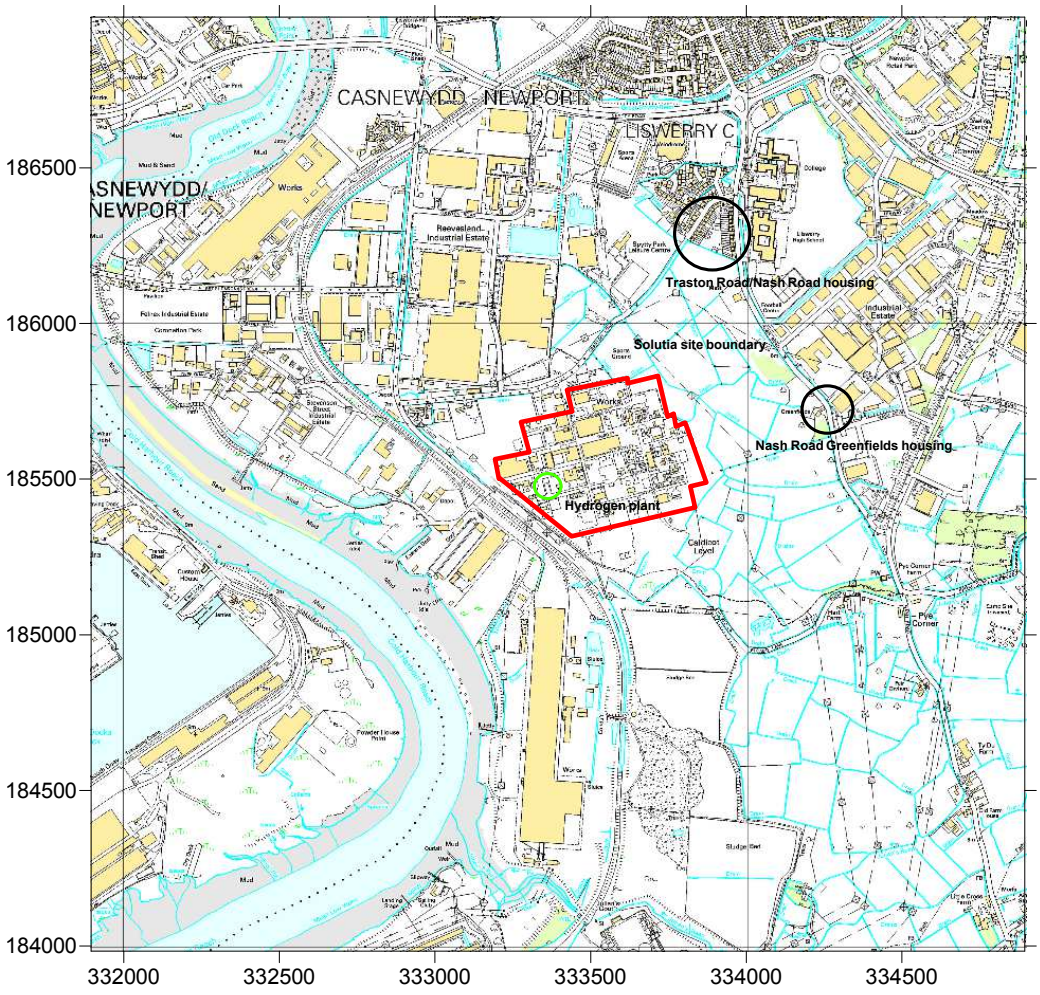
Table 14.4 Background concentrations compared with Air Quality Standards

Pollutant	AQS averaging basis	Concentration	
		µg/m^3	%AQS
Nitrogen dioxide	annual mean	31.8	80
	hourly mean	63.6	32
Carbon monoxide	maximum 8 hour mean	1644	16
Sulphur dioxide	hourly mean	10.0	3
	daily mean	5.0	4

14.2 Local area and sensitive receptors

The proposed installation will be located on the existing Solutia UK Limited site in Newport towards the western boundary of the site as shown in Figure 14.1. The nearest residential properties are around 800 m to the east on Nash Road at Greenfields. There is an estate of about 150 homes at a distance of around 900 m to the north east of the proposed site on Traston Road/Nash Road. The nearest industrial premises is around 200 m to the south west.

Figure 14.1 Proposed hydrogen plant location



The site is located within 10km of a several potentially sensitive sites. These are listed in Table 14.5.

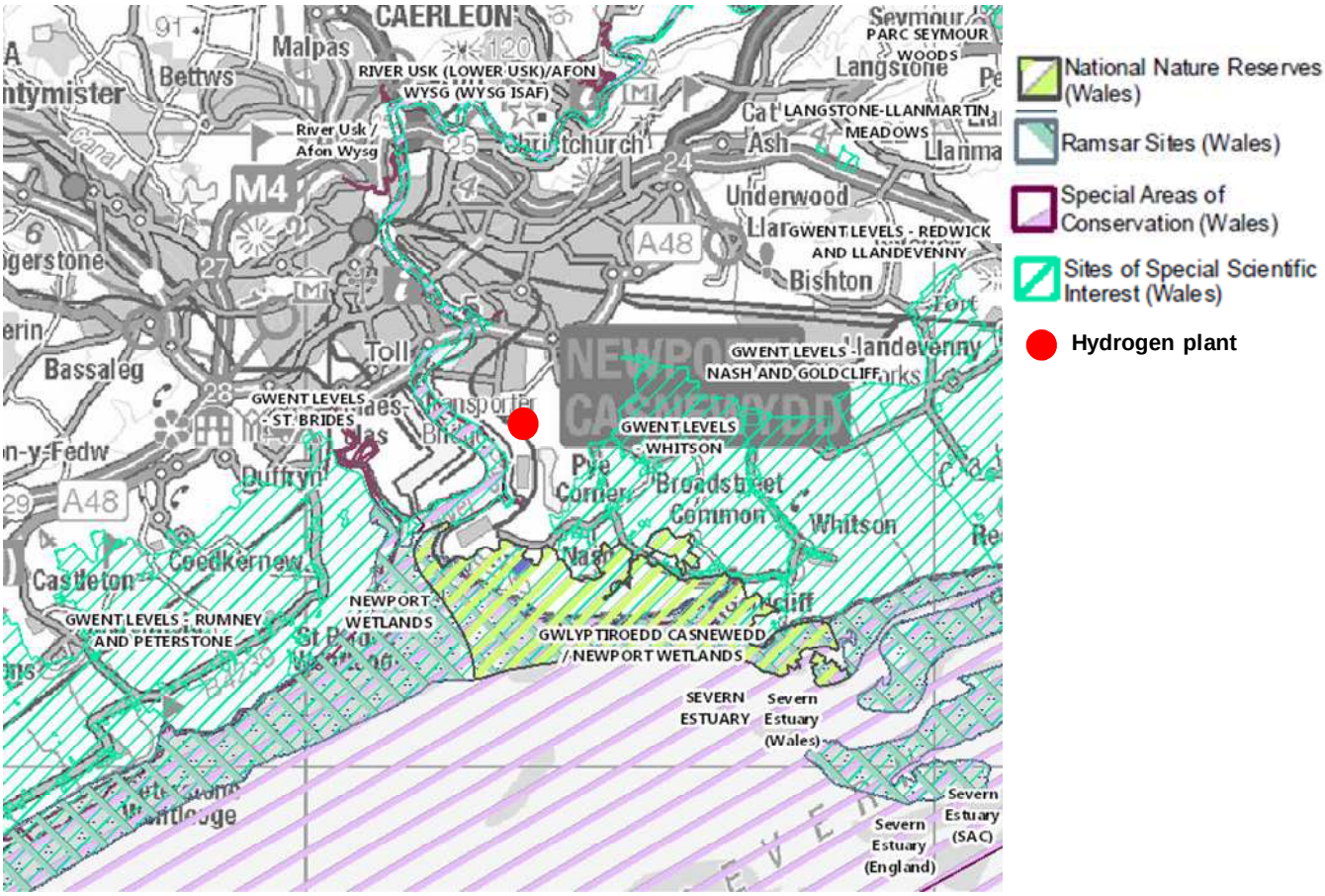
Table 14.5 Special environmental receptors

Site	Designation	Position
Gwent Levels – St Brides	SSSI	1 km west
River Usk	SSSI	1 km west
Uskmouth	RSPB Reserve	3 km south
Gwent Levels – Rumney & Peterstone	SSSI	5 km south west
Newport Wetlands	SSSI, NNR	5 km south east
Severn Estuary	SSSI, RAMSAR, SAC	5 km south
Plas Machen Wood	SSSI	8 km north west

SSSI – site of special scientific interest
SAC – special area of conservation
NNR – national nature reserve
RAMSAR – wetlands of international importance

Figure 14.2 illustrates the location of the special environmental receptors relative to the proposed location of the hydrogen plant.

Figure 14.2 Locations of special environmental receptors



14.3 H1 assessment of releases to air

The H1 methodology provides a procedure whereby releases to atmosphere which are insignificant in terms of environmental impact can be identified and screened out. Screening of the emissions is achieved using the simplified dispersion algorithm based on the release rate and the effective stack height of the release.

The effective stack height is calculated by assessment of the buildings close to the stack, which could affect the dispersion of the release. The release conditions of the three main point sources serving the hydrogen plant are summarised in Table 14.6.

Table 14.6 Point source release conditions

Property		Reformer flue gas stack	Deaerator steam vent	Vent gas header stack
Height	m	10.5	8.2	16.2
Diameter	m	0.4	0.05	0.15
Temperature	^{o}C	168[1]	-	-
Velocity	m/s	9.6[1]	-	-
Effective stack height[2]	m	0	0	7.6

1. Based on measurements from ESG report LEK09150[4].
2. Calculated based on H1 methodology

The nearest substantial building to the hydrogen plant, which is within 5 times the height of each stack, is the CHP plant. The primary building is the boiler house which is estimated to have a height at the roof apex of about 11.6 m. Based on the presence of this building the effective stack heights for use in the H1 calculations have been estimated as in Table 14.6.

Using H1 methodology the process contributions to ground level concentrations of pollutants of interest in Tables 14.7 to 14.9 have been determined.

Whilst the emission of nitrogen oxides is mostly in the form of nitrogen monoxide, subsequent reactions in the atmosphere produce nitrogen dioxide. As nitrogen dioxide (NO_2) is of considerably more importance to air quality than nitrogen monoxide (NO), it is essential that a representative measure of the conversion from NO to NO_2 is employed. H1[10] suggests that a worst case scenario for this screening is to assume:

- 50% conversion of NO to NO_2 for short term averaging
- 100% conversion of NO to NO_2 for long term averaging

This has been adopted in this assessment.

14.3.1 Reformer flue gas stack

Table 14.7 summarises the estimated process contributions to the ground level concentrations from the normal and peak releases from the reformer flue gas stack.

Table 14.7 Process contributions from reformer stack releases

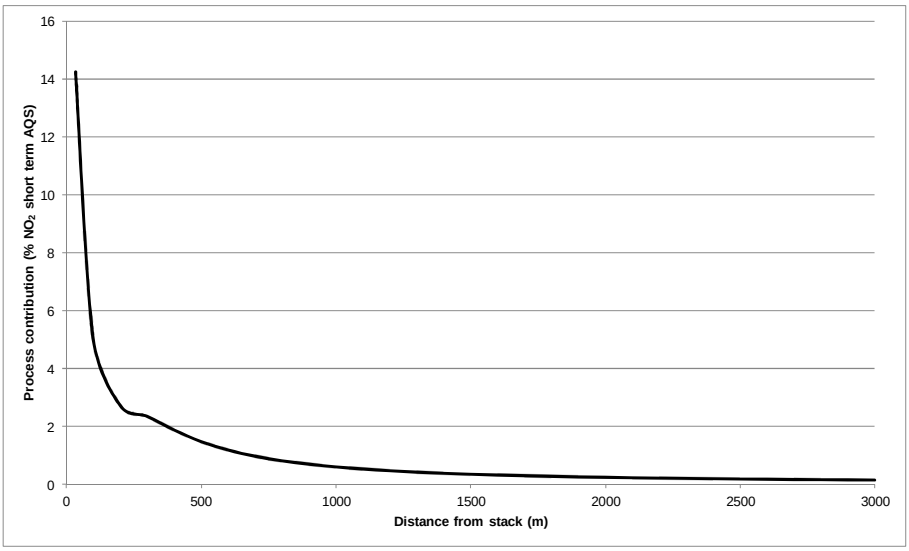
Pollutant	Averaging basis	Normal operation		Peak releases	
		Process contribution ($\mu g/m^3$)	% of EAL	Process contribution ($\mu g/m^3$)	% of EAL
NO_2	hourly mean	49	25	78	39
NO_2	annual mean	3.7	9	5.9	15
CO	maximum 8 hour mean	4.6	<1	4.6	<1
SO_2	daily mean	3.3	3	3.3	3
SO_2	hourly mean	5.91	2	5.91	2

It may be noted that the nitrogen dioxide is the only release that is considered to be significant. All others are below the levels of significance specified in H1[10].

The release of nitrogen oxides from the reformer stack has been further investigated using the US EPA SCREEN 3 dispersion model. This also provides a screening analysis for releases, but is somewhat more sophisticated than the H1 assessment, although still, provides a significant over estimate of impact than would be expected when employing a detailed dispersion model.

This assessment indicates that the maximum one hour concentration is equivalent to 14% of the AQS and occurs around 35 m from the stack. Concentrations are predicted to decline rapidly with distance such that at about 700 m from the stack the short term concentration falls below 1% of the EAL. Figure 14.3 illustrates the decay in concentration with distance from the stack. This indicates that this release is unlikely to present a risk to air quality standard attainment.

Figure 14.3 Predicted NO_2 dispersion profile from the reformer stack



14.3.2 Deaerator vent

Table 14.8 summarises the estimated process contributions to the ground level concentrations from the normal and peak releases from the deaerator vent.

Table 14.8 Process contributions from deaerator stack releases

Pollutant	Averaging basis	Normal operation		Peak releases	
		Process contribution ($\mu g/m^3$)	% of EAL	Process contribution ($\mu g/m^3$)	% of EAL
CO	maximum 8 hour mean	0.8	<1	0.8	<1

The release of carbon monoxide from the deaerator vent at both normal and peak emission scenarios is considered to be insignificant.

14.3.3 Vent gas header stack

Table 14.9 summarises the estimated process contributions to the ground level concentrations from the normal and peak releases from the deaerator vent.

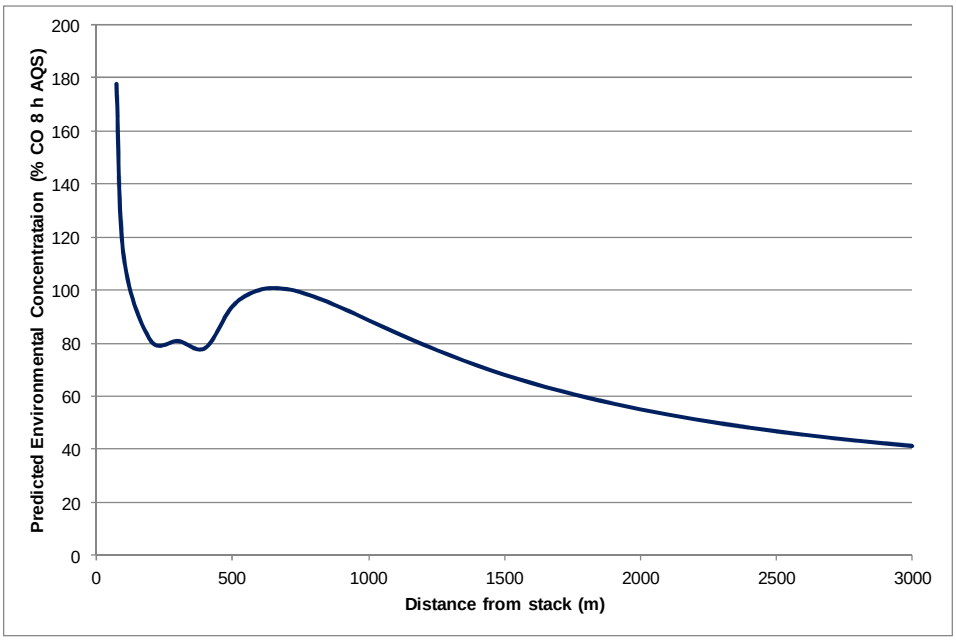
Table 14.9 Process contributions from gas header vent stack releases

Pollutant	Condition	Averaging basis	Normal operation	
			Process contribution ($\mu g/m^3$)	% of EAL
CO	Start up	maximum 8 hour mean	13878	139
	Shutdown		0.8	<1
	PSA blockage		884793	8847
	Cumulative		305	3

Start up and PSA blockage scenarios are estimated to provide short term process contributions of carbon monoxide which exceed the environmental assessment levels. These are however short term and infrequent occurrences (see section 5.1.3), which are unlikely to have a significant long term impact on the local environment. If the releases are assessed on a cumulative basis (i.e. all releases averaged over one year), then the process contribution is determined to be below the level of significance.

The PSA blockage scenario has been investigated further using the SCREEN 3 model. The assessment indicates that whilst the 8 hour air quality standard may be exceeded during a PSA blockage venting episode, the exceedence is largely confined within the site with the maximum concentrations predicted to occur around 70m from the stack. Predicted environmental concentrations (process contribution and existing background) beyond 500 m from the stack are at or below the AQS. This indicates that a venting episode following a PSA blockage is unlikely to compromise the attainment of the carbon monoxide air quality standard around the neighbouring residences or at any of the sensitive areas identified in Figure 14.2. Figure 14.4 illustrates the predicted dispersion of releases.

Figure 14.4 Predicted CO dispersion profile from the gas vent header stack



1 Based on release for a PSA blockage episode in Table 13.1 over a period of 3 hours.
2 Maximum predicted hourly concentration is multiplied by 0.7 to obtain 8 h average (se H1, Annex F[10]) and by 3/8 to account for 3 hour release period.

14.3.4 Impact on sensitive receptors

For the continuous releases assessed only the release of nitrogen dioxide from the reformer flue gas stack was considered to be significant based on the H1 screening analysis. Further analysis using the SCREEN 3 model indicated that maximum short term concentrations occurred within the site boundary with concentrations declining significantly with distance.

At distances beyond 1 km the process contribution is less than 1% of the environmental assessment level and as such it is not considered that there is any significant impact on the sensitive receptors identified in Table 14.5.

Maximum predicted environmental concentrations (process contribution and existing background concentration) in all cases are within the applicable air quality standards. At the nearest residential properties modelling indicates that the process contribution is equivalent to less than 3% of the short term air quality standards for carbon monoxide, nitrogen dioxide and sulphur dioxide. The only situation identified as causing a possible breech of the air quality standard is for releases of carbon monoxide from the vent gas header stack during a PSA blockage episode. Analysis using SCREEN 3 indicates that the impact is likely to be largely confined to the site boundary and unlikely to compromise AQS attainment around areas of habitation or at environmentally sensitive areas.

It is therefore concluded that the releases to air from the proposed hydrogen plant have no significant impact on air quality in the vicinity of the proposed location or at sensitive locations around the Newport area.

14.4 H1 assessment of photochemical ozone creation potential

The potential for photochemical ozone creation as a result of current emission levels from the principal installation point sources, is quantified in Table 14.10. Annual releases include emissions from both normal continuous operation and abnormal scenarios averaged on an annual basis as summarised in Table 13.1.

Table 14.10 Photochemical ozone creation potential of plant releases

Substance	Annual release (kg)	POCP value[1]	POCP
Methane	8316	0.6	4990
Nitrogen dioxide[2]	788	2.8	2208
Sulphur dioxide	26.3	4.8	126
Carbon monoxide	10080	2.7	27216
Total			34540

1. Factors from H1 Annex F[10], Appendix A.
2. Releases of nitrogen oxides are assumed to be in the form of nitrogen dioxide for the purposes of this calculation.

14.5 H1 assessment of global warming potential

The potential for contribution to global warming, as a result of current emission levels from the principal installation point sources, is quantified in Table 14.11. Annual releases include emissions from both normal continuous operation and abnormal scenarios averaged on an annual basis as summarised in Table 13.1.

Table 14.11 Global warming potential of plant releases

Substance	Annual release (kg)	GWP factor[1]	GWP
Methane	8316	21	174636
Carbon dioxide	6667545	1	6667545
Total			6842181

1. Factors from H1 Annex H[5].

The calculated carbon dioxide release from the overall process energy usage (Table 9.3) can be combined with the above process emissions to determine an overall global warming potential for the process as summarised in Table 14.12.

Table 14.12 Overall CO_2 release from plant

Source	Annual equivalent CO_2 release (t)
Direct process releases	6842
Indirect electricity consumption	799
Total	7641

15 Environmental Risk Assessment

As part of the Environmental Permitting Regulations it is necessary when applying for a permit to undertake an assessment to determine the risk to the environment and human health associated with operations within the permit application. It is necessary to demonstrate that all necessary measures have been taken in order to protect the environment and ensure that the proposed operations will not pose an unacceptable risk.

In this case the proposed installation of a hydrogen plant at the existing Solutia UK Limited, Newport site has been assessed in accordance with the guidance provided in H1[13] and its associated annexes and in consideration of the locality and in particular near areas of habitation and the sensitive receptors identified in Figure 14.2.

The operations proposed have been assessed in order to:

- identify potential risks to the environment
- screen out risks that are insignificant and don't need detailed assessment
- assess potentially significant risks in more detail if needed
- select appropriate control measures, if necessary

Risks have been assessed in the following categories:

15.1 Amenity and accidents
15.2 Surface water
15.3 Air
15.4 Site waste
15.5 Global warming potential
15.6 Ground water

The risk assessment has been confined solely to operations within the proposed hydrogen plant and is not concerned with any other process operation on the Solutia UK Limited site. Such operations will already have been assessed for risk under existing permits.

The proposed process and how it performs in respect of the above categories has been discussed in detail earlier. This risk assessment will reference these previous sections and will summarise the overall position to determine the level of risk. Often a risk assessment will be used to justify the selection of one process over another. In this case a detailed assessment was undertaken some 10 years ago which concluded that natural gas steam reforming was the most appropriate process for the production of hydrogen under the conditions pertaining at the Dalry site. As discussed earlier, whilst some optimisation to the plant has been possible based on operating experience, the general process still represents best available technique and a such no other options are being considered for use at the Newport site. This risk assessment therefore confines itself to consideration of the hydrogen plant being relocated from Dalry.

15.1 Amenity and accidents

The following risks are considered in this section:

15.1.1	Odour	section 5.5
15.1.2	Noise	section 5.6
15.1.3	Fugitive emissions	sections 5.3 and 5.4
15.1.4	Visible plumes	-
15.1.5	Accidents	section 11

15.1.1 **Odour**

The potential for annoyance arising from odourous releases is discussed in section 5.5. The two main sources of odour are:

- Sulphur dioxide from the reformer flue gas
- Mercaptans present in natural gas feedstock

Modelling using the US EPA SCREEN 3 screening model indicates that in both cases the concentration of sulphur dioxide and mercaptans at a distance of 200m is less than 1% of the respective odour thresholds. It is therefore considered that that there is insignificant risk of nuisance to nearby business premises or residential housing from odourous releases. This is largely confirmed by operation of the plant at Dalry where there is no perceptible odour in the vicinity of the hydrogen plant and no odour complaints attributable to hydrogen plant operations.

The odour assessment is summarised in Table 15.1.

Table 15.1 Odour assessment

Hazard	Receptor	Pathway	Risk management	Probability of exposure	Consequence	Overall risk
Sulphur dioxide from reformer flue gas	Commercial building at 200m Residential housing at 500 m	Air from reformer stack	Fuel has a very low sulphur content. Flue gases are released at high level (10.6 m)	Fairly probable	Modelling indicates exposure beyond 200 m is <1% of the odour threshold.	Insignificant risk of annoyance.
Mercaptans in natural gas feedstock	Commercial building at 200m Residential housing at 500 m	Air from vent gas header stack and leaks	Commercial gas has a low mercaptan content. Release episodes are infrequent. Gases are released at high level (16.2 m)	Fairly probable	Modelling indicates exposure beyond 200 m is <1% of the odour threshold.	Insignificant risk of annoyance.

The risk of nuisance from odour releases is considered insignificant.

15.1.2 **Noise**

The potential for annoyance arising from noise generated within the hydrogen plant is discussed in section 5.6. The hydrogen plant is considered to apply current BAT to noise levels with equipment being used which have comparatively low noise levels.

The persistent noise sources associated with the hydrogen plant will make a relatively low contribution to the overall site noise based on measured noise levels during operation at Dalry and the results of noise surveys at the Newport site. It would be expected that the persistent noise associated with the hydrogen plant would reduce to below 30 dB(A) at the site boundary. It is therefore considered that these sources of noise are insignificant.

The most significant noise contribution is likely to result from vent gas header stack emergency venting episodes. Typically during emergency venting there will be a pop at around 30 second intervals for a period of between 1 and 2 hours. Occurrences are likely to be infrequent with an average of one episode per year, although this is likely to have a high contribution to the overall site noise. Due to its nature it has not been possible to quantify the noise during a venting episode, although experience at Dalry has indicated that there have been no noise complaints attributable to hydrogen plant operation.

Table 15.2 summarises the assessment of noise.

Table 15.2 Noise assessment

Hazard	Receptor	Pathway	Risk management	Probability of exposure	Consequence	Overall risk
Gas vent header stack	Commercial building at 200m Residential housing at 500 m	Site may be close enough for noise to be audible	Venting episodes are infrequent and operation is managed to reduce frequency.	Fairly probable	Noise level not measured, although historically no complaints attributable to venting episodes were received during 10 years' operation at Dalry	Moderate, although very infrequent.
Plant fans	Commercial building at 200m Residential housing at 500 m	Site may be close enough for noise to be audible	Low noise level equipment employed. Regular maintenance to ensure efficient operation. All noise barriers (doors etc) remain closed as far as possible.	Fairly probable	Calculated noise levels at less than 30 dB(A) beyond site boundary.	Insignificant risk of annoyance.
Compressor pump	Commercial building at 200m Residential housing at 500 m	Site may be close enough for noise to be audible	Low noise level equipment employed. Regular maintenance to ensure efficient operation. All noise barriers (doors etc) remain closed as far as possible.	Fairly probable	Calculated noise levels at less than 30 dB(A) beyond site boundary.	Insignificant risk of annoyance.

The risk of nuisance from noise is considered insignificant.

15.1.3 Fugitive emissions

The potential for annoyance arising from fugitive emission release to air and water and land is discussed in sections 5.3 and 5.4

The primary components of fugitive emissions associated with the hydrogen plant are:

Organic compounds
Dust
Lubricating oil

Within the system containment there is a considerable inventory of gaseous hydrocarbons, although leaks are avoided by appropriate design of the piping and subsequent inspection. As part of the decommissioning and subsequent installation process all piping and vessels will be subject to a comprehensive programme of inspection and general refurbishment/replacement.

There is a small inventory of lubricating oil for the compressor units. This organic mixture has a high boiling point and is therefore unlikely to give rise to volatile organic compound releases. In the event of a release, any oil spill will be captured in a bund. All surfaces around the area of use are impermeable.

Dust creation and generation of pollutants will be minimised by implementation of effective design and operating practices.

The assessment of potential fugitive emissions is summarised in Table 15.3.

Table 15.3 Fugitive emissions assessment

Hazard	Receptor	Pathway	Risk management	Probability of exposure	Consequence	Overall risk
To air						
Leakage of hydrocarbons within system containment	Commercial building at 200m Residential housing at 500 m	Vapours carried on the wind	System containment is protected by appropriate design and maintenance regime including 100% radiography for hydrogen system lines.	Fugitive vapours could reach receptors although management measures should prevent this.	Potential for odour nuisance complaints.	Low if management techniques are successful. No history of significant leakage during operation at Dalry.
Dust from site	Commercial building at 200m Residential housing at 500 m	Windblown dust	Effective plant design and operation prevents significant dust generation.	Dust could reach nearest commercial building on strong winds.	Dust deposition nuisance.	Insignificant.
To water/land						
Lubricating oil spill	Local surface waters or groundwaters	Flow by gravity	Areas of oil use have an impermeable surface. Oil storage areas have a bund to contain any spill. Oil inventory is low.	Management actions should prevent any significant run off to receptors.	Pollution of local surface or ground water	Low if management techniques are effective.

The risk of nuisance or pollution from fugitive emissions is considered insignificant.

15.1.4 Visible plumes

There are two point source releases associated with the hydrogen plant which have the potential for producing a visible plume:

Reformer flue gas stack
Deaerator steam vent

Air can only hold a certain amount of water vapour and once it is saturated additional vapour will condense into droplets and if dense enough become visible. The discharge of exhaust gases into ambient air can result in saturated air and hence a visible plume forms. Plume visibility is determined by the temperature and moisture content of the discharge plume, its subsequent dispersion and the temperature and moisture content of the ambient atmosphere. In order to determine the frequency of plume visibility and its full extent detailed plume dispersion modelling using typical local meteorological data would be required.

An assessment using the US EPA SCREEN 3 model suggests that the a visible plume from either release point is in unlikely to persist beyond the nearest site boundary and would therefore be some 400m from the nearest dwellings. It is considered that the risk of nuisance in this case is insignificant. Table 15.4 summarises the assessment of risk from visible plumes.

Table 15.4 Visible plume assessment

Hazard	Receptor	Pathway	Risk management	Probability of exposure	Consequence	Overall risk
There are no visible impacts beyond the site boundary. All residential receptors are at least 400 m from the visible plume.	Screened out – no further assessment required.					Insignificant

The risk of nuisance from visible plumes is considered insignificant.

15.1.5 **Accidents**

The risk and consequences of accidents is discussed in detail in section 11. In general risks are maintained low by:

Minimising the inventory of potentially hazardous materials
Use of bunds and impermeable surfaces where liquids are in use
Effective spillage remediation measures
Effective plant control systems and emergency shutdown procedures

These procedures have been developed over many years' operation of hydrogen plants and in particular the current plant at Dalry. There have been no reportable accidents during operation at Dalry indicating the effectiveness of the control measures which are in place and which have been refined with operational experience.

Table 15.5 summarises the assessment of risk from accidents.

Table 15.5 Accident assessment

Hazard	Receptor	Pathway	Risk management	Probability of exposure	Consequence	Overall risk
Spillage of boiler feed water treatment chemicals Overfilling of storage tank	Surface and ground waters	Surface water drainage	Low inventory of materials. Bunded storage areas. Impermeable surfaces. Effective spillage remediation procedures.	Unlikely if preventative and remedial procedures are employed.	Contamination of surface and ground water	Low
Leakage or spillage of lubricating oil Over filling of storage tank	Surface and ground waters	Surface water drainage	Low inventory of materials. Bunded storage areas. Impermeable surfaces. Effective spillage remediation procedures.	Unlikely if preventative and remedial procedures are employed.	Contamination of surface and ground water	Low
Liquid containment failure (boiler feed water chemicals, lubricating oil)	Surface and ground waters	Surface water drainage	General housekeeping procedures require inspection of bunds and impermeable surfaces.	Unlikely if routine maintenance and inspection are undertaken	Contamination of surface and ground water	Low
Fire Plant failure Runaway reaction Vandalism	Air	Air transport	Low inventory (below COMAH) of materials. Effective emergency shutdown procedures.	Unlikely if system control and emergency procedures are employed.	Smoke, local nuisance, risk of fire spreading to other processes. Pollution of surface and ground waters.	Low
Hydrogen tanker filling failure	Air	Air transport	Effective automatic emergency shutdown procedures.	Unlikely if system control and emergency procedures are employed.	Release of hydrogen, potential for ignition	Low

The risk associated with accidents is considered to be low.

15.2 Surface water

The plant has no significant liquid inventory and there are no persistent releases to surface water.

Boiler feed water blow down will routed to the current site treatment system. The rate of blow down associated with the hydrogen plant is considered insignificant in comparison to the overall site throughput.

The plant offers few sources of contamination for storm water. Most areas will be of concrete whilst all others will be covered with gravel and the storm water will be allowed to soak into the ground. All chemicals will be stored in tanks with integral bunds, so no ground contamination can occur in case of spillage. Around pumps and compressors, where lubrication systems could result in small spillages of lube oil, measures will be taken to prevent rainwater washing off the contamination to ground. The machines are set on concrete foundations and areas deemed susceptible to oil drips will be protected by drip trays.

The risk of contamination of surface water is considered insignificant.

15.3 Air

The impact on air quality in the vicinity of the proposed plant from releases to atmosphere has been assessed and discussed in Section 14. The main findings of the assessment are summarised in Table 15.6.

Table 15.6 Impact of releases to air

Release point	Release	Impact on air quality	Overall risk to air quality standard attainment
Reformer flue gas stack	Nitrogen dioxide	Insignificant beyond 700m	Low
	Carbon monoxide	Insignificant	None
	Sulphur dioxide	Insignificant	None
Gas header vent – start up	Carbon monoxide	High	Short term and infrequent event. AQS attainment not compromised.
Gas header vent – shutdown	Carbon monoxide	Insignificant	None
Gas header vent – PSA blockage	Carbon monoxide	High	Short term and infrequent event. AQS attainment not compromised or at any sensitive receptor or area of permanent habitation.

Whilst some infrequent modes of operation were estimated to result in high releases of carbon monoxide, more detailed modelling of the releases indicated that even in the worst case the air quality standard was met at all sensitive receptors and at all areas of permanent habitation. It should also be noted that these events are extremely infrequent and when they occur are limited to a short period of up to 3 hours.

The risk to air quality standard attainment of releases to air is considered to be low.

15.4 Site waste

Site waste and its avoidance is discussed in section 7.

Table 15.7 summarises the waste streams generated within the process and the disposal routes to be adopted in accordance with the methodology specified in H1 Annex G[14].

Table 15.7 Plant waste streams

Waste stream	Description of waste stream	Amount produced (t/y)	Nature of waste		Disposal or recovery option	Impact score
1	Desulphurisation absorbent	0.12[1]	zinc oxide	Non-haz (2)	D5 (30)	7.2
2	Desulphurisation catalyst	0.02[1]	cobalt molybdenum oxide	Non-haz (2)	R8 (4)	0.2
3	Reformer catalyst	0.15[1]	nickel oxide	Non-haz (2)	R8 (4)	1.2
4	HT shift catalyst	0.16[1]	ferric chromic copper oxide	Non-haz (2)	R8 (4)	1.3
5	PSA adsorbent	0.10[1]	zeolite, alumina activated carbon	Inert (1)	D5 (30)	3.0
6	Lubricating oil	0.70[2]	mineral oil	Hazardous (10)	R9 (4)	28
7	Boiler blow down	254[3]	water	Hazardous (10)	D9 (12)	30480
8	General office waste	0.2[4]	paper glass	Inert (1)	R3 (3)	0.6

1.Annual amount based on plant inventory and life time in Table 7.1.
2 Oil usage in section 7.3.3
3 Blow down rate from design specification in section 7.5.
4 General office and maintenance waste is an estimate based on current operating experience.

Site inventories of catalysts and adsorbents are low and the waste produced is minimal and where possible recovery options are employed, via material vendors, for the treatment of spent catalysts. The most significant waste stream is the boiler water blow down. This will be treated within the existing Solutia site water treatment plant and is considered to constitute a relatively small proportion of the overall site water treatment burden from the site.

It is concluded that within the process waste production is minimised and the most appropriate industry standard disposal and recycling options are employed.

The environmental impact of the plant waste production is considered to be low.

15.5 Global warming potential

The global warming potential of the proposed hydrogen plant operations is discussed and quantified in Section 14.5. The natural gas steam reforming process is considered to be the most effective available hydrogen production process in terms of carbon dioxide release (BREF[1]). Of the technologies that might be considered for this application natural gas steam reforming produces the least carbon dioxide per unit hydrogen as shown in Table 4.2.

Whilst the process selected for this application has the lowest CO_2:H_2 ratio, minimisation of greenhouse gas releases, in terms of the process and indirect sources, requires effective process

control. Global warming potential will be strongly linked to the effective control of the process in particular the control of the amount of hydrogen vented (see 7.4.3). This is a key performance indicator which is continuously monitored.

The global warming potential of the selected process is lower than the available alternatives.

15.6 Ground water

The potential for releases to ground water is discussed in section 10.

The delivery storage and containment measures described in section 7.3 will be put in place to ensure that there will be no direct or indirect releases from the plant of process materials to ground water. Containment of liquid is ensured by the use of integral bunds and suitably engineered and maintained piping systems. Whilst there is quite limited handling of solid and liquid materials, appropriate working procedures, based on best practice and previous extended operating experience, will be in place. This should ensure that the potential for release to ground water and subsequent contamination is low.

Based on the guidance provided in H1 Annex J[15] it is considered that the sources of potential pollution are of minimal significance and that the processes in place ensure adequate containment. A ground water risk assessment in this case has not been undertaken.

The risk of contamination of ground water is considered to be low.

15.7 Risk assessment conclusion

The environmental risk assessment discussed above is summarised in Table 15.8.

It is concluded that with the process generally has an insignificant to low risk of environmental impact. This largely comes from the characteristics of the process, however an important factor in maintaining a low environmental risk is the operation and maintenance regime which has been developed and refined over many years of operational experience. These procedures will continue to be reviewed, evaluated and refined as part of the standard BOC management system to maintain the low level of environmental risk.

Table 15.8 Risk assessment summary

Section	Risk from	Level of risk	Comment
15.1	Amenity and accidents		
15.1.1	Odour	Insignificant	Predicted odour impact beyond the site boundary is less than 1% of the odour threshold and unlikely to cause nuisance.
15.1.2	Noise	Insignificant	Potential for nuisance from emergency venting, although likely to be very infrequent.
15.1.3	Fugitive emissions	Insignificant	Adherence to procedures will maintain a low risk of subsequent pollution.
15.1.4	Visible plume	Insignificant	Rudimentary modelling suggests that visible plumes are unlikely to persist beyond the site boundary and hence unlikely to cause annoyance.
15.1.5	Accidents	Low	Adherence to procedures will maintain a low risk of subsequent pollution.
15.2	Surface water	Insignificant	There are no persistent releases to surface water. Effective management is in place to cope with accidental spills.
15.3	Air	Low	Potential for air quality breech for CO during emergency venting, although expected to be very infrequent and outside areas of permanent habitation.
15.4	Site waste	Low	Waste production is relatively low and industry standard operations for treatment, recycling and disposal are employed.
15.5	Global warming potential	Low	Effective management of hydrogen venting is crucial to minimising global warming potential.
15.6	Ground water	Low	Potential contaminants are small in quantity and are well contained.

16 Compliance with BAT

The IPPC Directive requires that best available technique (BAT) be used and it is therefore necessary in any permit application to describe how the process complies with current BAT. In the following section the proposed hydrogen plant installation at Newport is benchmarked against the indicative BAT requirements available from current guidance. In this assessment reference is made to:

- EPR 4.03, The inorganic chemicals sector – How to comply with your environmental permit additional guidance. – Environment Agency[9]
- Joint Research Centre, Best available techniques (BAT) reference document for the refining of mineral oil and gas, Final draft July 2013[1].

The general issues considered are:

16.1 Managing activities
- 16.1.1 Environmental performance indicators
- 16.1.2 Accident management
- 16.1.3 Energy efficiency
- 16.1.4 Efficient use of raw materials and water
- 16.1.5 Avoidance recovery and disposal of wastes

16.2 Operations
- 16.2.1 Process design and selection
- 16.2.2 Storage and handling of raw materials, products and wastes
- 16.2.3 Plant systems and equipment
- 16.2.4 Reaction stage
- 16.2.5 Separation and purification stages
- 16.2.6 Chemical process controls
- 16.2.7 Analysis

16.3 Emission and monitoring
- 16.3.1 Point source emissions to air
- 16.3.2 Point source emissions to water
- 16.3.3 Point source emissions to land
- 16.3.4 Fugitive emissions
- 16.3.5 Odour
- 16.3.6 Noise and vibration
- 16.3.7 Monitoring

Within each section a statement is provided on compliance with the requirements of BAT. In general it is considered that the hydrogen plant installation, its operation and management meet, where feasible, the applicable requirements of BAT as described in the available guidance.

16.1 Managing activities

16.1.1 Environmental performance indicators

A range of key performance indicators will be defined and targets set for the proposed operation at Newport in a similar manner to other BOC operations. These indicators will report on both the SHEQ and economic management of the operation.

Key performance indicators are recorded at weekly or monthly intervals as appropriate and reported to the BOC Group at monthly intervals. Under normal circumstances these will be subject to a high level review at 6 monthly intervals. The Margam Plant Manager will have overall responsibility for plant performance and will, along with the local control team and wider Group resources, be continually

seeking to enhance performance in these key areas. Table 6.2 summarises the key environmental performance indicators that will be assessed for the proposed plant. This is in accordance with the procedures developed at other similar plant operated by BOC throughout the UK to demonstrate and benchmark environmental performance.

It is considered that the key environmental performance indicators proposed meet current industry best practice for this application and represent BAT.

16.1.2 Accident management

Section 11 discusses the management of risk and accidents.

BOC employ procedures to ensure that risk is minimised throughout its operations. Specifically the measures that will be put in place for this proposed installation have been developed and refined over 10 years' operational experience at the Dalry site and from experience at similar BOC sites throughout the UK and represent best industry practice.

The assessment undertaken in section 15.1.5 indicates that the operating and maintenance regime in place provides a low risk of environmental impact from accidents.

It is considered that the measures to be put in place during operation of the proposed plant represent BAT.

16.1.3 Energy efficiency

Indicative BAT:
Assess the environmental impact of each process and choose the one with the lowest environmental impact

Energy use and efficiency is discussed in detail in section 9.

The process is inherently energy efficient:

- Excess heat from the reformer is used to raise steam and heat exchangers are used to preheat the natural gas, the combustion air and boiler feed water. By these means the flue gas temperature from the reformer is reduced significantly prior to discharge. More extensive cooling of this stream would result in condensation problems and subsequent corrosion.
- The tail gas from the process is used as the principal fuel for the reformer, reducing natural gas requirements.
- Electricity and natural gas usage are key performance indicators which are monitored and reviewed regularly. Trends are investigated with the aim of improving process efficiency.

The main area affecting the efficiency of the plant is demand and the also the ability to effectively change plant load without significant venting of product. Whilst operation at high loads is unlikely in the short term at Newport, it is intended that experience at Dalry will be used to better control generation and demand so as to operate the plant effectively.

It is considered that the process and mode of operation meet indicative BAT for energy efficiency.

16.1.4 **Efficient use of raw materials and water**

Indicative BAT:
Maximise heat transfer between process streams where water is needed for cooling. Use a recirculating system in preference to a once-through system.
Where water is in direct contact with process materials recirculate the water after stripping out the absorbed substances.
Use cleaning techniques that reduce the amount of water needed.

Efficient use of raw materials and water is discussed in detail in section 7.

The natural gas steam reforming process has a relatively low raw material inventory and usage. In this case the use of raw materials is further reduced by:

- extending the life time of catalysts and sorbent by effective process control. In most cases operation is managed such that catalysts and sorbent are effectively used beyond their guarantee periods.
- boiler feed water treatment chemicals selection and dosing are managed by NALCO and represent the industry standard such that usage is minimised whilst providing effective treatment and minimising blow down losses.
- an effective maintenance schedule for compressors and pumps reduces the total usage of lubricating oils

Water usage is managed efficiently by an integrated recirculating water/steam:

- steam raising and feed stock heating is achieved by incorporation of extensive heat interchange systems
- water losses via steam venting and boiler feed water blow down are considered to be effectively managed through process optimisation and good boiler water treatment respectively
- process condensate is treated within the deaerator where carbon dioxide other contaminants are partially stripped out and then recycled for further use

Routine wash down of equipment during plant maintenance is not envisaged.

It is considered that the process and mode of operation meet indicative BAT for the efficient use of raw materials and water.

16.1.5 **Avoidance, recovery and disposal of wastes**

Indicative BAT:
Demonstrate that the chosen routes for recovery or disposal represent the best environmental option.

The avoidance recovery and disposal of wastes is discussed in detail in section 8.

Wastes arising from process operations will be intermittent and well developed procedures will be in place to ensure such wastes are handled effectively and the most appropriate environmental option selected for their treatment, recycling or disposal:

- BOC has selected a catalyst supplier who is also contracted to recover catalysts. All catalysts are returned to the manufacturing site for recovery and subsequent re-generation.

- PSA adsorbent will be disposed of to authorised landfill, as inert waste. Currently no suitable recovery option for this material is available.
- there is a very low inventory of lubricating oil in the hydrogen compressor sump. Fortnightly disposal of lubricating oil is undertaken by a specialist contractor with facilities for treatment and recovery.
- general waste arising during normal operation will be disposed of under the existing Solutia UK Limited site system and will be appropriately labelled and segregated to enable effective recycling.
- BOC has implemented a solids waste minimisation programme for all its operating sites. However, in this case the amount of waste generated is very low in terms of total quantities therefore there are few opportunities for waste minimisation.
- effective process control and monitoring assists in prolonging the lifetime of catalysts and sorbents and hence minimising the production of solid wastes.
- extensive evaluations of the most appropriate recovery options for solid waste have already been undertaken during plant operation at Dalry. Current procedures, which are intended for implementation at Newport reflect industry best practice.

An assessment of site waste indicated a low risk of environmental impact in this case (15.4).

It is considered that the indicative BAT for avoidance, recovery and disposal of waste is met in this case.

16.2 Operations

16.2.1 Process design and selection

Indicative BAT:
Consider all potential environmental impacts from the outset in any new projects for manufacturing chemicals
Undertake appropriate stages of a formal HAZOP study as the project progresses through process design and plant design phases.

Section 4.2 describes the alternatives currently available for the production of hydrogen on the scale intended at the Newport site. Methane steam reforming was selected as the most appropriate option on the basis of:

- the most efficient use of the available natural gas feedstock
- the least adverse impact on the environment

The releases to air, water and land are minimised. In particular, there are no significant liquid hydrocarbon inventories or releases. In addition the amount of carbon dioxide released per unit production of hydrogen is lower than any of the alternatives.

All BOC projects are subject to a project safety review which is an ongoing procedure following a project from conception through construction, commissioning to examination of operational experience. This ensures that health and safety issues are considered during all stages of project development.

At the design stage Hazard and Operability (HAZOP) studies, are undertaken to ensure that the design and engineering of the facility is suitable to safeguard against foreseeable failure events. The HAZOP team comprises several qualified process, engineering and operations specialists who are required to analyse each plant system systematically at the direction of an experienced HAZOP leader. Although the plant intended for installation at Newport was previously operational at Dalry the standard project safety procedure described above will be undertaken throughout the decommissioning at Dalry and subsequent installation at Newport.

It is considered that the indicative BAT for is met for process design and selection.

16.2.2 Storage and handling of raw materials, products and wastes

Indicative BAT:
Store reactive chemicals in such a way that they remain stable.
Use measures to reduce the risk of contamination from large storage tanks.
Use HAZOP studies to identify risks to the environment for all operations involving storage and handling of chemicals and wastes.

Section 7.3 describes the procedures to be applied for the storage and handling of raw materials products and wastes. The procedures that will be employed to manage delivery, storage and handling will be aimed at minimising the site inventory of materials and receiving, storing and handling in the most appropriate manner to avoid accidental release. Storage facilities will be designed to contain accidental releases and minimise the risk of subsequent contamination. These will be based on experience of plant operation at Dalry and similar plant elsewhere.

The process does not require the storage of large quantities of reactive chemicals.

The raw materials inventory is summarised in Table 7.1. The quantities of stored raw materials, wastes and products handled and stored are largely insignificant:

- there is no requirement for storage of catalysts or sorbents. When spent materials need to be removed and replaced this is undertaken by a specialist vendor who will remove the materials from the process containment and remove from site under the supervision of BOC.

- the site storage capacity for the hydrogen compressor lubricating oil will be around 50 litres. This will be stored in two 25 l containers in a 30 l capacity bunded area. The oil storage area will be located close to the compressor and will have an impermeable surface to prevent seepage of any drips/spills into the ground. The compressor area will be covered to reduce the potential for contamination of rainwater and hence minimise the volume of contaminated water for disposal. Used oil from the compressor will be transferred back into empty oil drums and stored in a separate bunded area. This is then sent to an approved specialist contract for treatment and recovery.

- all boiler water treatment chemicals will be stored in tanks with integral corrosion resistant bunds within a separate building which is kept locked at all times. The floor and bunds will be impenetrable to the liquid chemicals. The storage tanks will have a capacity of 325 l with each tank sitting within its own bunded area. All handling is undertaken by NALCO, a specialist boiler water treatment contractor. The chemicals are manually transferred from a 200 l drum into the storage tank via a pumped fill, supervised at all times under the control of BOC personnel. Each storage tank is permanently connected to a pump, which is used to transfer the required dosage of chemicals into the deaerator. Both BOC and NALCO have responsibility for clearing up and disposing of any spillage which may occur.

- hydrogen product will normally be piped to the Solutia UK Limited site operations, although on occasions, it may be necessary to send the product to a road tanker. The transfer is controlled automatically and incorporates the necessary precautions to avoid leaks and fires.

It is considered that the indicative BAT for is met for the storage and handling of materials.

16.2.3 Plant systems and equipment

Indicative BAT:
Identify procedures to protect against overpressure of equipment
Maintain in a state of readiness all equipment installed in the venting system
Consider leak detection, corrosion monitoring and materials of construction.

Details of plant systems and equipment and the procedures in place for operation and maintenance are discussed in section 4.6. The pertinent points relating to BAT are:

- Protection has been provided in the event of control or equipment failure. Each vessel and plant item is protected from over pressure. All relief valves connect into the vent header and are discharged to atmosphere through the process vent. The relief valves and vent have been sized for worst case emergency relief conditions.

- Leaks from these lines are avoided by appropriate design of the piping and subsequent inspection. All piping and vessels are constructed of materials meeting the required standards for this type of plant. 100% radiography is specified for all lines in hydrogen service and alloy materials. All other process service is subject to 10% radiography.

- As part of the decommissioning at Dalry and subsequent installation process at Newport all piping and vessels will be subject to a comprehensive programme of inspection and general refurbishment/replacement.

It is considered that the indicative BAT for is met for plant system and equipment selection and maintenance.

16.2.4 Reaction stage

Indicative BAT:
Assess the potential for release to air of VOCs and other pollutants along with discharges purge gas
Maximise process yields from the selected reactor design and minimise losses and emissions by the formalised use of optimised process control and management procedures
Minimise the potential for release of vapours to air from pressure relief systems and the potential for emissions of organic solvents to air or water by formal review of procedures
Review your operating practices and review vent flows to see if improvements need to be made.
Carry out HAZOP studies to minimise the generation of wastes and to examine their treatment and disposal.

It is considered that indicative BAT is met as below:

- There is no liquid inventory of volatile hydrocarbons within the hydrogen plant and hence no release of volatile organic compounds is anticipated. There is a small inventory of lubricating oil for the compressor units. This organic mixture has a high boiling point and is therefore unlikely to give rise to volatile organic compound releases. In the event of a release, any oil spill will be captured in a bund.

- As discussed in section 4.7, BOC intend to operate the plant continuously to obtain maximum efficiencies, requiring shutdowns for pre-planned maintenance only , or unforeseen equipment failures. A multi-variable control system is used to help with the efficient running of the plant. The multi-variable controller adjusts pertinent operation parameters simultaneously to maintain key controlled variables within control limits.

- The most significant release which affects process efficiency is the venting of hydrogen in order to balance load with demand (see 5.1.3). The control system has been refined and daily communications with the customer and BOC's central planning department for the merchant market will be made to ensure, as far as possible, matching of load with demand to avoid significant product venting. This is still a significant process loss and continued efforts are required for further minimisation, although this may only be significantly reduced by a sustained increase in demand.

- As discussed in 15.4 and 16.2.2 the plant design and subsequent procedure refinement has assisted in minimising the generation of waste. Where waste disposal is necessary this is undertaken in accordance with best industry practice and generally disposal to land fill is only used where a recovery option is not feasible. An assessment (15.4) indicates that site wastes have only a low potential for subsequent environmental impact.

It is considered that the indicative BAT relating to the process reaction stage is met.

16.2.5 Separation and purification stages

As discussed in 4.3.3, pressure swing adsorption is used in virtually all situations where high purity hydrogen (>99%) is required. Whilst the yield of hydrogen is apparently low (typically 80-85%), the tail gas is used as the principal fuel in the reformer reducing natural gas fuel firing by up to 90%. In consequence on a total natural gas consumed basis (fuel plus feed) recovery levels are acceptable.

It is considered that the use of PSA for this particular application and plant arrangement is effective.

It is considered that the use of pressure swing adsorption for separation and purification in this case represents BAT.

16.2.6 Chemical process controls

Indicative BAT:
Monitor the relevant process control and set with alarms to ensure they do not go out of the required range.

As discussed in section 4.7, a multi-variable control system is used to help with the efficient running of the plant. The controller adjusts the following operation parameters simultaneously:

- natural gas feed rate
- process steam feed to reformer
- reformer firing
- reformer forced draft fan

Key controlled variables are extremely reliably maintained within control limits:

- steam to carbon ratio
- steam reformer outlet temperature
- reformer furnace drafts
- flue gas oxygen content

- methane slip from the reformer
- steam pressure

In accordance with the aim of the plant design and operating philosophy, the plant will normally be unmanned receiving only routine visits from the Newport-based operational staff for log taking, routine maintenance and abnormal operating conditions. During and after the commissioning phases the plant will be manned .Transfer of control to BOC's European Operation's Centre (EOC) will only be made once reliable operating conditions have been established and maintained and competencies of operational staff confirmed.

It is considered that the indicative BAT relating to the control of the process is met.

16.2.7 Analysis

Indicative BAT:
Analyse the components and concentrations of by products and waste streams to ensure correct decisions are made regarding onwards treatment and disposal. Keep details records of decisions based on this analysis in accordance with managements systems.

BOC utilises the services of licensed waste disposal contractors for all waste handling. All waste materials generated on site are well defined and no analysis is undertaken at site. It is the contractors' responsibility to ensure that the treatment route selected is appropriate for the material.

Catalyst movements will be recorded in accordance with BOC procedures; transfer notices and receipts will be required to ensure the catalyst is returned. The catalyst vendor will also be required to provide an audit trail to authorised waste disposal contractors for any material which cannot be re-used.

Any wastes designated for authorised landfill will be managed in accordance with BOC procedures. Waste transfer notices will be completed and the waste will go to a licensed disposal site appropriate for the waste category. Wastes will be segregated and arrangements put in place to record the quantity and nature of the waste and to track waste movements to the selected authorised waste management contractor and the authorised landfill.

It is considered that the indicative BAT relating to the control of the analysis of by products and wastes is met.

16.3 Emissions monitoring

16.3.1 Point source emissions to air

Indicative BAT:
Benchmark values for point source emission to air should be achieved
Identify the main chemical constituents of the emissions
Assess vent and chimney heights for dispersion capability and assess the fate of substances emitted to the environment

As discussed in 5.1, there are three point source releases to air from the process:

- Flue gases from the reformer stack
- Steam venting from the deaerator vent
- Releases from the vent gas header stack

Releases at the reformer stack and deaerator stack are continuous, whilst the vent gas header stack has an intermittent release, the frequency and composition of which will be dependent on plant operation. Based on current experience it is likely that only the reformer flue gas stack will be subject emission limit values and a routine monitoring requirement.

As shown in Table 16.1, the general concentrations measured at this emission point during operation at Dalry are well within both the H1 benchmark values[13] and the draft BAT associated emission levels (AEL)[1] .

Table 16.1 Reformer stack gas concentrations and limits

Parameter		Measured[1]	H1 Benchmark	BAT - AEL
Nitrogen oxides	$mgNO_2/m^3$	51	50-200	30-150
Carbon monoxide	mg/m^3	1	100	-

Concentrations are expressed at reference conditions of Standard Temperature (0^oC) and Pressure (1.013b) (STP) in a dry gas containing 3% by volume oxygen.

1.Measured concentrations from monitoring on 15 October 2012[4] at Dalry

The composition of point source releases to air have been well characterised, based on commissioning measurements and subsequent routine monitoring. A full inventory of releases is provided in Table 13.1 and discussed in section 5.1.

An assessment of the dispersion of releases and their subsequent impact on local air quality is presented in section 14 and summarised in Table 15.6. The continuous emission from the reformer stack and the deaerator steam vent were found to have an insignificant impact on air quality in the plant vicinity. Some infrequent modes of operation of the vent gas header resulted in high releases of carbon monoxide. At worst case conditions the air quality standard was met at all sensitive receptors and at all areas of permanent habitation. It should also be noted that these events are extremely infrequent and when they occur are limited to a short period of up to 3 hours. It is concluded that point source emissions to air have a largely insignificant environmental impact (15.3).

It is considered that the indicative BAT relating to the point source emissions to air is met.

16.3.2 Point source emissions to water

Indicative BAT:
Control all emissions to avoid a breach of water quality standards as a minimum.
Use the following control measures to minimise water use and emissions to water:

- Maximise heat transfer between process streams where water is needed for cooling. Use a recirculating system in preference to a once-through system.
- Where water is in direct contact with process materials recirculate the water after stripping out the absorbed substances.
- Use cleaning techniques that reduce the amount of water needed.
- Strip process liquor and treat if necessary and then recycle/reuse

As discussed in sections 15.2 and 15.6:

- The plant has no significant liquid inventory and there are no persistent releases to surface water.

- Boiler feed water blow down will routed to the current site treatment system. The rate of blow down associated with the hydrogen plant is considered insignificant in comparison to the overall site throughput.

- The plant offers few sources of contamination for storm water.

- The delivery storage and containment measures will ensure that there will be no direct or indirect releases from the plant of process materials to ground water. It is considered that the sources of potential pollution are of minimal significance and that the processes in place ensure adequate containment.

As discussed in 16.1.4, water usage is managed efficiently by an integrated recirculating water/steam:

- steam raising and feed stock heating is achieved by incorporation of extensive heat interchange systems

- water losses via steam venting and boiler feed water blow down are considered to be effectively managed through process optimisation and good boiler water treatment respectively

- process condensate is treated within the deaerator where carbon dioxide other contaminants are partially stripped out and then recycled for further use

Routine wash down of equipment during plant maintenance is not envisaged.

It is considered that the indicative BAT relating to the effective control and minimisation of point source emissions to water is met.

16.3.3 Point source emissions to land

Indicative BAT:
To minimise emissions to land catalysts, many of which contain precious metals should be recovered usually by return to the supplier.

As discussed in 16.1.5, solid wastes arising from process operations will be intermittent and well developed procedures will be in place to ensure such wastes are handled effectively and the most appropriate environmental option selected for their treatment, recycling or disposal:

- BOC has selected a catalyst supplier who is also contracted to recover catalysts. All catalysts are returned to the manufacturing site for recovery and subsequent re-generation.

- PSA adsorbent will be disposed of to authorised landfill as inert waste. Currently no suitable recovery option for this material is available.

- general waste arising during normal operation will be disposed of under the existing Solutia UK Limited site system and will be appropriately labelled and segregated to enable effective recycling.

It is considered that the indicative BAT relating to the effective control and minimisation of point source emissions to land is met.

16.3.4 **Fugitive emissions**

Indicative BAT:
Identify all potential sources and develop and maintain procedures for monitoring and eliminating or minimising leaks.
Provide hard surface areas where spillage or leakage may occur.
Hold stocks of suitable absorbents at appropriate locations for use in mopping up minor leaks and spills.

The potential for annoyance arising from fugitive emission release to air and water and land is discussed in sections 5.3 and 5.4 and the risk of environmental impact is assessed in section 15.1.3.
.
The primary components of fugitive emissions associated with the hydrogen plant are:

- Organic compounds
- Dust
- Lubricating oil

Within the system containment there is a considerable inventory of gaseous hydrocarbons, although leaks are avoided by appropriate design of the piping and subsequent inspection. As part of the decommissioning and subsequent installation process all piping and vessels will be subject to a comprehensive programme of inspection and general refurbishment/replacement.

There is a small inventory of lubricating oil for the compressor units. This organic mixture has a high boiling point and is therefore unlikely to give rise to volatile organic compound releases. In the event of a release, any oil spill will be captured in a bund. All surfaces around the area of use are impermeable.

Dust creation and generation of pollutants will be minimised by implementation of effective design and operating practices.

The assessment of potential fugitive emissions concluded that adherence to procedures will maintain a low risk of subsequent pollution.

It is considered that the indicative BAT relating to the effective control and minimisation of fugitive emissions to both air and water is met.

16.3.5 **Odour**

Indicative BAT:
Manage the operations to prevent release of odour at all times.
Where odour releases are expected these should be modelled to demonstrate the odour impact at sensitive receptors.

As discussed in sections 5.5 and 15.1.1, there are two main sources of odour from the proposed plant which may have the potential for annoyance:

- Sulphur dioxide from the reformer flue gas
- Mercaptans present in natural gas feedstock

Modelling was undertaken to demonstrate the impact on sensitive receptors. Screening modelling indicated that in both cases the concentration of sulphur dioxide and mercaptans at a distance of 200m is less than 1% of their respective odour thresholds. It is therefore considered that that there is insignificant risk of nuisance to nearby businesses or residential housing from odourous releases. This is largely confirmed by operation of the plant at Dalry where there is no perceptible odour in the vicinity of the hydrogen plant and no odour complaints attributable to hydrogen plant operations .

The environmental impact of odour releases was assessed to be insignificant (15.1.1).

It is considered that the indicative BAT relating to the effective control and understanding of the impact of odour releases is met.

16.3.6 Noise

The potential for annoyance arising from noise generated within the hydrogen plant is discussed in section 5.6. The hydrogen plant is considered to apply current BAT with equipment being used which have comparatively low noise levels.

The persistent noise sources associated with the hydrogen plant are expected to have an insignificant on noise levels around areas of permanent habitation.

The most significant noise contribution will result from gas vent header stack emergency venting episodes. Occurrences are likely to be infrequent with an average of one episode per year, although this is likely to have a high contribution to the overall site noise. Due to its nature it has not been possible to quantify the noise during a venting episode, although experience at Dalry has indicated that there have been no noise complaints attributable to hydrogen plant operation.

The environmental risk assessment (15.1.2) concluded that there was a potential for noise nuisance from emergency venting, although this is likely to be very infrequent.

It is considered that the BAT relating to the control of noise is met where practicable.

16.3.7 Monitoring

Indicative BAT:
Air
Carry out an analysis covering a broad spectrum of substances to establish that all relevant substances have been taken into account when setting release limits.
Monitor more regularly any substances found to be of concern.
Waste
Monitor and record physical and chemical composition, hazard characteristics and handling precautions
Process
Identify process variables that may affect the environment and monitor as appropriate.

Extensive monitoring of point sources releases to air has been undertaken and a detailed inventory established as summarised in Table 13.1. The process is well established elsewhere and substances for routine monitoring have been indentified and limits set. In this case it is expected that routine monitoring will be a permit requirement and as such the plant design will include monitoring facilities in accordance with the requirements of TGN M1[16].Monitoring for the required substances will be undertaken by a contractor holding UKAS accreditation to the MCERTs performance standard for the measurement of the substances of interest.

As discussed in section 16.2.7, BOC utilises the services of licensed waste disposal contractors for all waste handling. All waste materials generated on site are well defined and no analysis is undertaken at site. It is the contractors' responsibility to ensure that the treatment route selected is appropriate for the material. All waste materials leaving site are recorded in accordance with BOC procedures and contractors are expected to maintain an audit trail.

As discussed in section 16.2.6 a multi-variable control system is used to help with the efficient running of the plant to control key variables which can influence the amount of pollutant released (e.g. nitrogen oxides/carbon monoxide from the reformer stack or hydrogen venting). Key variables have set control limits to ensure effective control of plant operation and environmental releases.

It is considered that the BAT relating to the monitoring of releases is met.

17 Application site condition report

1.0 Site details	
Name of the applicant	BOC Group Limited
Activity address	Solutia UK Limited Corporation Road Newport NP19 4XF
National grid reference	333350 185470 (area of interest for permit application)

Document reference and dates for Site Condition Report at permit application and surrender	Application Site Condition Report January 2014 (section 17 of permit application EPR/VP3736EF supporting documentation).

Document references for site plans (including location and boundaries)	Section 18 of permit application EPR/VP3736EF supporting documentation, Figures 18.1 and 18.3. A Phase 2 site condition report is provided in section 18 of this permit application and is an edited version of full Phase 2 site condition report for 2002 (SU0280007A) prepared for Solutia UK Limited.

2.0 Condition of the land at permit issue	
Environmental setting including: • geology • hydrogeology • surface waters	The site relating to the EPR application and the subject of this SCR application is part of the Solutia UK site at Newport. The area of interest is close to the western boundary of the site (see Figure 18.1) and is intended for the siting of a hydrogen manufacturing process (see section 2 permit application EPR/VP3736EF supporting documentation). The site is situated on the Caldicot level, which comprises a flat expanse of mainly agricultural land with some industrial and retail developments approximately 3.5 km southeast of Newport City Centre. The site occupies 128 hectares, 41 of which are used for chemical manufacturing operations. The area forms part of the flood plain of the lower river Usk and Severn estuary, the western boundary lying approximately 400m from the river Usk. The site is at an elevation of approximately 7m AOD (see 18.1 permit application EPR/VP3736EF supporting documentation). The site was assessed to be of low sensitivity with respect to groundwater because of the substantial thickness of alluvial clay, which overlies Keuper Marl which is a minor aquifer. The site was assessed to be of high sensitivity with respect to surface waters being located relatively close to the extensive network of reens on the Gwent levels some of which are SSSIs (see 14.2 permit application EPR/VP3736EF supporting documentation). The site predominantly has a cover of concrete hard standing, and is underlain by up to 2.5m of made ground which comprises a mid to dark brown, fine to medium, angular to sub-rounded silty sand and gravel of slag and ash. Beneath the made ground are alluvial deposits (up to 15m thick) which are predominantly cohesive in nature but contain bands of peat and granular deposits. A thick sand and gravel unit is present at the base of the alluvium. Mercia Mudstone Group deposits are present beneath the alluvium.

Pollution history including: • pollution incidents that may have affected land • historical land-uses and associated contaminants • any visual/olfactory evidence of existing contamination • evidence of damage to pollution prevention measures	The site is owned by Solutia UK Limited which was previously part of Monsanto until September 1997 when the new company was formed from the chemical businesses of Monsanto. Since 1949 the site has been used for a variety of chemical manufacturing and associated operations, such as effluent neutralisation, steam generation, and product distribution. Prior to its use for chemical production, the site was agricultural land. Whilst there was some evidence of discoloration in the made ground at the locations closest to the proposed hydrogen plant area and a slight organic odour this was not as pronounced as at many other locations assessed, particular those to the south and east of the site. There is no evidence of damage to pollution control measures.
Evidence of historic contamination, for example, historical site investigation, assessment, remediation and verification reports (where available)	2002 site condition report was the first substantial assessment of the Solutia UK Limited site. The report considers that some contamination present is likely to be a result of previous operations (pre 2002) at the site.
Baseline soil and groundwater reference data	See section 18.5 permit application EPR/VP3736EF supporting documentation.

3.0 Permitted activities	
Permitted activities	Proposed hydrogen manufacturing process (4.2, Part A(1) a) (i)
Non-permitted activities undertaken	-
Document references for: • plan showing activity layout; and • environmental risk assessment.	Figure 2.2, permit application EPR/VP3736EF supporting documentation. Section 15 permit application EPR/VP3736EF supporting documentation.

18 Phase 2 Site condition report

The current site condition report relies on a previous site condition report prepared by Enviros Aspinwall in June 2002 on behalf of Solutia UK Limited and covering the entire Newport site[8]. The area of the site designated for installation of the hydrogen plant is included within this report.

BOC are confident in relying on this report that conditions within this specific area have not altered significantly since 2002 in view of:

- The location is relatively remote from the main process areas and was found to have low levels of organic contamination, compared with other parts of the site, presumably in view of its usage.
- Activities undertaken in this area in preceding years do not give rise to concern over significant additional contamination.
- Solutia UK Limited have confirmed that there have been no recorded incidents of significant spillage or other contamination in the area intended for the hydrogen plant for the past 10 years.

The report prepared in 2002 covers the entire site with 29 sampling locations. Just three of these (A22, A23 and A24) are close to the area proposed for the siting of the hydrogen plant. The 2002 report has therefore been edited to cover just these points, although those parts reproduced are essentially presented as originally published. Where the current report differs substantially from the original this is generally done for presentational purposes. It should be noted that the area around the sampling positions has changed since 2002 and now includes a combined heat and power process to the east and a hydrogen tanker reception facility. The general area has a concrete base and it is not considered that these subsequent developments would have significantly altered the site condition.

The application site condition report in section 17 references much of the information contained within this report.

18.1 Background

This report is employed by BOC to support the EPR permit application for the proposed hydrogen plant installation. The report covers a Phase 2 initial site investigation and was originally commissioned by Solutia UK Limited and undertaken by Enviros Aspinwall in 2002.

The hydrogen plant installation at Newport will be subject to the Industrial Emissions Directive which requires all plant producing or releasing relevant hazardous substances to undertake baseline monitoring. This installation does not produce or release significant qualities of such substances, although as recommended in guidance a site condition report is still appropriate.

18.2 Summary of Phase 1a Site report findings

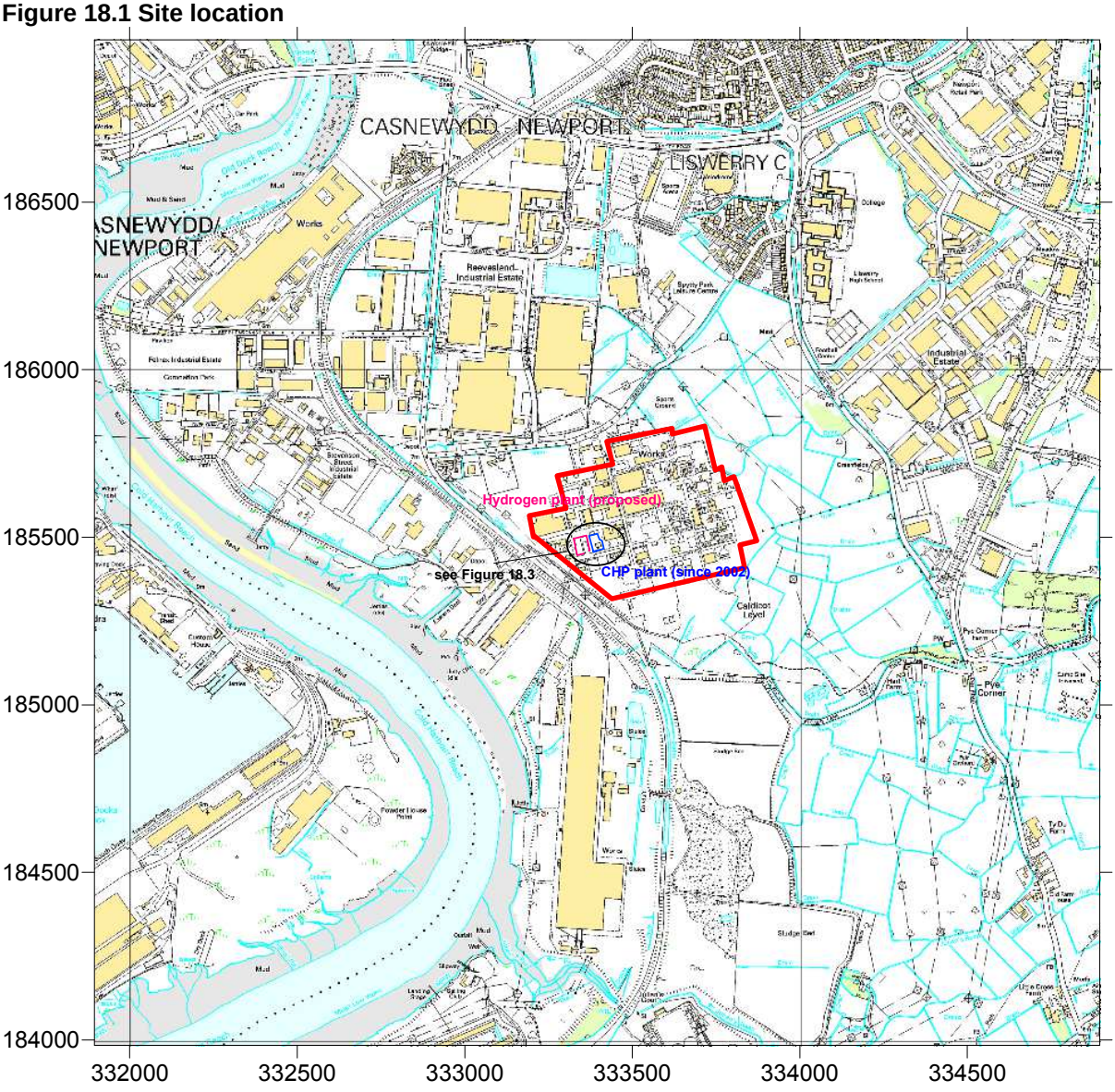
The Phase 1 site condition report was completed by Enviros Aspinwall in 2001.

18.2.1 Site description

The site is situated on the Caldicot level, which comprises a flat expanse of mainly agricultural land with some industrial and retail developments approximately 3.5 km southeast of Newport City Centre. The site occupies 128 hectares, 41 of which are used for chemical manufacturing operations. The area forms part of the flood plain of the lower river Usk and Severn estuary, the western boundary

lying approximately 400m from the river Usk. The site is at an elevation of approximately 7m AOD. The site location is illustrated in Figure 18.1 and is located at a grid reference of approximately 333580 185570.

Figure 18.1 Site location



18.2.2 Current site operations

The installation comprises the existing EPR permitted process, including the following technical linkages and common areas – south tank farm, cooling water system, effluent treatment plant, CHP and lorry park. A Therminol 3 process is currently being installed.

18.2.3 Site history

The site is owned by Solutia UK Limited which was previously part of Monsanto until September 1997 when the new company was formed from the chemical businesses of Monsanto. Since 1949 the site has been used for a variety of chemical manufacturing and associated operations, such as effluent neutralisation, steam generation, and product distribution. Prior to its use for chemical production, the site was agricultural land.

18.2.4 Site setting

The environmental setting of the site was assessed to determine the sensitivity of local receptors. The site was assessed to be of low sensitivity with respect to groundwater because of the substantial thickness of alluvial clay, which overlies Keuper Marl which is a minor aquifer. The Environment Agency does not consider the alluvium to be an aquifer in its own right, however the alluvium is water bearing. The site was assessed to be of high sensitivity with respect to surface waters being located relatively close to the extensive network of reens on the Gwent levels some of which are SSSIs. In addition, the soil and shallow groundwater should be considered as sensitive receptors for the purposes of EPR because the operator is responsible for restoration of the site to baseline levels on cessation of the permitted process irrespective of environmental risk.

18.2.5 Conceptual model

The Phase 1a report indicated contaminants potentially present in the ground from current and historical activities. This indicated that there are a large number of potential sources of contamination associated with current and historical activities. The site chemical inventory includes a large range of organic chemicals as well as many inorganic species (including precious metals). Table 18.1 indicates the contaminants that were expected be detected at the locations around the proposed site of the hydrogen plant.

Table 18.1 Possible contaminants at assessment area

Process location	Borehole No.	Possible contaminants
Hydrogen plant location (previously storage area and hydrogen tanker bay)	A22	metals, sulphate, sulphide, phosphorus, cyanide, various organics
	A23	
	A24	

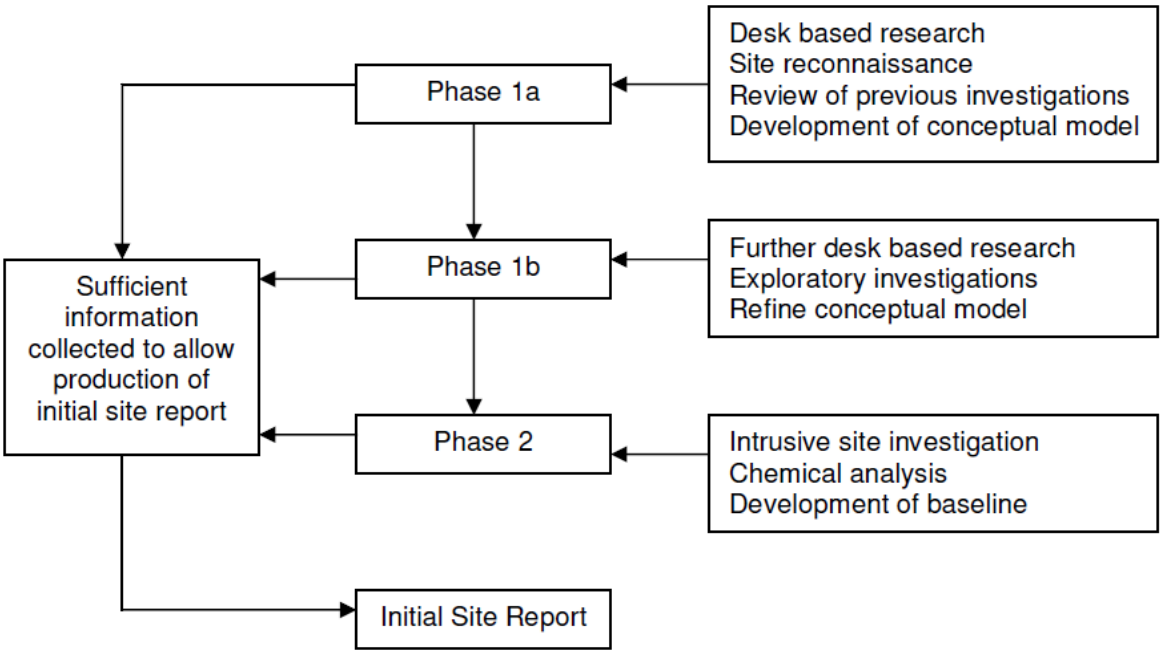
18.3 Objectives

There is a requirement to provide a report on the condition of the site on which the process is to be operated at the time an EPR permit application is made. The main objectives of the “initial” or baseline site report are as follows:

- to create a point of reference to allow later determination of whether deterioration of the site has taken place through the operations covered by the EPR permit for the installation. This is achieved through the identification of any substances that are already in, on or under the land of the site which may constitute a pollution risk.
- to provide information on the physical attributes of the site and its vulnerability with regard to soil and groundwater contamination.
- to identify parameters to be monitored during the operation of the process to ensure that land quality is maintained.
- to aid the regulator in setting appropriate permit conditions.

A further site report is required when the operator wishes to surrender the permit to demonstrate that the site has been returned to a satisfactory state. The methodology used in the preparation of site reports is based on guidance in H5[17]published by the Environment Agency. This approach is summarised in Figure 18.2.

Figure 18.2 Initial site condition report methodology



The objective of the Phase 2 assessment is to collect the additional information and data to enable the development and production of the initial site report. Specific objectives are as follows:

- To confirm the conceptual model presented in the Phase 1a assessment, particularly with respect to ground conditions and the vulnerability of the site with respect to contamination.
- To determine the concentrations in soil and groundwater of contaminants relevant to permitted activities. These represent a 'point of reference' against which the site conditions on cessation will be compared to determine site restoration requirements.

The role of the site report is not to consider whether the condition of the land is acceptable, but to establish a reference against which any subsequent deterioration may be assessed.

18.3.1 Structure of the report

The rest of this report is structured as follows:

18.4 Details of site investigation
18.5 Investigation and analysis findings
18.6 Data interpretation
18.7 Conclusions

Whilst the original report covered all processes within the Solutia UK Limited Newport installation, this edited version is restricted to the area in which the hydrogen plant will be sited.

18.4 Site investigation details

An intrusive investigation of site conditions was completed by Enviros Aspinwall in May 2002. The purpose of the sampling was to supplement the information in the Phase 1a initial site report in order to establish the site's baseline conditions.

18.4.1 Scope of intrusive investigation

The intrusive site investigation was completed between 1st and 10th May 2002 and involved the following:

- Drilling of twenty-five boreholes (BH) to approximately 0.5m past the made ground/natural ground interface to establish the shallow ground conditions across the site and to determine if any contamination is present. It is considered that the alluvial clays underlying the made ground will provide an impermeable barrier to the vertical downward migration of any contaminants, and as such the concentration of any contamination may be present at the made ground/natural ground boundary.
- Drilling of four boreholes to a depth of 5m to monitor deeper ground conditions across the site.
- Groundwater samples were taken at all locations where water was struck, although no ground water was struck around the proposed hydrogen plant area.

The boreholes were drilled using a Berretta dynamic rotary rig and cores taken for sampling and logging of the strata.

18.4.2 Sampling strategy

The sampling strategy focused on obtaining data for those areas of the site where there is a risk of future releases to ground from permitted activities and where the same substances are likely to be already present. The sampling also focused on characterising the shallow strata (made ground and alluvium) and groundwater because deeper aquifers such as the Keuper Marl are protected from downward movement of contaminants by the substantial thickness of alluvial clay (>9m thick).

The sampling locations were chosen to give a baseline condition of the site, but locations were strategically positioned to target possible sources of contamination. The possible sources of contamination for the area around the proposed hydrogen plant (sampling locations BH A22-24) are summarised in Table 18.1 and illustrated in Figure 18.3. It should be noted that Figure 18.3 illustrates the relevant part of the site as it is in 2013. It has changed somewhat from the layout in 2002, although these changes have not significantly affected the immediate area around the borehole locations.

18.4.3 Sampling of soil and groundwater

During sampling, arisings were logged to descriptions conforming to BS5930:1999. Two bulk samples were taken at each location; one from the made ground, where visual and olfactory evidence suggested the most elevated levels of contamination and one from the made ground/natural ground interface. All soil samples were screened on site using an intrinsically safe, portable, flame ionisation detector (FID). The sample depth from which the sample representative of the made ground in each location was taken, was chosen by FID screening of the soil while still in their cores. The depth with the most elevated detection was sampled and scheduled for analysis.

On completion of the boreholes, the depth of any groundwater was recorded, and a grab sample taken. The holes were then back-filled with bentonite pellets, which were left to swell before reinstatement to surface level with concrete. No groundwater was recorded at any of the boreholes relevant to the proposed hydrogen plant location.

18.4.4 Chemical analysis

Soil samples (made ground and alluvium) were selected for chemical analysis on the basis of visual or olfactory evidence and known potential sources of contamination. All chemical analysis was completed by Alcontrol Geochem of Chester. Alcontrol Geochem held UKAS accreditation for all the tests reported, except platinum, total sulphate by inductively coupled plasma mass spectroscopy (ICP), acid soluble sulphide and semi volatile organic compounds (SVOCs) including tentatively identified

compounds (TICs). The methods employed for these species conform to internal laboratory quality assurance procedures. Chain-of-custody documentation was used to trace samples from the site to the laboratory.

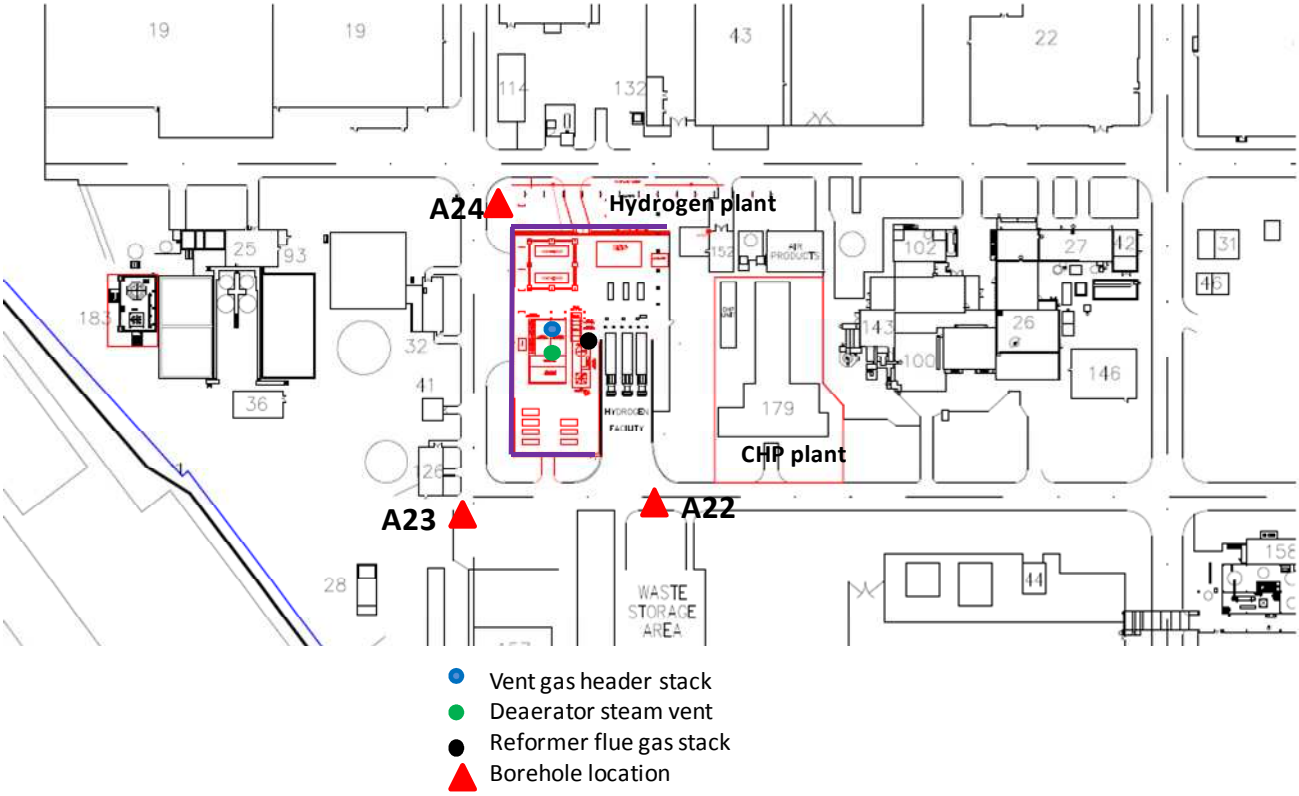
The following analyses were performed on all scheduled soil samples to assess the baseline conditions on site with respect to inorganic and organic contamination:

pH, As, Cd, Cr, Pb, Hg, Se, Cu, Ni, Zn, total sulphate, acid soluble sulphide, total sulphur, solvent extractable matter (SEM), phosphorus, total phenols, total cyanide, VOC and SVOC (including TIC).

No additional analyses for plant specific organic contaminants were undertaken on samples from around the proposed hydrogen plant location.

Whilst groundwater analysis was undertaken at some locations on the site, no groundwater or subsequent analysis was undertaken from the samples located around the proposed hydrogen plant area.

Figure 18.3 Borehole locations



18.4.5 Limitations and constraints

As recommended in guidance, limitations and constraints in data quality have been considered, to assist in the future interpretation of the results. Generally limitations in the site baseline are associated with data quantity and quality. Data quantity can include consideration of whether there are sufficient amounts of data available in terms of location, depth/type of strata and breadth of analysis to ensure that all relevant sources of contamination have been investigated. The sampling locations may be constrained by access, operational or safety requirements. Data quality issues include accuracy of

sampling locations, use of best practice in sampling and analytical methods, comparability of different data sets and representativeness of the data.

18.4.5.1 Data quality

The data described are considered to be of good quality since the sampling and analytical methods used conform to best practice at the time. Standard sampling methods have been used and arisings have been logged to BS5930: 1999. Chemical analysis of soil and groundwater samples has been completed by an independently accredited laboratory using standard methods.

18.4.5.2 Data quantity

Soil sampling has been completed at twenty-nine locations across the area of the installation, although just three are applicable to the proposed hydrogen plant location and these are around the edges of the location.

The sampling locations had to be positioned to avoid the presence of underground services in the desired area. In certain areas, due to site operational constraints and access restrictions, the sampling location had to be moved slightly further from the target area than desired but still within a distance that would pick up any contamination resulting from the target.

The sampling has focused on determining contaminant levels throughout the made ground and at the made ground/alluvium interface. Deeper strata are unlikely to be impacted by site operations due to the extensive thickness of alluvial clay and silt present.

The chemical analysis completed has been based on substances that could be released from activities within the installation as identified in the Phase 1a initial site report. These analytical suites are considered to be appropriate for characterisation of the types of contaminants likely to be present.

Overall the data are expected to be as representative as possible of the baseline conditions subject to the limitations imposed on sampling at an operational industrial site.

18.5 Investigation and analysis findings

The factual data collected from the site investigations described in section 18.4 are summarised below.

18.5.1 Ground conditions

The sampling logs from the excavations made at points A22 to A24 are illustrated in Figures 18.4 to 18.6. The geological conditions encountered agreed with the description provided in the Phase 1a report.

Figure 18.4 Sampling log for borehole A22

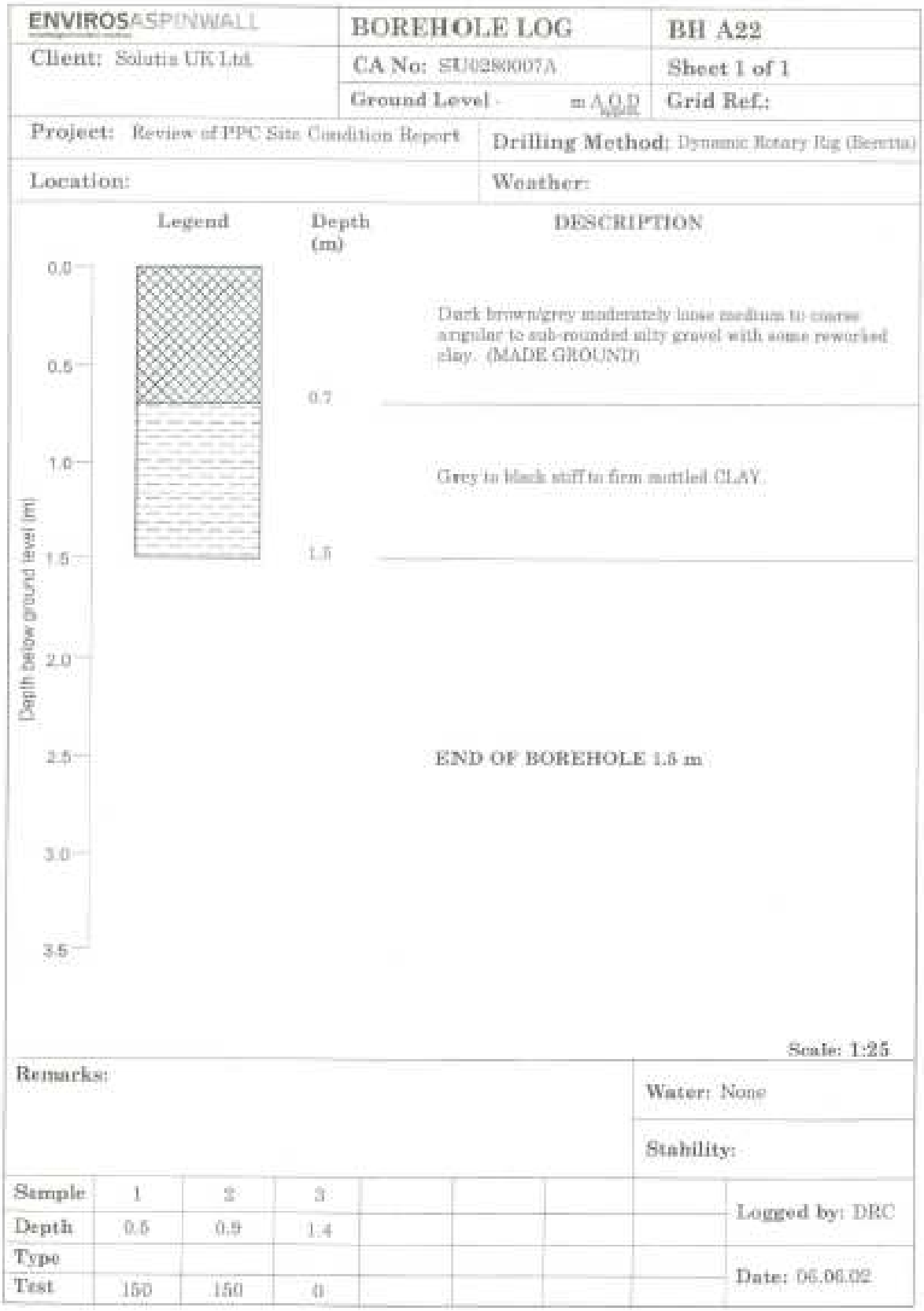
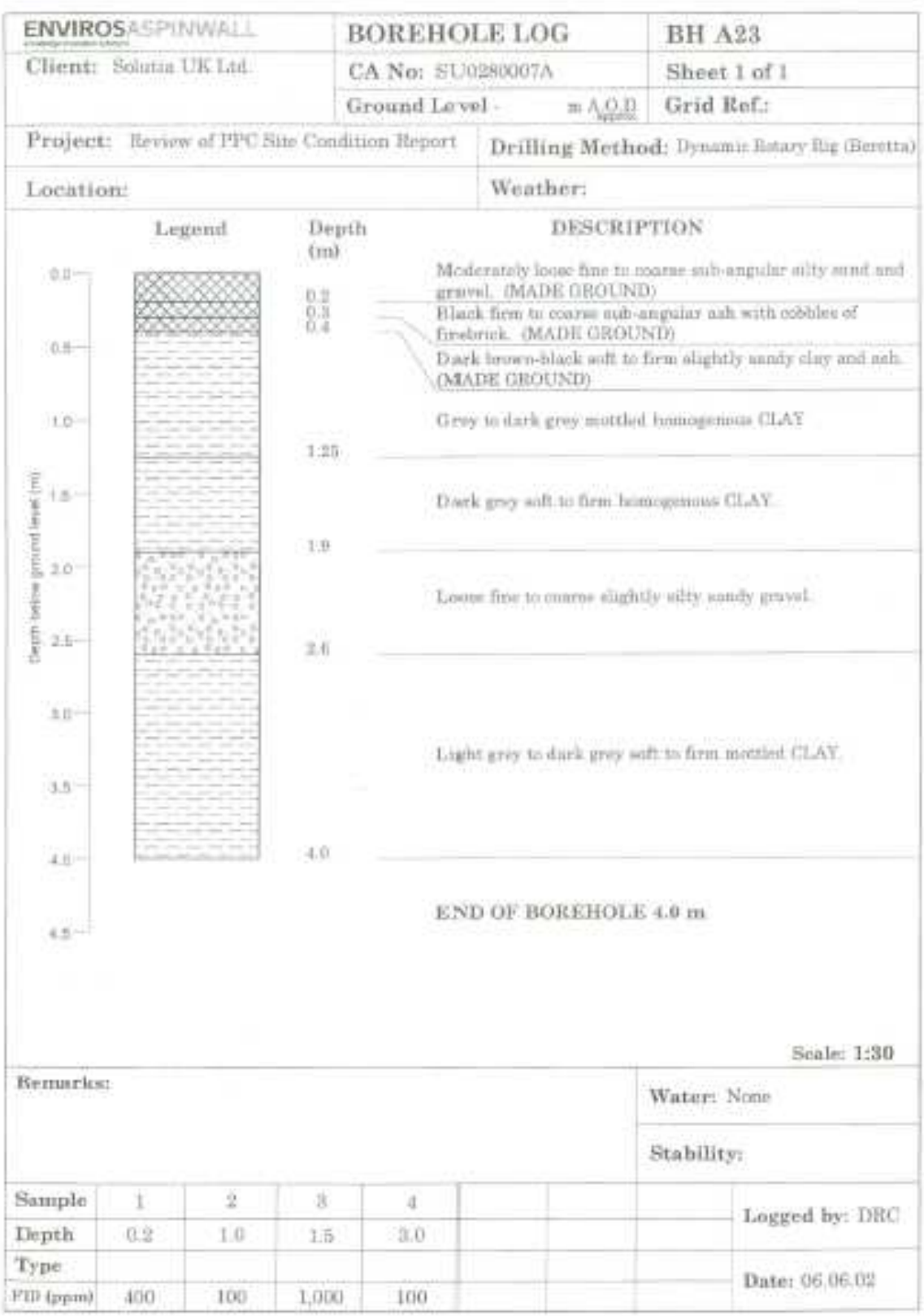


Figure 18.5 Sampling log for borehole A23



ENVIROS ASPINWALL

BOREHOLE LOG

BH A23

Client: Solutia UK Ltd.

CA No: SU0280007A

Sheet 1 of 1

Ground Level - m A.O.D approx.

Grid Ref.:

Project: Review of PPC Site Condition Report

Drilling Method: Dynamic Rotary Rig (Beretta)

Location:

Weather:

Legend	Depth (m)	DESCRIPTION
	0.2	Moderately loose fine to coarse sub-angular silty sand and gravel. (MADE GROUND)
	0.3	Black firm to coarse sub-angular ash with cobbles of firebrick. (MADE GROUND)
	0.4	Dark brown-black soft to firm slightly sandy clay and ash. (MADE GROUND)
		Grey to dark grey mottled homogenous CLAY
	1.25	
		Dark grey soft to firm homogenous CLAY
	1.9	
		Loose fine to coarse slightly silty sandy gravel
	2.6	
		Light grey to dark grey soft to firm mottled CLAY
	4.0	
		END OF BOREHOLE 4.0 m

Depth below ground level (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

Scale: 1:30

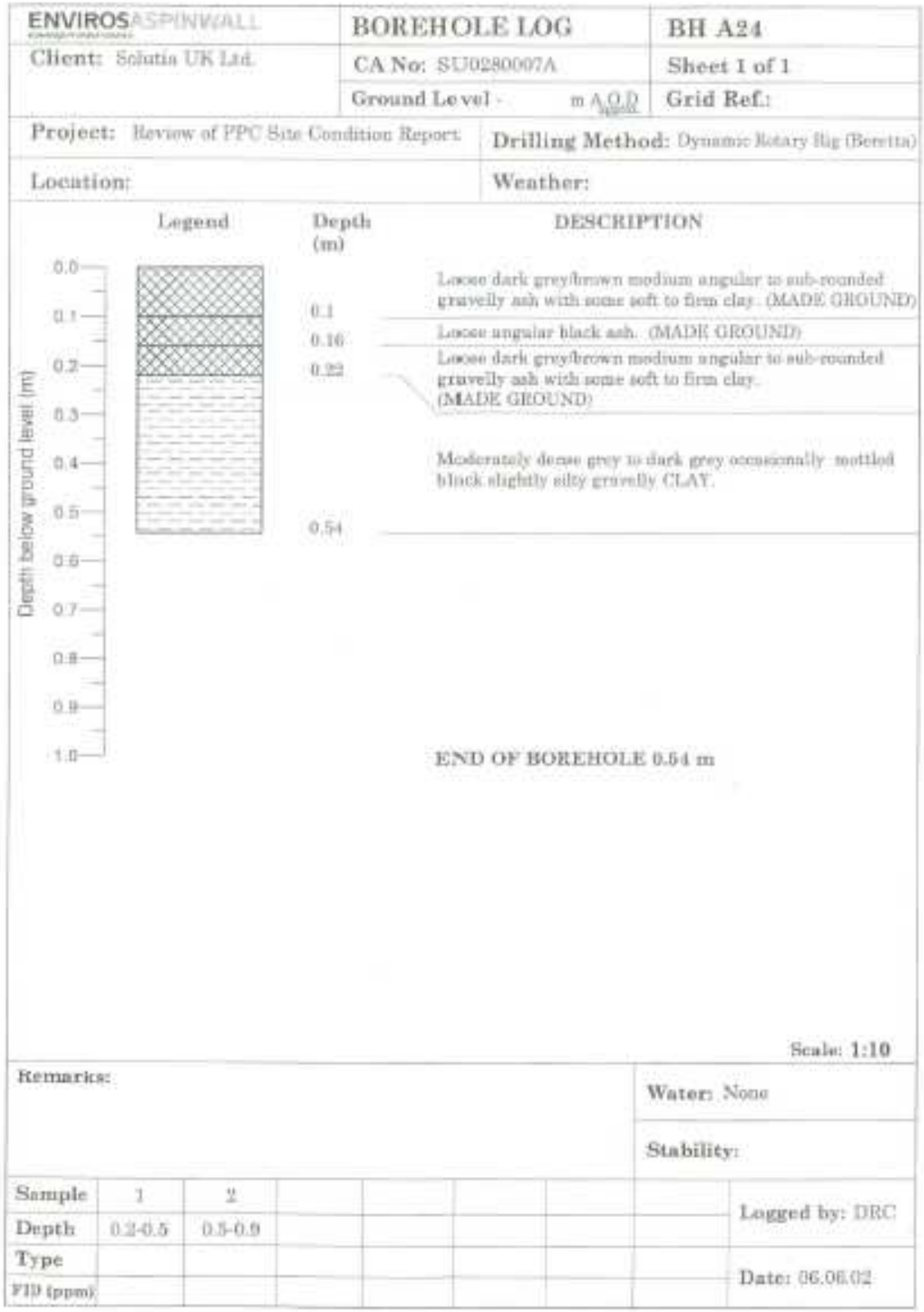
Remarks:

Water: None

Stability:

Sample	1	2	3	4				
Depth	0.2	1.0	1.5	3.0				Logged by: DRC
Type								
PID (ppm)	400	100	1,000	100				Date: 06.06.02

Figure 18.6 Sampling log for borehole A24



18.5.2 Made ground

Most locations consisted of a surface layer of concrete which varied in thickness between 0.10 and 1.80m depth. Made ground was found to be present at every sampling location up to a maximum depth of 2.40m. This generally comprises mid to dark brown, fine to medium, angular to sub-rounded silty sand and gravel of slag and ash. Roots, concrete, firebrick and metal fragments were also encountered amongst the slag in a number of the boreholes. In several places the made ground also contained a proportion of reworked clay.

18.5.3 Alluvium

The made ground was underlain by alluvium, consisting of silty clay and gravelly layers as identified in previous investigations. This was found to be soft to firm directly below the made-ground becoming stiff with depth. The clay was generally brown to grey in colour with a slightly silty consistency and occasional intermittent orange-brown mottling. In places the clay contained quite high levels of organic material, generally in the form of black carbonaceous nodules, but occasionally being at a lower stage of degradation, especially at the made-ground/alluvium interface. The moisture content within the alluvium was also noted to be quite variable. Dark staining around the made ground/alluvium interface was noted at several locations especially to the east of the site which was generally accompanied by an organic odour, frequently that of petroleum/diesel.

A gravel layer was encountered beneath the silty clay within a few boreholes at depths of between 1.20-4.70m. The gravel recovered was found to be moderately loose with a light grey colour accompanied by much soft clay. The gravel stratum appeared to be water bearing. This gravel layer was only located in boreholes to the east of the site and may or may not be part of a continuous stratum.

18.5.4 Bedrock – Mercia Mudstone group (formerly Keuper Marl)

Bedrock was not reached in any location.

18.5.5 Groundwater

Groundwater was not encountered at any of the three locations around the proposed hydrogen plant area.

18.5.6 Visual and olfactory evidence of contamination

Whilst there was some evidence of discoloration in the made ground at the locations closest to the proposed hydrogen plant area and a slight organic odour, this was not as pronounced as at many other locations assessed, particularly those to the south and east of the site.

18.5.7 In situ testing results

Arisings from the boreholes were screened on site by Enviros Aspinwall with a Flame Ionisation Detector (FID) to detect the presence of volatile organic compounds. The most positive results were recorded in the arisings recovered from the boreholes where there was visual and olfactory evidence of contamination. Of the three locations around the proposed hydrogen plant, arisngs from borehole A23 provided a positive measurement as shown in Table 18.2.

Table 18.2 In situ volatile organic compound measurements at BH A23

Depth	VOC concentration (ppm)
0.2 m in made ground	400 (maximum on site 4000)
1.5 m in alluvium	1000 (maximum on site 1500 at made ground/alluvium interface)

18.5.8 Chemical analysis data

At the three sampling locations closest to the proposed hydrogen plant area 6 samples of soil were scheduled for chemical analysis. At each location one sample was taken from the made ground where the most elevated FID reading was recorded, and one sample was taken from made ground/alluvium interface (at A23 the sample at 1.5m was in the alluvium).

The full chemical analysis data are shown in Tables 18.3 to 18.5.

In order to put the analytical results into context, the data have been assessed in relation to soil guideline values (SGVs) currently specified for commercial premises by the Environment Agency, or where not available, the Dutch Intervention Level published by the Dutch Government (Soil Remediation Circular 2009) .

Table 18.3 Contaminants in soil samples

Borehole No.	Depth (m)	Arsenic mg/kg	Cadmium mg/kg	Chromium mg/kg	Copper mg/kg	Mercury mg/kg	Nickel mg/kg	Phosphorus mg/kg	Lead mg/kg	Selenium mg/kg
Soil guideline value		640	230	-	-	26	1800	-	-	13000
A22	0.20-0.60	9	<1	35	3	<1	48	479	37	<1
A22	0.70-0.90	<1	<1	109	22	11	40	383	34	<1
A23	0.25-0.60	<1	<1	42	22	9	45	570	43	<1
A23	0.60-0.90	5	<1	40	14	<1	42	749	49	<1
A24	0.20-0.50	<1	<1	23	24	2	37	550	58	<1
A24	0.50-0.90	11	<1	29	1	<1	48	1583	34	<1

Table 18.4 Contaminants in soil samples (continued)

Borehole No.	Depth (m)	Total Sulphate by ICP mg/kg	Zinc mg/kg	Solvent Extractable Matter mg/kg	Acid Soluble Sulphide mg/kg	Total Phenols HPLC mg/kg	Total Sulphur %	pH Value	Total Cyanide mg/kg
Soil guideline value		-	-	-	-	3200	-	-	-
A22	0.20-0.60	732	96	286	2	34.75	0.02	7.60	<2.5
A22	0.70-0.90	2315	201	18273	222	11.17	0.17	8.09	<2.5
A23	0.25-0.60	2891	84	19284	108	0.05	0.45	7.78	<2.5
A23	0.60-0.90	1492	115	1676	2320	0.01	0.27	8.12	<2.5
A24	0.20-0.50	1335	185	5072	54	<0.01	0.18	8.12	<2.5
A24	0.50-0.90	600	98	245	60	0.01	0.02	6.93	<2.5

Table 18.5 Organic contaminants in soil including tentatively identified compounds

Compound	Content (µg/kg)					
	A22		A23		A24	
	0.2-0.6	0.7-0.9	0.25-0.6	0.6-0.9	0.2-0.5	0.5-0.9
C_9-C_{28} hydrocarbons		260400				
C_{10}-C_{20} hydrocarbons			61500			
C_{10}-C_{26} hydrocarbons				134000		
C_{10}-C_{30} hydrocarbons					147100	
C_{12}-C_{24} hydrocarbons	23500					5700
Terpine type compounds			800			
Chlorinated biphenyls			123990			
Molecular sulphur						160
Benzothiazole		1370				
Biphenyls		450				

It may be seen from Tables 18.3 and 18.4 that for all parameters considered which have soil guideline values (arsenic, cadmium, mercury, nickel, selenium and phenol) the measured concentration in all samples are within the guideline value.

18.6 Data Interpretation

18.6.1 Conceptual model

A conceptual model was been developed for the entire Newport site by looking at the environmental setting of the site, along with site specific data gathered during previous investigations. This model has been supported by data collected during this investigation. A full account of the conceptual model is presented in the Phase 1a report and is summarised below.

The site is located close to the mouth of the River Usk, located approximately 400m to the east of the river. Land to the east and south east comprises low lying artificially drained pasture. The site is at an elevation of approximately 6.9 to 7.8m AOD, with the surrounding land being at an elevation of 6m AOD.

The site predominantly has a cover of concrete hard standing, and is underlain by up to 2.5m of made ground which comprises a mid to dark brown, fine to medium, angular to sub-rounded silty sand and gravel of slag and ash. Beneath the made ground are alluvial deposits (up to 15m thick) which are predominantly cohesive in nature but contain bands of peat and granular deposits. A thick sand and gravel unit is present at the base of the alluvium. Mercia Mudstone Group deposits are present beneath the alluvium.

The alluvium is classified as a non-aquifer by the Environment Agency, yet is, however water bearing. Groundwater within the alluvial deposits flows towards the south west. The Mercia Mudstone Group strata are classed as a minor aquifer. A perched groundwater is also present locally within the made ground.

Potential contaminating activities on site, both current and historical can be summarised as:

- Past waste disposal practices, where some wastes were buried on site.
- On-site storage of PCB taken back from customers for disposal as part of the voluntary phase-out of production.
- Spills, leaks and abnormal events for the manufacturing processes, drainage and associated chemical storage.
- Utilities – steam generation, and effluent treatment and discharge.

18.6.2 **Baseline condition**

The baseline conditions on the site based on the intrusive investigations completed are described below. The data are described in terms of the concentrations of contaminants in soil (made ground and the made ground/alluvium interface). Comments are confined to the results of the investigations of the three locations closest to the proposed hydrogen plant area.

The original study nominally spilt the site into two zones of differing organic contaminants concentrations. The hydrogen plant area is located in zone 2 which is determined to have the lower level of organic contamination. The original report also looked at the distribution of data. This was appropriate as there were some 60 sets of analytical data. However in this particular application data from just 6 samples are considered and as a statistical analysis of the data was not considered necessary. Instead these data are presented as reported from the analytical laboratory on a sample by sample basis (see Tables 18.3 to 18.5).

18.6.3 **Organic contaminants in soil**

The general organics concentration around the proposed hydrogen plant is significantly less than that exhibited in other parts of the site, particularly towards the east of the site and essentially reflects the current and historical usage of materials in these areas.

18.6.3.1 Solvent extractable matter

Solvent extractable matter (SEM) was present at concentrations in the range 245 to 19284 mg/kg (Table 18.4). Particularly elevated concentrations were found in the samples taken at the at the made ground/alluvium interface at A22 and in the made ground at A23.

18.6.3.2 Volatile and semi volatile organic compounds and tentatively identified compounds

A range of different species were detected in the analysis for volatile and semi volatile organic compounds (Table 18.5). All samples had significant concentrations of long chain hydrocarbons and sample A23 indicated significant concentration of chlorinated biphenyls (in the made ground).

18.6.3.3 Phenols

The measured concentration of total phenols (Table 18.4) in the samples ranged between >0.01 and 35 mg/kg. These values are well below the soil guideline value of 3200 mg/kg.

18.6.4 **Inorganic contaminants in soil**

For the samples taken from the area around the proposed hydrogen plant, the analyses undertaken indicated all concentrations to be below guideline or intervention levels. Levels of contamination were generally lower in this area than in the rest of the site, although the area did have some of the highest concentrations of total sulphur and acid soluble sulphide on the entire site.

18.6.4.1 pH

pH values ranged between 6.9 and 8.1 (Table 18.4) which are within current drinking water standard requirements (6.5 to 9.5).

18.6.4.2 Arsenic

Arsenic levels in the samples (Table 18.3) ranged between >1 and 11 mg/kg and were well below the soil guideline value (640 mg/kg).

18.6.4.3 Cadmium

The measured cadmium content in all samples (Table 18.3) was less than 1 mg/kg compared with the soil guideline value of 230 mg/kg (Dutch Intervention Level is 13 mg/kg).

18.6.4.4 Chromium

Chromium levels in the samples (Table 18.3) ranged between 23 and 109 mg/kg. This is well below the CLR guideline value of 5000 mg/kg.

18.6.4.5 Copper

Copper levels in the samples (Table 18.3) ranged between 1 and 24 mg/kg. This is well below the Dutch Intervention Level of 190 mg/kg.

18.6.4.6 Mercury

The measured mercury content in the samples (Table 18.3) ranged between >1 and 11 mg/kg. This is below the soil guideline value of 26 mg/kg.

18.6.4.7 Nickel

The measured nickel content in the samples (Table 18.3) was fairly consistent ranging between 37 and 48 mg/kg. This is below the soil guideline value of 1800 mg/kg (Dutch Intervention Level is 100 mg/kg).

18.6.4.8 Phosphorous

The measured phosphorous content of the samples range between 383 and 1583 mg/kg (Table 18.3). This was generally at the lower end of the range of measurements for all samples from the site (mean 1535 mg/kg, maximum 32000 mg/kg).

18.6.4.9 Lead

The measured lead content in the samples (Table 18.3) was fairly consistent ranging between 34 and 58 mg/kg. This is well below the Dutch Intervention Level of 530 mg/kg.
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18.6.4.10 Selenium

The measured selenium content in all samples (Table 18.3) was less than 1 mg/kg compared with a soil guideline value of 13000 mg/kg.

18.6.4.11 Zinc

The measured zinc content in the samples (Table 18.4) ranged between 84 and 201 mg/kg. This is well below the Dutch Intervention Level of 720 mg/kg.

18.6.4.12 Total sulphate

The total sulphate content of the samples range between 600 and 2891 mg/kg (Table 18.4) and were generally consistent with analysis of other samples from around the site. Concentrations were generally lower at the made ground/alluvium interface than in the made ground.

18.6.4.13 Acid soluble sulphide

The acid soluble sulphide content of the samples range between 2 and 2320 mg/kg (Table 18.4). The A23 sample recorded the highest content from all samples on the site. All values at this location were generally toward the higher range of measurements made on the whole site (mean of all samples 73 mg/kg).

18.6.4.14 Total sulphur

The total sulphur content of the samples (Table 18.4) ranged between 0.02 and 0.45%.Values were generally higher than the mean value for all of the site samples (mean of all samples 0.12%).

18.6.4.15 Total cyanide

The measured total cyanide content in all samples (Table 18.4) was less than 2.5 mg/kg. This is consistent with the other samples obtained from the whole site and may be compared with the Dutch Intervention Level of 20 mg/kg (free cyanide).

18.7 **Conclusions**

The Phase 2 assessment has described the baseline conditions based on data obtained from an intrusive investigation. The sampling strategy focused on obtaining data for those areas of the site where there was envisaged to be a risk of future releases to ground from permitted activities

Twenty-nine boreholes were excavated within the installation boundary, although only three are relevant to the area proposed for the hydrogen plant. No ground water was struck at these locations.

The sampling logs indicate that there is made ground present across the site comprising a mid to dark brown, fine to medium, angular to sub-rounded silty sand and gravel of slag, and ash. This is underlain by alluvium, consisting of silty clay and gravelly layers as identified in previous investigations. This is underlain by the Keuper Marl which is reported to be approximately 16m below ground level by previous site investigation data. Perched groundwater was occasionally encountered in the made ground at the made ground/alluvium interface, although not in the area proposed for the hydrogen plant.

There was visual and olfactory evidence of organic/hydrocarbon contamination observed during the investigation especially in samples taken from the east part of the site, although this was somewhat less around the area of interest in this case.

Chemical analysis was undertaken on soil samples from each borehole from both the made ground and made ground/alluvium interface. The chemical analysis of samples obtained from the area of interest focused on toxic and phytotoxic metals, sulphate, sulphide, solvent extractable matter, volatile and semi volatile organic compounds, VOC's and SVOC's. The area of interest was not considered to

be subject to any plant specific contamination and as such no other specific analyses were undertaken.

The sampling logs and chemical analysis data have been reviewed to determine the baseline conditions (at 2002). All areas of the installation are considered to be equivalent in terms of ground conditions and concentrations of inorganic contaminants, however, organic contamination exhibits a variation with the east of the site demonstrating significantly more elevated concentrations than the west of the site (around the location of the proposed hydrogen plant).

The results of the analyses of samples from the locations relevant to the proposed hydrogen plant have been compared with accepted guideline values to allow the degree of contamination to be put into context.

In general the range and level of organic contamination in the hydrogen plant area was less than that at other parts of the site and none of the samples exhibited a level of organic contamination above guideline levels.

In respect of inorganic species the analyses undertaken indicated all concentrations to be below guideline or intervention levels. Levels of contamination were generally lower in this area than in the rest of the site, although the area did have some of the highest concentrations of total sulphur and acid soluble sulphide on the entire site.

Limitations in the data have been considered in accordance with the guidance on site reports. Overall the data are expected to be as representative as possible of the baseline conditions subject to the limitations imposed on sampling on an operational industrial site

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