Humber Refinery

Environmental Permit Variation Application
Main Supporting Document

Phillips 66 Limited

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Quality information

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1. Non-Technical Summary

This document presents the supporting information for an Environmental Permit variation application under the Environmental Permitting (England and Wales) Regulations 2016 (as amended) ('the EP Regulations'), submitted on behalf of Phillips 66 Limited ('Phillips 66') to vary the Environmental Permit for the Humber Refinery (the 'Installation') under the existing Environmental Permit, reference EPR/UP3230LR. The Installation's location and Installation Site Boundary are provided in Figures 1 and 2 (Appendix A).

Phillips 66 intend to retrofit a Post-Combustion Carbon Capture (PCC) plant on the Fluid Catalytic Cracking (FCC) Unit at the Humber Refinery to remove the carbon dioxide (CO_2) from the flue gas emitted from the unit. The FCC is the largest CO_2 emitter at the Installation and therefore is considered to be the logical first step to moving towards decarbonisation for the Installation. At full load, the Phillips 66 PCC Plant will capture up to 0.5 million tonnes of CO_2 per year from the flue gases from FCC Unit.

A substantial variation to the Environmental Permit for the Installation is required to incorporate the PCC Plant as a new Schedule 1 activity.

The Phillips 66 PCC Plant comprises part of the wider Humber Zero Project (HZP), which consists of two linked projects to install PCC plants and associated facilities at the Phillips 66's Humber Refinery and the adjacent VPI Immingham Combined Heat and Power (CHP) Power Plant. The progress of the Humber Refinery PCC Plant is subject to the necessary consents being received, including the Environmental Permit, and government policy/ funding support being in place to enable final investment decisions to be taken.

The CO_2 transmission network that the developments within the HZP will connect into is currently under development by others. There are two potential Transport and Storage (T&S) networks that the Humber Refinery PCC Plant could be connected to: either the Viking CCS CO_2 gathering network (promoted by Harbour Energy) or the East Coast Cluster Humber Low Carbon Pipelines, also known as Zero Carbon Humber, for transport to storage sites under the North Sea. Both pipeline networks will run close to the Installation and the decision as to which network will be connected to initially will be made following Government funding announcements and pipeline availability. It is likely that access to both transportation networks would be available in the long-term.

The PCC Plant will be located in the northwest corner of the Installation, on land currently comprising hardstanding, material storage, and temporary usage (such as site cabins for maintenance contractors), within the existing Installation boundary. The PCC Plant will be immediately to the west of the FCC plant area and the proposed layout of the PCC Plant is shown in Figure 3 (Appendix A).

The FCC Unit flue gas will need to pass through a number of new pre-treatment stages prior to entering the PCC Plant, to ensure the PCC Plant operates effectively. These will include Selective Catalytic Reduction (SCR) to reduce oxides of nitrogen (NOx), a Wet Gas Scrubber (WGS) to reduce sulphur dioxide (SO_2) and particulates and a Wet Electrostatic Precipitator (Wet ESP) to further reduce fine particulates and aerosols within the FCC flue gas. The WGS will have a new Emission Point (A6d), which will not be used when the PCC Plant is operational, but will be available for times when the PCC Plant is not available (for example during start-up/ shut-down or maintenance activities).

The PCC Plant will use an amine-based solvent to strip CO_2 from the treated FCC flue gas within a packed absorber column, via a weak acid-base reaction. The CO_2-depleted flue gas will then pass through further emissions abatement equipment (a water wash and mist eliminator) prior to its release to atmosphere via a dedicated stack on top of the PCC Plant absorber tower. This will comprise a new Emission Point (A6c).

The CO_2 will be removed from the CO_2-rich solvent in a CO_2 stripper (or regeneration column) by heat, using the existing steam supply line, provided by the adjacent VPI Immingham CHP Power Plant, enabling the lean amine-solvent to be recycled back into the absorption process for reuse.

The CO_2 gas will undergo low-pressure (LP) compression, with dewatering and de-oxygenation also carried out. It will then undergo high-pressure (HP) compression on-site to dense phase before being exported off-site to a third-party for transportation by pipeline and underground storage.

Over time, the amine-based solvent can accumulate impurities, and these are removed via a solvent thermal reclaiming process which will be carried out continuously within the PCC Plant. A slip stream of solvent from the absorber will be fed to the thermal reclaimer unit, and be heat treated to remove solvent degradation products which may occur within the PCC Plant.

The capture of CO_2 using amine-based solvents is a proven technology used for many years in oil refineries and gas processing plants. More recently, it has been employed at a number of power stations worldwide, although its use at scale in the UK is still very much in the early phase of development and deployment.

The design and operation of the PCC Plant is intended to meet the indicative guidance of Best Available Techniques (BAT) as defined for Carbon Capture and Storage (CCS), as summarised in this Main Supporting Document and described in full in Appendix C.

The main PCC Plant stack emissions will comprise residual pollutants from the FCC Unit after pre-treatment, including NOx, ammonia (NH_3), carbon monoxide (CO), SO_2, particulates and some residual CO_2. The PCC Plant will be designed to optimise CO_2 capture (designed to achieve approximately 95% capture) balanced against additional energy use. There may also be other trace pollutants within the flue gas, including trace levels of amine from the solvent and amine break-down products from within the carbon capture process. These emissions will be monitored and minimised using a water wash section and mist eliminator at the top of the PCC Plant absorber prior to final release of the waste gas.

Emissions from the main PCC Plant stack and the WGS stack will meet the associated emission levels for FCC Regenerators and Refineries under the Industrial Emissions Directive (IED).

The stack height and emission levels required to minimise impacts on air quality receptors from the main pollutants to 'insignificant' have been determined through an air quality impact assessment, undertaken in accordance with Environment Agency (EA) guidance. The assessment includes dispersion modelling of maximum emission parameters and prediction of maximum process contributions, to determine the worst-case predicted environmental concentrations that have been compared with air quality standards.

The assessment also includes consideration of the potential impacts associated with breakdown products of the amine-based solvent, from both within the process (as 'direct' emissions) and as a result of chemical interactions within the atmosphere (as 'indirect' emissions) which is beyond the normal scope of the EA's risk assessment method. The impact assessment for the operation of the PCC Plant is presented in Appendix D.

In addition to the main PCC Plant emission point on the absorber (and the WGS emission point for when the PCC Plant is not operational), there will be a CO_2 vent on the CO_2 compression plant, which will only operate intermittently on start-up/ shut-down. An assessment of CO_2 venting has been carried out and is presented in Appendix E. Any venting required for the off-site T&S Network pipeline will be provided by the T&S Network provider and therefore will not be from the Installation.

The majority of wastewater generated by the PCC process can be treated in the Installation's existing Effluent Treatment Plant (ETP) and then discharged to the existing Emission Point W2a to South Killingholme Drain. This will also include rainwater run-off from the PCC Plant area of the Installation.

An additional wastewater stream from the WGS, that cannot be treated in the existing ETP, will undergo treatment onsite in a new Purge Treatment Unit (PTU) to reduce the sulphite and COD present in the wastewater generated. This PTU wastewater will bypass the existing ETP and be discharged to the existing Emission Point W2a to South Killingholme Drain. A screening assessment of the impacts associated with this discharge is provided in Section 7.4.3.

General wastes from the PCC Plant are expected to be minimal and will be appropriately disposed of via licensed 3rd party contractors, in line with regulatory requirements and Installation procedures.

Solid wastes generated by the PCC Plant, such as waste from the thermal reclaimer and waste from the PTU, will be collected and stored onsite prior to disposal off site via a licensed 3rd party waste contractor in line with regulatory requirements and Installation procedures.

A Noise Impact Assessment (NIA) has been carried out and concludes that, considering the noise levels from the proposed PCC Plant alone, the BS 4142 assessment shows a potential for significant adverse impacts at one Noise Sensitive Receptor (NSR) and a potential adverse impact at two further NSRs when the rating level is compared to the background sound level without the contribution from the existing Refinery. However, when the predicted rating level for the proposed PCC Plant alone is compared to the existing background sound levels (which includes contributions from the existing Refinery), there is no excess of rating level over background sound level at any NSRs during the daytime. During the night-time, the excess is only 1 dB at two NSRs. This is less than the level above which adverse impacts are likely to be indicated in accordance with BS 4142.

Depending on the background sound levels applied to the assessment, the noise levels from the combined existing operations at the Humber Refinery and the PCC Plant would show a maximum of up to a 2 dB increase during the night-time in the excess of rating level over background sound level, when the existing and proposed operations are combined, compared to only the existing operations, for two of the identified NSRs and 1 dB increase at three of the NSRs during the daytime. These increases are not expected to be perceptible at the NSRs, given the existing sound climate and the proposed PCC Plant predictions are a worst-case scenario.

Overall, considering the BS 4142 assessment outcomes and the context of the existing sound environment, it is considered that the addition of the proposed PCC Plant would have a low impact on NSRs.

The NIA is presented in Appendix F. Following the outcome of the NIA, a Noise Management Plan has been developed for the Installation and is provided in Appendix G.

The Installation is operated in line with the existing ISO14001:2015 accredited Environmental Management System (EMS), which will be updated to include additional operating procedures to manage the various aspects of the operation of the PCC Plant, including but not limited to emissions monitoring, accident management, waste minimisation and management, and infrastructure maintenance. The Noise Management Plan (NMP) developed as part of this Permit variation application will be incorporated into the existing EMS.

2. Introduction

Phillips 66 Limited (‘Phillips 66’) operates the Humber Refinery (the ‘Installation’) in Immingham, North Lincolnshire, under the existing Environmental Permit reference EPR/UP3230LR. The Installation’s location and Site Boundary are provided in Figures 1 and 2 (Appendix A).

Phillips 66 intend to retrofit a Post-Combustion Carbon Capture (PCC) Plant to treat the flue gas emitted from the existing Fluid Catalytic Cracking (FCC) Unit to remove the carbon dioxide (CO_2) in the flue gas for subsequent transportation and storage. At full load, the Phillips 66 PCC Plant will capture up to 0.5 million tonnes of CO_2 per year from the flue gases from FCC Unit.

This document presents the supporting information for a substantial Environmental Permit variation application made under the Environmental Permitting (England and Wales) Regulations 2016 (as amended) (‘the EP Regulations’), and is submitted on behalf of Phillips 66, to vary the Environmental Permit to incorporate the PCC Plant as a new Schedule 1 activity. There will be an additional Schedule 1 activity associated with wastewater treatment, which will be required as a result of the additional emissions abatement systems needed to ensure effective operation of the PCC Plant.

The installation of the PCC Plant on the FCC Unit comprises part of the Humber Zero Project (HZP) which consists of two linked projects to install PCC plants and associated facilities at the Phillips 66’s Humber Refinery and also at the adjacent VPI Immingham Combined Heat and Power (CHP) Power Plant. The development of the Humber Refinery PCC Plant is subject to receipt of all applicable consents, including the Environmental Permit variation, and to government policy and funding support being in place to enable a final investment decision.

The Humber is the largest industrial cluster in the UK in terms of existing CO_2 emissions, emitting approximately 20 million tonnes of CO_2 per year. If installed, the Phillips 66 PCC Plant will be designed to remove approximately 95% of CO_2 emissions from the FCC Unit, representing a 2.5% reduction in the overall emissions from the Humber industrial cluster, thereby contributing towards the UK Government’s legally binding target to reach net zero by 2050. In addition, the FCC Unit within the Humber Refinery is the largest CO_2 emitter at the Installation and therefore is considered to be the logical first step towards decarbonisation for the Installation. By providing a high-pressure (HP) CO_2 booster compression station close to the Humber Refinery and establishing a tie-in to the CO_2 Transport and Storage (T&S) network it will assist the development of further carbon capture projects at the Installation.

The CO_2 T&S Network that the HZP developments will connect into is currently under development by others. There are two potential T&S Networks that the Phillips 66 PCC Plant could be connected to: either the Viking CCS CO_2 gathering network (promoted by Harbour Energy) or the East Coast Cluster Humber Low Carbon Pipelines, also known as Zero Carbon Humber, for transport to storage sites under the North Sea. Both pipeline networks will run close to the Installation and the decision as to which network will be connected to initially will be made following Government funding announcements and pipeline availability. It is likely that access to both transportation networks would be available in the long-term.

A Town and Country Planning application (TCPA) for the Proposed Development of the Phillips 66 PCC Plant has been made and is currently being determined by North Lincolnshire Council. A copy of the Environmental Statement (ES) prepared to support the TCPA is included in Appendix B.

Due to the critical project time lines, and long Environment Agency (EA) determination periods, this Environmental Permit variation is being made before detailed project design has been completed. As such, it is recognised that further information may need to be provided to the EA following completion of detailed design in order to reflect design changes that may have occurred after this variation application has been submitted. Where possible, conservative or worst-case assumptions have been used in this Environmental Permit variation application.

The PCC Plant will be located in the northwest corner of the Humber Refinery, within the existing Installation Site Boundary, on land directly to the west of the FCC Unit area. The land currently comprises hardstanding, material storage, and temporary usage, such as site cabins for maintenance contractors. There are some existing buildings within the area, however, it is likely that most of these will be demolished prior to construction of the PCC Plant. The CO_2 pipeline will run along the northern boundary of the Installation, to the CO_2 T&S Network tie-in.

An indicative layout plan of the PCC Plant area is shown in Figure 3 (Appendix A).

2.1 Proposed Operations

2.1.1 Listed Activities under Schedule 1 of the EP Regulations

There are number of activities carried out at the Installation which fall under Schedule 1 of the EP Regulations, as detailed in Table S1.1 of the Installation's Environmental Permit. The EP Regulations also include a listed activity in Section 6.10 for the *Capture of carbon dioxide streams from an installation for the purposes of geological storage pursuant to Chapter 3 of Part 1 of the Energy Act 2008 and other EU-derived domestic legislation which transposed Directive 2009/31/EC of the European Parliament and of the Council on geological storage of carbon dioxide in relation to England and Wales.* This variation application will add the Section 6.10 listed activity of Carbon Capture and Storage together with a number of additional directly associated activities (DAA) to the Installation's Environmental Permit.

An additional Section 5.4 Part A(1) (a) (ii) *Disposal of non-hazardous waste in a facility with a capacity of more than 50 tonnes per day by physico-chemical treatment* listed activity will also need to be added to the Environmental Permit for the Purge Treatment Unit associated with the WGS.

It is therefore proposed to vary Schedule 1 Table S1.1 of the existing Environmental Permit, as shown in Table 2.1.

Table 2.1: Table S1.1 Schedule 1 Listed Activities

Activity listed in Schedule 1 of the EP Regulations	Description of Specified Activity	Limits of Specified Activity	Changes Detailed in this Variation
Section 1.1 Part A(1)(a)	Burning of any fuel in an appliance with a rated thermal input of 50 MW or more.	Refinery fuel gas (including the cryogenic unit) and natural gas supply systems to combustion units and any associated activities necessary to maintain the operation of the plant and fuel supplies though to the discharge of exhaust gasses from the stacks, abatement plant and the export of steam to the steam systems, including: (i) Onsite 42MWth CHP unit (GTA 711 and GTA 712)	No change to this activity.
Section 1.2 Part A(1) (d)	Refining mineral oil (Primary operations)	From feed to oil refining unit to use including each of the following units: (i) #1 vacuum distillation unit (#1 VDU), including process heater (ii) #2 vacuum distillation unit (#2 VDU), including process heater (iii) #3 vacuum distillation unit (#3 VDU), including process heater (iv) Gas oil hydrodesulphurisation unit (GOHDS), including process heater (v) Heavy oil filtration unit (vi) #1 Calciner including coke handling, storage and rail/ road loading, and petroleum coke unloading, handling, storage and loading area (including flare pad) (vii)#2 Calciner including coke handling, storage and rail/ road loading, and petroleum coke unloading, handling, storage and loading area (including flare pad) (viii) #3 Calciner including coke handling, storage and rail/ road	No change in the description of activities (i) – (xix) and (xxi) – (xxv). (xx) Additional treatment of flue gas from the FCCU using Selective Catalytic Reduction, Wet Gas Scrubbing, Wet-ESP and Post-combustion Carbon Capture plant.

Activity listed in Schedule 1 of the EP Regulations	Description of Specified Activity	Limits of Specified Activity	Changes Detailed in this Variation
		loading, and petroleum coke unloading, handling, storage and loading area (including flare pad) (ix) Virgin hydrodesulphuriation unit (VHDS), including process heaters (x) Cracked hydrodesulphuriation unit (CHDS), including process heaters (xi) Diesel hydrodesulphuriation unit (DHDS), including process heaters (xii) Gasoline hydrodesulphuriation unit (GHDS), including process heaters (xiii) Penex unit, including process heater (xiv) Saturated gas plant (SGP) (xv) Cracked gas plant (CGP), including CPU Merox, Selective Hydrogenation Process (SHP-2) and flare gas recovery compressors (xvi) Catalytic reforming unit #2 (CRU-2) including process heaters and hydrogen system (xvii) Catalytic reforming unit #3 (CRU-3) including process heaters and hydrogen system (xviii) Pressure swing absorber (PSA) (xix) Aromatics extraction unit (AEU) (xx) Fluid catalytic cracking unit (FCCU), process heaters, FCCU gasoline heart-cut treatment (Minalk system) and selective hydrogenation unit (xxi) Propylene recovery unit (PRU) including PRU Merox and selective hydrogenation process (SHP-1) (xxii) Vapour recovery unit (VRU) including VRU Merox (Minalk) (xxiii) Alkylation Unit including process heater and Butamer unit (xxiv) Thermal cracking unit (TCU) including process heater (xxv) GTA 706	
Section 1.2 Part A(1) (d)	Refining mineral oil (Secondary operations – oil movements and blending)	From receipt of feed, through blending (where necessary) to feed, intermediate and product storages and export including: liquified petroleum gases, white oils (including rail loading of petrol/ diesel and petrol vapour recovery unit), heavy gas oils and other black oils, slops, etc. in support of the above primary operations.	No change to this activity.
Section 1.2 Part A(1) (e) (i)	The handling, storage and physical/ thermal treatment of crude oil	From receipt and storage of crude (including unloading from road tankers and blending of slops) to operation of crude distillation units including: (i) #1 Crude topping unit (#1CTU), process heather and associated feed and product system for this activity	No change to this activity.

Activity listed in Schedule 1 of the EP Regulations	Description of Specified Activity	Limits of Specified Activity	Changes Detailed in this Variation
		(ii) #2 Crude topping unit (#2CTU), process heather and associated feed and product system for this activity	
Section 1.2 Part A(1) (f) (v)	Activities involving the pyrolysis, carbonisation, distillation partial oxidation or other heat treatment of mixtures of carbonaceous materials and oil	From feed to unit to discharge to further processing including: (i) #1 Coker, process heaters and green coke storage pit (ii) #2 Coker, process heaters and green coke storage pit (iii) FCCU (R9 Oil re-refining or other reuses of oil)	No change to this activity.
Section 4.1 Part A(1) (a) (i)	Producing organic chemicals, such as aromatic hydrocarbons	Hydro de-alkylation unit (HDA), for the manufacture of benzene, process heaters and associated feed and product storage/ export systems for this activity	No change to this activity.
Section 4.2 Part A(1) (a) (v)	Producing inorganic chemicals such as non-metals (e.g. sulphur)	Sulphur recovery unit plant (with associated amine systems, amine recovery unit, sour water stripper units), including: (i) #1 Sulphur recovery unit (#1 SRU) utilising Claus technology (ii) #2 Sulphur recovery unit (#2 SRU) utilising Claus technology (iii) Tail Gas Treatment Unit (TGTU) utilising Beavon sulphur removal process (iv) Incineration of remaining tail gas, storage/ loading of products	No change to this activity.
Section 5.3 Part A(1) (a) (i)	Disposal of hazardous waste in a facility with a capacity of more than 10 tonnes per day (by biological treatment)	The receipt and treatment of liquid waste for disposal in the main biological effluent treatment plant (ETP), including oil water separators, IAF units, activated sludge unit, #1, #2, #3 and Alkylation holding ponds, storage of sludge and waste receipt detailed in table S2.2.	Additional wastewaters from the PCC Plant area that are suitable for treatment in the ETP.
Section 5.4 Part A(1) (a) (ii)	Disposal of non-hazardous waste in a facility with a capacity of more than 50 tonnes per day (by physico-chemical treatment)	Physical treatment of South tank farm (STF) surface waters in oil-water separator, including bund/ surface water collection systems and holding pond	No change to this activity.
Section 5.4 Part A(1) (a) (ii)	Disposal of non-hazardous waste in a facility with a capacity of more than 50 tonnes per day (by physico-chemical treatment)	Treatment of wastewaters generated in the Wet Gas Scrubber on the FCCU in a Purge Treatment Unit	New activity proposed to be added to the permit. Treatment of wastewaters for the removal of catalyst fines and sulphite oxidation.
Section 6.10 Part A(1): Carbon Capture and Storage	Operation of a Carbon Capture plant.	From receipt of exhaust gas from the HRSG into the CCP to the treatment of the gas prior to pipeline export or release to atmosphere.	New activity proposed to be added to the permit. The treatment of exhaust gas from the FCCU in a PCC Plant using an

Activity listed in Schedule 1 of the EP Regulations	Description of Specified Activity	Limits of Specified Activity	Changes Detailed in this Variation
			amine-based solvent to extract the CO_2, followed by compression and dehydration of the treated CO_2 for off-site transfer; and release of CO_2-abated flue gas to atmosphere.

2.2 Environmental Setting

The topography of the area surrounding the Installation comprises a low-lying estuarine landscape consisting of extensive stretches of intertidal habitats containing mudflats, saltmarsh, coastal dunes and wetland adjacent to the Humber Estuary.

The Installation is located to the south of the Lindsey Oil Refinery, with the Humber Ports facility further to the north and the VPI Immingham CHP Power Plant to the east.

The nearest settlements are the villages of South and North Killingholme, located approximately 500m and 800m to the west of the Installation respectively. The town of Immingham is located approximately 1km southeast of the Installation.

The Humber Estuary Special Area of Conservation (SAC), Special Protection Area (SPA), Site of Special Scientific Interest (SSSI) and Ramsar is approximately 2km to the east, and there are six Local Wildlife Sites (LWS) within 2km of the Installation.

The location of the Installation is shown in Figure 1 (Appendix A).

Further detail on the environmental setting and local receptors is presented in Section 7.

3. Site Condition Report

An Application Site Report was submitted with the original Environmental Permit application for the Installation, which detailed the environmental sensitivity of the Installation and surrounding area, and informed the Site Protection and Monitoring Programme (SPMP) that is currently in place.

The PCC Plant will be installed on approximately 2.7 hectares of land within the northwest corner of the existing Installation Site Boundary (Figure 3, Appendix A). The land currently comprises hardstanding, material storage and temporary usage, such as site cabins for maintenance contractors, and therefore it is considered that there has been minimal potential for contamination to occur since the Application Site Report was prepared and submitted to the EA. No update to the Site Condition Report has therefore been submitted with this Variation application; however a Baseline Assessment and Conceptual Site Model is presented in the Environment Statement prepared for the TCPA (Appendix B of this document (see ES Volume II, Appendix 10A)).

A brief summary of the sensitivity of the PCC Plant area is provided here:

> Groundwater - Medium sensitivity - The underlying Devensian Till (Diamicton) - is classified as Secondary Undifferentiated Aquifer, however the bedrock of Burnham Chalk is a Principal Aquifer.
>
> Surface water - Low sensitivity – The Humber Estuary, located approximately 2 km to the east of the PCC Plant area. The PCC Pant area is located within the North Beck Drain Water Body catchment. The current (2019) classification has a ‘Moderate’ ecological status and a chemical status of ‘Fail’ due to priority hazardous substances mercury and its compounds and polybrominated diphenyl ethers (PBDE). This is also designated as a heavily modified water body.
>
> Land use – Low sensitivity – the PCC Plant is mainly surrounded by industrial land use to the northeast and south, with commercial use directly to the west. The village of South Killingholme is 500m to the west.

4. Operating Techniques

4.1 Technical Standards

The FCC Unit will continue to operate in accordance with the conditions of the existing Environmental Permit and also applicable EA Sector guidance, namely:

- EPR 1.01: How to Comply with your Environmental Permit, Additional Guidance for: Combustion Activities [1]; and,
- Best Available Techniques (BAT) Reference (BRef) Document for the Refining of Mineral Oil and Gas [2] and associated BAT Conclusions (Refineries BATc) [3].

The EA issued an Environmental Permit variation in 2018, for the operation of the Humber Refinery considering and implementing the requirements of the Commission Implementing Decisions 2014/738/EU Best Available Techniques for Refineries (Refineries BATc). Since the operation of the FCC has not changed in relation to these requirements since their implementation, no further review to assess the FCC against the Refineries BATc has been undertaken as part of this Variation application.

The installation and operation of the PCC Plant is covered as a Section 6.10 A(1)(a) activity - *Capture of carbon dioxide streams from an installation for the purposes of geological storage pursuant to Chapter 3 of Part 1 of the Energy Act 2008 and other EU-derived domestic legislation which transposed Directive 2009/31/EC of the European Parliament and of the Council on the geological storage of carbon dioxide in relation to England and Wales.*

In the absence of specific BAT for PCC Plant for Refineries, the following EA guidance has been considered in the preparation of this application:

- Post-combustion Carbon Dioxide Capture: BAT Guidance[4], and accompanying BAT Review for New Build and Retrofit Post-Combustion Carbon Dioxide Capture Using Amine-Based Technologies for Power and CHP Plants Fuelled by Gas and Biomass and for Post-Combustion Carbon Dioxide Capture Using Amine-Based and Hot Potassium Carbonate Technologies on EfW Plant as Emerging Technologies under the IED for the UK[5].

It should be noted that the EA guidance does not have the same legal status as BRefs and BAT Conclusions published under the IED, and indeed the webpage containing the EA's guidance states that *"Except where stated, this BAT guidance is not a regulatory requirement but identifies important environmental issues to address and best practice"*. However, a review of the PCC Plant to be installed at the Installation has been carried out against the EA's Post-combustion Carbon Dioxide Capture BAT Guidance and is provided in Appendix C.

The Phillips 66 PCC Plant will be a First of a Kind (FOAK) application to an FCC and therefore there are no operational plants to provide information to support this application. Also, as stated previously, this Environmental Permit variation is being made before detailed project design has been completed and therefore it is recognised that updates to the Environmental Permit may need to be undertaken following completion of detailed design in order to reflect design changes that may have occurred after this Environmental Permit variation application has been determined. It is anticipated that these can either be dealt with through the application of appropriate Pre-Operational Conditions within the Environmental Permit, or if required a further variation application may be required. Where appropriate, Pre-Operational Conditions have been suggested.

It is considered that being a FOAK development the Phillips 66 PCC Plant will help shape the development of BAT for PCC plant on refineries for the future.

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[1] How to comply with your environmental permit, Additional guidance for: Combustion Activities (EPR 1.01), EA, March 2009

[2] Best Available Techniques (BAT) Reference Document for the Refining of Mineral Oil and Gas, under Directive 2010/75/EU of the European Parliament and of the Council, European IPPC Bureau, February 2015

[3] Commission Implementing Decision of 9 October 2014 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions, for the refining of mineral oil and gas

[4] Available at: Post-combustion carbon dioxide capture: best available techniques (BAT) - GOV.UK (www.gov.uk)

[5] Available at: Best Available Technology (BAT) information for CCS | UKCCSRC

The PCC Plant will be operated in accordance with the existing Environmental Management System (EMS) for the Installation, which will be amended as required to include the proposed operation of the PCC Plant prior to commencement of its operation. The existing EMS is compliant with the EA's guidance - 'Develop a management system: Environmental Permits'[6].

4.2 Process Description

4.2.1 Overview

Following the installation of the PCC Plant, there will be no change to the existing FCC Unit's operation from that described in the original Environmental Permit application for the Installation, and therefore no discussion of the FCC process is included in this Environmental Permit variation application.

The flue gas from the FCC Unit currently passes through cyclones for the removal of entrained catalyst dust, then through either a restriction orifice chamber or a turbo-expander and a waste heat boiler. The flue gas is then routed through an electrostatic precipitator (ESP) to remove any remaining catalyst before entering the existing 115m tall stack (ST-3401 (Emission Point A6b)). In addition, emissions from the FCC Feed Heater (H3401) and the Isostripper Reboiler (H3631) are also routed directly to the exiting 115m tall stack (ST-3401 (Emission Point A6a)). Start-up Heater H3402 also vents to Emission Point A6a, however this is only used once every 6 years for 1-2 days.

The PCC Plant to be installed at the Installation will take the flue gas from the FCC Regenerator only. The FCC Feed Heater and the Isostripper Reboiler will not go to the PCC Plant as the flue gas pressure from these sources is too low and therefore would need numerous fans to drive the flue gas to the PCC Plant. Failure of the fans would result in back-pressures that could result in potential safety issues for the heaters. In addition, these sources only represent approximately 15% of the flue gas flow to the FCC stack and have a lower CO_2 content than the FCC Regenerator flue gases. As such, these emission sources will continue to be released from the existing FCC stack via Emission Point A6b.

The hot FCC Regenerator flue gas will continue to be treated in the existing cyclones, but will then pass through a number of new pre-treatment stages prior to entering the PCC Plant, in order to reduce the concentrations of oxides of nitrogen (NOx), oxides of sulphur (SOx) and particulates and also reduce the temperature of the flue gas. This is required to ensure the PCC Plant operates effectively and to reduce the potential for solvent degradation to occur. As such, the existing waste heat boiler and ESP will no longer be required and therefore will be removed.

The new flue gas pre-treatment stages will include a waste heat exchanger (to lower the flue gas temperature for treatment), a Selective Catalytic Reduction (SCR) unit (ammonia based) to reduce NOx, a Wet Gas Scrubber (WGS) to reduce SO_2 and particulates with an integrated Wet Electrostatic Precipitator (Wet ESP) to further reduce fine particulates and aerosols in the FCC Regenerator flue gas. The waste heat exchanger will recover energy to be used in the PCC Plant.

The flue gas will then pass into the PCC Plant where it will travel up through a counter-flow, packed absorption column against a falling solvent into which the majority of the CO_2 content will be absorbed. The treated flue gases (CO_2-abated flue gas) will then pass through solvent retention and air emissions mitigation stages and will subsequently be released to atmosphere via a stack on top of the PCC Plant CO_2 Absorber Column.

The CO_2-rich solvent will leave the bottom of the CO_2 Absorber Column and be routed to the top of a CO_2 Stripper, via a crossflow heat-exchanger, where it will pass down a packed column, counter-current to hot rising vapour from the reboiler at the CO_2 Stripper base, releasing the absorbed CO_2. The CO_2-lean solvent at the bottom of the CO_2 Stripper will then return to the solvent system via the cross-flow heat-exchanger, and the CO_2 from the top of the CO_2 Stripper will pass to the CO_2 Compression Plant.

The water-saturated CO_2 gas from the PCC Plant will undergo staged compression to dense phase, with oxygen and water removal, to achieve the pipeline CO_2 specification. The dense phase CO_2 stream will then be transported off-site into the CO_2 T&S Network.

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[6] Develop a management system: Environmental Permits, EA, Published: February 2016, Last Updated on: 14th January 2019, accessed at https://www.gov.uk/guidance/develop-a-management-system-environmental-permits

The water, steam and power required for the PCC Plant will be supplied from existing Installation systems and from the adjacent VPI Immingham CHP Power Plant.

The PCC Plant will be designed to operate 24 hours a day, 7 days a week as per the existing Installation and will be designed for up to 95% CO_2 capture during steady state operation, capturing up to 0.5 million tonnes per year of abated CO_2.

The PCC Plant area is located within the Installation Site Boundary and is shown in Figure 2. The proposed indicative PCC Plant layout is illustrated in Figure 3 (Appendix A).

The PCC Plant will include the following main components:

- ducting to connect the FCC Unit to the PCC Plant;
- waste gas heat exchanger/ air-cooled heat exchangers;
- flue gas pre-treatment: SCR, WGS and Wet ESP;
- a Purge Treatment Unit (PTU) to treat the effluent from the WGS;
- a PCC Plant with a CO_2 Absorber Column and associated stack, and a CO_2 Stripper Column;
- LP CO_2 compression;
- oxygen removal and dehydration facilities;
- HP CO_2 booster compression;
- CO_2 pipelines connecting the PCC Plant to the compression facilities and the CO_2 T&S Network interface;
- chemical offloading, storage and distribution facilities for ammonia for the SCR, caustic for the WGS and amine-based solvent for the PCC Plant;
- a thermal Solvent Reclaimer Unit;
- utilities (including chillers, steam generator and air compressors);
- electrical substation; and
- instrument equipment house.

A process flow diagram of the PCC Plant is shown in Figure 4 (Appendix A).

The tie-in to the existing FCC flue gas duct is anticipated to be carried out during the planned FCC turnaround in 2028 and therefore will not impact on the functioning of the existing system.

4.2.2 FCC Regenerator Flue Gas Pre-Treatment

In the existing system, the flue gas from the FCC Regenerator is vented to a 115m stack (Emission Point A6b) via cyclones and an ESP for the removal of entrained catalyst dust. The proposed PCC Plant will take the flue gas for CO_2 removal after the existing cyclones.

Existing emission concentrations within the FCC flue gas are in line with the monthly BAT-Achievable Emission Levels (AELs) for Catalytic Cracking processes, as follows:

- NOx – <100 - 300mg/Nm^3;
- CO - 100mg/Nm^3
- SO_2 - <100 - 800mg/Nm^3; and
- Particulates – 10 - 50 mg/Nm^3.

For the PCC Plant to operate optimally, emissions of NOx, SO_2 and particulates need to be reduced from their current concentrations before entering the CO_2 Absorber Column. Acid gases, such as NO_2 and SO_2, can preferentially react with the amine solvent within the PCC Plant, causing degradation of the solvent, and therefore reducing levels of CO_2 capture.

The pre-treatment is also in place to remove the fine particulates and aerosols, in particular sulphuric acid mist formed by the presence of sulphur trioxide (SO_3). If these are not removed, they act as a nucleus to form larger aerosols in the CO_2 Absorber Column which leads to increased amine emissions from the Absorber stack. As such, additional secondary abatement measures to prevent solvent degradation and the generation of aerosols will be installed prior to the PCC Plant, as described in the following sections.

4.2.2.1 Selective Catalytic Reduction

SCR is a secondary abatement technique involving the injection of ammonia (in the presence of a catalyst) into the exhaust gas to react with any NOx present. The SCR equipment will be installed following the existing cyclones, within the heat exchanger unit. The heat exchanger will ensure that the FCC flue gas (at approximately 650°C) is reduced to the optimum catalyst temperature zone (300 - 450°C) through a series of steam coils. Following the catalyst section there will be additional steam coils and then an economiser section. By extracting heat from the FCC flue gas, the heat exchanger will raise steam for use in the PCC Plant.

The use of SCR may lead to ammonia slip (i.e. unreacted ammonia being present in the resulting flue gas), however as it reduces solvent degradation downstream in the PCC Plant it therefore improves the overall performance of the PCC Plant and reduces solvent residue waste. Ammonia is currently used within the existing ESP on the FCC Unit, and therefore it is already present in the flue gas from the FCC Unit, with the current monthly Emission Limit Value (ELV) of 15mg/Nm^3.

It is anticipated that ammonia slip from the SCR plant will be in accordance with the Refineries BATc monthly BAT-AEL of <5 – 15mg/Nm^3 as a yearly average, or average over the sampling period.

The NOx emissions from the FCC Regenerator will be reduced, such that they are expected to be below the monthly BAT-AEL range applicable to existing units detailed in the Refineries BATc of <100 – 300mg/Nm^3.

4.2.2.2 Wet Gas Scrubber/ Wet Electrostatic Precipitator

The bottom section of the WGS will comprise an absorber tower which will use caustic to remove the SO_2 and particulates from the flue gas. The top section of the WGS is the Wet ESP for further fine particulate and aerosol removal.

SO_2, particulates and aerosols within the flue gas will come into contact with the recirculating caustic within the WGS absorber tower section. SO_2 will react with the caustic forming sulphur salts that will dissolve in the recirculating liquid, whereas the particulates and aerosols will become suspended within the liquid.

Caustic will be supplied from a new caustic storage tank to be installed on the PCC Plant area, to maintain the pH of the recirculating liquid within the absorber section of the WGS. Make-up water will also be available, if required. Air and water cooling will be provided to regulate the temperature of the recirculating liquid within the WGS.

A purge stream will be drawn off from the WGS into a Purge Treatment Unit (PTU) to ensure that the recirculating liquid does not accumulate suspended solids and dissolved compounds which have been removed from the flue gas. The PTU will include a clarifier which will enable the separation (through sedimentation) of solids, promoted by the addition of coagulant and flocculant. The resulting wet solids will be discharged into dewatering bins below the clarifier, which will hold a membrane to allow the content of the bins to dewater. Liquid drained from the dewatering bins will be collected in a sump and then returned to the clarifier. The dewatered solids will be collected for disposal off-site via a licensed waste contractor.

The liquid level in the clarifier will be maintained, with overflow liquids being routed to a Sulphite Oxidation Tank. The liquid from the de-watering process will contain ammonium salts and sulphites from the SCR process and the WGS respectively. The Sulphite Oxidation Tank will allow the sulphites present in the liquid to oxidise to sulphates, thereby reducing the Chemical Oxygen Demand (COD) of the liquid effluent. The contents of the Sulphite Oxidation Tank will be recirculated and caustic will be dosed into the recirculation loop for pH control. A blower will introduce air bubbles into the contents of the Sulphite Oxidation Tank to aid the oxidisation process. The Sulphite Oxidation tank generates a liquid effluent which will contain sulphates, which is discussed further in Section 5.2.1.2.

A flow diagram of the PTU is provided in Figure 5 (Appendix A).

It is envisaged that the WGS will reduce the SO_2 emission concentrations from the FCC Regenerator to below the monthly BAT-AEL for existing units detailed in the Refineries BATc of <100 – 800 mg/Nm^3 (or a max of 600 mg/Nm^3 where low sulphur feed and/ or scrubbing is applicable), to concentrations of <50 mg/Nm^3.

The particulate emission concentrations from the FCC Regenerator are anticipated to be reduced to nearer the lower end of the monthly BAT-AEL range detailed in the Refineries BATc for particulate matter from existing FCC units of <10 – 50 mg/Nm^3.

4.2.3 Post-combustion Carbon Capture Process

The PCC Plant is an amine-based solvent, post-combustion carbon capture plant that is designed to capture approximately 95% of the CO_2 present in the exhaust gas from the FCC Regenerator. Following the pre-treatment stages described, the FCC flue gas will enter the PCC Plant.

The CO_2-rich flue gas will enter at the bottom of the CO_2 Absorber Column, where it will contact the lean amine solvent that will remove the CO_2 from the flue gas. The CO_2-rich flue gas will pass up through the CO_2 Absorber Column, with the lean solvent flowing down through the packing beds, to ensure good contact efficiency is maintained throughout the CO_2 Absorber Column. The CO_2 will become chemically bound by the amine solvent as the alkaline nature of the solvent will mean that it will selectively absorb acidic gases such as CO_2.

The equilibrium limit for this reaction will be reached at the top of the absorption section of the CO_2 Absorber Column where the leanest lean solvent contacts the exhaust gas with minimum CO_2 concentration. The overall carbon capture efficiency is given by the quantity of CO_2 removed from the inlet exhaust gas in relation to the total CO_2 in the inlet exhaust gas.

Typical operating temperatures in the CO_2 Absorber Column range from 40°C to 80°C, depending on the process design parameters such as the compositions of the solvent and the exhaust gas, as well as the presence of any intercooling arrangement in the CO_2 Absorber Column. The reaction between the solvent and the CO_2 is exothermic, as such the flue gas temperature is increased through the main packed bed of the absorber column. The lean solvent will be cooled through an intercooler within the absorber column to limit the temperature increase and to improve CO_2 absorption efficiency.

The CO_2 Absorber Column will have a single water wash section at the top, which will remove any entrained solvent in the now CO_2-lean flue gas, in order to minimise solvent carry-over into the waste gases from the PCC Plant. The water used in the water-wash section will be continuously recycled and cooled in the Water-Wash Cooler. As such, water will be condensed from the flue gas in the water wash section, and any excess water will be drained to the solvent loop to prevent solvent build-up in the water wash section and to minimise both solvent and water consumption.

The proportion of water in the recirculating amine solvent needs to be managed to ensure that it does not accumulate due to condensation of the flue gas. The amine solvent will be routinely sampled and analysed to determine whether excess water requires purging from the system. Purged water would be taken from the water wash loop and will be retained and utilised as amine dilution water when fresh amine is required by the PCC Plant to prevent waste generation.

No acid wash is proposed for the CO_2 Absorber Column, as it is considered that the amine emissions can be controlled to sufficiently low concentrations without requiring further treatment, as shown in Section 5.1.1.1. This then avoids the cross-media effects associated with the disposal of acid wash wastewaters.

A Mist Eliminator will also be located at the top of water wash section to prevent the entrainment of droplets into the waste gases before they are released to air from the top of the CO_2 Absorber Column via dedicated stack (new Emission Point A6c).

The CO_2 Absorber Column will be an approximately 51m high packed tower utilising structured packing to minimise gas path pressure drop. The packed column design meets indicative BAT requirements for maximising CO_2 absorption efficiency.

4.2.3.1 Technology and Solvent Selection

Phillips 66 have selected the Cansolv DC-103 amine-based carbon capture processes, utilising the very latest in amine solvent. Shell is a leading provider of CO_2 capture technologies, and their technology was selected by Phillips 66 following an extensive assessment which found it to be the Best Available Technology for the FCC flue gases in terms of capture efficiency and environmental performance. Shell also has significant operational experience of their technology and solvents, which have been commercially deployed since 2012. The Shell Cansolv system was also used in the first large scale capture of CO_2 from a coal-fired power station (Boundary Dam) commencing in 2014 and still operational today.

Proprietary solvents, such as Cansolv DC-103 are considered to offer significant benefit over the mature single solvent option of Monoethanolamine (MEA), due to its lower volatility leading to significantly lower amine emissions and solvent degradation rates.

4.2.4 CO_2 Stripping and Solvent Regeneration

The solvent from the base of the CO_2 Absorber Column, entrained with CO_2 (CO_2-rich solvent), will be pumped into the CO_2 Stripper Column via a lean-rich solvent heat exchanger, which will pre-warm the incoming CO_2-rich solvent. The CO_2 Stripper will consist of a stripping section with a collector tray below the packing and a reflux section on top of the column to maximise the solvent-CO_2 separation. The rich amine will enter the CO_2 Stripper on top of the stripping section of the column and the CO_2 is removed from the amine by steam rising up through the column which breaks the CO_2-amine bond.

The lean solvent will then accumulate in the bottom tray of the column and be routed to the CO_2 Stripper Reboiler. The solution will be heated by steam and transferred back to the bottom section of the CO_2 Stripper where the flashed vapours will be separated from the liquid and the vapour will re-enter the stripping section to strip out any remaining CO_2 from the solvent.

There will be a Mechanical Vapour Recompression (MVR) compressor, which compresses the flashed vapours from the hot lean solvent and reboiler condensate prior to re-injection into the CO_2 Stripper. This reduces the reboiler duty, improving the energy efficiency of the PCC Plant.

The gas from the stripping section passes through the reflux section of the CO_2 Stripper and will be routed to the reflux condenser. The residual steam will be condensed, and liquid separated from the gas in the reflux drum. The bulk of the now lean solvent will be returned via the lean-rich solvent heat exchanger to the top of the absorption section of the CO_2 Absorber Column for reuse. The CO_2 will flow from the CO_2 Stripper reflux drum at approximately 37°C to the CO_2 Compressor.

4.2.5 Solvent Management and Reclaiming

The recirculating solvent can accumulate insoluble contaminants entrained within the flue gas (e.g. any remaining catalyst fines not removed by the pre-treatment stages). The efficient management of the solvent is therefore fundamental to the maximisation of efficiency of the PCC Plant. In addition, oxidative degradation, where amines react with oxygen, NO_2 or SO_2 to form corrosion products including ammonia, can occur at temperatures between 40 - 55°C and particularly in the presence of catalytic impurities. The flue gas pre-treatment proposed to reduce the concentration of such species in the flue gas entering the PCC Plant will help to minimise oxidative degradation, via this process. In addition, thermal degradation of the solvent will be minimised by ensuring the temperature of the regeneration process in the CO_2 Stripper is optimised for the Cansolv solvent to be used within the PCC Plant. The selection of appropriate materials of construction is also necessary to minimise this risk.

The use of solvent management techniques specific to the solvent will ensure minimum waste generation and optimum capture performance in accordance with indicative BAT for PCC plant.

To prevent the build-up of such contaminants, a filtration system comprising a mechanical filter, a carbon bed filter and a carbon bed after filter will be in place to process a slip stream of the lean solvent returning to the CO_2 Absorber Column from the CO_2 Stripper. Once filtered, the majority of solvent will return to the PCC Plant for reuse, however a portion (anticipated to be 0.1% of the total PCC Plant solvent inventory) will be sent to the Thermal Reclaimer Unit to remove solvent degradation products, to prevent their build up.

The solvent reclaiming process will be carried out as a continuous bleed of the hot lean solvent returning to the CO_2 Absorber Column. The Thermal Reclaimer Unit will be a single column with a reboiler heated by medium pressure (MP) steam at the column base. The column will operate at vacuum and will separate out of most of the water and reclaimer lean solvent (overheads) from the degradation products (bottoms). Steam sparging will be available at the base of the Thermal Reclaimer Column to reduce viscosity and aid solvent reclamation.

The overheads will be partially condensed in the Thermal Reclaimer Condenser and the resultant two-phase mixture will then be separated in the Thermal Reclaimer Reflux Drum. The vapour (composing mostly of non-condensables) will be sent to the Thermal Reclaimer Vacuum System. The degradation products build up in the Thermal Reclaimer until they reach a specified level when they will be collected at the bottom of the Thermal Reclaimer Column and pumped to the Degraded Solvent Drum for storage, prior to disposal offsite via a licenced waste contractor.

The chosen technology for the removal of degradation products is thermal reclamation and it is considered that this represents BAT. Thermal reclamation is a mature technology, capable of removing non-ionic heavier molecular weight degradation products, including metals and polymeric compounds all formed via thermal degradation. In applications with low flue gas contamination, such as the FCC Unit flue gas after treatment through the SCR and WGS, the amounts of ionic degradation products (low molecular weight acids) and heat stable inorganic salts is considered to be low, and therefore the use of ion-exchange resins is not considered appropriate. These species are more readily removed via thermal reclamation and therefore it is considered that this is the best method of removing all types of potential degradation products.

In addition, reclamation via ion-exchange resins is not considered to be a mature technology, and there are a number of disadvantages to its use, including:

- Ion-exchange resins have a limited life expectancy, and therefore will require replacement over time, increasing waste generation;
- Ion-exchange resins can be contaminated or otherwise have their performance affected by the presence of trivial anions such as carbonate and bicarbonate;
- Ion-exchange resins do not remove polymeric (uncharged) material and have a limited performance in the removal of metals; and
- Ion-exchange resins might produce more effluent than thermal reclamation, as the resins need to be recovered by flushing with dilute caustic.

Thermal reclamation is also considered to be more energy efficient. The steam requirements for reclamation are much lower than for solvent regeneration, and therefore represents a comparatively small amount of additional steam.

Thermal reclamation is proven technology for the Cansolv DC-103 solvent to be used in the PCC Plant, whereas other methods of reclamation have not been validated for this solvent.

4.2.6 CO_2 Conditioning and Compression

The gaseous CO_2 stream from the PCC Plant will be saturated with water and will contain traces of oxygen that will need to be removed prior to export to the CO_2 pipeline and T&S Network.

The water-saturated CO_2 gas will undergo low-pressure (LP) compression to approximately 30 barg. Hydrogen will then be injected upstream of a deoxygenation reactor which will contain a platinum-based catalyst to promote the reaction of hydrogen with oxygen to produce water. Hydrogen will be provided from the Installation’s existing hydrogen distribution system.

The resulting water will then be removed from the CO_2 stream via a dehydration step, in order to meet the onward CO_2 pipeline specification.

The dehydration unit will be a temperature swing adsorption process comprising 2 or 3 beds of silica gel desiccant. It will operate in a cyclic manner such that when one bed is in dehydration mode, the other bed(s) are in regeneration or standby mode. Water removed during the compression process will be recovered into the solvent loop, to minimise wastewater generation where possible, or if not possible, this will go to the existing ETP for treatment.

The dehydrated LP compressed CO_2 will undergo further HP compression (approximately 135 barg) onsite prior to being transferred to the T&S Network via a metering station and then on to underground offshore storage. Cooling will be required in stages during the compression process.

A CO_2 export cooler is also included to ensure the CO_2 meets the T&S Network export specification (after the compression).

The type of CO_2 Compressor to be employed has yet to be finalised during the ongoing detailed design process, however it is likely to be an integrally geared compressor, undertaking both the LP and HP compression stages.

Integrally geared multi-stage compressors have not yet been widely deployed, and therefore potential for heat recovery is not fully understood. It is envisaged that integrating a heat recovery scheme to the compressors would introduce significant risk to the performance of such a compressor, given its relatively limited industry experience and especially in PCC plant applications. However, the number of compression stages employed will be optimised to minimise heat rejection, and therefore it is envisaged that opportunities for heat recovery would be limited in any case.

The final specification for the conditioning equipment/ processes to enable the gaseous CO_2 stream to meet the purity requirements will be dependent on the pipeline specification for the CO_2 gathering network utilised. The CO_2 must meet the pipeline specification and therefore appropriate monitoring will be in place.

The current design provides the CO_2 compression system with a single CO_2 vent stack for both LP and HP venting, for the safe disposal of CO_2 to atmosphere, if required. More details of CO_2 venting are provided in Section 4.3.

4.2.7 Carbon Dioxide Export Metering

The quality of the CO_2 will be monitored for compliance with export specifications for the following parameters:

- temperature;
- pressure;
- water content;
- oxygen content;
- hydrogen content;
- CO content;
- hydrogen sulphide content;
- oxides of sulphur (SOx);
- NOx; and
- amines.

There will also be a requirement for sampling and analysis of other components that are included in the export specification (potentially including ammonia, formaldehyde, acetaldehyde, ethanol, combined methanol and ethanol, mercury, cadmium, thallium and total sulphur). In addition to quality monitoring, fiscal flow metering is to be provided for custody transfer of CO_2 sent to the export pipeline.

The limit of the proposed Installation Site Boundary is at the tie-in to the export T&S pipeline.

4.3 Abnormal Operation

During the infrequent start up and shut down of the PCC Plant (for example before and after a maintenance outage, for which the FCC Unit has an outage schedule of every 6 years), or for discrete unplanned operational issues, it may be required to safely vent CO_2 to the atmosphere for a limited period of time. This could be to enable purging of pipework and downstream equipment, de-pressuring to prepare for maintenance or to ensure CO_2 sent to the T&S Network is on specification. As such, a CO_2 vent stack is included in the plant design, with the height of the emission point (40m) designed to ensure safe dispersion of the CO_2.

All CO_2 venting will be minimised as far as possible, and will be covered by start-up, shutdown and abnormal operating procedures to ensure the safety of personnel in the area, and to ensure that appropriate actions are taken in a timely manner to minimise the venting period.

A CO_2 venting assessment has been carried out to support this Environmental Permit variation and is included in Appendix E. Whilst all foreseeable venting scenarios have been identified at this stage of design, additional vent scenarios may be identified during detailed design. It is therefore recommended that a Pre-operational Condition is include in the Environmental Permit to review the CO_2 vent modelling following completion of detailed design and full plant HAZOP to determine whether additional modelling or assessment is required.

4.3.1 Start-up

In order to minimise venting during start-up, the PCC Plant will be started in a number of phases, namely:

Phase 1 – The FCC Unit will be brought online, and the flue gas will be vented to the WGS (Emission Point A6d).

Phase 2 – The FCC flue gas will be routed to the CO_2 Absorber Column and CO_2 Stripper whilst the solvent is brought up to normal operating temperature. The flue gas will be vented from the Absorber stack (Emission Point A6c). CO_2 stripped from the solvent will be sent back to the inlet of the CO_2 Absorber Column until the solvent becomes saturated. When this occurs, CO_2 will be vented through the Absorber stack with the rest of the FCC flue gas, as per normal CO_2 unabated operation.

Phase 3 – Once the CO_2 Absorber and CO_2 Stripper have reached normal operating temperatures, CO_2 will be sent to the Deoxygenation and Dehydration units and the LP compressor will be started. At the low flow rates experienced during start-up, it is likely that the required oxygen and water specification would be achieved, however if this is not the case, the concentrated CO_2 may need to be vented from the CO_2 vent.

It is anticipated that venting will be avoided by again routing the CO_2 from downstream of the LP analyser back to the CO_2 Absorber Column inlet, with the CO_2 leaving with the flue gas exiting the Absorber stack. Where this is the case, the CO_2 will be a dilute stream and no venting of concentrated CO_2 will occur.

Phase 4 – The HP meter and export line will need to be purged using on-specification LP CO_2 prior to commencing export. As with Phase 3, there is the potential to vent concentrated CO_2 during this phase however it is anticipated that the normal method shall be to route the CO_2 stream back to the CO_2 Absorber Column inlet, as detailed for Phase 3.

4.3.2 Shut-down

On shut-down, CO_2 will need to be removed from the solvent prior to it being put into storage for the maintenance period and the LP and HP systems will need to be depressurised prior to purging and maintenance. During the shut-down process, the FCC flue gas will be vented to the WGS stack (Emission Point A6d). Shut-down will be performed in a number of phases, namely:

Phase 1 – The flue gas flow to the CO_2 Absorber Column will be stopped and as much CO_2 as possible will be removed from the solvent. The forward flow of CO_2 from the CO_2 Stripper will reduce, which will cause the CO_2 Compressor to go into recycle. CO_2 will continue to be exported until the minimum turndown rate is met, or until the CO_2 goes out of specification for onward export.

Phase 2 – Once export of the CO_2 has been stopped, there will still be some residual CO_2 in the solvent that will need to be removed prior to storage. CO_2 will need to be vented during this time, until all the CO_2 has been removed from the solvent. As the CO_2 in the solvent is depleted, the CO_2 vent flow rate will decrease.

Phase 3 – The final phase of shut-down is to depressurise the LP and HP systems though the CO_2 vent. Depressurising the HP system directly to atmosphere would result in significant Joule Thompson cooling, which would result in liquid and solid CO_2 formation. Therefore, the pressure will first be let down from HP conditions to 120 psig, resulting in a vapour/ liquid stream being formed which will be routed to a knock-out drum. The knock-out drum will be heated to vapourise the liquid formed and the combined vapour stream leaving the knock-out drum will be further heated before being let down to atmospheric pressure and vented via the CO_2 vent. It is envisaged that it will take 8 hours to vent the HP system.

Venting of the LP systems will not result in Joule Thompson cooling and so will not require heating prior to venting, and venting will be quicker than the HP system.

4.3.3 CO_2 Off-specification

Continuous analysis in both the LP and HP compression systems will provide early indication of the CO_2 going out of specification, which would enable corrective actions to be taken to prevent it from occurring. In the event that process upset cannot be remedied in a reasonable period of time, the PCC Plant will be shut down, and the FCC flue gas will vent from the stack on the WGS. The CO_2 compressors would need to be vented via the CO_2 vent in such a scenario.

CO_2 venting may also be required during emergency situations to ensure safe operation of the PCC Plant.

Any venting required for the off-site T&S Network pipeline will be provided by the T&S Network provider and therefore will not be from the Installation.

4.3.4 Other Abnormal Operating Conditions

The new flue gas pre-treatment train, which includes the SCR and WGS, will form part of the FCC Unit and as such it will not be possible to bypass this equipment and release unabated emissions of NOx, SOx and particulates from the FCC Unit to air.

There is potential that the SCR could lose ammonia injection, which could result in a short-term increase in NOx emissions whilst the ammonia injection system is repaired. It should however be noted that ammonia is already directly injected into the FCC flue gas for NOx control and therefore the current system could also lose ammonia injection, therefore the SCR does not add any additional risk of excursion from the FCC Unit emission limits from that of the current operational installation. Spares will be held on site such that any issues with the ammonia injection can quickly be rectified.

The WGS abates SOx and particulates in the FCC flue gas stream. A failure in the caustic pump could lead to a short-term increase in SOx and/ or dust emissions whilst the pump is switched to the spare. The FCC Unit SOx emissions are currently reduced by the application of DeSOx additive in the FCC. The addition of DeSOx is intended to continue following installation of the WGS to remove at least 50% of the SOx from the flue gas, and this would minimise increases in SOx emissions from unabated levels.

Dust is abated by the WGS and the Wet ESP. In normal operation the WGS will remove the larger dust particles and the Wet ESP will provide a ‘polishing’ step to remove very fine dust particles in order to meet the PCC Plant specification. However, if the WGS caustic circulation pump was to trip, the Wet ESP would continue to remove some particulate matter, thereby reducing any increase in particulate emissions whilst the caustic pump is switched to the spare.

4.4 Utilities

4.4.1 Steam

The steam requirements of the PCC Plant will be supplied by the Installation’s existing steam supply, which is fed by the adjacent VPI Immingham CHP Power Plant.

There will be a new Steam Power Recovery Turbine to let down the HP 600 psig steam from the VPI Immingham CHP Power Plant to 50 psig steam (LP steam) for use in the PCC Plant. This will also recover approximately 5MW of energy for reuse in the PCC Plant.

The PCC Plant will require LP steam for the operation of the CO_2 Stripper reboiler, Thermal Reclaimer Preheater, Thermal Reclaimer Column, the amine solvent storage tank and the fresh solvent tank.

MP steam will be required for the Thermal Reclaimer Reboiler.

Condensate will be returned to the VPI Immingham CHP Power Plant, as per existing arrangements.

4.4.2 Water

It is not considered at this stage in the design that additional raw-water treatment will be required for the PCC Plant. However, if additional raw-water treatment is required, it is envisaged that this will be provided by an expansion to the Installation's existing demin plant.

As such, all water will be taken from the existing water systems as necessary, to maximise efficient use of treatment chemicals, minimising raw material use and waste production in accordance with BAT.

Demin water will be required for dilution and top up purposes including:

- Wet ESP intermittent washing;
- fresh solvent dilution (intermittent);
- caustic dilution (continuous);
- flocculant preparation (continuous); and
- maintaining the PCC Plant water balance (intermittent).

The PCC Plant will have a Recovered Water Tank and distribution system. The Recovered Water Tank will receive water from the CO_2 Compressor (suction drum/ knockout drums) with the intention that this water will be used in the either the WGS or the PCC Plant (for solvent dilution, degraded solvent dilution or top-up water).

It is anticipated that additional water use for the PCC Plant will be up to 20% of the existing Installation's water usage, although this will be dependent on the amount of water reuse that is achievable within the PCC Plant.

Fire water and potable water will be provided via a tie-in and extension of existing Installation systems.

4.4.3 Cooling Systems

The majority of cooling for the PCC Plant and CO_2 compression will be provided by air cooling (fin fans), with closed loop systems. Air cooling has been selected due to the limited water resources available in the Humber area and the relatively similar thermal efficiency of air cooling against wet cooling for the PCC Plant application.

However, Phillips 66 are investigating potentially using some water cooling, to reduce the number of fin fans required, and therefore reducing the potential for noise impacts from the PCC Plant. This work is ongoing and will be completed during detailed design. The additional water use indicated in Section 4.4.2 includes the assumption that some water cooling will be provided, and the Noise Impact Assessment assumes that a 4-cell cooling tower will be employed.

In addition, a trim cooling water exchanger will be required for the WGS caustic loop and a chiller package on the CO_2 export cooler.

The PCC Plant main requirement for cooling will be to lower the temperature of the flue gas coming from the FCC, prior to amine stripping. Prior to the SCR, the flue gas will pass through a Waste Heat Exchanger then an economiser section after the SCR to cool the gas and improve energy efficiency by producing steam for use in the PCC Plant.

The remaining flue gas cooling will be undertaken in the WGS by contacting the flue gas with a sub-cooled circulating caustic solution. The caustic will be cooled by air cooled heat exchangers with an additional trim cooling water exchanger for use when ambient temperatures are too high to achieve the required cooling with air cooling alone.

Additionally cooling for the PCC Plant will be required for the water wash cooler, the CO_2 Stripper Condenser and the lean amine cooler.

The CO_2 Compressor will also require cooling. A CO_2 export cooler is also included to ensure the CO_2 meets the T&S Network export specification (after the compression). This cooler has a dedicated closed loop cooling water system that is cooled by a chiller package.

4.4.4 Compressed Air and Nitrogen Blanketing Systems

Compressed air, for valve activation, will be provided by the existing Installation Instrument air system, however additional air compressors on the PCC Plant will also be installed for this duty.

Nitrogen blanketing may be required e.g., for aqueous ammonia storage, and if required, this will be provided. Nitrogen will also be available to the PCC Plant for equipment purging on start-up/ shutdown for example.

4.5 Process Control

The PCC Plant will be highly automated and will be controlled via a Distributed Control System (DCS), providing monitoring and control. The design philosophy of the DCS will be to provide the maximum possible level of automation for all systems installed and the plant will, in general, operate automatically under operator supervision during normal operation. The DCS for the PCC Plant will be integrated with the Humber Refinery's existing Honeywell Experion and legacy systems.

Semi-automatic sequences and manually requested actions will also be available via the DCS when required, for instance operator intervention may be required to maintain minimum utility flows by the opening of equipment by-passes or shutting down unnecessary equipment (e.g. cooler fans, circulation pumps, amine pumps). Generally, plant operations will be carried out from the operator desk in the control room. The DCS will allow items, systems and the entire plant to be started, operated and stopped in a safe manner.

The DCS will display and record the plant operating parameters required for best practice process control and minimisation of environmental impacts. The Humber Refinery has detailed procedures for defining, monitoring and responding to Safe Operating Limits (SOLs), Reliability Operating Limits (ROLs), and Environmental Operating Limits (EOLs), which will also be applied to the PCC Plant. This information will be available on-line to the operator via the plant operating screens as instantaneous values, with historical data available via trend screens. The DCS will also include typical Continuous Emissions Monitoring systems (CEMS) information. CEMS on the PCC Plant will comprise monitoring of parameters applicable to the PCC Plant and will include exhaust gas concentrations of pollutants, air flow and moisture content in the exhaust gas. In addition, online process analysers will be in place for sampling CO_2 being sent for compression in the CO_2 Compressor and to the export pipeline system. This information will also be available for analysis by operators and site engineering.

The PCC Plant's operational data will allow the PCC Plant processes and maintenance procedures to be reviewed and optimised. The data available via the DCS, and stored in the plant's data historian (PIVision) will also allow reporting of plant performance and environmental compliance.

Furthermore, the DCS will provide the operators with a series of alarms should an operating parameter approach, or exceed, its control set point value. These alarms will be displayed on the appropriate plant operating screen as well as a dedicated alarm screen for operator review and relevant action.

The DCS will use control logic and trips to prevent an undesirable situation from occurring or continuing.

4.6 Management Systems

The PCC Plant will be operated in line with the existing Environmental Management System (EMS) for the Humber Refinery, which is accredited to the requirements of ISO14001:2015, and is compliant with the guidance set out by the EA[7]. The EMS will be amended to include the proposed operations of the PCC Plant prior to commencement of its operation.

The EMS and associated procedures will be available for inspection by the EA upon request, and are applicable to all staff, contractors and visitors to the Installation. The EMS has been developed to enable compliance with the Environmental Permit and other legislative requirements for the protection of the environment and human health.

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[7] Develop a management system: environmental permits - GOV.UK (www.gov.uk)

4.7 General Maintenance

The objective of plant maintenance is to ensure that the Installation, including utility connections, operate safely and reliably. Inspection and maintenance activities have been considered in the PCC Plant's design and layout during the design process.

Ongoing maintenance, occurring during normal operation, will be planned and scheduled via the Installation's existing maintenance management system.

In addition to ongoing maintenance, the Humber Refinery carries out major turnaround cycle maintenance, where plant is shut down. The FCC Unit has an outage schedule of every 6 years, and therefore if possible, the schedule for PCC Plant maintenance will be aligned with the FCC Unit dependent on availability of appropriate resources.

The maintenance strategy to be adopted will use established methods such as Risk Based Inspection (RBI) and Reliability Centred Maintenance (RCM) to support the required facility availabilities. Therefore, to support the maintenance strategy for the PCC Plant, each major equipment item will be provided with appropriate access and overhaul laydown areas and the internal road layout for the PCC Plant will be designed to enable free movement for cranes and heavy lifting equipment.

It is anticipated that an integrated Operations and Maintenance (O&M) team will have responsibility for daily operations, including troubleshooting and effecting minor maintenance on the PCC Plant. Major and specialist O&M interventions are likely to be outsourced and major equipment items serviced by original equipment manufacturers (OEM).

If required, pipeline inspection plans will be prepared and Pipeline Inspection Gauge ('pig') launching and receiving facilities for intelligent 'pigging' operations will be considered for the CO_2 export pipeline to the T&S Network provider.

4.8 Raw Materials

The use of hazardous materials will be eliminated by design where possible, and minimised where it is not practical to eliminate. Areas handling chemicals will be paved and kerbed/ bunded to ensure that spillages and/ or leaks in those areas are contained, manually cleaned up and disposed of appropriately, in line with the existing Installation's spillage management procedures which are detailed in the Strategy for the Prevention of Site Contamination - HR -TEC-ENV-016 and the Effluent Manual HR-TEC-ENV-001. All liquid chemicals stored will be kept in appropriately bunded and segregated areas.

Any spillages occurring in general plant areas will be contained within the site drainage and ETP system. Any spills within bunds or kerbed areas would be contained within closed sumps and be tested for contamination before being transferred to the ETP or disposed of offsite via a licensed waste contractor, as appropriate.

Bulk storage of chemicals in new above ground storage tanks (ASTs) will include the fresh amine solvent for the PCC Plant, ammonia for use in the SCR plant and sodium hydroxide for the WGS.

Fresh solvent for PCC Plant top-up will be delivered to a Fresh Solvent Storage Tank ($93m^3$), from where fresh solvent will be pumped to the Lean Solvent Flash Vessel or the CO_2 Absorber base, as required. Indirect LP steam heating will be provided to the fresh solvent storage tank for winterisation. Space in the design has been assumed for an additional fresh solvent tank ($93m^3$), if required.

Additional considerations for the storage of amines include the potentially high reactivity of the solvents, leading to corrosion of some metals, and generation of degradation products.

The materials of construction for the amine storage and dilution tanks and pipework materials will be confirmed during the detailed design process, however it is anticipated that this is likely to include carbon steel tanks with stainless steel cladding and atmospheric fixed roofs. Further information is provided in Section 4.10.

The amine solvent to be used in the PCC Plant has a low volatility. Its boiling point is 105°C, i.e. higher than water, and it has a very low vapour pressure of <0.13 kPa at 20°C. Although it is described as having a 'sweet' odour, it is considered that due its low volatility there is minimal potential for odour issues to arise from storage or delivery operations. As such, it is not considered that abatement is required on the breather vent for the storage tanks, nor that back venting for tanker deliveries will be required.

There will be one or two additional Amine Solvent Storage Tanks (providing a total solvent storage volume of 357m^3), designed to hold the entire inventory of solvent held in the PCC Plant, with some margin for flushing. During normal operation these tanks will remain empty, but they will be required in the event that the whole PCC Plant needs draining of solvent (i.e. for maintenance periods, envisaged to occur every 6 years). Following maintenance, this solvent would be returned to the PCC Plant.

The Ammonia Tank will be a closed system, with a Pressure Safety Value (PSV) vent potentially being directed to the Refinery's main flare, although this is to be confirmed during detailed design. Back venting to delivery tankers is likely to be employed to help minimise fugitive ammonia emissions.

All ASTs will be located within appropriately sized and constructed bunds, in line with CIRIA 736[8]. All bulk liquid chemicals stored will be kept in bunded controlled areas with a volume of at least 110% of storage capacity, where the bund contains a single vessel, or 25% of the total system volume where the bund contains multiple vessels. In some instances, the governing factor for the bund size will be layout and/ or the space required for the tanks rather than the volume required for containment, and therefore some bunds will be larger than 110%/ 25% rule. Bulk chemicals will be appropriately segregated. Additional information on containment systems is provided in Section 4.10.

The principal raw material to be used in the PCC Plant will be the amine-based solvent, Cansolv DC-103. The initial quantity of amine-based solvent is anticipated to be 400 tonnes (at 50% strength), which will be delivered to site at 100% and diluted within the PCC Plant. The PCC Plant will include equipment for recovering and reclaiming used solvent for reuse within the process, as described in Section 4.2.5, thereby minimising fresh solvent usage. Over time, some make-up with fresh solvent will be required, although the annual quantities of this will be comparatively small (estimated to be 20% of the PCC Plant solvent inventory per year).

Small quantities of other raw materials, such as maintenance chemicals, may also be required, however it is anticipated that these substances will only be required in small quantities and are already used at the Installation. Such materials will be stored in appropriate containers, within suitable spill protection including bunds, on bunded pallets, on drip trays, in specifically designed cabinets and cupboards or other appropriate storage units and areas. Additional hazardous materials will be supplied, stored and used in containers of 1 m^3 or less.

The raw materials and their predicted storage volumes are detailed in Table 4.1. The indicative locations for raw materials storage are shown in Figure 3 (Appendix A).

Table 4.1: Additional Raw Materials for use in the PCC Plant

Material	Purpose	Estimated Maximum Storage Quantity	Estimated Annual Consumption
Sodium hydroxide (caustic)	WGS, PTU, PCC Plant	351m^3	15,300m^3
Cansolv DC-103 Fresh Solvent	CO_2 scrubbing solvent - 100% solvent for PCC Plant make-up	186m^3	95 tonnes
Aqueous ammonia	SCR	60m^3	280m^3
Oxygen removal catalyst	For use in Oxygen Removal Reactor	Not held on site, brought in for change over when required.	Extent of usage not known until operation commences

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[8] CIRIA (2014). Containment Systems for the Prevention of Pollution, Secondary, tertiary and other measures for industrial and commercial premises – CIRIA C736.

Material	Purpose	Estimated Maximum Storage Quantity	Estimated Annual Consumption
Silica Gel	Dehydration Package	Not held on site, brought in for change over when required	Extent of usage not known until operation commences
Antifoam	Added to the re-circulating amine to prevent foaming in the CO_2 Absorber.	1m^3 - Stored in IBCs	Extent of potential foaming not known until operation commences.
Coagulant, flocculant,	PTU to remove sulphides.	1m^3 - Stored in appropriate containers	<10m^3
Activated Carbon	Solvent filtration units	Not held on site, brought in for change over when required	Extent of usage not known until operation commences

The PCC Plant will use small quantities of additional water, anticipated to be an increase of up to 20% in the overall Installation usage, sourced from the existing Anglian Water supply. Within the PCC Plant there is water recovery and reuse where possible (as described in Section 4.4.2), to minimise additional water use, and the requirement for cooling water has been reduced by providing the majority of cooling by air coolers.

4.9 Waste

The PCC Plant will be integrated with the existing EMS to manage raw material and water use, in order to minimise waste generation in accordance with existing procedures and indicative BAT requirements. Phillips 66 ensures that waste is minimised, reused, recycled or recovered in accordance with the waste hierarchy.

As detailed in Section 4.2.2.2, catalyst fines wet with dilute caustic from the WGS will require disposal off-site. It may be possible for this waste to be used in cement manufacture, however this has yet to be confirmed. This re-use option will be investigated in order to try to avoid disposal if at all possible.

Hazardous waste from the solvent Thermal Reclaimer (consisting of degraded amine, heat stable salts and corrosion products) will be generated and stored locally within the Reclaimer area prior to transfer off-site. Options to minimise the quantity of the Thermal Reclaimer waste requiring off-site disposal will be explored through design development, however at present it is envisaged that disposal via off-site incineration at a licensed waste contractor’s facility will be required.

There will be cartridges from the mechanical filters which will require disposal. The frequency and quantity will be dependent on the quantity of solids within the recirculating solvent, and therefore it is likely that more frequent changes will be required following initial plant start-up and after plant maintenance activities. During normal PCC Plant operation, less frequent cartridge changes are anticipated. In addition, carbon from the carbon filters will also require changing, anticipated to be on a twice year frequency during steady operation. Prior to disposal offsite the carbon will be flushed with water.

Dehydration waste, i.e. silica gel, will be replaced once spent. The frequency of this will depend on operating experience, however it is anticipated to require replacement approximately every 4 - 6 years.

There will be small quantities of lubricating oils generated for disposal and these will be stored and disposed of as per existing Installation routes.

All wastes will be stored in appropriate, labelled containers and stored in designated bunded waste storage areas. All bulk waste storage tanks will be within bunds with 110% capacity of the tank.

All other wastes generated within the PCC Plant such as packaging and general wastes will be managed through existing waste management practices at the Installation, implemented through the site-wide EMS and in accordance with BAT.

Wastes anticipated to be generated by the PCC Plant's operation, including estimated quantities and generation frequency i.e. continuous/ intermittent/ occasional, are shown in Table 4.2.

Table 4.2: Anticipated Waste Stream Generated in the PCC Plant

Waste Stream	Estimated Annual Quantity	Generation frequency	Disposal Route
WGS de-watered solids (catalyst fines)	1,300 tonnes	Continuous	Collected for off-site treatment/ disposal by licenced 3rd party waste contractor.
Reclaimer waste (degraded solvent)	300 tonnes	Continuous	Collected by licenced 3rd party waste contractor in the Degraded Solvent Drum for tankering off-site for treatment/ incineration.
Solvent from Solvent Drain Vessel	Solvent will be re-used in the process wherever possible, and only disposed of if cannot be re-used, therefore disposal quantity unknown.	Intermittent	Collection and disposal by 3rd party via vacuum truck only if it cannot be re-used within the PCC Plant.
Filter Elements	-	Occasional	Likely to be hazardous waste. Collected in suitable containers for collection by licenced 3rd party waste contractor for disposal.
Activated Carbon	20 tonnes/ replacement	Intermittent, expected to be every 6 – 12 months depending on filter performance	Likely to be hazardous waste. Collected in suitable containers for collection by licenced 3rd party waste contractor for disposal.
Oxygen Removal Catalyst	5 tonnes/ replacement	Occasional, expected to be replaced every 4 – 6 years	Removal and disposal by specialist 3rd party contractor.
Dehydration Desiccant	15 tonnes/ replacement	Occasional, expected to be replaced every 4 – 6 years	Removal and disposal by specialist 3rd party contractor.

4.10 Containment

The Humber Refinery is an Upper Tier CoMAH site and operates a hierarchy of containment measures from primary, secondary through to tertiary containment. The site receives regular inspection by the CoMAH Competent Authority, including reviews of emergency response plans and capabilities. The EA, in their role as the Competent Authority (CA) under CoMAH, last audited the existing site bunding and containment arrangements in December 2023 as part of a containment scorecard review with no major findings identified.

Fire water containment for the site is also designed in line with CoMAH requirements, specifically ensuring there is *"sufficient capacity to hold safely the anticipated or foreseeable volume of hazardous liquids, including firewater, compatible with the intended operational characteristics"*. A detailed study has been carried out to assess the tertiary containment for the Humber Refinery site, which culminates in the completion of a holistic Environmental Risk Assessment. The pillars of this assessment focus on flood, spill and additional firewater impact on tertiary containment and environmental receptors.

Primary and secondary containment systems at the Installation are regularly inspected and maintained as detailed in the Installation's EMS and described in Sections 4.6 and 4.7 of this Supporting Document, and this will be expanded to cover the PCC Plant area. Such measures include; regular visual inspections and emptying of rainwater regularly to maintain the containment capacity and programmed engineering inspections.

Phillips 66 have corporate standards (Refining Engineering Practices (REPs)) in place for the design, installation and maintenance of tanks and bunding across their sites. REPs have been developed to establish a minimum standard for all aspects of design and construction. Additionally, Phillips 66 has a set of Required Standards (RS). The RSs address specific subject areas deemed to be of special significance to safe, reliable, and environmentally sustainable design, construction, operation, inspection, and maintenance of Phillips 66 sites. RSs are different to the REPs, but may inform content of certain REPs.

Specifically, the REPs and RSs aim to:

- ensure compliance with applicable legislation, recognised and accepted codes, national and industry consensus standards covering or governing the engineering disciplines;
- provide supplemental standards based on oil industry and Phillips 66 practice for situations not covered or not adequately covered by the more general national and industry consensus standards;
- address decisions left to the user's discretion in national and industry consensus standards;
- provide supplemental standards to decrease life cycle costs, increase reliability or increase safety of Phillips 66 facilities based on Phillips 66 and industry experience;
- provide standard solutions and tools to enhance engineering productivity of standards users; and
- be used as a basis of comparison with partner's or contractor's standards.

The REPs also recognise that in some cases "one size may not fit all" and they allow engineering judgement to be applied. The engineering practices and required standards may reflect and build-on industry codes and standards, or they may define other requirements developed from a combination of Phillips 66 and industry experience.

All new tanks, bunding and containment within the PCC Plant area will be designed and installed in line with the existing REPs and the requirements of CIRIA 736 and any other relevant guidance or standards, as is required.

CIRIA 736 provides guidance to Operators on the identification and management of potential risks associated with the storage of hazardous substances and their potential impact on the environment. To effectively address these risks, the guidance recommends the use of a source pathway receptor model to assess whether there is a source, a receptor and a pathway by which the source material could reach the receptor. Using the guidance, the outcome of the model can be used to provide a site hazard rating (low, moderate or high) depending on the potential risk. The risk assessment then considers the likelihood of a loss of containment which is then combined with the site hazard rating to provide an overall site risk rating.

CIRIA 736 outlines a three-tiered classification framework (Class 1, 2 and 3) each representing a different level of integrity of secondary and tertiary containment to match the different requirements of high, moderate and low overall site risks. The classification system recommends different standards of construction, or levels of performance in accordance with each of the three levels of risk. A low-risk site is Class 1, moderate is Class 2 and a high-risk site is Class 3. The site risk rating informs which of the three-tier risk-based classifications the site falls within. The primary goal of the containment system, as outlined in the guidance, is to effectively mitigate the potential pathway between a source and receptor.

Based on risk assessment framework, the site is considered to be Class 1 although this will be reviewed during detailed design.

During the initial design stage of the project, Hazard Identification (HAZID) studies have been carried out to assess potential risks associated with the storage and use of the chemicals to be used as part of the PCC Plant. The project has still to go through detailed design and therefore specific details of some materials of construction for tanks and bunds are not finalised, however all materials of construction for primary and secondary containment will be selected to ensure compatibility with the stored liquids in each primary containment tank. In addition, bunds will be designed so as to be resistant to the materials held in the storage tanks and to ensure that pipework does not penetrate the bund walls and be designed so as to catch leaks from tanks or fittings.

A full risk assessment for the containment infrastructure will be undertaken as part of the next phase of the project. This will be a multi-discipline approach and include a formal risk review meeting and summary, held in conjunction with Phillips 66/ their project engineers/ CoMAH CA, as appropriate. The outcome of this meeting will confirm the basis for containment design and construction. Suitably qualified engineers have been employed to design/ specify the necessary tank level gauges, alarms, high level trips/ overfill protections and specification of leak detections systems.

The secondary containment bunds will be designed to have low point sumps. From the sump positions the secondary containment bund will be connected directly to the existing refinery Oily Water Sewer (OWS) system, with new sections of OWS drainage connections as necessary. Drainage from bunds will be via a normally closed valve pit with appropriate sampling of bund contents prior to opening of the value for drainage.

The sumps will be sized for one week's worth of average rainfall falling on the entire bund area up to a maximum of 1m^3. Each sump will be provided with a plug type drain connected to the PCC Plant area OWS, which will tie into the existing Refinery OWS. Operators will identify high levels in bund sumps visually as part of routine walkarounds.

A schematic showing the PCC Plant area drainage arrangements is provided in Figure 6 (Appendix A) and details of the storage and containment arrangements, based on the current design, are provided in Table 4.3.

Table 4.3: Bunding and Containment Arrangement for Bulk Storage

Tank	Primary Containment				Secondary Containment		Tertiary Containment
	Size	Storage Capacity	Material of Construction	Other info	Bund Size	Bund Construction	
Caustic tanks x 3	3.2m diameter 12.4m length	117m^3 per tank 385m^3 total	Carbon steel	Level gauge. Tank level checked to confirm sufficient capacity for road tanker contents. Operator in attendance during road tanker offloading. High level alarm. High-high level trip. Overflow line to bund.	Bunds will be sized appropriately, following the CIRIA Risk Assessment process, but will be at least either 110% of the volume of the largest tank in the bund or 25% of the total volume of all the tanks in the bund. 1.5m high x 24m length x 17m width = total capacity 612m^3	Bunds will be constructed of reinforced concrete, designed to Eurocode 2 Design of concrete structures - Part 3 Liquid retaining and containment structures. Additives will be added to the concrete mix or bund liners will be specified in suitable materials, to provide additional resistance for product storage, (where it is identified that the presence of reinforced concrete alone will not be adequate for long term containment). Such materials have not yet been confirmed, however this information can be provided to the EA when detailed design is complete, as part of a pre-operation condition in the Environmental Permit, if required.	The tank contents are not flammable, with the exception of the ammonia storage tank, which has the potential to form a flammable mixture in the vapour space. Design will incorporate suitable mitigation measures. The tanks are not located near areas that are used for the storage of flammables, hence, no additional containment provision is required for firewater management (for firefighting and/ or tank cooling due to a fire in an adjacent area). Tertiary containment measures shall minimise the consequences of a simultaneous loss of primary and secondary containment (requires multiple failures). Tertiary containment measures shall prioritise preventing offsite impacts.
Fresh solvent tanks x 2 (1 tank required initially. Provision for installation of future 2nd tank)	4.3m diameter 6.4m height	93m^3 per tank 186m^3 total	316 Stainless Steel	Level gauge. Tank level checked to confirm sufficient capacity for road tanker contents. Operator in attendance during road tanker offloading. High level alarm. High-high level trip. Overflow line to bund.	1.5m high x 16.5m length x 8.65m width = total capacity 214m^3		
Ammonia tank	3.4m diameter 6.6m height	60m^3	Carbon steel	Level gauge. Tank level checked to confirm sufficient capacity for road tanker contents.	1.5m high x 7m length x 7m width = total capacity 73.5m^3		

Tank	Primary Containment				Secondary Containment		Tertiary Containment
	Size	Storage Capacity	Material of Construction	Other info	Bund Size	Bund Construction	
				Operator in attendance during road tanker offloading. High level alarm. High-high level trip. Overflow line to bund.			As such, spillages from secondary containment will be routed into a kerbed area(s) whenever possible. Action shall also be taken to mitigate the impact to the site ETP and outfall to the South Killingholme Drain by using available attenuation/ holding pond capacity.
Solvent Storage Tanks x 2 (to store solvent inventory when PCC Plant drained down for maintenance approximately every 6 years)	6.7m diameter 10.1m height	357m^3 per tank 714m^3 total	316 Stainless Steel	Level gauge. Tank filling monitored by an operator(s). High level alarm. High-high level trip. Overflow line to bund.	1.5m high x 18m length x 15m width = total capacity 405m^3		

4.11 Energy Efficiency

The PCC Plant and the CO_2 Compressor require additional steam and power and therefore optimised integration of utilities for energy efficiency is paramount to minimising the carbon intensity impact of the project as a whole, when considering direct and indirect emissions associated with the PCC Plant.

The overall performance of the PCC Plant, for optimised energy efficiency, depends on the integration, as far as practicable, of electrical, steam and water circuits. The Cansolv DC-103 solvent and associated process configuration was selected to maximise energy efficiency.

Opportunities for maximising thermal energy efficiency will continue to be explored during the detailed design process and integrated in the design of the PCC Plant where viable. The key interfaces for energy efficiency within the PCC Plant will include:

- exhaust-gas pre-treatment including SCR, WGS and cooling, prior to the PCC Plant;
- optimised use of incremental steam from the VPI Immingham CHP Power Plant for solvent stripping (CO_2 Stripper Reboiler) and solvent recovery (Thermal Reclaimer);
- steam condensate recovery for return to the VPI Immingham CHP Power Plant;
- recovery of process water streams for solvent dilution/ make-up water;
- use of cross-flow heat exchangers within the PCC Plant solvent streams; and
- optimised cooling of condensate within the PCC Plant to minimise flash/ hammer potential and maximise useful heat recovery.

General measures to maximise energy efficiency across the PCC Plant include:

- the plant components will be sized appropriately for the design capacity of the plant, so that each element is operating optimally and efficiently;
- use of high efficiency motors and drives to minimise electricity load;
- use of variable speed drives, where appropriate, to optimise power consumption;
- the effective insulation of hot surfaces; and
- regular planned maintenance in order to maximise the efficiency of the equipment and plant, with performance monitoring and audits to optimise the maintenance schedule.

Specific energy efficiency measures built into the design include:

- plate and frame exchangers used on the solvent circuit to maximise heat exchange efficiency;
- Mechanical Vapor Recompression (MVR) i.e. a heat pump compressor on the CO_2 Stripper to reduce duty on the associated reboiler;
- robust pre-treatment of the flue gas to remove contaminants and minimise fouling in the PCC Plant;
- recovering energy from the steam import by installing a steam let-down power-recovery turbine; and
- connection to the Installation’s 50 psig steam system to maximise recovery and use of low-grade heat from existing refinery processes from the Refinery processes.

The energy performance of the system will be further refined during detailed design through an Energy Efficiency Value Improvement Practices study, to identify, validate and implement further opportunities.

4.12 Energy Use

The electricity load of the PCC Plant is estimated to be 18 MWe of additional electrical energy provided by the VPI Immingham CHP Power Plant and the PCC Plant’s steam let-down power-recovery turbine generator. The generator is anticipated to provide 5 MWe of the required power.

The main electrical equipment to be used in the PCC Plant includes:

- CO_2 compression – 9 MWe;
- air cooling – 2 MWe;

- pumps – 2 MWe;
- MVR – 2 MWe;
- Wet ESP – 0.3 MWe;
- lighting and small power, sockets etc.; 0.2 MWe; and
- Other (inc. instrumentation, air heaters/blowers, mixers, trace heating etc.) – 2.5 MWe

The main electricity use is therefore associated with the CO_2 compression.

5. Emissions to Air, Water and Land

5.1 Emissions to Air

5.1.1 Point Source Emissions

Existing emissions from the FCC Regenerator are released via the 115m high Emission Point A6b and meet the monthly BAT-AELs for existing plant through primary and secondary measures, e.g.

- NOx is controlled through process optimisation and low-NOx CO oxidation promoters, in line with BAT 24 I(i) and I(ii) for Refineries. Current monthly emission limit – 300mg/Nm^3. This limit is applied as part of an Integrated Emissions Management (IMET) bubble (see Section 5.1.2).
- particulates are controlled through both cyclones and an ESP with ammonia injection, in line with BAT 25 II(i) and II(ii) for Refineries. Current monthly emission limit – 50mg/Nm^3.
- SOx emissions are currently controlled by the use of SOx reducing catalyst additives (DeSOx) and use of low sulphur feedstocks, in line with BAT 26 I(i) and I(ii) for Refineries. Current monthly emission limit for SO_2 – 800mg/Nm^3. This limit is applied as part of an IEMT bubble (see Section 5.1.2).
- CO emissions are currently controlled by combustion operation controls and the use of catalysts with carbon monoxide oxidation promoters, in line with BAT 27 (i) and (ii) for Refineries. Current daily emission limit – 200mg/Nm^3.

There is also ammonia slip from the ESP, which has a monthly emission limit of 15mg/Nm^3.

Although there are no emission limits associated with metals applied in the existing Environmental Permit, there is a requirement to monitor metals (nickel, vanadium and antimony) every 6 months (or after significant changes to the unit), due to their potential to be present in the catalyst and therefore the particulates released from the FCC stack.

As a result of the installation of the PCC Plant, the flue gas from the FCC Regenerator will cease to be released from Emission Point A6b and will be released via a new Emission Point (A6c), as described in the following Sections.

Emissions from the heaters will continue to be released from Emission Point A6a.

5.1.1.1 PCC Plant – New Emission Point A6c

Under normal operation of the PCC Plant, the abated FCC Regenerator flue gas emissions will release to air through the PCC Plant stack located on top of the CO_2 Absorber Column. This will be new Emission Point A6c and will be at a height of approximately 65m above ground level. The final stack height will be confirmed following the detailed design process; however it is currently designed to be 65 – 70m above ground level. A height of 65m has been assumed for the dispersion modelling assessment as this will lead to the worst-case impacts. A higher stack would improve dispersion and therefore result in lower impacts. That said, a stack height of 65m is considered to lead to acceptable impacts, and demonstrates a reduction in impacts from the current FCC stack, due to the lower released pollutant concentrations.

The additional secondary abatement to be installed (i.e. SCR, WGS and Wet ESP) on the FCC Regenerator flue gas prior to the PCC Plant will result in a reduction in the emission concentrations of NOx, SOx and particulates from Emission Point A6c, and will reduce these emissions towards the lower end of the BAT-AEL range for existing FCC plant, as follows:

- NOx will be reduced further through SCR, in line with secondary abatement BAT 24 II(i) for Refineries. Existing plant monthly BAT-AEL <100 – 300 mg/Nm^3.
- Particulates will be controlled through the existing cyclones, and then further through the new WGS and new Wet ESP, in line with BAT 25 II(i), (ii) and (iv) for Refineries. Existing plant monthly BAT-AEL 10 – 50 mg/Nm^3. The reduction in particulate emissions will also result in a reduction in metals concentrations.
- SOx emissions will be further controlled by non-regenerative wet gas scrubbing, in line with BAT 26 for Refineries II(i) and (ii). Existing plant monthly BAT-AEL <100 - 800 mg/Nm^3 (max range of 600mg/Nm^3 where low sulphur feedstocks or wet gas scrubbing is used).

- CO emissions – no change as a result of the PCC Plant.

There will be ammonia slip within the current permitted level from the SCR abatement, a very small amount of residual amine solvent, and potentially some solvent degradation products within the CO_2 Absorber Column flue gas, which will be vented with the rest of the combustion flue gases to Emission Point A6c.

The additional emissions could include amines, ammonia, amides, formaldehyde and acetaldehydes and trace quantities of amine degradation products, such as nitrosamines and nitramines (collectively referred to as N-amines). Emissions of such species will be abated through a water wash section and a mist eliminator at the top of the CO_2 Absorber Column, however a very small amount of carry over into the emission is envisaged.

There are currently no BAT-AELs relating to carbon capture processes, and although the EA has issued BAT guidance for PCC plants, the guidance does not propose any associated emissions levels for amines and their degradation products at this time, as it is intended that these will be developed once PCC plants becomes operational in the UK, and collated monitoring data can confirm suitable levels for which the BAT-AELs should be set. Emissions levels from the carbon capture process are therefore based on anticipated levels that are considered can be met by the Cansolv DC-103 solvent through operational experience and pilot plant testing.

5.1.1.2 Wet Gas Scrubber – New Emission Point A6d

When the FCC Unit first comes back into service following the outage when the SCR, WGS and PCC Plant will be installed, there will be a period of approximately 12 months when the PCC Plant will not be operational until it can be tied into an operational T&S Network. As such, the FCC Regenerator flue gas will be released through a new stack on top of the WGS (new Emission Point A6d), at the reduced emission concentrations. The WGS stack will be the same height as the PCC Plant stack.

In addition, when the PCC Plant is not operational, for example for short periods during PCC Plant start-up and shut down, the FCC flue gas will be released via the WGS stack. There may be longer periods when the PCC Plant is undergoing maintenance, or the CO_2 pipeline is out of service, when the FCC flue gas will also need to be released from this stack.

When the FCC Regenerator flue gas is released from this point, it will be unabated for CO_2 and therefore will comprise only the FCC Regenerator combustion gases, as treated through the SCR, WGS and wet ESP, with additional ammonia slip from the SCR.

The emissions from the new point sources detailed in Table 5.1 are shown as annual average concentrations that are considered to be achievable through the additional abatement applied to the FCC and are intended to represent new annual average ELVs for the Environmental Permit.

Table 5.1: New Point Source Emissions to Air – Anticipated Emissions

Parameter		Emission Point A6c PCC Plant	Emission Point A6d WGS Stack[1]
Stack height (m above finished ground level)		65 – 70	65 – 70
Assessed stack locations (OS grid reference)		515598, 416841	515604, 416816
Average efflux velocity (m/s)		23.7	11.0
Volumetric flow at stack exit parameters (Am^3/s)		74.4	80.4
Approx. flue diameter (m)		2.0	3.1
Volumetric flow (Nm^3/s)[2]		50.4	63.5
Average stack exit conditions	Temp (°C)	49	42
	O_2 (% dry)	5.4%	4.0%
	Moisture (%)	7.7%	4.8%
Oxides of nitrogen (NOx) mg/Nm^3 (annual average)		50	50

Parameter	Emission Point A6c PCC Plant	Emission Point A6d WGS Stack[1]
NOx emission rate (g/s) (annual average)	2.52	3.18
Carbon monoxide (CO) mg/Nm^3	100	100
CO emission rate (g/s)	5.04	6.35
Sulphur Dioxide (SO_2) mg/Nm^3 (annual average)	50	50
SO_2 emission rate (g/s)	2.52	3.18
Particulates mg/Nm^3 (annual average)	10	10
Particulates emission rate (g/s)	0.50	0.64
Ammonia (NH_3) mg/Nm^3	5	5
Ammonia (NH_3) emission rate (g/s)	0.25	0.32
Total Amines mg/Nm^3	1.1	-
Total Amines emission rate (g/s)	0.055	-
N-amines (direct release) mg/Nm^3	0.0028	-
N-amines emission rate (g/s)	0.00014	-
Amide mg/Nm^3	0.032	-
Amide (g/s)	0.0016	-
Formaldehyde mg/Nm^3	0.067	-
Formaldehyde (g/s)	0.0034	-
Acetaldehyde mg/Nm^3	0.20	-
Acetaldehyde (g/s)	0.010	-

[1] Emissions will only release via Emission Point A6d when the PCC plant is not operational

[2] Concentration normalised to reference conditions: 273K, 101.3kPa, dry, 3%v/v oxygen

An Air Quality Impact Assessment (Appendix D) has been carried out for the anticipated emissions from the PCC Plant and the WGS, comparing the impacts of the emissions detailed in Table 5.1 with those from the existing emissions from the A6 Emission Point and the results are summarised in Section 7.4.2. The locations of the new Emission Points to air are shown in Figure 2 (Appendix A).

5.1.2 Integrated Emissions Management Bubble

5.1.2.1 Current Performance Against the BRef Bubble

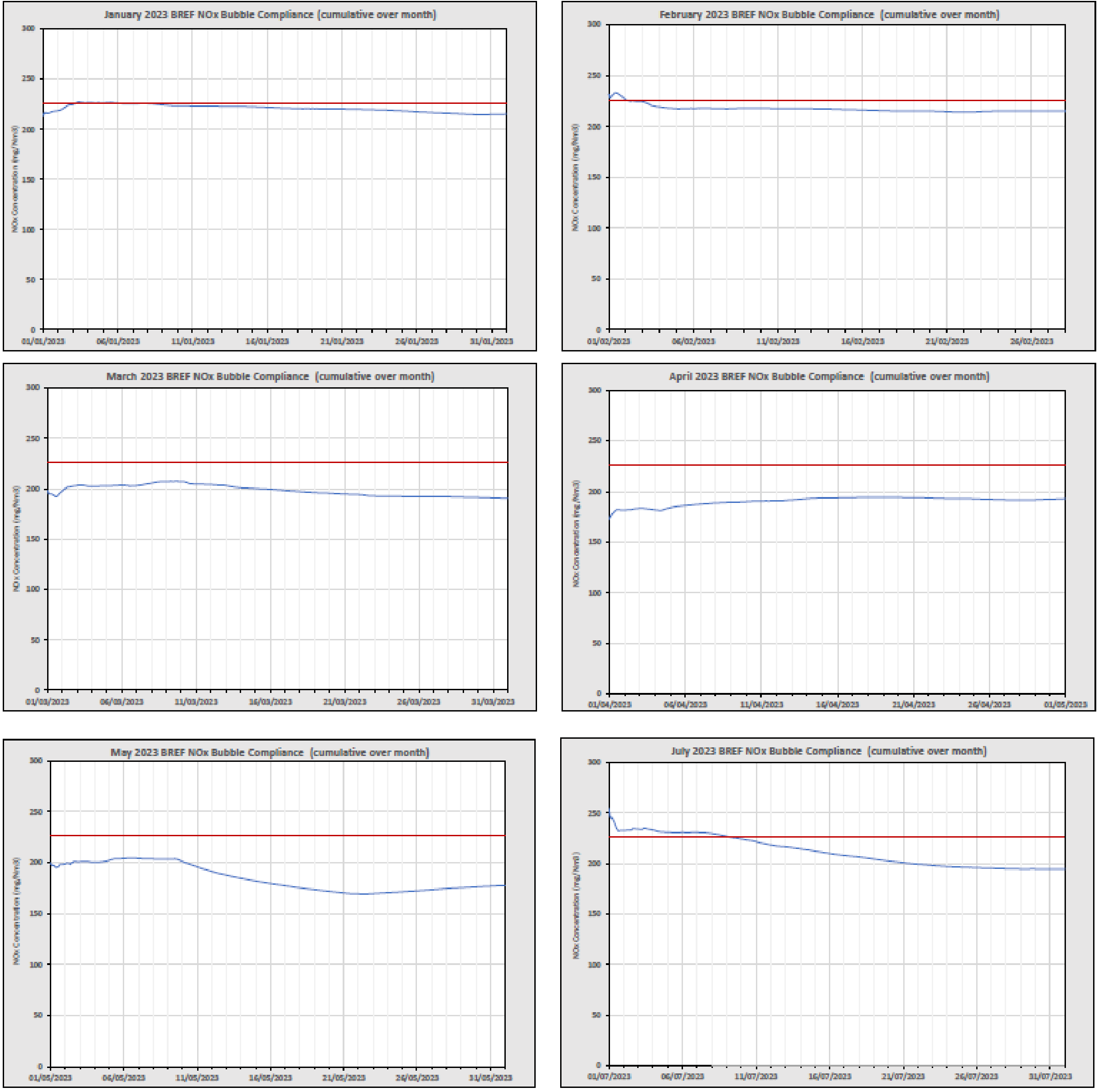
The Refineries BATc must be applied within refinery Environmental Permits. BAT 57 and BAT 58 in the Refineries BATc describe an Integrated Emissions Management Technique (IMET) that can be used as an alternative to the unit-by-unit application of BAT-AELs for the management of NOx and SO_2 emissions to air respectively, from such installations.

Therefore, as well as the annual average ELVs proposed above, consideration of the application of the Refinery's approach to the use of the IMET advocated in the Refineries BATc is required.

The Humber Refinery employs the IMET (or "BRef Bubble"), as detailed in their existing Environmental Permit, to manage the overall performance of the Refinery's emission sources on a monthly concentration basis in accordance with the BATc. The BRef Bubble for NOx and the BRef Bubble for SO_2 include different Refinery sources, however both BRef Bubbles include the FCC Unit.

The NOx BRef Bubble monthly ELV is calculated as a weighted average concentration based on the relevant monthly BAT-AELs for the emission sources included in the BRef Bubble and the representative flue gas flowrates for these sources. the FCC Unit Regenerator contributes a large proportion (approximately 30%) of the NOx BRef Bubble ELV, comprising the largest single flue gas flow source at the Refinery. Therefore, a significant reduction in the monthly ELV for the new emission point from the CO_2 Absorber (Emission Point A6c) or WGS (Emission Point A6d) would potentially impact on the ability of the Refinery as a whole to stay within the current BRef Bubble monthly ELV. This can be demonstrated in Graph 5.1, which show the Refinery's monthly performance (blue line) against the NOx BRef Bubble ELV (red line) over the first 7 months of 2023 (note that data for June has not been provided as the refinery was in shutdown during this period and therefore the BRef Bubble was not applicable).

Graph 5.1: NOx Monthly BRef Bubble Compliance for Jan 2023 – Jul 2023



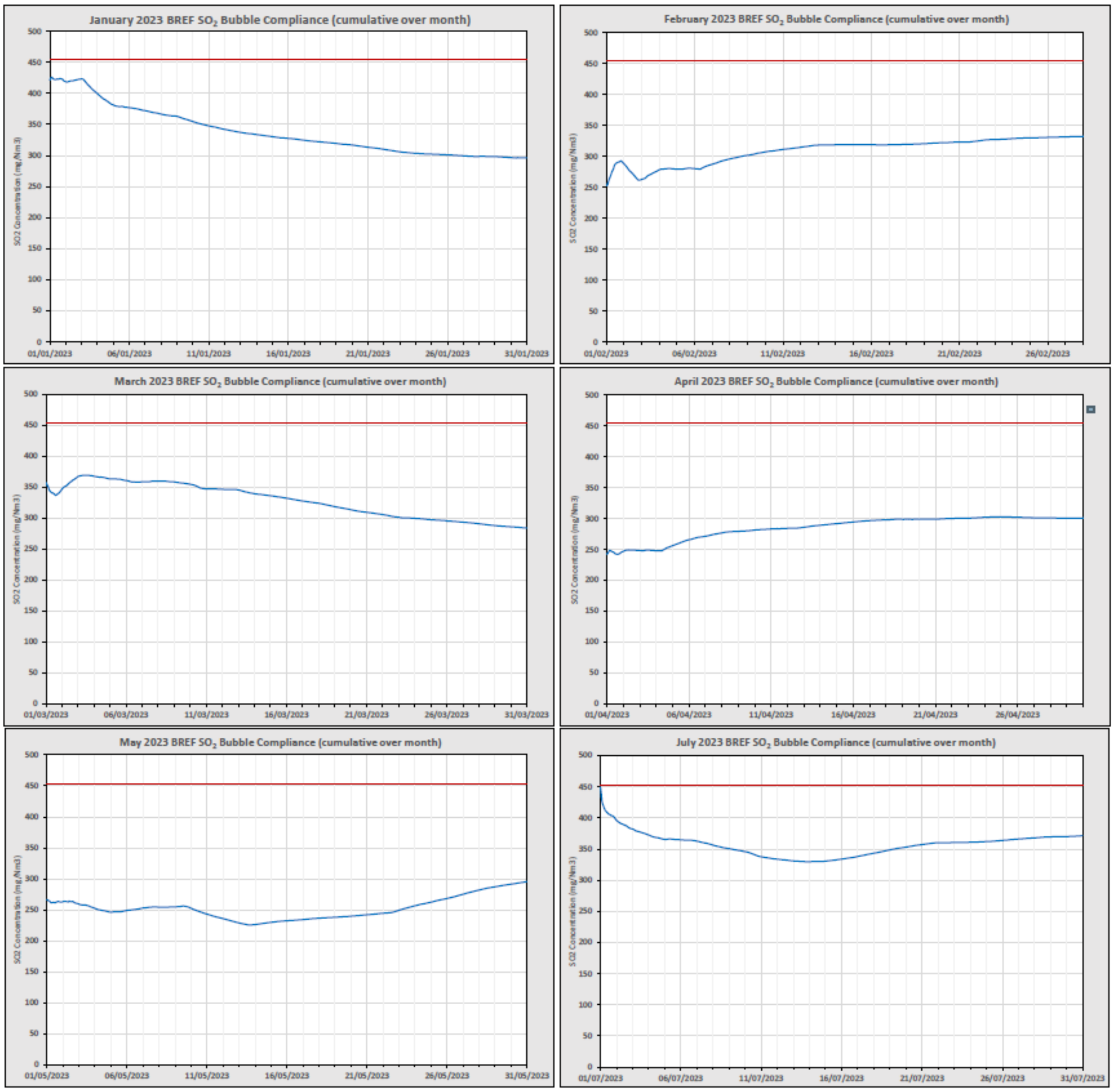
It can be seen in Graph 5.1 that there is limited flexibility in the NOx BRef Bubble monthly ELV based on current performance at the Refinery, with actual emissions being nearly at the BRef Bubble ELV, particularly for the months of January and February 2023.

As well as the sources included in the NOx BRef Bubble, the SO_2 BRef Bubble contains additional combustion plant, the Sulphur Recovery Units (SRUs) and Calciners 1 and 2.

The SO_2 BRef Bubble monthly ELV is calculated as a weighted average concentration based on the relevant monthly BAT-AELs for the emission sources included in the BRef Bubble and the representative flue gas flowrates for these sources. Again, the FCC Unit Regenerator contributes a approximately 30% of the SO_2 BRef Bubble and is again the largest single flue gas flow source contribution to the SO_2 BRef Bubble ELV.

Graph 5.2 shows the Refinery's performance against the monthly BRef Bubble limit for SO_2 over the first 7 months of 2023 with the Refinery's monthly performance (blue line) shown against the BRef Bubble limit for SO_2 (red line) (note that data for June has not been provided as the BRef Bubble is not in application during a refinery shutdown period).

Graph 5.2: SO_2 BRef Bubble Compliance for Jan 2023 – Jul 2023



Actual monthly Refinery emissions are typically well below 400mg/Nm^3 compared to the BRef Bubble limit of 454 mg/Nm^3. However, flexibility in the SO_2 BRef Bubble is essential due to the potentially variable composition of refinery feedstocks.

SO_2 emissions are also limited by individual hourly stack limits, hourly Refinery BRef Bubble limits and annual Refinery SO_2 limits. Annual SO_2 limits are more restrictive than the hourly and monthly SO_2 limits pro-rated on an annual basis, which effectively prevents emissions at the level of the hourly and monthly limits on a continuous basis. This allows for some short-term emissions up to the level of the limits based on feedstock variability, whereas emissions would more often be significantly lower than the level of the emissions limits, as shown by the graphs. Compliance with the annual Bubble Limit is currently achieved through the addition of DeSOx.

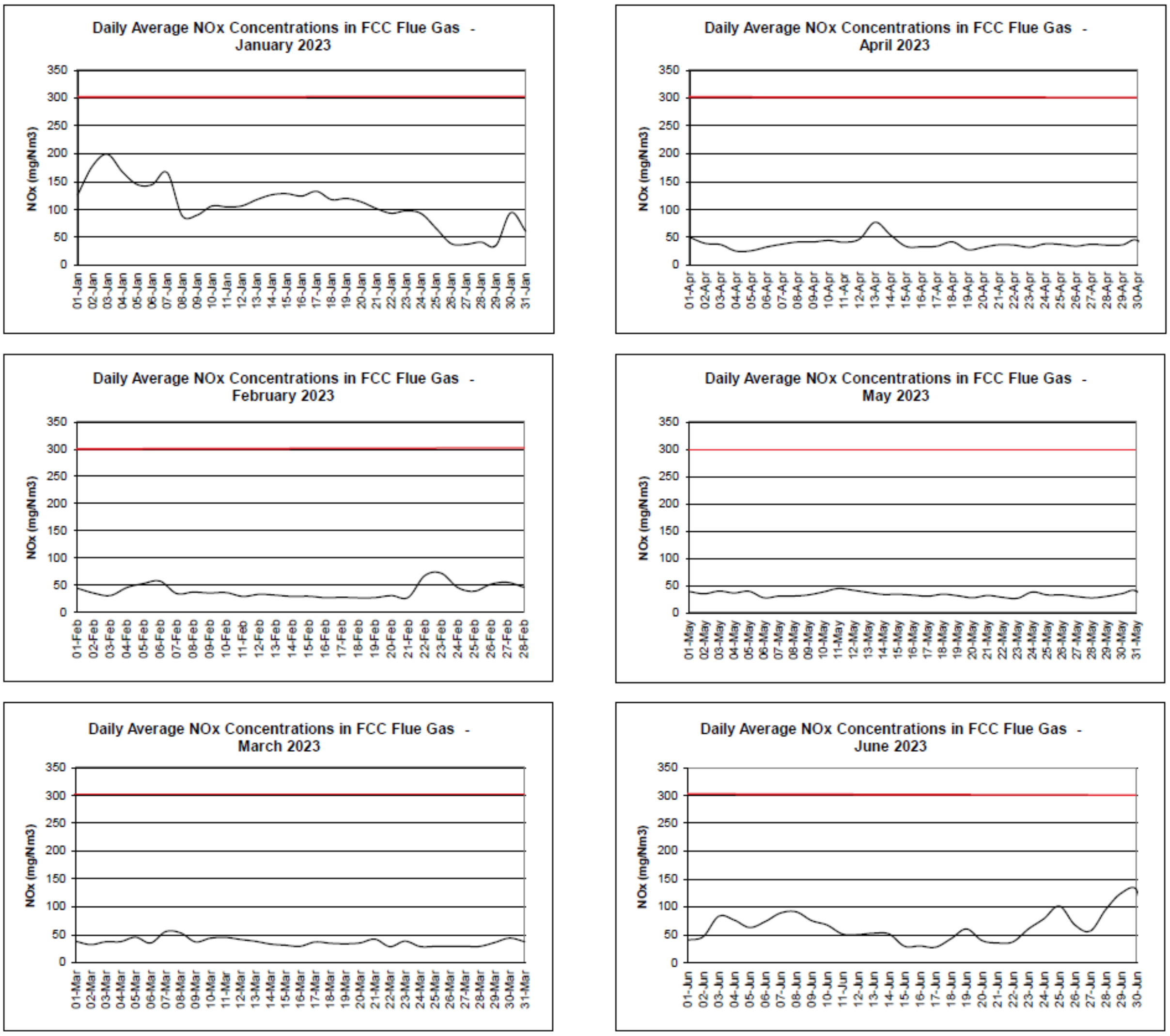
5.1.2.2 Current Performance of the FCC Unit Against the Emission Limit Values

The existing emissions limits for NOx and SO_2 from the FCC Unit Regenerator meet the BAT-AELs for existing plant through primary and secondary measures, as follows:

- NOx is controlled through process optimisation and Low-NOx CO oxidation promoters, in line with BAT 24 I(i) and I(ii) for Refineries. Current monthly emission limit – 300mg/Nm^3. This limit is applied within the IEMT (Monthly BRef Bubble).
- SOx emissions are currently controlled by the use of SOx reducing catalyst additives (DeSOx) and use of low sulphur feedstocks, in line with BAT 26 I(i) and I(ii) for Refineries. Current monthly emission limit – 800mg/Nm^3. This limit is applied within the IEMT (Monthly BRef Bubble).

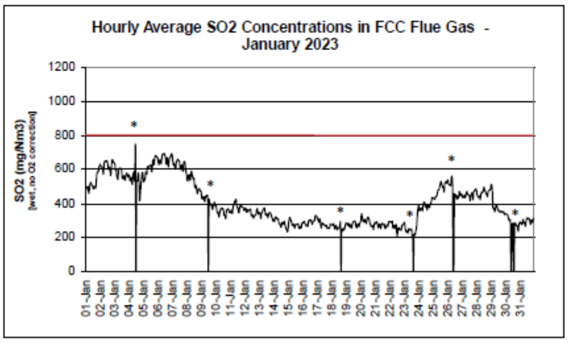
The actual performance of the FCC Unit Regenerator however results in emissions that are significantly below the current ELVs applied in the existing Environmental Permit for both NOx and SO_2. This can be demonstrated by a review of the Quarterly Returns that are provided to the EA to meet the requirements of the Environmental Permit and is shown in Graphs 5.3 and 5.4 for NOx and SO_2 respectively. The monthly BAT-AELs for the FCC Unit are shown by the red line, with actual performance shown by the black line.

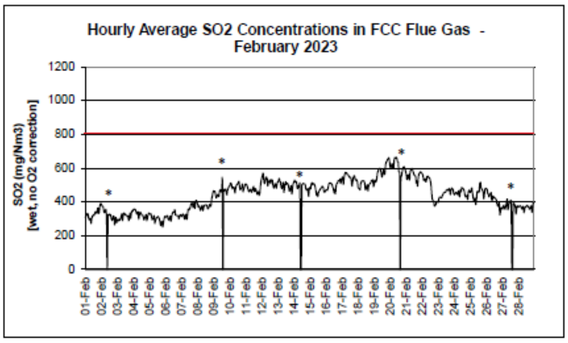
Graph 5.3: Monthly NOx Emissions from the FCC Unit Regenerator Jan 2023 – Jul 2023

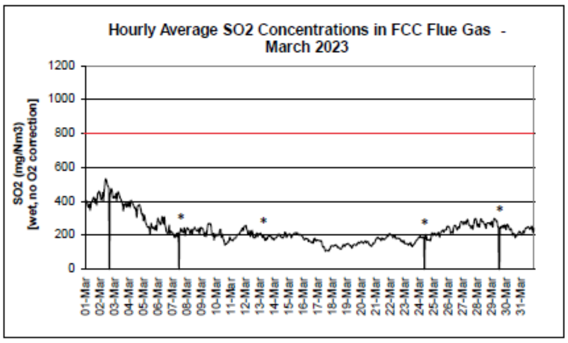


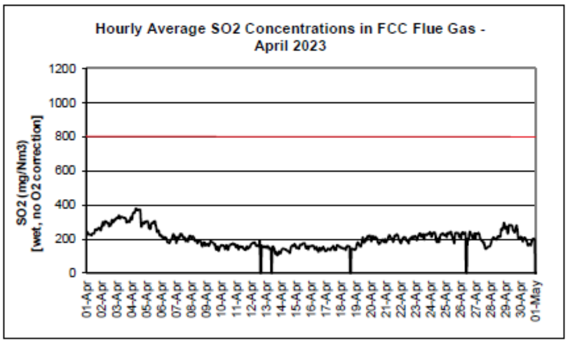
Although there is some variance shown in the daily NOx emissions in Graph 5.3, it can be seen that during months with no abnormal operation, NOx emission concentrations are typically less than 50mg/Nm^3, significantly lower than the monthly ELV of 300mg/Nm^3 currently applied to this emission source and used for the calculation of the current NOx BRef Bubble ELV. Phillips 66 have optimised performance on the FCC Unit Regenerator for NOx to help them manage compliance with the NOx BRef Bubble.

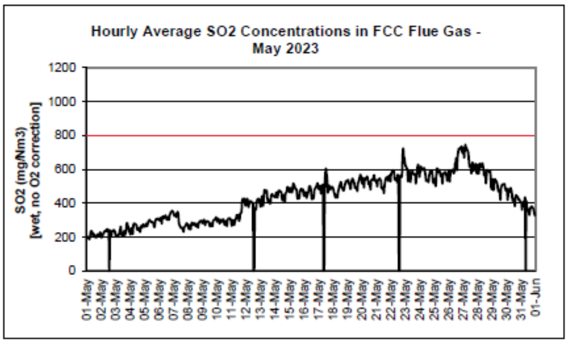
Graph 5.4: Monthly SO_2 Emissions from the FCC Unit Regenerator Jan 2023 – Jul 2023

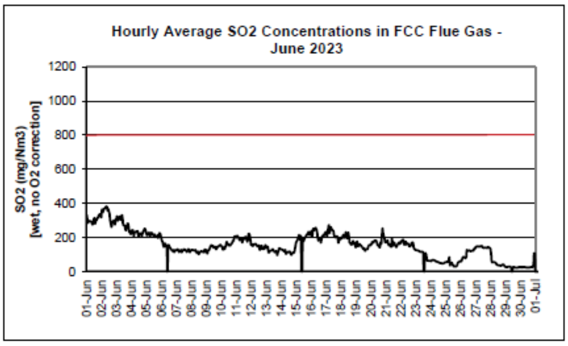












SO_2 concentrations typically show greater variance than NOx emissions, however the SO_2 emissions shown in Graph 5.4 are generally between 400mg/Nm^3 and 600mg/Nm^3, again below the monthly ELV of 800mg/Nm^3 currently applied to this emission source and used for the calculation of the monthly SO_2 BRef Bubble ELV.

5.1.2.3 Proposed BRef Emission Limits for the Environmental Permit Variation

As detailed in Section 4.2.2, the FCC Unit Regenerator flue gas will need to pass through a number of new pre-treatment stages prior to entering the PCC Plant, to ensure the PCC Plant operates effectively. These will include SCR to reduce NOx, a WGS to reduce SO_2 and particulates and a wet ESP to further reduce fine particulates and aerosols within the FCC flue gas. As such new monthly BRef ELVs, for inclusion in the BRef Bubble calculations, should be applied to the new Emission Points (A6c and A6d) that reflect these reductions in NOx and SO_2 emissions.

However, it is important that these new monthly BRef ELVs do not impact on the overall Refinery's performance compared to the BRef Bubble Limits, given that the FCC Unit is a major contributor to the current BRef Bubble Limit calculation and that current emissions concentrations from the FCC Unit are already well below the monthly ELVs.

In addition, the removal of the CO_2 from the flue gas exiting the CO_2 Absorber would also have an impact on the proposed monthly BRef Bubble limits, as CO_2 comprises approximately 15% of the flue gas from the FCC Unit Regenerator. Removal of the CO_2 from the flue gas would therefore reduce the flue gas flow used in the BRef Bubble calculations if the compliance point for the BRef Bubble ELV was the exit of the CO_2 Absorber. This would further constrain compliance with the monthly BRef Bubbles and is not reflective of the basis for the BATc, which has been established through the BRef process of data gathering and review of actual performance from existing FCC units, none of which have PCC plant installed. Attempting to apply this to new technology would introduce considerable uncertainty in the ability of Refinery to comply with the BRef Bubble ELVs.

That said, it is recognised that new monthly BRef ELVs should be derived to reflect that the aim of the IEMT is to reduce overall Refinery emissions over time. As such, there should be no increase in the flexibility provided by the BRef Bubble limits following introduction of the PCC Plant and the associated reduction in NOx and SO_2 emissions from the FCC Unit.

It is therefore proposed that as well as the annual ELVs detailed in Table 5.1, the monthly SO_2 and NOx BRef Bubbles Limits are updated to reflect the modifications to the FCC following the installation of the PCC Plant to ensure that the new annual ELVs do not adversely impact on the Refinery's ability to meet the BRef Bubble ELVs. The additional monthly ELVs for NOx and SO_2 will be applied in the Environmental Permit for use in BRef Bubble calculations. The monthly ELVs applied for the BRef Bubble need to ensure that the current flexibility provided by the BRef Bubble is maintained, so as not to give additional headroom to emit higher levels of emissions on other units at the Refinery, nor to increase constraints on Refinery operation.

As shown in Graph 5.3, current NOx emissions from the FCC Unit regenerator are typically less than 50mg/Nm^3 compared to the current monthly ELV of 300mg/Nm^3 and therefore the actual reduction in the proposed annual ELV from the new A6c/ A6d Emission Points is not as marked as it may initially seem possible. The actual reduction in the NOx concentrations from the FCC Unit emissions is only likely to be in the region of 20mg/Nm^3 from current NOx concentrations. Actual performance of the Refinery is already close to the NOx BRef Bubble monthly ELV, as demonstrated in Graph 5.1. Therefore, this should be reflected in the setting of a new NOx monthly ELV for BRef Bubble calculations.

As shown in Graph 5.2, there is more flexibility in SO_2 concentrations against the existing SO_2 BRef Bubble monthly ELV, however this is required due to the greater variance in emissions of SO_2 from the Calciners (due to variability in feedstock composition). Graph 5.4 shows current emissions of the FCC Unit to be between 400mg/Nm^3 and 600mg/Nm^3, again below the monthly ELV of 800mg/Nm^3 currently applied to this emission source and used for the calculation of the SO_2 BRef Bubble monthly ELV.

Current work has considered 7 months of monitoring data, and it is recognised that data over a longer period (several years) should be reviewed to assist the derivation of suitable new monthly ELVs. When the original BRef Bubbles were defined for the Refinery, this took over a year of discussions between Phillips 66 and the EA and considered monitoring data over an extended period.

Further work and review is therefore needed in conjunction with input from the EA to determine the appropriate update to the FCC BATc ELVs for application in the Refinery monthly NOx and SO_2 BRef Bubble ELVs. It has been agreed with the EA in pre-application discussions that this work can continue during the Environmental Permit determination period.

For the purpose of the Air Quality Impact Assessment provided in Appendix D, monthly BRef ELVs of 300mg/Nm^3 for NOx and 600mg/Nm^3 for SO_2 have been assumed for the assessment of short-term impacts, as a worst case.

5.1.3 Visible Plumes

Due to the initial water content of the emission from the PCC Plant, and the relatively low temperature of the release, there is potential for the plume from the CO_2 Absorber stack to be visible.

The potential for visible plumes to impact local receptors (including loss of light and ice on roads from plume grounding) has been reviewed with consideration of the frequency, length and direction of visible plumes generated during daylight hours with reference to local sensitive receptors, and an assessment is provided in Appendix D and is summarised in Section 7.4.1.4.

5.1.3.1 CO_2 Vent

In addition to the two new emission points detailed above, the current design is to include a single CO_2 vent associated with both the LP and HP CO_2 compression. The release of CO_2 from this vent would be abnormal operation, for example on start-up of the PCC Plant, as previously detailed in Section 4.3. An assessment of the impacts of the CO_2 venting releases has been carried out and is provided in Appendix E.

5.1.4 Fugitive Emissions

Fugitive emissions have the potential to occur from tanks, flanges, seals and equipment vents during transfer operations and during unloading operations from tankers. The PCC Plant will be designed such that items where fugitive emissions could occur will be specified as low emission items wherever possible, with suitable packing/ seals etc. Seal-less or dual seal pumps will be utilised for liquids with high vapour pressure.

The Installation currently operates a Leak Detection and Repair (LDAR) programme to minimise fugitive emissions of Volatile Organic Compounds (VOC), and this will be extended to cover the PCC Plant where needed. Potential fugitive emissions from the PCC Plant will be identified during the detailed design process. The detailed design will ensure that the containment of these releases is built into the design of the PCC Plant so they can be controlled as far as is practicable.

BAT for the storage and transfer of materials will be applied to minimise all fugitive emissions to air from the proposed PCC Plant, such as:

- back venting of displaced air from storage to any delivery container or vehicle for high volatility liquids;
- use of low emission or low release valves;
- risks from leaks shall be reduced by minimising the number of flanged joints, valves and connections to as low as reasonably practicable (ALARP) levels;
- use of double seal or canned pumps where feasible;
- dry gas seals on the CO_2 Compressor where possible;
- high integrity compressor and pump seals for high pressure system; and
- venting of gases from process facilities, utility units, storage and unloading/ loading activities will be minimised and where possible routed to knock-out pots.

5.2 Emissions to Water

5.2.1 Point Source Emissions

5.2.1.1 Existing Installation Drainage

The Installation has two existing discharges to water, Emission Points W1 and W2 (W2a and W2b), shown in Figure 2 (Appendix A).

W1 is limited to surface water drainage from the south tank farm area of the Installation and therefore will not be affected as a result of the installation of the PCC Plant. Therefore, no further consideration is given to this emission point in this variation application.

W2 releases uncontaminated surface water drainage and wastewaters that have been treated through the Installation’s existing ETP to South Killingholme Drain (via W2a) or, a proportion can be re-routed to the VPI Immingham CHP Power Plant for reuse (via W2b). The Installation’s existing ETP consists of primary, secondary and biological treatment.

There are two holding ponds; Holding Pond No. 1 and Holding Pond 2. Holding Pond 1 receives wastewaters from the existing site that have been collected in the Oily Water Sewer (OWS) drainage system and have been treated through the ETP.

The Surface Water Sewer (SWS) is routed to a Tilted Plate Interceptor (TPI) after which the stream can be routed either through the Refinery ETP, or to the No.2 Holding Pond and to offsite discharge at Emission Point W2. The default operation is to route the SWS stream through the ETP, however, during periods of high flow due to heavy rainfall, the surface water can be routed directly to No.2 Holding Pond to reduce the load going through the ETP. The No.2 Holding Pond provides attenuation before water is discharged via Emission Point W2a to the South Killingholme Drain and the No.2 Holding Pond effluent must meet the refinery effluent discharge limit specifications prior to discharge.

The outlet of Holding Pond No.1 is combined with the outlet from Holding Pond No.2 and the combined stream passes through Induced Air Floatation (IAF) before being discharged to South Killingholme drain via Emission Point W2a.

A flow diagram of the existing site drainage and ETP is shown in Figure 7 (Appendix A).

The Installation's current Environmental Permit includes a limit on the volume of wastewater discharged from W2 (16,000m^3/ day) and there are ELVs on the concentrations of various compounds potentially presented within the wastewater, including; pH, Total Organic Carbon (TOC), COD, Suspended Solids, oil, total nitrogen (as N), BTEX (benzene, toluene, ethyl benzene and xylene), lead, cadmium, nickel, mercury, phenols, fluoride, chromium, copper and zinc.

The Installation's ETP already receives effluents with the potential to contain amines from existing onsite process. These effluents can be generated during plant turnarounds during plant cleaning activities and are collected and fed at a controlled rate to the existing ETP, so as not to impair its performance. There is no limit on the amine concentration in the wastewaters water being released to W2, rather this is controlled through the COD limit applied.

5.2.1.2 PCC Plant Area Drainage

There will be no new Emission Points to water as a result of this Environmental Permit variation.

In line with the existing Installation, the PCC Plant area's drainage will comprise an OWS and a SWS drainage system.

Surface water that can be collected in the PCC Plant area's SWS drainage will comprise rainwater falling on non-process areas of the PCC Plant and CO_2 compression areas. This will include paved areas, building roofs, roads and parking areas. In addition, process areas that do not contain equipment requiring frequent or routine maintenance and equipment where potential leakage may occur will also go to the SWS. The PCC Plant area SWS will tie into the Installation's existing SWS prior to the existing TPI.

Potentially contaminated surface waters will drain to the PCC Plant area's OWS. This will include waters collected in bunded areas, kerbed areas, road tanker loading/ unloading areas and where there is intentional drainage of equipment during normal operation, maintenance or shut down. The PCC Plant area's OWS will tie into the existing Refinery's OWS prior to the existing API Separator, and then be treated in the existing ETP.

During routine operation there will be process wastewaters generated from a number of operations. Wherever possible, this water will be recycled back into the process, however where this is not possible, it will be routed to the OWS provided that the ETP can treat the wastewater and ensure that the existing ELVs are met. Water that does not meet this criterion will be taken offsite for treatment by a 3rd party licenced waste contractor.

The Waste Heat Exchanger will be subject to continuous and intermittent blowdown, as required, however this is not considered to contain any pollutants which are not already present in site wastewaters and therefore this will be sent to the PCC Plant area's OWS.

There will be no routine discharge of process wastewaters containing the amine solvent, as these will be contained and reused with the PCC Plant wherever possible. A closed Solvent Drain System will be provided to minimise solvent losses during plant maintenance activities. Prior to maintenance, the inventory of solvent in an item of equipment will be reduced as far as possible. Any residual solvent will be drained down to the closed Solvent Drain System. Any liquids collected in the Solvent Drain System will be tested and where possible be reused in the PCC Plant. If this is not possible, they will be disposed of offsite by a licensed 3rd party waste contractor.

If wastewaters with the potential to contain amines (i.e. bleed water from the water wash loop) were sent to the ETP, they would be processed at a controlled rate so as to not overwhelm the nitrogen treating capacity of the ETP, in line with current Installation procedures for dealing with such waste waters.

At this stage of the plant design, a detailed site drainage plan is not available, however a schematic showing how the PCC Plant area's drains will tie into the existing site system is provided in Figure 6 (Appendix A) and an indicative site drainage plan for the PCC Plant area is provided in Figure 8 (Appendix A).

5.2.1.3 Purge Treatment Unit Wastewater

The wastewater from the PTU on the WGS will contain sulphates from the removal of SO_2 from the flue gas, ammonia from the SCR and potentially metals due to their presence in the catalyst fines used in the FCC Unit and their potential use in flocculants and coagulants. It is considered that the majority of the catalyst fines present in this wastewater would be removed by the PTU clarifier, which separates solids from the wastewater for collection and offsite disposal by a licensed 3rd party waste contractor. However, some solids may remain in the wastewater.

The coagulant and flocculant to be used in the PTU have yet to be confirmed during detailed design, however it is expected that these will be similar to chemicals already used in the existing ETP. Such chemicals are developed and widely used for use in both drinking water and wastewater treatment processes and therefore their chemistry is well understood. Maintaining the pH of the PTU wastewater within the optimum range for the specific coagulant and flocculant chemicals to be used will be essential to ensure that release of soluble aluminium/ and iron-based coagulants (if these are used) does not occur.

There is no information from an existing operational plant that can be used to inform the project on the levels of contaminants that will be present in the PTU wastewater, as different FCCs use different feeds, catalysts and additives, so there are no comparable flue gases being treated in existing WGS. In addition, the WGS for the PCC Plant application at the Installation, will treat flue gases to a much higher level than WGSs at other refinery sites, which are only treating flue gases to meet BAT-AELs and not the lower emission levels required for the PCC Plant.

It is also not known whether the sulphite oxidation tank would result into the oxidation of other species too, such as ammoniacal nitrogen to nitrates, elemental metals to metal oxides, etc. and whether this will change the distribution of the oxidised products between the phases (i.e. soluble vs. suspended solids).

Characterisation of the PTU wastewater stream therefore has been undertaken based on engineering studies carried out by the WGS vendor. This information has been reviewed by Phillips 66 and used to calculate the future emissions from the wastewater following its treatment in the PTU when combined and discharged with the existing Phillips 66 Refinery effluent. The combined future effluent has been compared to the ELVs in the existing Environmental Permit for Emission Point W2 and this is shown in Table 5.2.

The values presented in Table 5.2 are considered to be conservative as it is expected that a portion of the salts will be retained within the sludge from the clarifier rather than ending up in the discharged effluent stream.

Table 5.2: Characterisation of the PTU Wastewater and the Existing Refinery Effluent

Flows	Unit	PTU Wastewater	Existing Phillips 66 Effluent	Combined Future Effluent to W2	Current W2 ELVs
Mean effluent flowrate	m^3/s	0.00154	0.10536	0.10690	-
Max effluent flowrate	m^3/s	0.00295	0.16876	0.17171	0.185*
Average concentrations					
pH	=	8.7	8.8	8.8	5 - 9
Na_2SO_4	µg/l	55,657,176	-	-	-
Na_2SO_3	µg/l	818,488	-	-	-
$(NH_4)_2SO_4$	µg/l	900,337	-	-	-
Catalyst fines	µg/l	49,109	-	-	-
COD	µg/l	100,000	100,000	100,000	125,000
Phenols	µg/l	0	70	70	500
Suspended Solids	µg/l	50,000	20,000	21,000	25,000
Salts broken out:					
Total Nitrogen**	µg/l	190,869	16,111	18,628	25,000
Ammoniacal Nitrogen	µg/l	190,869	1,267	3,997	Not included
Ammonia	µg/l	232,082	1,540	4,860	Not included
Sulphates	µg/l	38,294,806	261,122	808,822	Not included
Sulphites	µg/l	519,887	-	-	Not included
Catalyst fines broken out:					
Nickel	µg/l	39	8	9	100
Vanadium	µg/l	90	6	7	No limit applied, but monitoring required
Copper	µg/l	1	7	7	100
Iron	µg/l	369	122	126	Not included

* Based on 16,000m^3 total daily flow

** Total Nitrogen (ammoniacal nitrogen = total nitrogen for the new stream as all the nitrogen is present as ammonium)

The PTU wastewater will need to be routed through dedicated piping to a discharge point that is either into or downstream of the No.1 and No.2 Holding Ponds. The exact location of the tie-in will be confirmed during detailed design, however the discharge point will be after the existing ETP and will need to be at a suitable location upstream of the analysers on the W2 refinery outfall to the South Killingholme Drain to ensure adequate mixing has occurred prior to discharge off site.

As can be seen from Table 5.2, the PTU wastewater will contain salts in the form of sodium sulphate (Na_2SO_4), sodium sulphite (Na_2SO_3) and ammonium sulphate ($(NH_4)_2 SO_4$). In order to determine the impact this new effluent will have on measured components in the total combined effluent, it has been necessary to calculate how the constituents of these salts could contribute towards the total nitrogen, ammoniacal nitrogen, ammonia, sulphates and sulphites. Worst-case assumptions have been used in each case, for example, assuming all the ammonia present in the ammonium sulphate would be picked up as ammonia, all the nitrogen as total nitrogen etc.

Based on these worst-case assumptions it is considered that metals, COD, suspended solids and total nitrogen concentrations within the PTU wastewater will not result in an exceedance of the current emission limits within the Environmental Permit from Emission Point W2, as demonstrated in Table 5.2.

There are some uncertainties in the ammonia figures, given that the vendor of the SCR unit has not been selected yet. The levels of ammonia slip present in the flue gas that will be sent to the WGS are currently based on a worst case assumption of 10ppm, however the current design basis for the unit is 2ppm.

Table 5.4 shows that there will be an increase in the concentration of sulphate in the combined effluent as a result of the PTU wastewater. There is no current emission limit or requirement to monitor sulphate in the current Environmental Permit. Nor is there a BAT-AEL for sulphates in discharges to receiving water in the Refineries BATc. The Large Combustion Plant BATc does contain a BAT-AEL for emissions of sulphate to receiving waters of 1,300 – 2,000 mg/l for wastewaters from wet Flue Gas Desulphurisation activities where calcium compounds are used in the flue gas treatment. This BAT-AEL does not apply to discharges to the sea or to brackish waters, where natural background sulphate levels are already high.

Sulphate is not included in the indicative list of polluting substances in Annex II to the IED (2010/75/EU) to be taken into account for setting ELVs. In addition, sulphate is not a Water Framework Directive listed pollutant.

Calculations of the sulphate present in the wastewater from the PTU indicate that following dilution, sulphate concentrations within the emission from Emission Point W2 could be approximately 808 mg/l, as shown in Table 5.4.

The Common Wastewater and Waste Gas Treatment BRef[9] indicates that wastewaters loaded with sulphate can be treated by nanofiltration and reverse osmosis, but indicates that these techniques are not used by any of the directly discharging Wastewater Treatment Plants looked at in preparation of the BRef. It then gives no further information on either technique for removal of sulphates in isolation, but rather as a treatment for heavy metal ions. It also briefly mentions the addition of calcium hydroxide or lime which leads to the precipitation of calcium sulphate as a treatment, but again provides no further information.

The only method of treatment discussed in the BRef in any detail specifically for the removal of sulphur, is the biological removal of sulphur compounds and heavy metals using special application of anaerobic treatment.

In addition, the Refineries BRef details SO_2 removal from FCC units by non-regenerative and regenerative scrubbing, with regenerative scrubbing resulting in lower wastewater volumes.

Based on this information, a number of potential options for sulphate removal from the WGS have been considered as part of the project, including:

- biological removal;
- nanofiltration/ reverse osmosis – i.e. membrane technologies;
- ion exchange technologies;
- regenerative scrubbing, using a Cansolv system;
- chemical precipitation; and
- DeSOx catalyst addition.

Biological Removal

The biological removal of sulphur compounds requires an Upflow Anaerobic Sludge Blanket (UASB) reactor, where the biological reduction of sulphate into sulphide takes place. Experience of such systems is at sulphate levels <8,000 mg/l and therefore the use of the anaerobic technology at the high sulphate level of up to 38,294 mg/l calculated for the PTU wastewater is not considered appropriate. Biological reduction of sulphate by sulphate reduction bacteria yield sulphides and free hydrogen sulphide which could potentially inhibit the reaction. The sulphide toxicity levels are typically reported as 100 to 189 mg/l as free hydrogen sulphide and 200 to 300mg/l as total sulphide. With sulphate influent levels of 2,500 mg/l the toxicity effects on the biological reaction are manageable, however, with influent sulphate levels up to 38,294 mg/l the reaction could be heavily inhibited.

In addition, biological processes need electron donors, which are normally provided by the Chemical Oxygen Demand (COD) content in the wastewater. If the COD content is not sufficient, electron donors need to be added. There would be no organics within the WGS effluent and therefore significant dosing

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[9] Best Available Techniques (BAT) Reference Document for Common Waste Water and Wate Gas Treatment/ Management Systems in the Chemical Sector (2016).

of an organic source to increase the COD would be required to make biological removal effective for the PTU wastewater.

As part of the design process, an anaerobic treatment technology supplier has been contacted regarding the suitability of the PTU wastewater for biological sulphate removal and they concluded that due to the high salt concentrations in the WGS effluent, it would not be suitable for biological treatment. It is therefore considered that this is not a viable option for reducing sulphates in the WGS effluent.

Membrane Technologies

The most commonly used membranes for wastewaters that have a high dissolved solid content, are capable of treating approximately 36,000 mg/l of dissolved solids. It is considered that the PTU wastewater will have dissolved solids concentrations in excess of this. As such, this treatment option is also not considered viable for the PTU wastewater stream.

In addition, this treatment method would only in affect concentrate up to the sulphate within the wastewater, and therefore there would still be a very high sulphate wastewater stream that would require disposal.

Ion Exchange

Ion exchange has much less capacity to deal with total dissolved solids than membrane technologies, such as reverse osmosis. There are proprietary ion exchange techniques that have been developed for sulphate removal, which are used as a polishing step after chemical precipitation on mine waters, however the high sulphate concentrations in the PTU wastewater make it unsuitable for ion exchange treatment.

Regenerative Scrubbing

Regenerative scrubbing with a proprietary solvent, such as Cansolv, means that the SOx-absorbing reagent used in the scrubber can be regenerated for reuse. The resulting concentrated SO_2 stream also has the potential to be recovered, through additional appropriate processing technology, to liquid SO_2, sulphuric acid or elemental sulphur. There is therefore no sulphate containing effluent generated by this process.

However, regenerative scrubbing is suited to flue gas streams with a very high SOx concentration (i.e. 1,000 – 2,000ppm), higher than that from the FCC flue gas (current ELV 800mg/Nm^3, although with actual emissions typically between 400 – 600mg/Nm^3). In addition, for the specific treatment of the FCC flue gases, it is considered that a non-regenerative WGS upstream of the regenerative scrubber would still be required to remove particulates and SO_3 to ensure that the subsequent regenerative scrubber operated effectively and to reduce the degradation of the Cansolv solvent used in the regenerative process. In addition, a final caustic polisher would also be required to meet the required concentrations at the inlet of the CO_2 Absorber.

Although the size of the upstream non-regenerative WGS would potentially be smaller than that currently proposed, there would still be a sulphate containing wastewater generated that would require disposal from both this, and also the final caustic polisher. Therefore, even with regenerative scrubbing, there would be a resulting wastewater with high sulphate concentrations that would require disposal.

The regenerative scrubber would also need an ion exchange unit to remove degradation products (heat stable salts) from the Cansolv solvent used in the regenerative scrubbing process, and therefore there would be additional caustic and water usage for resin regeneration. This would also result in an additional wastewater stream containing sulphates, sulphites, nitrates and amines that would also require additional treatment or off-site disposal.

The increased complexity of a regenerative WGS versus non-regenerative unit adds considerable cost and complexity to the project and also requires more plot space in the already plot-constrained PCC plant area. It is therefore considered that a regenerative scrubber approach is not a viable for the project.

Chemical Precipitation

Calcium hydroxide or barium carbonate could be added to enable the resulting insoluble sulphate salt to be precipitated out from the PTU wastewater. The process involves multiple steps; the liquid is taken through a buffer tank to a mixer to add the precipitation chemical, then to a flocculation tank, a clarifier and finally the resulting sludge is dewatered before being sent for disposal. Again, this would require additional equipment to be added to the PCC plant, which is already space constrained.

This option would generate large quantities of sludge that would require disposal off site, therefore resulting in significant cross-media effects. Quantities of sludge requiring disposal have been estimated as 34m^3/day, equating to approximately two skips per day. This would require disposal as hazardous waste, and as landfill options for such waste are limited, this would add significant cost. In addition, the quantities of waste involved would result in significant additional traffic movements, and the resulting emissions. It is therefore considered that this option is also not BAT due to the cross-media effects that would result.

DeSOx

DeSOx additive is currently already used in the FCC Regenerator to reduce SOx concentrations in the resulting flue gas. The original design for the WGS had meant the DeSOx addition would no longer be required, however further consideration of the continued use of up to 50% DeSOx additive to remove up to 50% of the FCC flue gas SOx has concluded that this could reduce the resulting sulphate concentrations in the PTU wastewater from 808 mg/l originally calculated and shown in Table 5.2 to 533mg/l. The characterisation of the PTU wastewater assuming that DeSOx is applied to achieve a 50% SOx removal is shown in Table 5.3.

Table 5.3: Characterisation of the PTU Wastewater and the Existing Refinery Effluent – with DeSOx Applied

Flows	Unit	PTU Wastewater	Existing Phillips 66 Effluent	Combined Future Effluent to W2	Current W2 ELVs
Mean effluent flowrate	m^3/s	0.00154	0.10536	0.10690	-
Max effluent flowrate	m^3/s	0.00295	0.16876	0.17171	0.185*
Average concentrations					
pH	=	8.7	8.8		5 - 9
Na_2SO_4	µg/l	27,344,693	-	-	-
Na_2SO_3	µg/l	409,244	-	-	-
$(NH_4)_2SO_4$	µg/l	900,337	-	-	-
Catalyst fines	µg/l	49,109	-	-	-
COD	µg/l	100,000	100,000	100,000	125,000
Phenols	µg/l	0	70	-	500
Suspended Solids	µg/l	50,000	20,000	21,000	25,000
Salts broken out:					
Total Nitrogen*	µg/l	190,869	16,111	18,628	25,000
Ammoniacal Nitrogen	µg/l	190,869	1,267	3,997	Not included
Ammonia	µg/l	232,082	1,540	4,860	Not included
Sulphates	µg/l	19,147,403	261,122	533,092	Not included
Sulphites	µg/l	252,723	-	-	Not included
Catalyst fines broken out:					
Nickel	µg/l	39	8	9	100
Vanadium	µg/l	90	6	7	No limit applied, but monitoring required
Copper	µg/l	1	7	7	100
Iron	µg/l	369	122	130	Not included

* Total Nitrogen (ammoniacal nitrogen = total nitrogen for the new stream as all the nitrogen is present as ammonium)

Given the limited availability of other viable options to reduce the sulphate in the PTU wastewater, this technique is considered to potentially represent the most viable option for reducing the sulphate concentration in the effluent and hence BAT for the Installation. There may be potential to increase the amount of DeSOx additive further (to achieve up to 80% removal of SO_2 from the flue gas), and this would reduce the concentration in the Combined Future Effluent to W2 to approximately 360 mg/l. The ability to deliver further SOx reduction through additional DeSOx application reduces beyond 50% removal. As such, further consideration through detailed design will explore optimising the use of DeSOx dosing to determine whether further SOx reduction is achievable.

For the purpose of this application it has been assumed that 50% DeSOx application will be applied.

The requirement to remove sulphates from the wastewaters released from the Installation is partially driven by the potential impacts of sulphates on the environment. Consideration of the potential impacts of sulphate emissions in the effluent therefore is provided in Section 7.4.3.

The wastewaters sent to the existing ETP from the PCC Plant will not result in an exceedance of the current Environmental Permit's volume limit, nor any of the emission limits currently within the Environmental Permit. No changes to the emission limits within the existing Environmental Permit are sought as a result of the operation of the PCC Plant.

5.2.2 Fugitive Emissions

Areas handling chemicals will comprise hardstanding and be kerbed/ bunded to ensure that spillages and/ or leaks in those areas are contained, manually cleaned up and removed for treatment off-site. To minimise rainwater collection (and therefore inventory), these areas will be located indoors or be provided with rain shelters, where practicable and safe to do so.

Road tanker unloading areas will have kerbed/ bunded areas as needed and in line with the CIRIA guidance in the event of a loss of containment.

5.3 Emissions to Sewer

There will be no emissions to sewer as a result of the operation of the PCC Plant.

5.4 Emissions to Land

There will be no emissions to land from the operation of the PCC Plant.

5.5 Odour

The Installation's Environmental Management System would ensure that any offsite odour issues were managed in accordance with the Enquires and Complaints Procedure (HR-TEC-ENV-004) which is reviewed annually, or in the event of odour complaints being received by the Installation.

The potential for odour to occur from the PCC Plant will be dependent on the volatility of the Cansolv DC-103 solvent. Cansolv DC-103 has a low volatility. Its boiling point is 105°C, i.e. higher than water, and it has a very low vapour pressure of <0.13 hPa at 20°C. Although it is described as having a 'sweet' odour, it is considered that due to its low volatility there is minimal potential for odour issues to arise through its use.

Ammonia is already used within the FCC area, and therefore its use within the SCR is unlikely to introduce further potential for odour issues arising from its use. Design development will consider options to minimise potentially odourous emissions associated with the off-loading, storage and use of liquid ammonia.

In the unlikely event that normal or abnormal emissions to air result in nuisance odour complaints during the operation of the PCC Plant, these would be recorded under the Environmental Complaints and Enquires Procedure.

5.6 Noise

The PCC Plant will be designed such that where possible plant and equipment will meet 80dB $L_{Aeq,T}$ at 1m, however there will be some key plant which will not be capable of meeting this specification, specifically:

- CO_2 Compressor (HP and LP);
- the steam turbine;
- the MVR Compressor; and
- fin-fan dual unit.

Specific noise mitigation for the PCC Plant has not been confirmed at this stage of the project, however these will be developed during the ongoing detailed design. Examples of mitigation measures that may be employed are discussed in Section 7.4.1.2. An assessment of the potential worst-case noise impacts has been completed for this Environmental Permit variation application and the Noise Impact Assessment (NIA) is provided in Appendix F. It is proposed that once detailed design has been completed, and noise mitigation measures have been fully developed, the NIA will be revised to determine more realistic noise impacts, and a Pre-operational Condition is proposed to provide the updated NIA to the EA.

There has been an existing Noise Management Plan (NMP) for the Installation, which was managed through a number of documents within the Installation's EMS, for example; the Top Tier Environmental Management Procedure (HR-TEC-ENV-000) covers external interests and information updates for the local community; the Environmental Permit Compliance Requirements (HR-TEC-ENV-006) states that excessive noise form Refinery activity's must be minimised and all staff can draw attention to excessive noise by informing the Shift Superintendent, who is responsible for ensuring that corrective action is taken; the Environmental Enquires & Complaints Handling Procedure (HR -TEC-ENV-004) covers what to do if we receive a noise enquiry or complaint; the Environmental Management Procedure (HR-TEC-ENV-000) covers Training and Competency – including a Training Needs Analysis for all employees and includes for training on Environmental Enquires & Complaints Handling. However, for the purpose of this Environmental Permit variation application, a standalone NMP document, following the EA's NMP template has been produced and is provided in Appendix G, and will be incorporated into the Installation's EMS.

The existing EMS for the Installation contains procedures related to the operation and maintenance of plant and equipment so as to minimise the emission of noise. These procedures will be extended to cover the PCC Plant.

6. Monitoring

6.1 Infrastructure

Monitoring of all Installation infrastructure is undertaken as part of the Installation's existing management systems, operational protocols and practices.

Regular inspection of the PCC Plant infrastructure, particularly that associated with the bulk storage of chemicals will be undertaken by dedicated operators. Routine operational checks and infrastructure audits are likely to comprise identification of issues relating principally to:

- minor leaks;
- standing water in bunded areas; and
- bulk storage tank bunds.

Any issues identified during operational checks or inspections are recorded and actions assigned to relevant personnel and closed out once they have been actioned. The management systems will be extended to cover the operation of the PCC Plant, and all its associated equipment.

Process monitoring will be undertaken at key stages of the process for a suite of parameters, including flow rate, temperature, pressure and concentrations of CO_2, H_2O, O_2, SO_2, NOx. This will be used to optimise operation of the PCC Plant process.

6.2 Emissions to Air

Continuous Emissions Monitoring Systems (CEMS) are currently in place on the FCC Regenerator Emission Point A6b to monitor the following species:

- oxides of nitrogen (NOx);
- sulphur dioxide (SO_2);
- carbon monoxide (CO)
- ammonia (NH_3);
- oxygen (O_2); and
- particulates.

The new PCC Plant covers pre-treatment of FCC Regenerator emissions including the WGS, followed by CO_2 absorption. The design is such that the WGS can run while the PCC Plant is not operational, in which case emissions will be from the WGS stack (Emission Point A6d). When the PCC Plant is online, the emissions from the WGS will be routed to the CO_2 Absorber where the CO_2 is removed and the remaining emissions pass through the CO_2 Absorber stack (Emission Point A6c). As such, the compliance point for the annual ELVs while the CO_2 Absorber is online would be the new Emission Point A6c, and while the CO_2 Absorber is offline, the compliance point would be the WGS Emissions Point A6d.

Following the installation of the additional abatement and the PCC Plant, additional CEMS will be required to demonstrate compliance with the annual ELVs proposed for the PCC Plant CO_2 Absorber stack (Emission Point A6c) and the WGS stack (Emission Point A6d). Both emission points will largely have equivalent CEMS monitoring in place to the existing FCC Unit monitoring.

The CO_2 Absorber stack (Emission Point A6c) will also require additional monitoring for amines and their degradation products. Where possible this will be with additional CEMS, provided that available technologies are compatible with the amines within the Cansolv DC-103 solvent. Where this is not possible, periodic extractive monitoring will be carried out.

Given that the CCS is still an emerging technology, there are currently no recommended monitoring methodologies available. To assist with this, the EA commissioned the National Physical Laboratory (NPL) to develop periodic monitoring methods for amines and breakdown species, and the NPL has recently published a review of possible monitoring techniques[10]. The review details potential for Fourier Transform Infra-red (FTIR) and Proton Transfer Reaction-Time of Flight-Mass Spectrometry (PTR-TOF-MS) to be appropriate for monitoring amine and nitrosamine emissions, as it is capable of measuring down to parts per trillion levels, however it is not widely established nor commercially available.

In addition, the NPL review describes extractive monitoring techniques by collecting samples in solution (e.g. sulfamic acid) filled absorbers or sorbent tubes, however due to the saturated nature of the flue gas and the requirement for sorbent tubes to have a dry sample, the first technique is favoured. Limits of detection are a concern, as degradation products are predicted to be present at very low levels in the PCC Plant flue gas.

The review detailed the limitations of potential monitoring methods. For continuous monitors, the heated sample lines required due to the presence of water would be likely to lead to the degradation of nitrosamines. Alternative condenser systems would remove nitrosamines due to their solubility. PTR-TOF-MS was largely discounted due to not being commercially available.

Extractive sampling techniques were therefore favoured in the NPL review, and a laboratory trial has since been carried out to gather more information into the knowledge gaps, such as the effect of temperature on degradation, and handling and storage conditions, and whether these effect the sample. This has resulted in a proposed methodology using impingers, which was found to be suitable for a wide range of nitrosamines, but not to low volatile compounds. At the time of submission of this application, the methodology was not available.

The solvent licensor has trialled the use of PTR-TOF-MS on several pilot plant campaigns, and it has been found to bring significant benefits in terms of limit of quantification of emissions (ppbv level), as well as the range of contaminants that can be monitored, with the possibility to perform full spectrum monitoring. However, at present PTR-TOF-MS cannot yet be used for real-time monitoring, as the instrument output data must be analysed and validated by specialised third parties – in the case of the pilot plant trial carried out for Shell, the University of Oslo. It is understood that the instrument Original Equipment Manufacturer are developing commercial versions that may become available in the timeline of the Humber Refinery PCC Plant start-up. The results obtained by the solvent licensor's monitoring campaigns have been published in several articles:

- Performance of an amine-based CO_2 capture pilot plant at the Fortum Oslo Varme Waste to Energy plant in Oslo, Norway. Johan Fagerlung and al., International Journal of Greenhouse Gas Control 106 (2021).
- Recent Improvements and Cost Reduction in the CANSOLV CO_2 Capture Process. Karl Stéphenne and al., 16th International Conference on Greenhouse Gas Control Technologies, GHGT-16 - 23rd - 27th October 2022, Lyon, France.
- PPB-level monitoring of amines and NO_2 at the Klemetsrud CO_2 capture pilot plant. Bapriste Languille and al., 16th International Conference on Greenhouse Gas Control Technologies, GHGT-16 - 23rd - 27th October 2022, Lyon, France.

Several extractive sampling and analysis techniques have also been used to monitor emissions of the Cansolv systems currently in operation. They rely on an impinger train isokinetic sampling, essentially modified EPA method 5, as described for example by Ramboll Analytics (Analysis and sampling methods – post-combustion CO_2 capture processes) or Technology Centre Mongstad and reviewed by the NPL. Such techniques have been found suitable for capture of amines and nitrosamines emitted by the Cansolv system. Liquid chromatography-mass spectrometry (LC-MS) methods have been used to analyse the samples collected in many pilot campaigns, while Saskpower has also used Ionic Chromatography for amines concentration and LC-MS for nitrosamines concentration.

Further work is required, both by the NPL and Shell, to identify appropriate monitoring techniques. It is therefore proposed that a Pre-operational Condition is included in the Environmental Permit to require Phillips 66 to confirm the proposed monitoring techniques for amines and degradation products from the PCC Plant Absorber (Emission Point A6c) prior to commissioning of the PCC Plant.

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[10] National Physical Laboratory (2022) Review of Emissions from Post-Combustion Carbon Capture using Amine Based Technologies and Current monitoring Techniques. Available: Microsoft Word - Review of emissions from PCCC v3.1.docx (ukccsrc.ac.uk)

It is proposed that particulate monitoring is carried out via periodic extractive monitoring for both the WGS stack when in operation and the PCC Plant Absorber in future, given that the wet ESP will significantly reduce the particulate emission concentrations released from the FCC Regenerator.

As discussed in Section 5.1.2, it is considered that it would be unreasonable to expect that the positive action of removing the CO_2 from emissions to atmosphere to adversely impact the ability of the wider Refinery to comply with its monthly BRef Bubble limits. Therefore, it is proposed that compliance with the monthly BRef Bubble ELVs should be determined prior to the removal of CO_2 from the flue gas stream. As such, an additional compliance point for monitoring compliance with the monthly BRef Bubble ELV is proposed to be located at the exit of the flue gas from the WGS.

The CEMS for monitoring compliance with the annual ELVs on the WGS stack may be the same as the compliance monitoring point for the monthly BRef Bubble (i.e. on the outlet of the WGS), however this is dependent on the final piping configuration employed, which will not be confirmed until detailed design.

Schematics showing two proposed options for the compliance monitoring points are provided in Figure 9 (Appendix A), and the option finally employed will be dependent on the availability of suitable locations to install the CEM equipment, ensuring that the Environment Agency's Monitoring Stack Emissions: Measurement Locations Guidance[11] is complied with as far as possible, within the design constraints of the new plant.

The new Emission Points will be added to the existing site emissions monitoring plan and sample locations will be compliant with the requirements of the EA's M1 Stack Monitoring Guidance, as far as reasonably practicable.

Table S3.1 of Schedule 3 of the Environmental Permit details the emissions and monitoring from all the existing Emission Points at the Installation. The monitoring required for existing Emission Point A6b (FCC Regenerator) will need removing from the Environmental Permit and the new Emission Points require adding. The monitoring proposed for the new Emission Points is shown in Table 6.1.

Article 15(5) of the Industrial Emissions Directive (IED) allows for the competent authority to grant temporary derogations from BAT-AELs for the testing and use of emerging techniques for a period not exceeding 9 months. As the PCC Plant will be a FOAK plant, it is therefore considered that some provision for flexibility with new ELV compliance should be made during the commissioning period.

Table 6.1: Proposed Monitoring for the New Point Source Emissions to Air

Emission Point Ref.	Source	Parameter	Limit (including unit)	Reference Period	Monitoring Frequency	Monitoring Standard or Method
A6c	PCC Plant Absorber Stack	Oxides of Nitrogen (as NO_2)	50 mg/Nm^3	Annual average	Continuous	BS EN 14181
		Carbon Monoxide	100 mg/Nm^3	Daily	Continuous	BS EN 14181
		Sulphur Dioxide	50 mg/Nm^3	Annual average	Continuous	BS EN 14181
		Particulates	10 mg/Nm^3	6 monthly – average over the sample period	Periodic Extractive	BS EN 13284-2
		Ammonia	5 mg/Nm^3	Annual average	Continuous	BS EN 14181
		Total Amines	1.1 mg/Nm^3 [2]	Annual average	Continuous if suitable	BS EN 14181

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[11] Monitoring stack emissions: measurement locations - GOV.UK (www.gov.uk)

Emission Point Ref.	Source	Parameter	Limit (including unit)	Reference Period	Monitoring Frequency	Monitoring Standard or Method
		N-amines	0.003 mg/Nm^3 [2]	Annual average	CEMS are developed by PCC plant start-up, otherwise extractive monitoring methodology under development by NPL.	or NPL method under development.
		Amide	0.03 mg/Nm^3	Annual average		
		Formaldehyde	0.07 mg/Nm^3	Annual average		
		Acetaldehyde	0.20 mg/Nm^3	Annual average		
A6d[1]	WGS Stack	Oxides of Nitrogen (as NO_2)	50 mg/Nm^3	Annual average	Continuous	BS EN 14181
			300[3] mg/Nm^3	Calendar monthly mean of validated hourly averages for BRef Bubble compliance	Continuous	BS EN 14181
		Carbon Monoxide	100 mg/Nm^3	Daily	Continuous	BS EN 14181
		Sulphur Dioxide	50 mg/Nm^3	Annual average	Continuous	BS EN 14181
			600[3] mg/Nm^3	Calendar monthly mean of validated hourly averages for BRef bubble compliance	Continuous	BS EN 14181
		Particulates	10 mg/Nm^3	6 monthly – average over the sample period	Periodic Extractive	BS EN 13284-2
		Ammonia	5 mg/Nm^3	Annual average	Continuous	BS EN 14181

[1] Applicable when emissions are directly from the WGS stack and for NOx and SO_2 monthly BRef Bubble ELV compliance.
[2] Proposed emissions are provided at the expected levels, however appropriate limits will need to be confirmed with the EA following monitoring during commissioning and operation.
[3] Monthly BRef Bubble limits to be refined during the determination period, as discussed in Section 5.1.2.

The CO_2 vent will only be used during start-up of the CO_2 Compressor, when CO_2 may not meet the onward transport and storage specification. In addition, venting may also occur during process upset scenarios, however through careful process control and management CO_2 venting will be minimised as far as is possible.

No monitoring of CO_2 vent is proposed, other than recording times and duration of when venting occurs.

6.2.1 CO_2 Export Monitoring

As stated previously, the PCC Plant is being designed to achieve a capture rate of approximately 95% for baseload operation. The CO_2 for export will be required to meet the design specification of the onward transport and storage system, and therefore monitoring will be in place to ensure that this is the case.

- CO_2 mass balance;
- CO_2 in fuel combusted;
- total capture level (as a percentage);
- CO_2 released to the environment; and
- CO_2 quality

As well as ensuring compliance with the pipeline specifications, it is also a requirement of the PCC BAT Guidance that these parameters are monitored.

6.3 Emissions to Water

Table S3.2 of the existing Environmental Permit provides the emission parameters and associated emission limits and monitoring requirements for the emissions to water from the Installation's existing ETP.

Monitoring of discharges via 24-hour composite sampling is already carried out, to ensure that discharges are meeting the current Environmental Permit conditions.

As discussed in Section 5.2.1.3, other than sulphates, the PCC Plant processes are not considered to result in emissions to water that would either add additional pollutant species within the wastewaters discharged from the site, nor increase existing pollutant species concentrations over the existing Permitted values.

There are no BAT-AELs for sulphate emissions to water than can be applied to the emissions to W2. In addition, there are limited viable options for reducing the concentrations of sulphates in the WGS effluent, as discussed in Section 5.2.1.3.

It is envisaged that after dilution from other Installation wastewaters, concentrations of sulphate in the PTU wastewater to be released from Emission Point W2 will be approximately 530mg/l (with the continued use of DeSOx additive to remove 50% of the SOx from the flue gas, as proposed).

It is therefore proposed that a sulphate limit be added to the Environmental Permit, although it is anticipated that further discussions on what would be an appropriate limit will be required during the Environmental Permit determination period. This limit needs to be appropriate considering the potential for sulphates at these concentrations to result in environmental impacts in the receiving waters. The potential for environmental impacts to occur as a result of the emission of sulphates is discussed in Section 7.4.3.

There will be no change to the existing monitoring that is carried out for the W2 Emission Point, arrangements other than the additional sulphate monitoring, as a result of this Environmental Permit variation.

7. Environmental Risk Assessment (Impact Assessment)

7.1 Introduction

This section discusses the potential impact on sensitive receptors and the surrounding area and shows how the emissions from the PCC Plant have been assessed and minimised. The EA document – 'Risk assessments for your environmental permit'[12] ('EA Risk Assessment guidance'), has been used to scope and assess the emissions from the PCC Plant.

Where necessary, baseline impact assessments and appropriate modelling has been completed to ensure that any predicted significant effects on sensitive receptors can be avoided/ mitigated.

The impact assessments are reported in the relevant Appendices of this Main Supporting Document:

- Air Quality Impact Assessment (Appendix D);
- CO_2 Modelling (Appendix E); and
- Noise Impact Assessment (Appendix F).

7.2 Installation Location and Sensitive Receptors

7.2.1 Human Receptors

The closest residential receptors to the Installation are those on the eastern edge of South Killingholme village. Table 7.1 lists the human receptors in the vicinity of the Installation.

Table 7.1: Human Receptors in the Vicinity of the Installation

I.D	Receptor	NGR Grid Reference	Approximate Distance and Direction from Site
R1	Hazel Dene, Marsh Lane	517330, 417311	790m east
R2	Station House, Station Road	517333, 418345	1.6km northeast
R3	Fairfield House, North Garth	514687, 418769	1.9km northwest
R4	Old Vicarage, North Garth	514428, 418197	1.5km northwest
R5	Manor Farm, North Killingholme	514515, 417653	1.0km northwest
R6	Church Lane, North Killingholme	514763, 417331	635m northwest
R7	Westfield Farm, North Killingholme	514708, 416785	680m west
R8	Melrose, South Killingholme	515115, 416417	460m west
R9	Town St/ Humber Road, South Killingholme	515516, 416120	240m west
R10	South Killingholme Primary School	514880, 416120	760m west
R11	East End Farm	515935, 415730	100m west
R12	Immingham	517765, 415255	950m southeast

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[12] Risk Assessments for your Environmental Permit, DEFRA and EA, Published on: 1st February 2016, Last updated on: 31st August 2022, accessed at: https://www.gov.uk/guidance/risk-assessments-for-your-environmental-permit

[1] R2 is currently understood to be an unoccupied residence owned by Able Humber Ports Limited, which is proposed to be demolished as part of Able Marine Energy Park enabling works

7.2.2 Ecological Receptors

EA Risk Assessment guidance requires that the effects of stack emissions on designated ecological sites be assessed where they fall within set distances of the source, up to 10 km (or 15 km for large emitters) for European designated sites and up to 2 km for nationally designated sites.

Statutory designated sites have been identified through a desk study of the Defra Magic mapping[13] website, which identifies Sites of Special Scientific Interest (SSSIs), Ramsar sites, Special Protection Areas (SPAs) and Special Areas for Conservation (SACs). In addition, non-statutory designated receptors have also been identified, including Local Wildlife Sites (LWSs) and Sites of Importance for Nature Conservation (SINC). Table 7.2 lists the ecological receptors in the vicinity of the Installation.

Table 7.2: Ecological Receptors in the Vicinity of the Installation

I.D	Receptor	Designation	NGR Grid Reference		Approximate Distance and Direction from Site
OE1	Humber Estuary	SAC, SPA, Ramsar, SSSI	517235 - 517868	419385 - 418379	1.9m northeast
OE2	North Killingholme Haven Pits	SSSI	516875	419530	2.6km north
OE3	Swallow Wold	SSSI	516950	404990	10.7km south
OE4	Wrawby Moor	SSSI	503350	411120	13.3km southwest
E5	Eastfield Road Railway Embankment	LWS	515313	417108	100m northwest
E6	Burkinshaws Covert	LWS	516432	417874	910m north
E7	Rosper Road Pools	LWS	517224	416937	500m east
E8	Chase Hill Wood	LWS	515702	418875	1.9km north
E9	Mayflower Wood Meadow	LWS	516000	415920	10m east
E10	Homestead Park Pond	LWS/ SINC	517935	415625	900m southeast
E11	Eastfield Road Pit	SINC	515350	417040	100m northwest

There are three additional SSSI within 15 km of the PCC Plant (Kirmington Pits, Kelsey Hill Gravel Pits and South Ferriby Chalk Pit) which are designated due to their geological features. It is therefore considered that these sites will not be affected by emissions from the Installation, as the Critical Levels and Critical Loads assigned to such sites are for the protection of vegetation and ecosystems only, and therefore they have been screened from further assessment.

In addition, it is understood that the Station Road Fields LWS that was located 1 km northeast of the Installation, has been lost due to the Able Marine Energy Park (AMEP) development.

7.2.3 Geology

A small area of the Installation is underlain by superficial deposits of Tidal Flat Deposits consisting of Clay and Silt. This area is restricted to a thin strip on the northern Site Boundary.

The remaining Installation has superficial deposits of Till, Devensian – Diamicton

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[13] Defra Magic mapping accessed at http://magic.defra.gov.uk/MagicMap.aspx

The bedrock across the entire PCC Plant area consists of Burnham Chalk Formation.

7.2.4 Hydrology

There are Ordnance Survey Water Network Lines within the Installation Site Boundary near the railway lines, all of which are designated as inland rivers located on the ground surface. The Humber Estuary is located approximately 2 km east.

The surface water flooding risk for the Installation indicates there is a Low Risk (1000-year return period) to a High Risk (30-year return period) of flooding. Areas with a High Risk are mostly located in the south of the Installation and across a small area parallel to the railway lines.

The Environment Agency's flood map for planning (https://flood-map-for-planning.service.gov.uk/ accessed September 2022) indicates that the south-east corner of the Installation, is within Flood Zones 2 and 3. Flood Zone 2 are areas where there is a 1 in 100 to a 1 in 1,000 annual probability of river flooding (0.1% to 1%) or a 1 in 200 to 1 in 1,000 annual sea flooding probability (0.1% to 0.5%). Flood Zone 3 are areas assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

The remainder of the Installation is classified as Flood Zone 1, which has a less than 1 in 1,000 annual probability of river or sea flooding (<0.1%). The flood zones do not take into account the presence of flood defences in the area.

7.2.5 Hydrogeology

The superficial Tidal Flat deposits (Clay and Silt) are classified as an Unproductive Aquifer. The Environment Agency (EA) defines an Unproductive Aquifer as *"largely unable to provide usable water supplies and are unlikely to have surface water and wetland ecosystems dependent on them"*.

The superficial Devensian Till (Diamicton) deposits are classified as a Secondary Undifferentiated Aquifer. The EA defines a Secondary Undifferentiated Aquifer as *"where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value"*.

The Burnham Chalk Formation underlying the Devensian Till (Diamicton) deposits is classified as a Principal Aquifer. The EA defines a Principal Aquifer as an aquifer that can "*provide significant quantities of drinking water, and water for business needs. They may also support rivers, lakes and wetlands*".

The Envirocheck Report (285387654_1_1) (see ES, Appendix B, Volume II, Appendix 10A) indicates the Principal Bedrock Aquifer within the Burnham Chalk Formation has a combined vulnerability of Low in the areas where it is underlain by the Tidal Flat deposits (Clay and Silt). This is due to the combination of a productive bedrock aquifer and an unproductive superficial aquifer associated with the Tidal Flat deposits (Clay and Silt). The EA describe Low vulnerability as *"areas that provide the greatest protection to groundwater from pollution. They are likely to be characterised by low leaching soils and/or the presence of low permeability superficial deposits"*. The 1:100,000 Groundwater Vulnerability Map on Magic Maps also suggests this area has a Low vulnerability.

The Secondary Undifferentiated Aquifer within the Devensian Till (Diamicton) deposits has a vulnerability of Medium to Low. This is due to the combination of a productive bedrock rock aquifer and a productive superficial aquifer. The EA describe Medium vulnerability as *"areas that offer some groundwater protection. Intermediate between high and low vulnerability"*.

The entire Installation is classified as a Source Protection Zone (SPZ) 3 (Total Catchment) and could be associated with an SPZ1 located approximately 1 km south-east and 2.52 km north-west from the Installation.

The Envirocheck report contains thirteen records for groundwater abstractions within the Installation, although no end dates for the abstraction permits were provided. The current Humber Refinery Abstraction Licence (AN/029/0009/001/R01) for two boreholes has been confirmed with Phillips 66. The licence was issued on 14th July 2017, with an effective date of 1st April 2018. The abstraction licence will expire on 31st March 2030.

7.3 Pathways for Pollution

In order for a pollution risk to occur, there has to be a source - pathway - receptor (S-P-R) linkage. Pathways to sensitive receptors primarily include, but are not limited to, the following:

- chemicals required for the operation of the PCC Plant could be accidentally released and leach into the ground and groundwater;
- chemicals required for the operation of the PCC Plant could be accidentally released into surface water via Emission Point W2;
- chemicals within the discharged effluent to Emission Point W2; and
- flue gases from the PCC Plant will be dispersed in the air to sensitive receptors.

In order to prevent and minimise the risk of pollution, the PCC Plant will be designed and managed to isolate or reduce the effectiveness of these pathways, preventing contaminants from migrating off site other than through properly managed abatement systems.

The detailed description provided in Section 4 demonstrates how BAT has been applied to prevent pollution from the PCC Plant.

7.4 Impact Assessment

The following sections provide an assessment of the impact of releases from the PCC Plant, so as to underpin and justify the measures that will be put in place for their control and that will adequately protect the environment.

The risk assessment approach has been based on the following four sequential stages:

- identify risks from the activity;
- assess the risks and check that they are acceptable;
- justify appropriate measures to control the risks, if necessary; and
- present the assessment as detailed in the EA Risk Assessments guidance.
- activities with the potential to impact on the surrounding environment have been identified in line with guidance provided by the EA, and include the following assessments:
- amenity and accidents;
- emissions to air;
- emissions to surface water;
- site waste;
- global warming potential; and,
- site closure.

7.4.1 Amenity and Accidents

A qualitative risk assessment covering potential minor accidents has been undertaken for the PCC Plant activities and is included in Appendix K of this document.

A short description of the key potential risks from the PCC Plant is provided in the following subsections.

7.4.1.1 Odour

Storage of ammonia for the SCR unit, and storage and use of amines within PCC Plant, may have the potential to generate odour.

The Installation currently utilises ammonia at small scale, and therefore is experienced in appropriate handling to minimise the potential for odour. The bulk ammonia storage and handling facilities will be appropriately designed so as to minimise potential for odour.

The site also handles amines, however the Cansolv DC-103 solvent is considered to be a very low odour risk, due to its very low volatility, as detailed in Section 4.4.5.

7.4.1.2 Noise and Vibration

An assessment of operational noise and vibration from the PCC Plant is provided in the Noise Impact Assessment (Appendix F).

The assessment of operational sound levels has been based upon calculations taking account of proposed plant and equipment sound power levels (L_w) relating to the proposed plant, distance between the proposed plant and Noise Sensitive Receptors (NSRs) and the acoustic screening offered by existing topography and existing and proposed new buildings.

Three-dimensional noise propagation models have been developed using the noise modelling software SoundPlan Version 8.2 to assess the current layout options for the PCC plant. SoundPlan implements the noise prediction method ISO 9613-2: 1996 'Attenuation of sound during propagation outdoors' (ISO, 1996), which has been employed to calculate sound levels at surrounding NSRs due to the operation of the PCC Plant.

Topographical features and buildings that may influence the transmission of sound to NSRs are included in the noise model. A digital terrain model created using publicly available ground elevation spot height data have been used to position buildings and other noise sources at the proposed heights relative to ground. Areas of acoustically soft (e.g. vegetation) and hard (e.g. concrete) ground have been identified from the Ordnance Survey MasterMap Topographic Layer and modelled accordingly.

The prediction method assumes that the prevailing wind direction is always from source to receiver, which is likely to overestimate the noise effects associated with the PCC Plant for much of the time for many NSRs given the predominant wind direction in the UK is from the south-west, i.e. away from the receptors.

Based upon the predicted sound levels from the noise model, an assessment of potential noise impact at nearby NSRs has been undertaken using the guidance in BS 4142:2014+A1:2019 'Methods for rating and assessing industrial and commercial sound' (BSI, 2014c).

The assessment concluded that for the worst-case scenario assessed, potentially significant impacts could occur at NSRs, subject to consideration of context. Phillips 66 are already a continuously operating industrial source in the study area, and there are other industrial/ commercial activities in the area, therefore it is likely that residents at all NSR are already accustomed to industrial noise sources.

Potential mitigation measures and general principles to minimise the impact on NSRs may include, but are not limited to, the following measures, depending upon the potential benefits achieved from such measures:

- reducing the breakout noise from the PCC Plant through the use of enhanced enclosures, or potentially containing them within a building;
- reducing air inlet noise emissions by the addition of further in-line attenuation;
- reducing stack outlet noise emissions by the addition of silencers or sound proofing panels;
- reducing fin fan cooler noise emissions by screening, re-sizing, fitting low noise fans or attenuation;
- screening or enclosing the compressors or other equipment;
- use of screening or bunding to shield receptors from noise sources; or
- orientation of plant to provide screening of low-level noise sources by other buildings and structures, or orientating fans and the air inlets away from NSRs.

Specific measures to be applied for mitigating noise emissions will be confirmed during the detailed design phase, and be provided to the EA for approval prior to commencement of operations.

7.4.1.3 Fugitive Emissions

Based on the various controls placed on the PCC Plant and equipment, it is expected that fugitive emissions, particularly process emissions to air and water will be negligible.

7.4.1.4 Visible Plumes

The Air Quality Impact Assessment (Appendix D, Annex E) includes a plume visibility assessment for the PCC Plant Absorber stack.

Visible plumes are predicted to occur for up to 22% of the time, with average plumes being up to 12m. Occasional longer plumes are predicted (up to 241 m), however these are predicted to occur for less than 1% of the time.

7.4.1.5 Accidents

The Installation is an Upper Tier COMAH site and therefore has a site Safety Report which considers all the Major Accident and Disasters foreseeable at the site. This will be updated to include considerations relating to the installation of the PCC Plant as needed.

In addition, a Major Accident and Disasters assessment has been carried out for the ES (Appendix B (see Volume I, Chapter 16)), which details the main hazards for the PCC Plant and identifies appropriate precautionary actions, to prevent or mitigate potentially significant risks associated.

For the management of day-to-day minor accidents, an Environmental Incident Reporting and Classification procedure is in place for the Installation and will be amended to include the PCC Plant including all associated equipment prior to commencement of the PCC Plant's operation. A number of environmental protection measures will be implemented on site via the EMS to prevent and control spill events, including but not limited to:

- plans to deal with accidental pollution and any necessary equipment (e.g. spill kits) will be held within the PCC Plant area and all site personnel will be trained in their use. The EMS details how to appropriately deal with accidental spillages;
- implementation of containment measures, including bunding for bulk storage tanks. All chemicals will be stored in accordance with relevant design and containment standards (i.e. CIRIA C736);
- incorporation of interceptors into the drainage system to prevent spilled oils entering the surface water drainage system or local water bodies; and,
- in case of a fire, the firewater will be contained on site and will subsequently be disposed off-site if contaminated or processed through the onsite ETP.

The EMS details controls in place to reduce emissions to air and/ or water during other than normal operating conditions (OTNOC) that includes the following elements:

- set-up and implementation of a specific preventive maintenance plan for these relevant systems;
- review and recording of emissions caused by OTNOC and associated circumstances and implementation of corrective actions if necessary;
- periodic assessment of the overall emissions during OTNOC (e.g. frequency of events, duration, emissions quantification/ estimation) and implementation of corrective actions if necessary.

The relevant management systems, procedures and protocols will be amended to include the PCC Plant prior to commencement of operations.

7.4.1.6 Flood Risk Assessment

A copy of the Flood Risk Assessment (FRA) undertaken for the Environmental Statement for the PCC Plant is included in the ES (Appendix B (see Volume II, Appendix 9A)).

The FRA details that the PCC Plant area will be located in Flood Zone 1, land assessed as having a less that 0.1% Annunal Exceedance Probability (AEP) of fluvial or tidal flooding (1 in 1,000-year return period) in any year.

As part of the development of the FRA, the EA has confirmed that tidal defences, consisting of earth embankments and concrete floodwalls protect the Installation. The EA owns, inspects and maintains these defences and advises that the defences are in fair condition and reduce the risk of flooding (at the defence) up to the 0.5% AEP (1 in 200-year return period) flood event. The flood defences (located along the coastline at South Killingholme) range in crest height from 5.96 m Above Ordnance Datum (AOD) to 6.35 mAOD.

The EA has provided breach location and associated breach hazard map, which is detailed in the FRA. Although a breach of flood defences would represent a significant hazard, the likelihood of breach is low, however the National Planning Policy Framework still requires plans and mitigation to be put in place to manage the risks should a tidal breach occur.

This risk of tidal flooding is considered to be low, given that the flood defences are approximately 0.59m higher than the critical flood level of 5.37 mAOD (including an allowance for sea level rise).

The risk of fluvial flooding for the Installation is considered to be low, given that the site is not located in proximity to any main rivers. There is a residual risk of flooding from ordinary watercourses in the event that they become tide locked.

The following mitigation measures are considered appropriate and will be utilised as needed to protect the PCC Plant, in accordance with the relevant legislative and regulatory authority requirements:

- critical infrastructure will be located at existing ground level for operational reasons therefore flood resilience and resistance measures will be put in place (e.g. raised plinths, watertight housing bunding where practicable etc), as with other critical infrastructure within the Installation;
- pipelines and storage tanks designed to withstand the water pressures associated with high return period event flooding;
- tanks securely tethered in such a way to ensure the infrastructure remains secure should flooding occur;
- electrical supply entering the PCC Plant from height and down to required connections;
- use of flood barriers on access points;
- protecting wiring for operational control of the PCC Plant, telephone, internet and other services by suitable insulation in the distribution ducts to prevent damage;
- materials with low permeability up to 0.3m and accept water passage through building at higher water depths;
- flood proofing including the use of flood resistant building materials, use of water-resistant coatings, use of galvanised and stainless steel fixings and raising electrical sockets and switches;
- utilising floor materials that are able to withstand exposure to floodwater without significant deterioration and that can be easily cleaned, e.g. concrete-based or stone;
- incorporating water resistant services within the buildings, i.e. avoid services using ferrous materials;
- design development to drain water away after flooding;
- provide access to all spaces to permit drying and cleaning;
- carefully considering the usage and layout of ground floor areas to minimise the potential impact on business operations following a flood;
- suitable waterproofing measures to development located below ground i.e. tanking below ground storage areas etc.; and
- updates to the existing Emergency Response Assessment and Emergency Response Plans, and provision of Emergency access and egress. Safe refuge will be provided to allow any individuals on the Site to wait safely until the flooding subsides or rescue can be affected.

7.4.2 Emissions to Air

An Air Quality Impact Assessment has been carried out for the PCC Plant, with reference to the EA Risk Assessment guidance, and is provided in Appendix D. The air dispersion modelling exercise has been undertaken to:

- assess the impact on local air quality as a result of the anticipated emissions identified in Table 5.1 above; and
- confirm the heights of the new Emission Point stacks so as to ensure adequate dispersion for the PCC Plant Absorber stack and the WGS stack, therefore ensuring acceptable impacts at receptors.

In addition to the dispersion modelling, a H1 screening assessment has been carried out to determine the impacts of metals present in the emissions from Emission Point A6c and A6d, to ensure that these will not have an adverse impact on human health given the reduction in the release height from the existing FCC Unit stack.

The key findings of the assessments are summarised below.

7.4.2.1 Impact on Local Air Quality

The additional secondary abatement to reduce the emission concentrations of NOx, SOx and particulates prior to the PCC Plant, will mean that there will be an overall reduction in the mass emissions of these pollutant species from the FCC Unit. The reduction in particulates will also lead to a reduction in the metal present in the emission.

However, there will be additional emissions of amines and their degradation products, as a result of the operation of the PCC Plant.

Detailed dispersion modelling has been used to calculate the Process Contributions (PCs) of pollutants at identified sensitive receptors and these have been compared with National Air Quality Strategy (NAQS) objectives and Environmental Assessment Levels (EALs) for human health receptors, and Critical Levels and Critical Loads for ecosystems, with consideration of the baseline air quality and ecological deposition rates, in accordance with the EA Risk Assessment guidance.

The assessment compares the predicted impacts of the future operation of the PCC Plant under normal operating conditions (i.e. the FCC Unit exhaust gas being abated by the PCC Plant, operating for 8,760 hours per year), to the current unabated operation of the FCC Unit to the existing Emission Point A6b.

The dispersion modelling assessment has considered the effects from combustion emissions of NOx, CO, SO_2 and particulates, associated with the operation of the FCC Unit, with consideration also of the impacts from NH_3 slip (from the SCR). These emissions have been assessed as occurring from both the PCC Plant and also the WGS, for periods when the PCC Plant is not operational.

In addition, emissions of amines and their potential degradation products from the PCC Plant have also been assessed.

7.4.2.1.1 Detailed Dispersion Modelling Results

The maximum PCs at the worst-case human health receptor of all species released except N-amines, can be screened as 'insignificant' by the dispersion modelling, at the first stage of screening, being either below the 10% threshold for short-term impacts, or the 1% threshold for annual mean impacts, when the emissions occur from either the WGS or the PCC Plant. In addition, the impacts at the worst-case human health receptor generally show a slight reduction over the current level of impacts from the FCC Unit Emission Point A6b.

The assessment of impacts at human health receptors has also considered the impact of emissions of N-amines degradation products from the PCC Plant. This assessment considers both the direct release of N-amines from the PCC Plant, as a result of solvent degradation within the process, and also the subsequent atmospheric degradation of the amines released from the stack.

Although there is large uncertainty in the modelling methodology for the atmospheric degradation of amines, the modelling assessment carried out takes into account worst-case assumptions and shows that an exceedance of the EAL is very unlikely as a result of the operation of the PCC Plant.

The impacts at ecological receptors have also been determined, and the assessment results show that there is generally a slight reduction in the predicted impacts at all receptors over the current operation of the FCC Unit, specifically for annual average and daily average NOx and SO_2. There are slight increases in NH_3 impacts, but these are considered to be insignificant.

Deposition impacts have also been assessed, and the full results are presented in Air Impact Assessment in Appendix D. Both the nutrient nitrogen and acid depositional impacts are largely insignificant (< 1% of the relevant critical loads at the majority of ecological sites), and where this is not the case, the increase in impacts is <1%, and therefore considered to be insignificant.

7.4.2.1.2 H1 Screening Assessment of Metals

The existing particulate ELV of 50mg/Nm^3 is anticipated to reduce to emissions below 10mg/Nm^3. This will therefore correspondingly result in a significant reduction in the metals concentrations in the emissions to air from the WGS/ CO_2 Absorber stacks.

Analysis carried out on the catalyst fines over the last 15 months has been reviewed and the relevant proportions of antimony, copper, nickel and vanadium have been determined and applied to the proposed future ELV of 10mg/Nm^3 to determine the future concentrations of the relevant metals in the

WGS/ CO_2 Absorber emission. This is shown in Table 7.3. Note the difference in emission concentrations between the WGS and the CO_2 Absorber is due to the different flow rates given the removal of the CO_2 from the flue gas in the CO_2 Absorber.

Table 7.3: Proportions of Relevant Metals in the Catalyst Fines and Corresponding Future Emissions

Substance	Proportion in Catalyst Fines	Concentration in CO_2 Absorber (A6c) Emission (mg/Nm^3)	Concentration in WGS Emission (A6d) (mg/Nm^3)
Nickel	0.08%	0.0080	0.0068
Antimony	0.002%	0.00016	0.00013
Vanadium	0.18%	0.018	0.016
Copper	0.002%	0.00021	0.00018

The calculated concentrations are approximately a fifth of the current measured concentrations, which corresponds to the reduction in the existing particulate ELV from 50mg/Nm^3 to the future proposed ELV of 10mg/Nm^3.

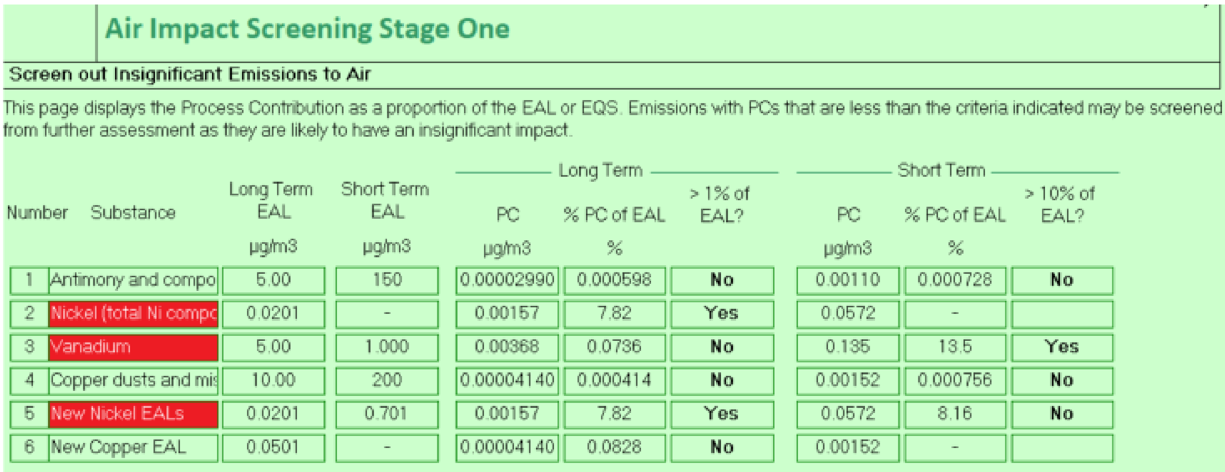
The calculated emission concentrations have been assessed using the Environment Agency H1 Access Database Screening Tool (Appendix H), to determine whether there are likely to be any environmental impacts associated with the metals emissions from the new stacks. As H1 only takes into account the effective stack height, flow rate and concentration, the emissions have been assumed to only occur from the WGS, as even though the concentrations are lower in the WGS, the higher flow rate from the WGS results in a slightly higher mass emission (and therefore results in higher Process Contributions (PCs)). The effective stack height and the emission concentrations are the same for both sources.

The effective stack height of the WGS stack has been calculated as follows:

Actual Stack Height = 65m
Absorber Building Height (highest building) = 51m

Effective stack height is therefore 65 - 51 = 15 x 1.66 = 23.2m

There are proposed new EALs for nickel and copper which have undergone public consultation but have not yet been adopted. The H1 assessment has been carried out to include the existing EALs and the new proposed EALs, and the Stage 1 screening results are shown below:



Air Impact Screening Stage One

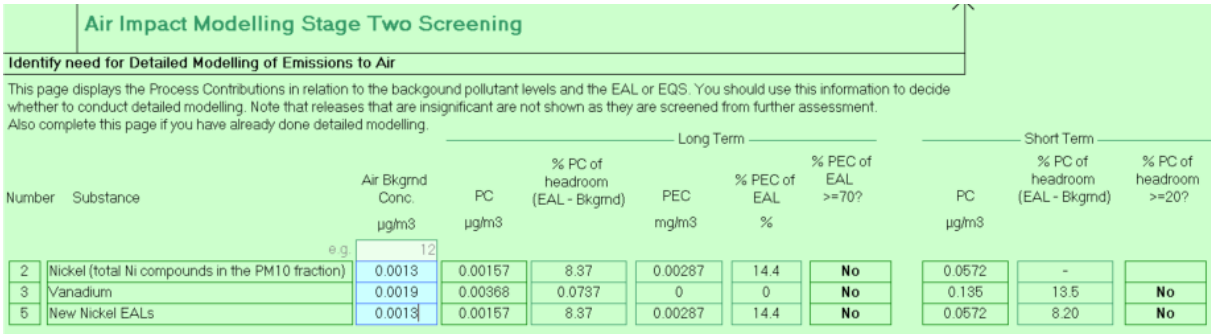
Screen out Insignificant Emissions to Air

This page displays the Process Contribution as a proportion of the EAL or EQS. Emissions with PCs that are less than the criteria indicated may be screened from further assessment as they are likely to have an insignificant impact.

Number	Substance	Long Term EAL µg/m3	Short Term EAL µg/m3	Long Term PC µg/m3	Long Term % PC of EAL %	Long Term > 1% of EAL?	Short Term PC µg/m3	Short Term % PC of EAL %	Short Term > 10% of EAL?
1	Antimony and compo	5.00	150	0.00002990	0.000598	No	0.00110	0.000728	No
2	Nickel (total Ni compc	0.0201	-	0.00157	7.82	Yes	0.0572	-	
3	Vanadium	5.00	1.000	0.00368	0.0736	No	0.135	13.5	Yes
4	Copper dusts and mi	10.00	200	0.00004140	0.000414	No	0.00152	0.000756	No
5	New Nickel EALs	0.0201	0.701	0.00157	7.82	Yes	0.0572	8.16	No
6	New Copper EAL	0.0501	-	0.00004140	0.0828	No	0.00152	-	

The first stage of screening, screens out antimony and copper (based on both the current and new proposed EAL), with PCs that are less than 1% of the annual average EAL and less than 10% of the EAL for the hourly average.

The results of the second stage of screening are shown below. Background metals concentrations have been taken to be the worst case of average 2022 values from either the Scunthorpe Town or Scunthorpe Low Santon monitoring site:



Air Impact Modelling Stage Two Screening

Identify need for Detailed Modelling of Emissions to Air

This page displays the Process Contributions in relation to the backgound pollutant levels and the EAL or EQS. You should use this information to decide whether to conduct detailed modelling. Note that releases that are insignificant are not shown as they are screened from further assessment.
Also complete this page if you have already done detailed modelling.

			Long Term					Short Term		
Number	Substance	Air Bkgrnd Conc. µg/m3	PC µg/m3	% PC of headroom (EAL - Bkgrnd)	PEC mg/m3	% PEC of EAL %	% PEC of EAL >=70?	PC µg/m3	% PC of headroom (EAL - Bkgrnd)	% PC of headroom >=20?
	e.g.	12								
2	Nickel (total Ni compounds in the PM10 fraction)	0.0013	0.00157	8.37	0.00287	14.4	**No**	0.0572	-	
3	Vanadium	0.0019	0.00368	0.0737	0	0	**No**	0.135	13.5	**No**
5	New Nickel EALs	0.0013	0.00157	8.37	0.00287	14.4	**No**	0.0572	8.20	**No**

Nickel (based on both the current and new proposed EAL) and vanadium are screened out from requiring further assessment through dispersion modelling at the second stage of screening, with annual average PECs less than 70% of the EALs and hourly PCs being less than 20% of the headroom.

No further assessment of metals impacts is therefore required given that they have been demonstrated through H1 to be not significant.

7.4.3 Emissions to Water

A H1 assessment to determine the potential impacts on receiving waters from the PCC Plant wastewaters, has been carried out and is detailed in the following sections. The H1 Access Database Screening Tool is provided in Appendix H.

Emissions of wastewater from the PCC Plant area will be discharged to South Killingholme Drain (SKD) via existing Emission Point W2. As detailed in Section 5.2.1 the discharges will remain within the existing emission limit values applied to this emission point. The only new component of the discharge, which does not have a current emission limit is sulphate.

Although the discharges from the PCC Plant will not result in changes to the W2 emission limits for chemical species that are already released, the H1 assessment has been carried out to determine the impact of the releases without the PCC Plant effluent (i.e. a baseline assessment) and then with the PCC Plant effluent (i.e. a future assessment), to determine the additional impact from the PCC Plant. It should be noted that the Humber Refinery responded to an improvement condition within their existing Environmental Permit (IC 28 and IC29[14]) with a H1 assessment of their existing effluent discharge in 2021 ('the Wood Report'). This assessment identified exceedances of some Environmental Quality Standards (EQS) for some of the pollutant species that will also be present in the PCC waste waters and this work is still under review with the EA.

7.4.3.1 Receiving Environment

Emission Point W2 flows into SKD, part of the North-East Lindsey Internal Drainage Board (IDB) network, which comprises three drains:

- A drain running west to east across the land to the south of the Humber Refinery (which includes any flows from intercepted headwater catchment areas to the east of South Killingholme, which are small, ephemeral and poorly connected);
- A drain to the west of Rosper Road into which VPI Immingham and potentially Lindsey Oil Refinery (LOR) currently discharges process water; and
- A drain to the east of Rosper Road, the source of which is uncertain but may include industrial discharges.

The drains combine before passing beneath Rosper Road in a small culvert and continuing south and then east where it eventually discharges to the Humber Estuary approximately 1 km east of Rosper Road. It flows into the Humber Estuary at the Port of Immingham. The Humber Estuary, at the point where SKD enters it, is designated under the Water Framework Directive (WFD), (Classifications and Standards) Directions (England and Wales) 2015 as the Humber Lower transitional water body.

When the tide is high, the water in SKD is prevented from flowing into the estuary due to the presence of tidal flaps and the watercourse is effectively 'tide locked'. This has a significant effect on the flow

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[14] Wood Group UK Limited (2021). Phillips 66 Limited. Humber Refinery – Environmental Permit Improvement Conditions IC28 and IC29. Environmental Risk Assessment.

regime causing a twice daily rise and fall in the water level in SKD. At low tide, flows from SKD run briefly across the intertidal mud area into the Estuary.

The other major control on the flow regime of SKD is the dominance of surface water runoff and treated effluent from industrial sites, which it is estimated make up around 97% of the total flow volume.

South Killingholme Drain itself is not classified under the WFD as a water body, and although WFD principles and objectives do extend to cover the entire catchment area of the North Beck Drain catchment (which SKD falls within) it should be noted that there is no hydrological connection between SKD and North Beck Drain.

Ecological surveys were carried out as part of the ES for the TCPA (Appendix B, Volume I, Chapter 13 Ecology and Nature Conservation) and confirmed that SKD had limited aquatic and marginal vegetation, which was limited to fennel-leaved pondweed and fool's watercress. Bankside vegetation comprises tall herbs to both banks and mixed scrub on the north bank.

SKD was surveyed from within the channel all the way through to the VPI Immingham CHP Power Station downstream, beneath Rosper Road, to its discharge point into Rosper Road Pools in 2022 and there was no evidence of protected species including water voles or otter.

SKD has limited geomorphic features, poor water quality and low habitat quality and biodiversity. It is therefore considered that it has negligible ecological value due to poor hydrological flow conditions, lack of geomorphic diversity and substrate and poor water quality.

Given that it has negligible ecological value and comprises 97% of industrial surface water run-off and effluent, it is considered that SKD should be classified as an industrial drain rather than a freshwater water course. Whilst it is recognised that the original PPC Permit Application for the Refinery from 2006 identified SKD as a freshwater course, it is considered that this was done purely on the basis of the distinction between the freshwater/ saline water categories employed for the EA's H1 screening assessment tool, and not due to any official classification given to the drain. As SKD is estimated to comprise around 97% of surface water runoff and treated effluent from industrial sites it would be unreasonable to consider it a freshwater water course.

SKD is hydrologically connected (via a shallow weir) to Rosper Road Pools, as a result of its function as surface water storage during periods of high rainfall when the tidal flaps at the outfall are closed at high water. Rosper Road Pools is an LWS which is functionally linked to the Humber Estuary SPA/ Ramsar due to its supporting function to the qualifying species of birds, which was confirmed through surveys carried out for the preparation of the ES. It provides feeding, loafing and roosting habitat for birds at high tide, as well as nesting habitat for avocet. Given this connectivity, the potential for pollution to surface water from PTU wastewater, may change the water chemistry and thus affect aquatic organisms on which designated features of the Humber Estuary feed.

Water quality and hydrological monitoring has been carried out during a 5-month period (July – November 2023) to provide a greater understanding of the water quality and connectively between SKD, Rosper Road pools and the Humber Estuary ('the AECOM Report', provided in Appendix I). The data collected has been used to develop a conceptual site model of the hydrological connectivity, which is presented along with the monitoring data and a simple mass balance and dilution analysis of the sulphate in the receiving waters.

7.4.3.2 H1 Assessment

The EA's H1 screening assessment tool can be used to assess impacts to freshwaters and to estuaries and coastal waters (TRaC) waters. Given that SKD is estimated to be 97% surface water runoff and treated effluent from industrial sites at the point of discharge to the Humber Estuary, and is surveyed as having negligible ecological value, it is therefore considered that this receptor does not represent a freshwater receiving water in its true sense, as previously discussed. As such, it could be considered that SKD does not represent an appropriate compliance point for assessing the impacts of the wastewater discharges from W2 and that a more appropriate compliance point would be the Humber Estuary. The H1 assessment has therefore been carried out for both the SKD and the Humber Estuary receiving waters, in line with the assessment carried out for the Wood Report.

There is no flow monitoring upstream of the Humber Refinery, and therefore flow data from the Wood Report has been used for inclusion in the H1 assessment tool (a baseline 95%ile (Q95) flow value of 0.002m^3/s).

The flow in SKD immediately upstream of the Humber Refinery only equates to <2% of the flow in SKD downstream of the W2 Emission Point. As such neither the Wood Report nor the AECOM Report sampled water quality in SKD upstream of the Humber Refinery. Background pollutant concentrations in SKD are therefore assumed to be zero for the purpose of the H1 assessment.

The H1 assessment has included sulphates, total Nitrogen (as N) and nickel, vanadium, copper and iron at the concentrations detailed in Table 5.3, assuming that DeSOx is applied to remove 50% of the SOx from the FCC flue gas prior to treatment in the WGS.

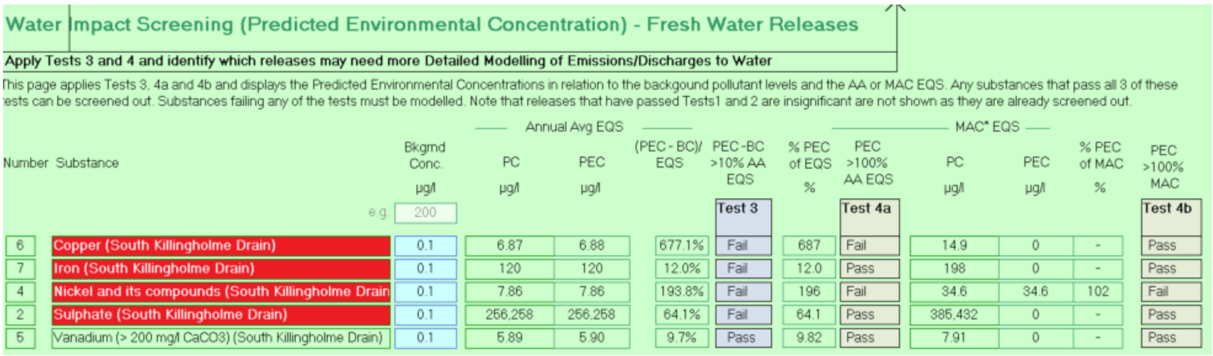
H1 Assessment for SKD

The EA's Surface Water Pollution Risk Assessment for your Environmental Permit guidance[15] details a number of screening steps for the H1 assessment for freshwaters as follows:

- Test 1 – screen-out substances whose concentration in the discharge does not exceed 10% of the EQS applicable to freshwaters;
- Test 2 – calculate the PC of the substance in the receiving water downstream of the discharge and screen-out substances whose PC is <4% of the EQS;
- Test 3 – Calculate the PEC and screen-out substances where the difference between the concentration of the substance upstream of the discharge and downstream is <10%; and
- Test 4 - The PEC in the receiving water downstream in the receiving water downstream is less than the EQS.

Substances can only be screened out at stages 3 and 4 if both Test 3 and Test 4 apply.

The baseline impacts of the existing effluent discharge are shown below:



Water Impact Screening (Predicted Environmental Concentration) - Fresh Water Releases

Apply Tests 3 and 4 and identify which releases may need more Detailed Modelling of Emissions/Discharges to Water

This page applies Tests 3, 4a and 4b and displays the Predicted Environmental Concentrations in relation to the backgound pollutant levels and the AA or MAC EQS. Any substances that pass all 3 of these ests can be screened out. Substances failing any of the tests must be modelled. Note that releases that have passed Tests1 and 2 are insignificant are not shown as they are already screened out.

			Annual Avg EQS						MAC* EQS			
Number	Substance	Bkgrnd Conc. µg/l	PC µg/l	PEC µg/l	(PEC - BC)/ EQS	PEC-BC >10% AA EQS	% PEC of EQS %	PEC >100% AA EQS	PC µg/l	PEC µg/l	% PEC of MAC %	PEC >100% MAC
		e.g. 200				Test 3		Test 4a				Test 4b
6	Copper (South Killingholme Drain)	0.1	6.87	6.88	677.1%	Fail	687	Fail	14.9	0	-	Pass
7	Iron (South Killingholme Drain)	0.1	120	120	12.0%	Fail	12.0	Pass	198	0	-	Pass
4	Nickel and its compounds (South Killingholme Drain	0.1	7.86	7.86	193.8%	Fail	196	Fail	34.6	34.6	102	Fail
2	Sulphate (South Killingholme Drain)	0.1	256,258	256,258	64.1%	Fail	64.1	Pass	385,432	0	-	Pass
5	Vanadium (> 200 mg/l CaCO3) (South Killingholme Drain)	0.1	5.89	5.90	9.7%	Pass	9.82	Pass	7.91	0	-	Pass

Although it is assumed that the background concentrations in SKD is zero, Tests 3 and 4 require a value to be entered into the 'Background Concentration' column to enable the tests to be applied. An arbitrary value of 0.1µg/l has therefore been entered.

Only vanadium passes the screening tests for the baseline assessment.

The figures in the H1 assessment presented above are very similar to figures that have previously been provided to the EA for these species, as part of the Wood Report addressing Improvement Conditions IC28 and 29 within the existing Environmental Permit. As stated previously, this work is still under review with the EA.

The future impacts with the PTU wastewater stream are shown below:

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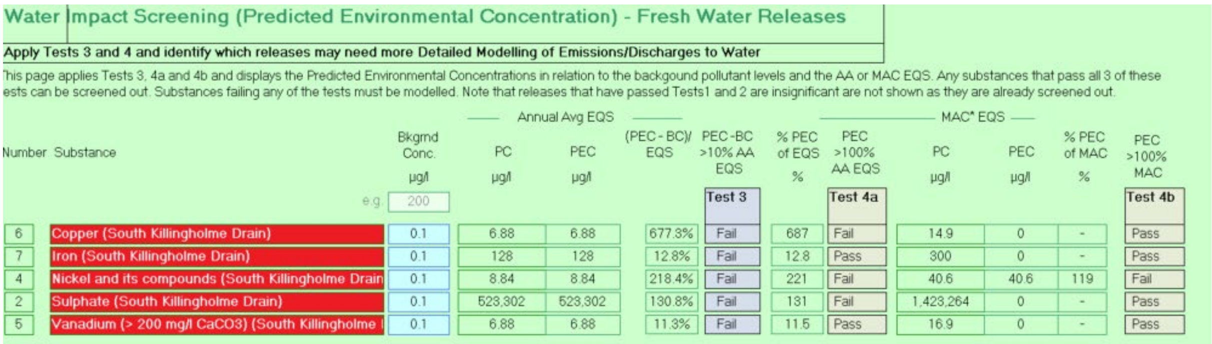
[15] Surface water pollution risk assessment for your environmental permit - GOV.UK (www.gov.uk)



Water Impact Screening (Predicted Environmental Concentration) - Fresh Water Releases

Apply Tests 3 and 4 and identify which releases may need more Detailed Modelling of Emissions/Discharges to Water

his page applies Tests 3, 4a and 4b and displays the Predicted Environmental Concentrations in relation to the backgound pollutant levels and the AA or MAC EQS. Any substances that pass all 3 of these ests can be screened out. Substances failing any of the tests must be modelled. Note that releases that have passed Tests1 and 2 are insignificant are not shown as they are already screened out.

			Annual Avg EQS						MAC* EQS			
Number	Substance	Bkgrnd Conc. µg/l	PC µg/l	PEC µg/l	(PEC - BC)/ EQS	PEC -BC >10% AA EQS	% PEC of EQS %	PEC >100% AA EQS	PC µg/l	PEC µg/l	% PEC of MAC %	PEC >100% MAC
	e.g.	200				Test 3		Test 4a				Test 4b
6	Copper (South Killingholme Drain)	0.1	6.88	6.88	677.3%	Fail	687	Fail	14.9	0	-	Pass
7	Iron (South Killingholme Drain)	0.1	128	128	12.8%	Fail	12.8	Pass	300	0	-	Pass
4	Nickel and its compounds (South Killingholme Drain	0.1	8.84	8.84	218.4%	Fail	221	Fail	40.6	40.6	119	Fail
2	Sulphate (South Killingholme Drain)	0.1	523,302	523,302	130.8%	Fail	131	Fail	1,423,264	0	-	Pass
5	Vanadium (> 200 mg/l CaCO3) (South Killingholme	0.1	6.88	6.88	11.3%	Fail	11.5	Pass	16.9	0	-	Pass

It can be seen that there is only a 0.2% increase in the impacts of copper and only a 0.8% increase in impacts of iron as a result of the future releases to SKD. Iron impacts are only just over the Test 3 criteria of 10% of the EQS and therefore can nearly be screened from the assessment. The increase in nickel is slightly greater than for copper and iron, however the baseline effluent is already exceeding the screening criteria for this species. Vanadium impacts are 11.3% compared to the 10% screening criteria, and therefore can nearly be screened from assessment.

Again, it is important to note that it is not considered that SKD represents a freshwater course in its true sense given that 98% of its flow immediately downstream of the W2 release point is the wastewater discharge from the Humber Refinery and that the additional pollutant loading as a result of the PTU wastewater is not anticipated to lead to a breach of the current Environmental Permit emission limits for W2.

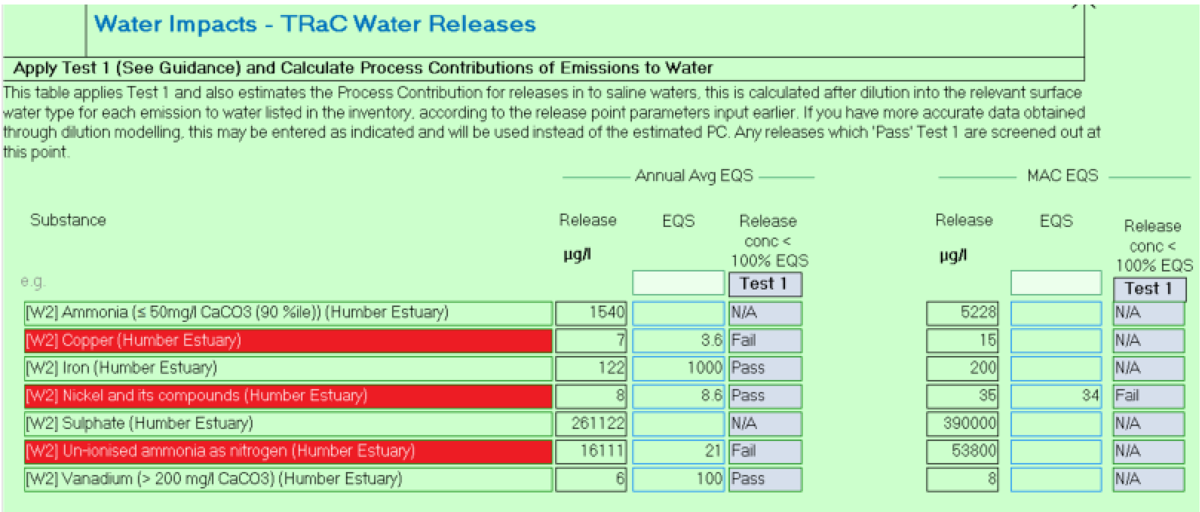
H1 Assessment for Humber Estuary

The EA's Surface Water Pollution Risk Assessment for your Environmental Permit guidance[16] details a number of screening steps for the H1 assessment of estuaries and coastal waters (TRaC) as follows:

- Test 1 – screen-out substances whose concentration in the discharge does not exceed 100% of the EQS applicable to TRaC waters;

Further tests are then carried out dependent on the discharge location, however due to the fact that SKD only flows into the Humber Estuary when the tidal flaps are open, and that at low tide the water flows across the intertidal muds, these tests are not appropriate for the Humber Refinery discharge. As such, only Test 1 can be applied.

The baseline impacts of the existing effluent discharge are shown below:



Water Impacts - TRaC Water Releases

Apply Test 1 (See Guidance) and Calculate Process Contributions of Emissions to Water

This table applies Test 1 and also estimates the Process Contribution for releases in to saline waters, this is calculated after dilution into the relevant surface water type for each emission to water listed in the inventory, according to the release point parameters input earlier. If you have more accurate data obtained through dilution modelling, this may be entered as indicated and will be used instead of the estimated PC. Any releases which 'Pass' Test 1 are screened out at this point.

	Annual Avg EQS			MAC EQS		
Substance	Release µg/l	EQS	Release conc < 100% EQS	Release µg/l	EQS	Release conc < 100% EQS
e.g.			Test 1			Test 1
[W2] Ammonia (≤ 50mg/l CaCO3 (90 %ile)) (Humber Estuary)	1540		N/A	5228		N/A
[W2] Copper (Humber Estuary)	7	3.6	Fail	15		N/A
[W2] Iron (Humber Estuary)	122	1000	Pass	200		N/A
[W2] Nickel and its compounds (Humber Estuary)	8	8.6	Pass	35	34	Fail
[W2] Sulphate (Humber Estuary)	261122		N/A	390000		N/A
[W2] Un-ionised ammonia as nitrogen (Humber Estuary)	16111	21	Fail	53800		N/A
[W2] Vanadium (> 200 mg/l CaCO3) (Humber Estuary)	6	100	Pass	8		N/A

The future impacts with the PTU wastewater stream are shown below:

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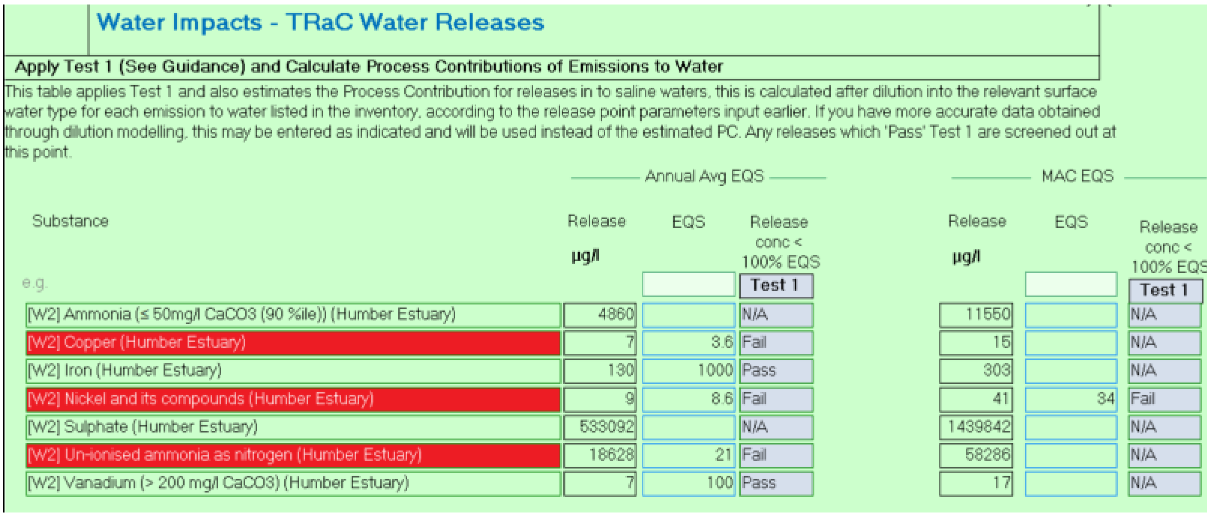
[16] Surface water pollution risk assessment for your environmental permit - GOV.UK (www.gov.uk)



Water Impacts - TRaC Water Releases

Apply Test 1 (See Guidance) and Calculate Process Contributions of Emissions to Water

This table applies Test 1 and also estimates the Process Contribution for releases in to saline waters, this is calculated after dilution into the relevant surface water type for each emission to water listed in the inventory, according to the release point parameters input earlier. If you have more accurate data obtained through dilution modelling, this may be entered as indicated and will be used instead of the estimated PC. Any releases which 'Pass' Test 1 are screened out at this point.

	Annual Avg EQS			MAC EQS		
Substance	Release µg/l	EQS	Release conc < 100% EQS Test 1	Release µg/l	EQS	Release conc < 100% EQS Test 1
e.g.						
[W2] Ammonia (≤ 50mg/l CaCO3 (90 %ile)) (Humber Estuary)	4860		N/A	11550		N/A
[W2] Copper (Humber Estuary)	7	3.6	Fail	15		N/A
[W2] Iron (Humber Estuary)	130	1000	Pass	303		N/A
[W2] Nickel and its compounds (Humber Estuary)	9	8.6	Fail	41	34	Fail
[W2] Sulphate (Humber Estuary)	533092		N/A	1439842		N/A
[W2] Un-ionised ammonia as nitrogen (Humber Estuary)	18628	21	Fail	58286		N/A
[W2] Vanadium (> 200 mg/l CaCO3) (Humber Estuary)	7	100	Pass	17		N/A

Iron and vanadium pass the Test 1 screening for both the existing effluent and the future effluent with the PTU wastewater. Copper, nickel and ammonia however fail Test 1, which is consistent with the results of the Wood report provided to the EA in 2020 and still undergoing evaluation. The increase in impacts over the existing effluent are considered to be minimal.

7.4.3.3 Environmental Impacts of Sulphate

As stated in Section 5.2.1.3, it is important to understand the potential impacts of emissions of sulphate to receiving waters, in order to determine a suitable emission limit to apply within the Environmental Permit.

In the Report to Inform the Habitats Risk Assessment (HRA) prepared as part of the TCPA (Appendix B), a review of the literature available on ecotoxicity of sulphate to aquatic organisms and potential effects on aquatic ecosystems demonstrates that there is no certainty regarding the effect levels of sulphate to aquatic organisms, including fish and macroinvertebrates. Government bodies, such as the EA state that *"reducing [Sulphate] concentrations is not, in itself, an objective of mine water treatment in the UK, […], partly because its impact on surface watercourses is usually limited, and partly because of the great difficulty of removing sulphate using conventional treatment technologies"*[17].

The UKTAG advisory group describe sulphate as *"a chemical that had no effect on the ecology"* [18]. Consequently, they have derived standards *"only for chemicals where there is general confidence that they cause biological impacts"*.

The sulphate ion is one of the major anions occurring in natural waters. There is no EQS for sulphate under the WFD. However freshwater organisms can be harmed by excessive sulphate concentrations. The EA's Risk Assessment guidance details an EQS for sulphates in freshwaters of 400,000µg/l, however there is no EQS for estuaries or coastal waters as background sulphate levels are in excess of 2,000,000 µg/l.

It is understood from the EA that the 400,000µg/l EQS was established in 1990 (and reviewed in 2002 without change) together with the EQS for chlorides. The available toxicity data for sulphates was limited at this time and insufficient information was available to derive an independent threshold for sulphates and therefore the toxicity was compared to that of chlorides in order to propose a threshold.

The available data indicated that sulphates were less toxic than chlorides and therefore an arbitory factor of approximately 1.5 times the threshold set for chlorides was determined from the available data to propose the sulphate EQS of 400mg/l. The EA therefore consider that the EQS of 400mg/l for sulphates is a suitable threshold for toxic effects on the freshwater aquatic ecosystem, however the justification for this value is not clear. In addition, it should be noted that the AECOM Report monitored concentrations within SKD that were already exceeding the sulphate EQS in some of the sample locations and in the receiving estuarine waters.

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[17] Environment Agency (2009) Ecological indicators for abandoned mines, Phase 1: Review of the literature

[18] UK Technical Advisory Group (UKTAG) on the Water Framework Directive (2008) UK Environmental Standards and Conditions (Phase 1). Final report

The AECOM Report details literature sources that state that sulphate discharge limits of 1,000mg/l have been applied in other countries, and that in some US states water quality standards of 1,000mg/l are applied.

Available information, therefore, indicates that sulphate it is not considered to be a priority in setting quality standards for the protection of aquatic life, and as such, challenges the EA's advised EQS of 400mg/l as a suitable threshold. Evidence would suggest that an appropriate concentration to protect aquatic life would be 1,000mg/l, especially as SKD is effectively an industrial drain with negligible ecological value.

Seawater contains about 2,700mg/l of sulphate[19] and therefore the level of sulphate in the PTU wastewater is below the naturally occurring levels in seawater. The AECOM Report details that average concentrations of sulphate in the Humber Estuary near the point of discharge were on average 1,543mg/l. As such, it can be concluded that the elevated level of sulphate in the PTU wastewater will not result in any discernible changes to the sulphate concentration of the Humber Estuary.

The potential for impact on Rosper Road Pools however still needs to be considered. The AECOM report concluded that water from SKD only overtops the weir into RRP during high rainfall events, usually in conjunction with high tide, when the tidal flaps are closed causing the water level in SKD to rise. At such times, there will be additional dilution from rainwater and therefore any water overtopping the weir into the pools will likely be at lower concentrations that those than may typically be present in SKD. The AECOM Report stated that background sulphate levels in RRP were found to be at concentrations between 160 – 390mg/l during the sampling campaign carried out, and therefore the maximum concentration measured is almost at the EQS of 400mg/l.

There is also anecdotal evidence of historically high concentrations of sulphate in SKD as a result of the VPI Immingham CHP site being constructed on blast furnace slag, which leached sulphates into SKD. This issue dates back to 2005 – 2007 and was known to the EA at the time.

As stated previously, Rosper Road Pools are functionally linked to the Humber Estuary SPA, due to it providing feeding, loafing and roosting habitat for birds at high tide, as well as nesting habitat for avocet. These same birds regularly feed on the mudflats of the Humber Estuary and therefore they will regularly be exposed to the naturally high sulphate concentrations that occur in their natural feeding habitat (noting concentrations of up to 1,900mg/l were monitored in the Humber Estuary).

It is therefore considered that historically high concentrations of sulphate form part of the baseline conditions for the SKD watercourse and Rosper Road pools, and therefore it is reasonable to assume that the current (and long-standing) elevated sulphate levels do not adversely affect the usage of Rosper Road Pools by SPA/ Ramsar birds, and that any aquatic flora and fauna present in the Pools are present within the context of this elevated sulphate input.

The Rosper Road Pools LWS has flourished under the presence of high sulphate concentrations already found in SKD. The Report to Inform the HRA prepared as part of the TCPA (Appendix B) therefore concludes that the impact of additional sulphate would not affect the designated function of the LWS.

7.4.4 Site Waste

The details of anticipated waste streams generated by the PCC Plant are provided in Section 4.9.

All operational waste will be dealt with in accordance with the existing Installation's waste management procedures, amended as required for the PCC Plant operation, with appropriated designated storage areas for hazardous and non-hazardous wastes, and consigned via a registered waste carrier for treatment or disposal at a suitably licenced waste facility.

It is therefore considered that further assessment of the waste from the PCC Plant operation is not required.

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[19] Hitchcock, D.R. (1975) Biogenic contributions to atmospheric sulphate levels. In: Proceedings of the 2nd National Conference on Complete Water Re-use. Chicago, IL, American Institute of Chemical Engineers.

7.4.5 Global Warming Potential

This section is based on guidance presented in the EA guidance – 'Assess the impact of air emissions on global warming'[20].

The PCC Plant enables the capture of approximately 95% of the CO_2 emissions from the FCC Regenerator, this equates to approximately 478,110 tonnes of CO_2 that would have been released into the environment being captured per year. Therefore, the global warming impact of the emissions to air from the FCC Unit will be significantly reduced over its current CO_2 emissions.

Additional energy (electricity and steam) is required to provide power and heat to the PCC Plant, therefore there is an increase in the release of greenhouse gas (GHG) emissions associated with the additional energy production. The adjacent VPI Immingham CHP Power Station provides both electricity and steam to the Humber Refinery, and is also planning to retrofit PCC plants on two of the gas turbines and the auxiliary boilers as part of the Humber Zero project. Table 7.3 shows the additional annual energy consumption for the Phillips 66 PCC Plant if the VPI PCC plants are not progressed, and Table 7.4 show the additional annual energy consumption if both developments are progressed.

The additional energy consumption for both scenarios are the same, however the emission factors for the additional energy consumption is different. The CO_2 emission factors applied to the VPI Immingham CHP Power Plant electricity and steam supply have been calculated specifically for the Humber Zero project, for use in the ES (Appendix B, Volume I, Chapter 14 Climate Change). The CO_2 emission factor used in Table 7.4 is the current emission intensity of VPI's CHP plant without the installation of PCC technology.

It is estimated that the additional electricity and steam required to operate the Humber Refinery's PCC Plant would result in approximately 110,102 tonnes of additional CO_2 being released to atmosphere, therefore the overall reduction in CO_2 being released to the environment as a result of the operation of the Humber Refinery PCC Plant would be approximately 368,007 tonnes per year.

Table 7.4: Additional Annual Energy Consumption for the Phillips 66 PCC Plant – VPI PCC Plants Not Progressed

Energy Source	Energy Consumption Primary		
	At Primary Source	CO_2 Emission Factor ($kgCO_2e$/unit)	Annual CO_2 Emissions (tonnes)
FCC CO_2 Captured	-	-	- 478,110
Electricity (VPI supply)	88,371,600 kWh	0.377	33,316
Steam (VPI supply)	345,500 tonnes	222.2	76,770
Total CO_2 Reduction	**-**	**-**	**- 368,024**

Table 7.5 shows the reduction in annual CO_2 emissions as a result of the PCC Plant installation at the VPI Immingham CHP Power Station, the effective CO_2 emission factor applied to the additional energy consumption would need to be a negative number; this would imply that as energy consumption increases, less GHG emissions would be released into atmosphere. This is clearly not the case for the Phillips 66 PCC Plant and therefore the CO_2 emission factor and annual emissions have not been supplied. The emissions from the additional energy requirements have been captured within the operational emissions of the Proposed Development in the ES (Appendix B, Volume I, Chapter 14 Climate Change, Table 14.19).

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[20] Assess the impact of air emissions on global warming, DEFRA and EA, published on: 1st February 2016, available at: https://www.gov.uk/guidance/assess-the-impact-of-air-emissions-on-global-warming

Table 7.5: Additional Annual Energy Consumption for the Phillips 66 PCC Plant – VPI PCC Plants Progressed

Energy Source	Energy Consumption Primary		
	At Primary Source	CO_2 Emission Factor	Annual CO_2 Emissions (tonnes)
FCC CO_2 Captured	-	-	- 478,110
Electricity (VPI supply)	88,372,600 k	N/A	N/A
Steam (VPI supply)	345,500	N/A	N/A
Total CO_2 Reduction	**-**	**-**	**N/A**

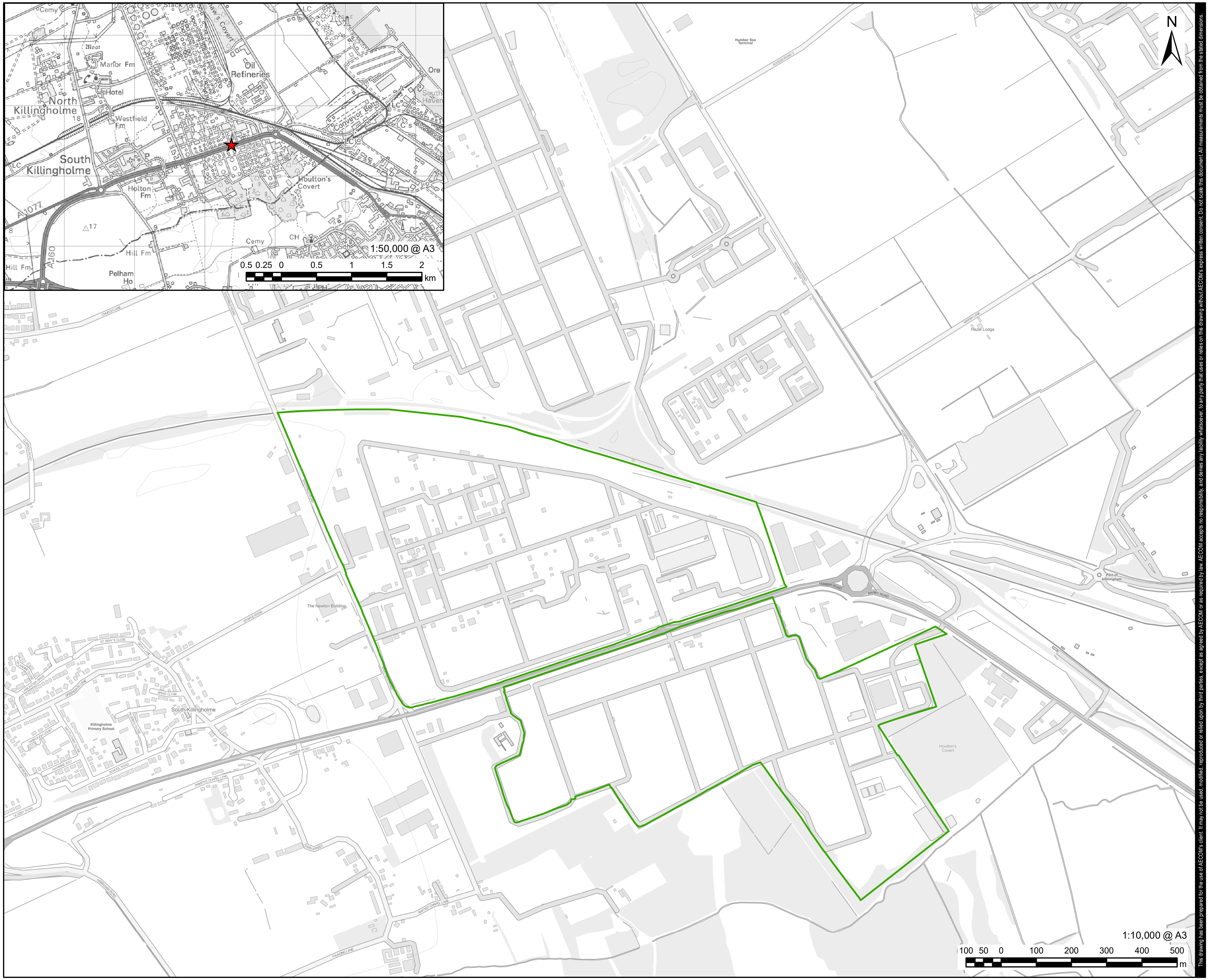
7.5 Site Closure

A plan for appropriate decommissioning and closure of the PCC Plant at the end of its operating life will be developed. The plan will ensure that the site is returned to the Installation condition, as outlined in this application.

Appendix A - Figures

Revision: 01 Drawn: ER Checked: LC Approved: HW Date: 2023-01-10

Filename: \\na.aecomnet.com\lfs\EMEA\Leeds-UKLDS2\Legacy\UKLDS2PFPSW001\WIP\LE_Projects\Newproje\60668866 - Humber Zero\900_CAD_GIS\02_Maps\P66 Environmental Permit Variation\HZ_EPV_Fig1_Site_Location_Plan_20230110_ER_v1.mxd



PROJECT

Environmental Permit Variation Application

CLIENT

Phillips 66 Limited

CONSULTANT

AECOM Limited
2 City Walk
Holbeck, Leeds
LS11 9AR
www.aecom.com

LEGEND

🟩 Installation Site Boundary
★ Site Location

NOTES

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ISSUE PURPOSE

FINAL

PROJECT NUMBER

60668866

FIGURE TITLE

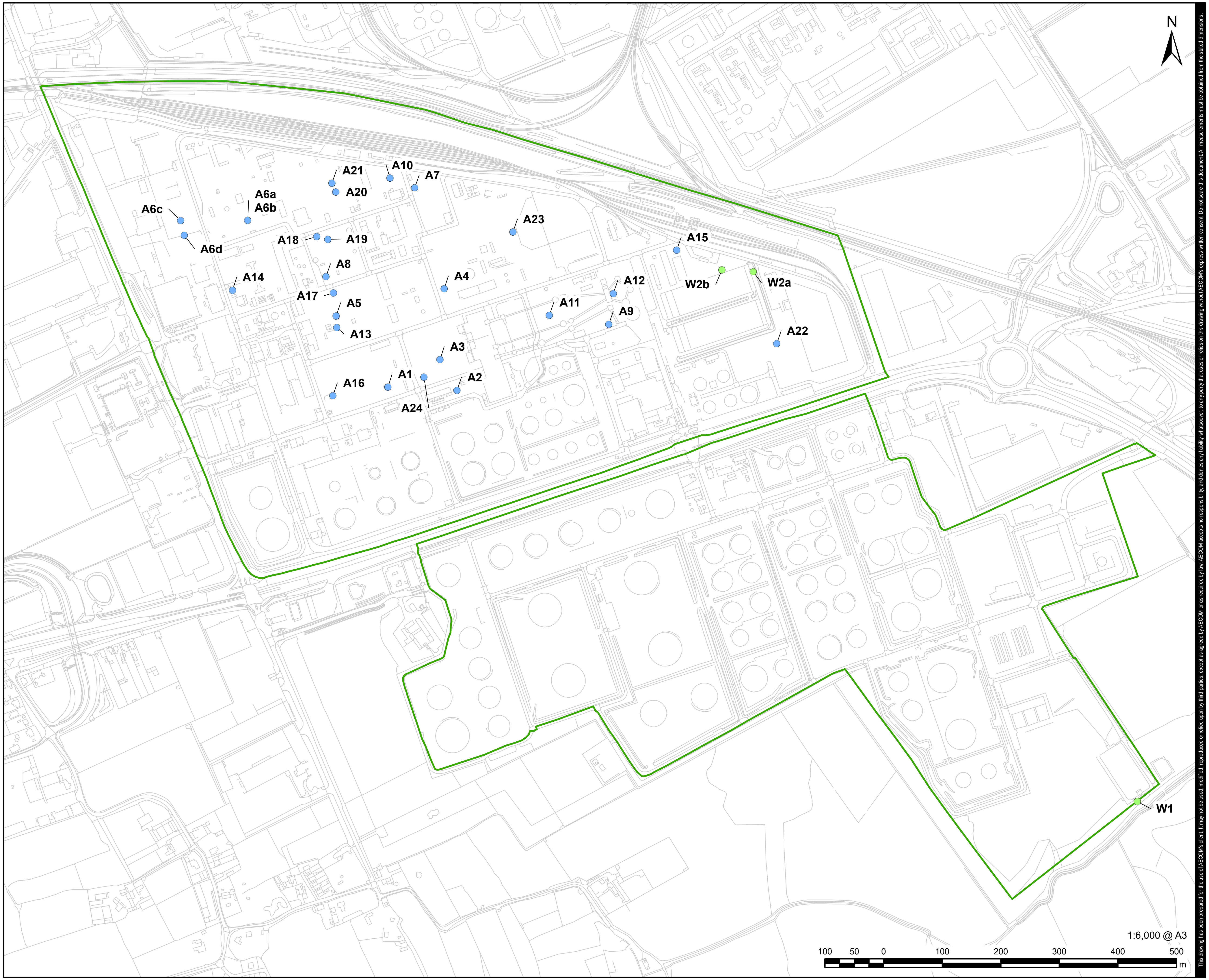
Site Location Plan

FIGURE NUMBER

Figure 1

Revision: 02 Drawn: ER Checked: LC Approved: HW Date: 2023-03-02

Filename: \\na.aecomnet.com\lfs\EMEA\Leeds-UKLDS2\Legacy\UKLDS2PFPSW001\WIP\LE_Projects\Newproje\60668866 - Humber Zero\900_CAD_GIS\02_Maps\P66 Environmental Permit Variation\HZ_EPV_Fig2_Installation_Boundary_20230119_ER_v2.mxd



AECOM

PROJECT

Environmental Permit Variation Application

CLIENT

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CONSULTANT

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Holbeck, Leeds
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www.aecom.com

LEGEND

▭	Installation Site Boundary
●	Emission Point to Air
●	Emission Point to Water

NOTES

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ISSUE PURPOSE

FINAL

PROJECT NUMBER

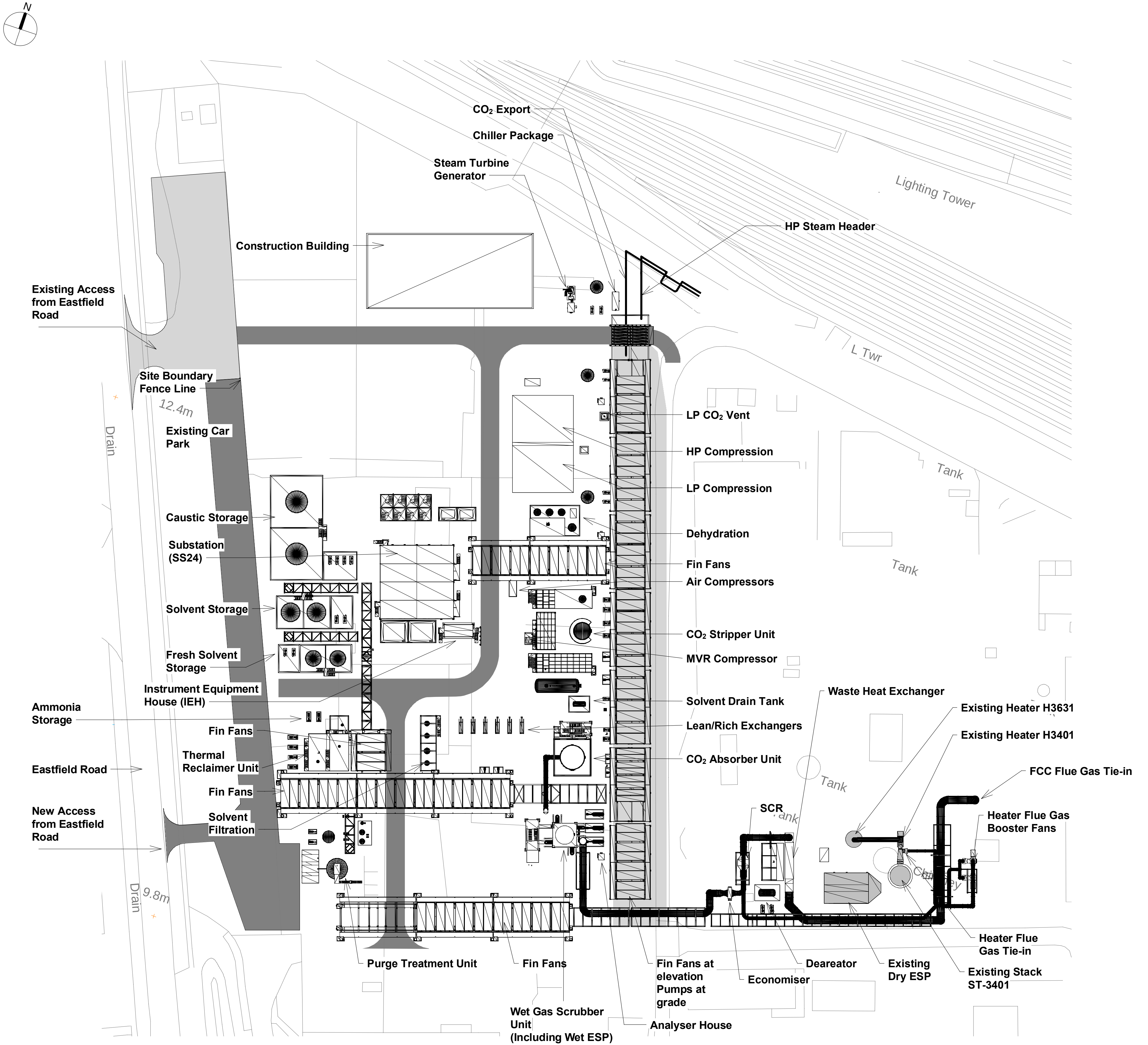
60668866

FIGURE TITLE

Installation Boundary Location

FIGURE NUMBER

Figure 2



PCC Plant Layout

1 : 1250

0 5 10 15 20 25 30 35 40 45 50m

LEGEND

■ New Road

□ Existing Road / Equipment

NOTE:
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REV	DATE	DRW	ING	DESCRIPTION
A	14/02/23	SJ	AEC	For Permitting

Key Plan

Advisian
Worley Group

Worley
energy | chemicals | resources

Paseo de la Castellana 184, Madrid 28046 - Spain
TEL: +34913 53 51 00 - FAX: +34913507615
www.worleyparsons.com

Client

PHILLIPS 66 Humber Refinery

Project

Humber Zero: Phillips 66 FCC Post Combustion Carbon Capture

Project No:

215005-00703

Drawing title

Figure 3 - Indicative PCC Plant Layout

Scale	Size	Project Date	PROJ. LEAD	DEPT. LEAD
1:1250	A3	14/02/23	AP	MG

Drawing Number

215005-00703-00-AR-DXG-90001

Rev

A

Figure 4- Humber FCC Carbon Capture Schematic

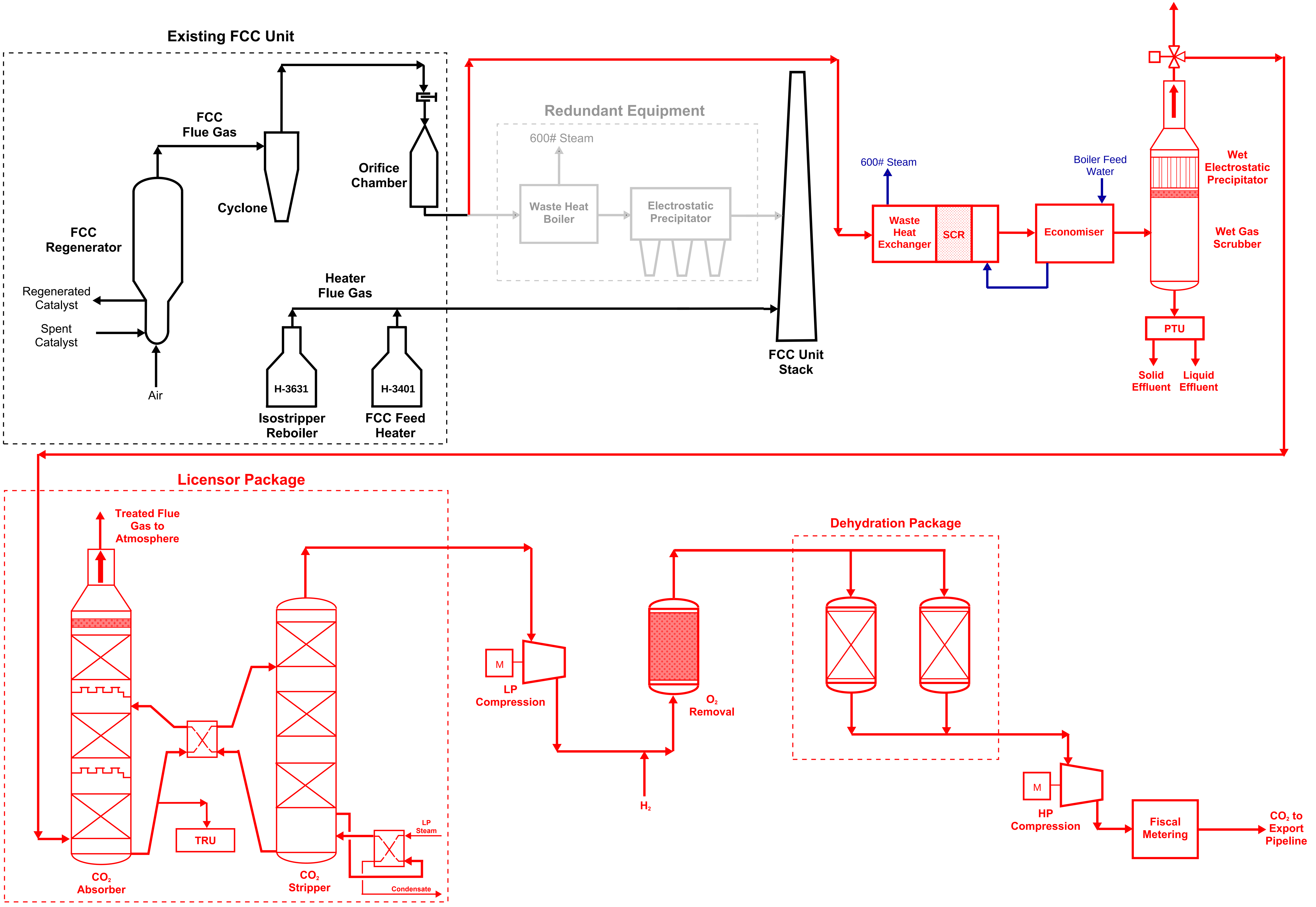


Figure 5: PTU Flow Diagram

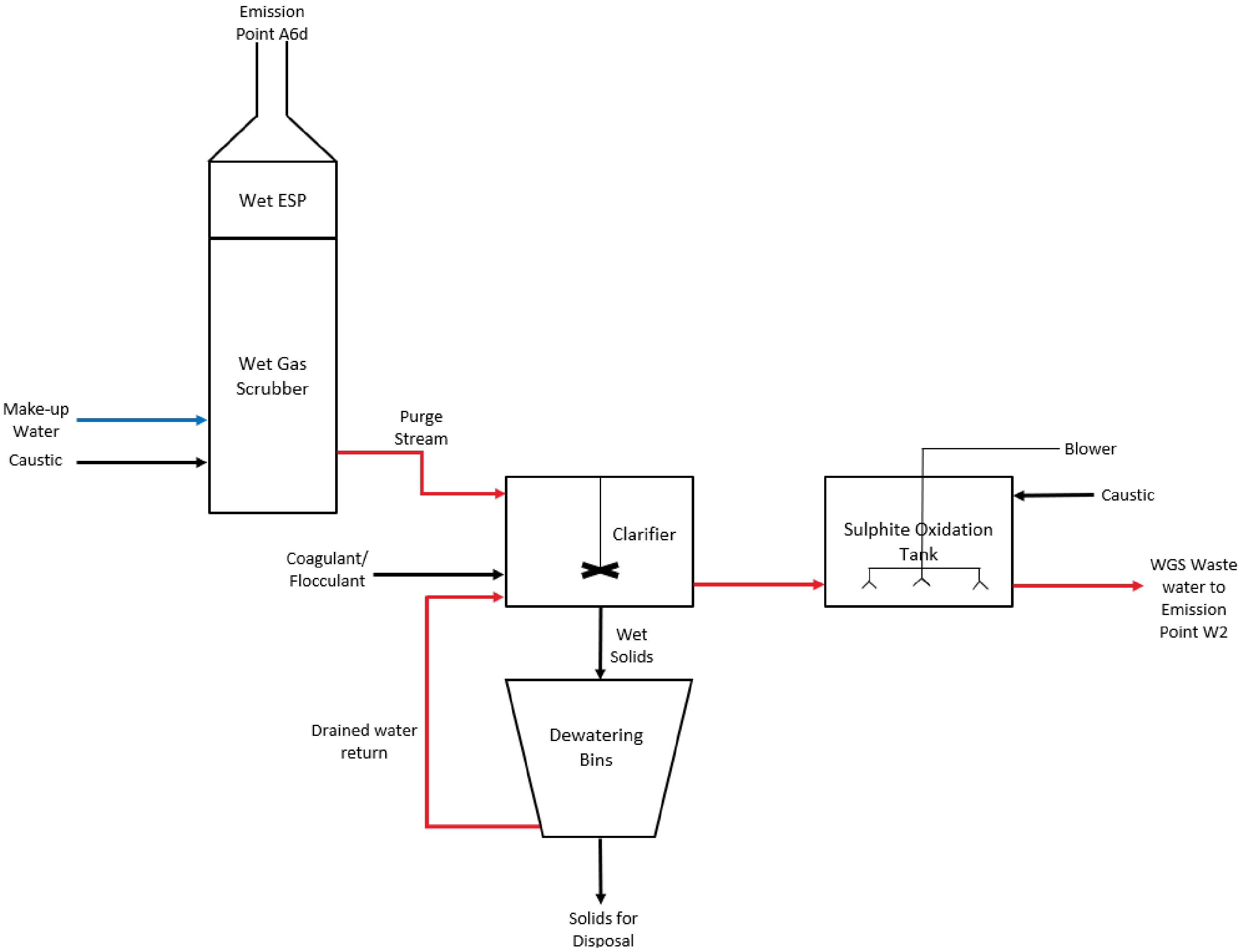


Figure 6: Schematic of PCC Area Drainage

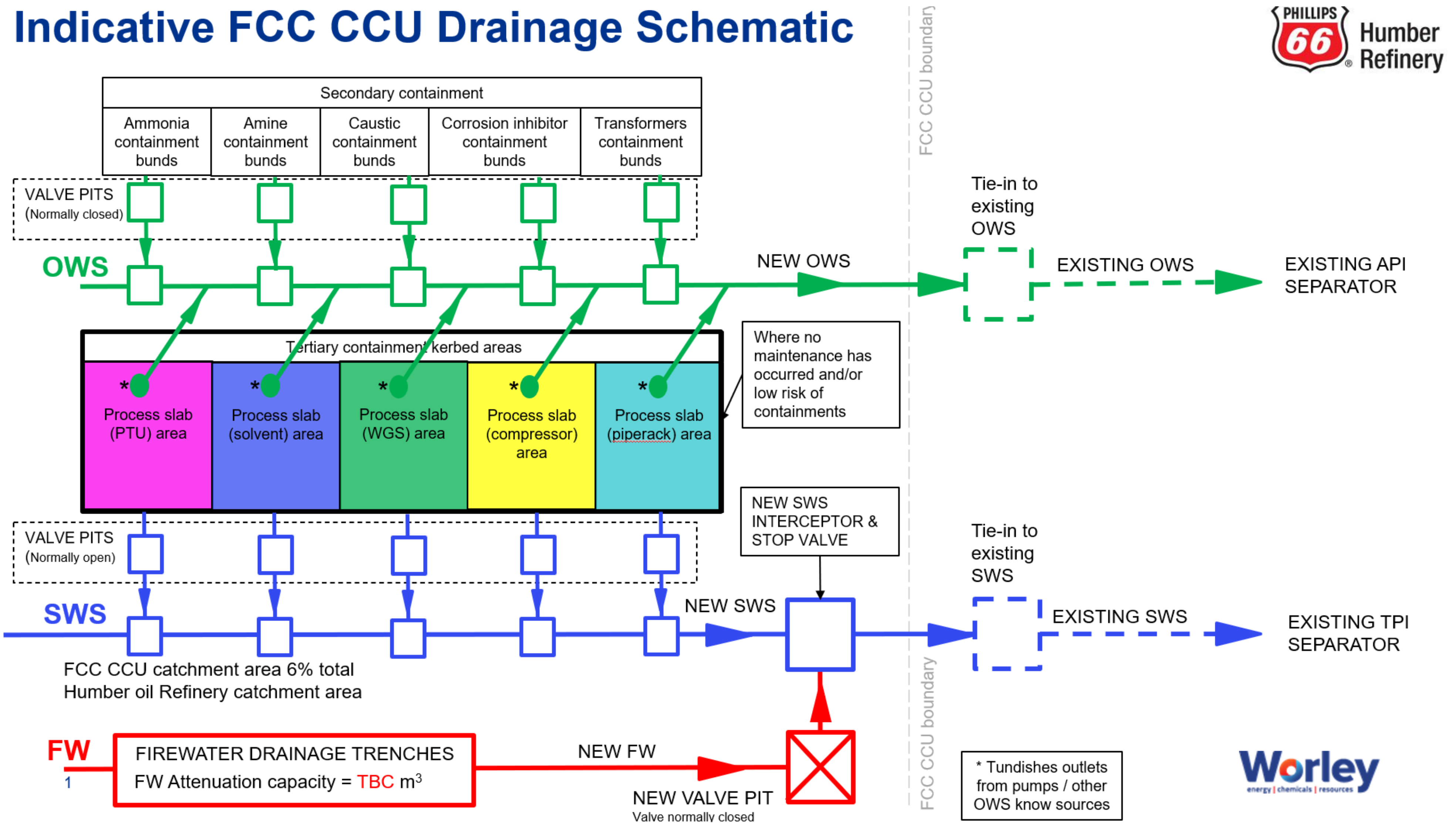
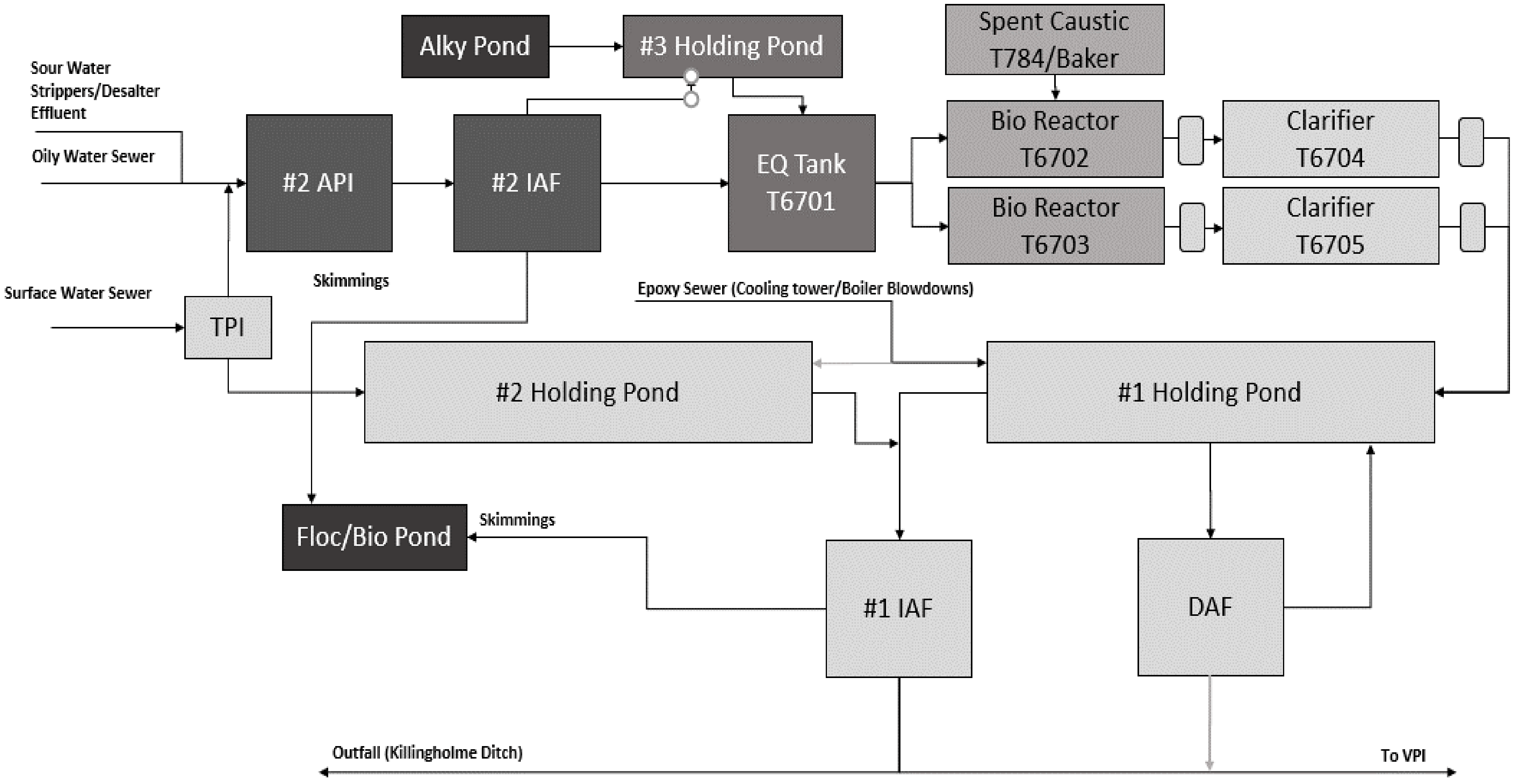
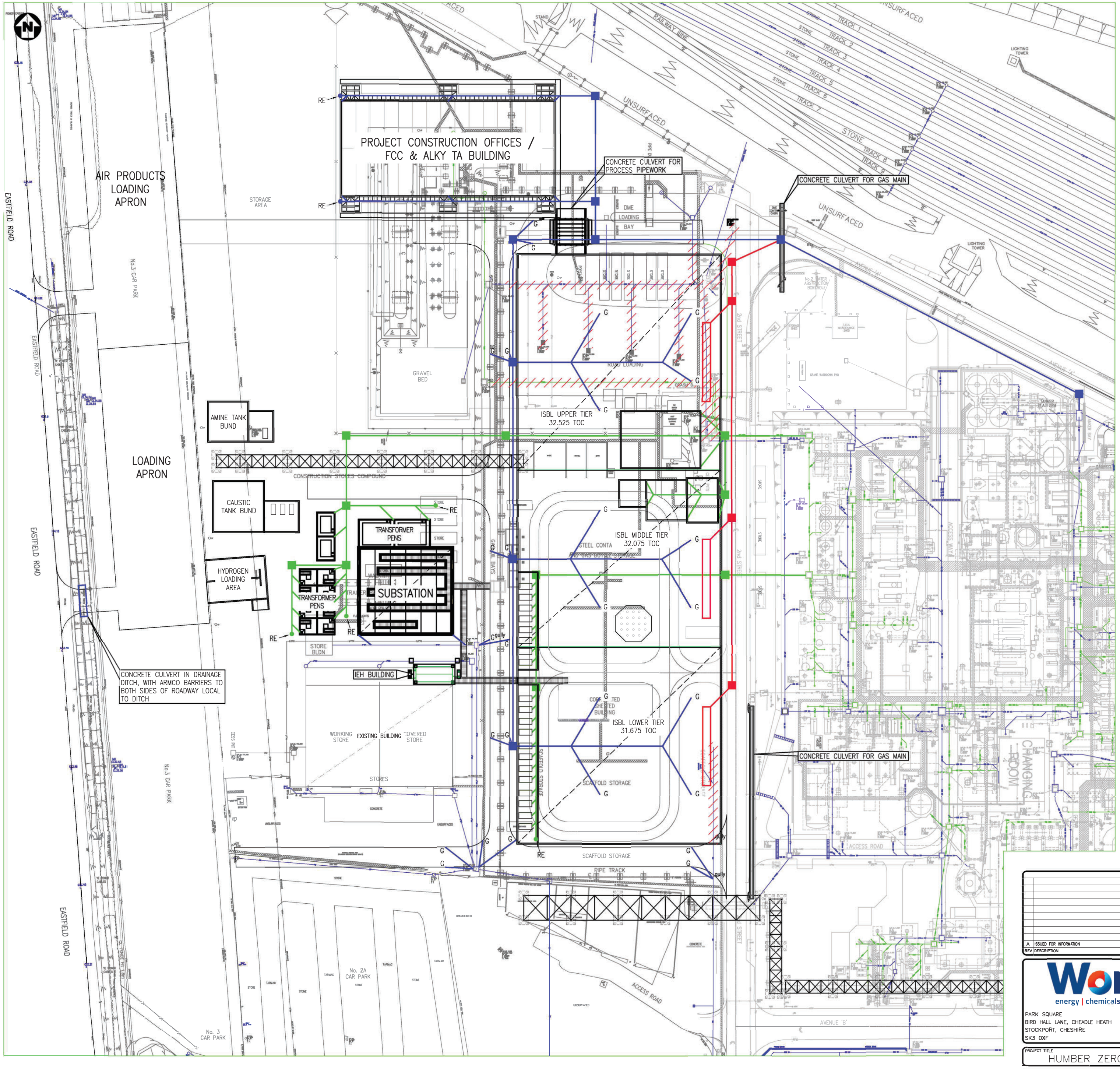


Figure 7: Existing Site ETP



API = American Petroleum Institute oil/water gravity separators, IAF = Induced Air Flotation, TPI = Tilted Plate Interceptor, DAF = Dissolved Air Filtration, EQ = Equalisation Tank



Notes

KEY

🟦	NEW SURFACE WATER MANHOLE
🟩	NEW OILY WATER MANHOLE
🟥	NEW FIRE WATER MANHOLE
☐	NEW FIRE WATER DRAIN (20000x2000x2000 DEEP)
—	NEW SURFACE WATER DRAIN
—	NEW OILY WATER DRAIN
—	NEW FIRE WATER DRAIN
G	NEW GULLY
RE	NEW RODDING EYE
//	EXISTING DRAINS/MANHOLES REMOVED
☐	EXISTING SURFACE WATER MANHOLE
☐	EXISTING OILY WATER MANHOLE
—	EXISTING SURFACE WATER DRAIN
—	EXISTING OILY WATER DRAIN

Reference Drawings

WA14–A21–D100–1827–6200–B001	CIVIL LAYOUT DRAWING ROAD LAYOUT & SLAB ELEVATIONS PLAN
WA14–A21–D100–1827–6200–B002	SITE UNDERGROUND SERVICES FIREWATER MAIN, NATURAL GAS LINE & PRIMARY TRENCH ROUTES
WA14–A21–D100–1827–6200–B003	SITE DRAINAGE SYSTEM PLAN SWS NETWORK

Figure 8 - Indicative Site Drainage Layout

Preliminary for Information Only

REV	DESCRIPTION	DWN	CHK	APPROVED	DATE
A	ISSUED FOR INFORMATION	·	·	·	

Worley
energy | chemicals | resources

PARK SQUARE
BIRD HALL LANE, CHEADLE HEATH
STOCKPORT, CHESHIRE
SK3 0XF
Tel: +44(0)161 741 7800

PROJECT TITLE
HUMBER ZERO FCC FEL 1

PROJECT NO	DRAWING NO	REVISION
60–PY13–01	CI.C120/0003	A

Rev.	Date	Description	Drn	Chk.	App'd.
A	·	ISSUED FOR INFORMATION	·	·	·

T.I.D. No.	·
Tech Memo/ eMOC No.	·
A.S.C.	·
Unit Description	·
Discipline	CIVIL
Drawn	PL
Date	OCT.
Scale	1:500

PHILLIPS 66 Humber Refinery

Title
HUMBER ZERO FCC FEL 1
SITE DRAINAGE SYSTEM PLAN
SWS & OWS NETWORKS

Drg No. WA14-A21-D100-1827-6200-B003

Rev. A

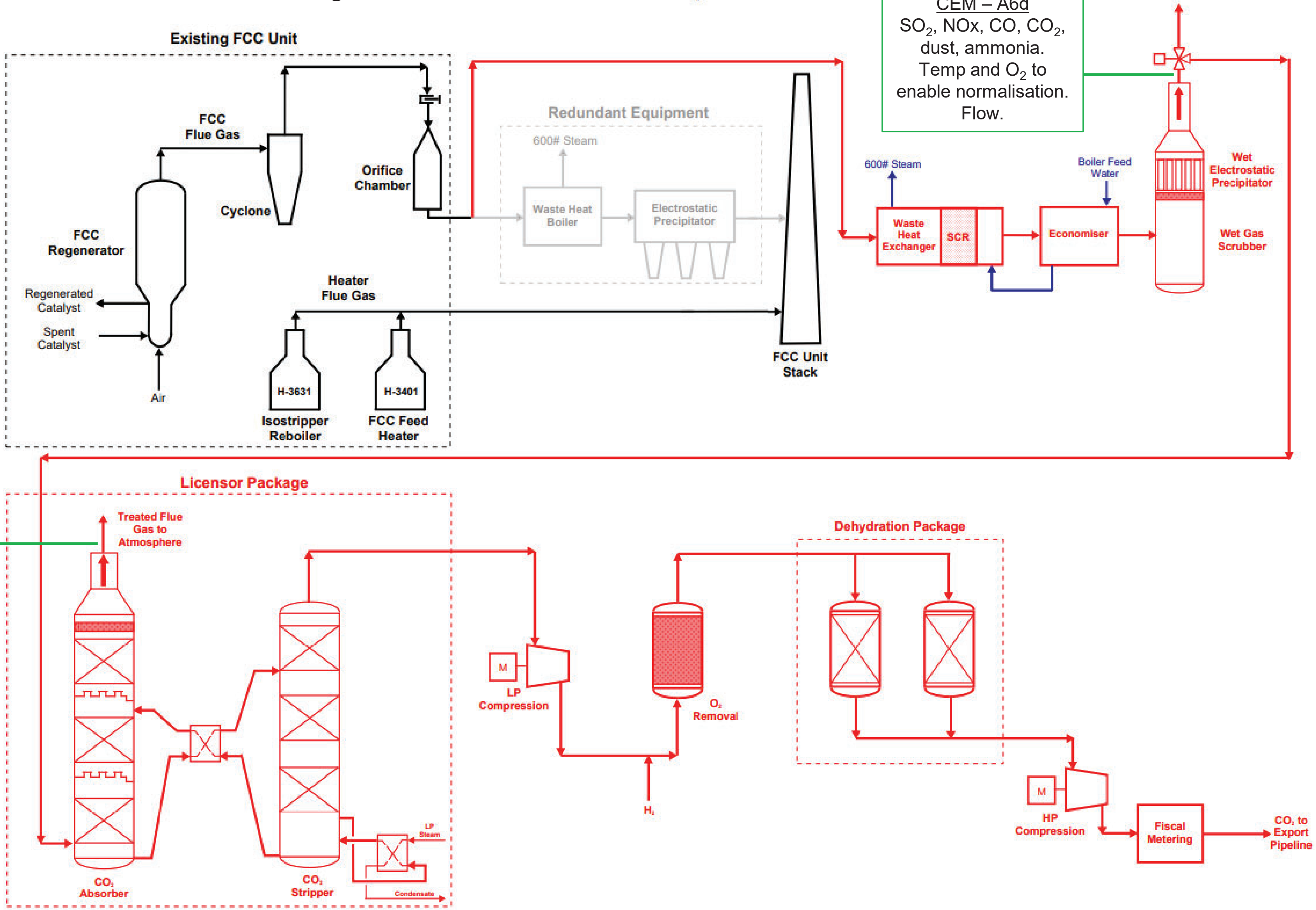
Cad File Ref. B003

A1 841x594

Figure 9 - Humber FCC Carbon Capture Schematic

Emissions Compliance/ CEMs Locations - Option 1 (preferred)

- 2 CEMs needed
- A6d – covers WGS stack annual ELVs when PCC plant is offline and will be needed to demonstrate compliance with monthly BRef Bubble ELVs all the time
- A6c – covers PCC plant annual ELVs when PCC plant online



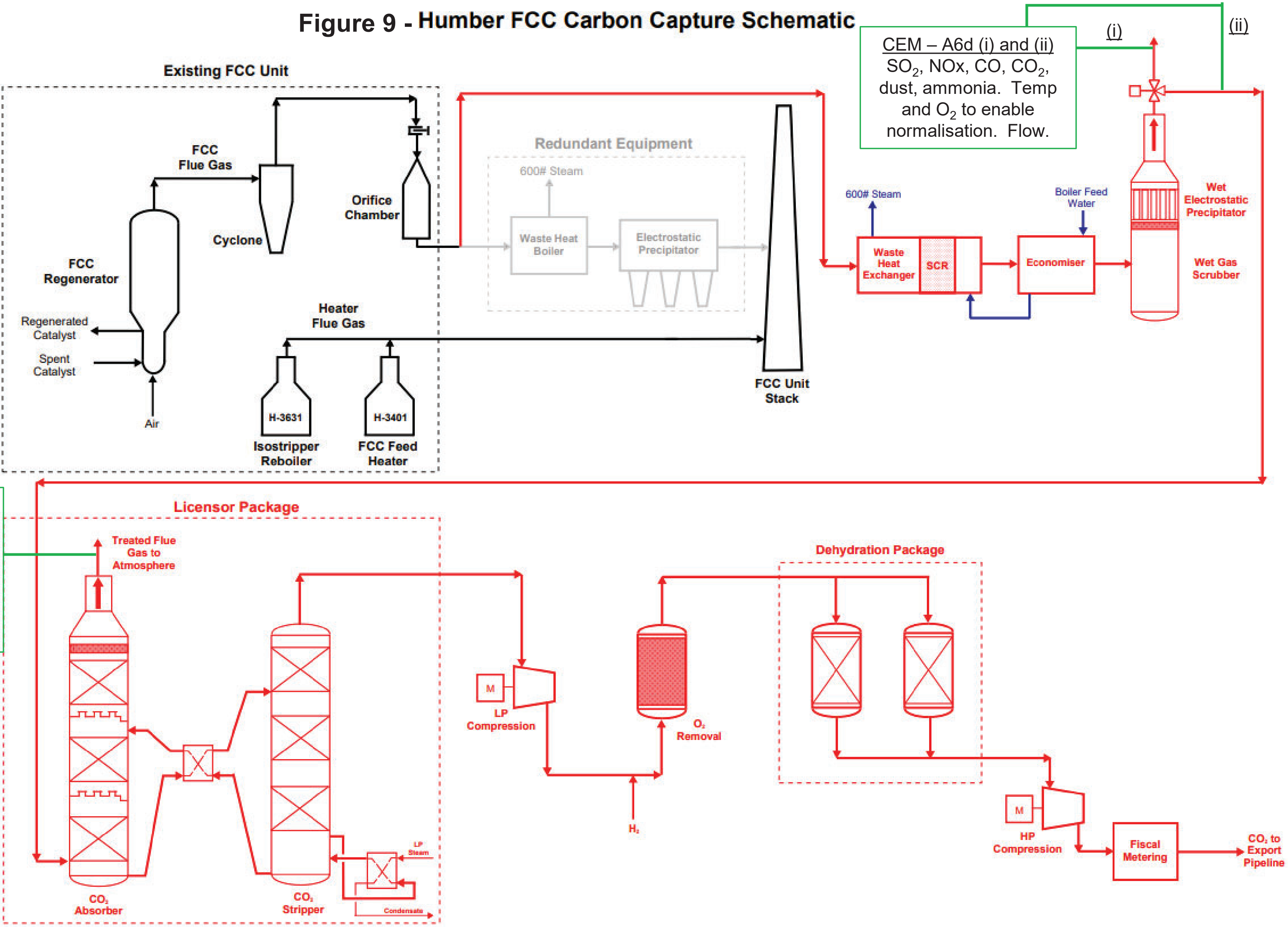
CEM – A6d
SO_2, NOx, CO, CO_2, dust, ammonia.
Temp and O_2 to enable normalisation.
Flow.

CEM – A6c
SOx, NOx, CO, CO_2, dust, ammonia, amines if suitable equipment available.

Figure 9 - Humber FCC Carbon Capture Schematic

Emissions Compliance/ CEMs Location - Option 2

- 3 CEM locations needed
- A6d(i) – covers WGS stack annual ELVs when PCC plant is offline and compliance with monthly BRef Bubble ELVs when PCC plant is offline
- A6d(ii) – covers compliance with monthly BRef Bubble ELVs when PCC plant is online
- A6c – covers PCC plant annual ELVs when PCC plant online



CEM – A6d (i) and (ii)
SO_2, NOx, CO, CO_2, dust, ammonia. Temp and O_2 to enable normalisation. Flow.

CEM – A6c
SOx, NOx, CO, CO_2, dust, ammonia, amines if suitable equipment available.

Appendix B – Environmental Statement

See Appendix B Electronic Folder

Appendix C - PCC Indicative BAT Assessment

It should be noted that the EA Guidance does not have the same legal status as BRefs published under the IED, and indeed the webpage states that *"Except where stated, this BAT guidance is not a regulatory requirement but identifies important environmental issues to address and best practice".*

https://www.gov.uk/guidance/post-combustion-carbon-dioxide-capture-best-available-techniques-bat

Ref.	BAT Requirement	Response
1. Power Plant Selection and Integration with the PCC Plant		
BAT for efficiency of fuel use in power and CHP plants with PCC		
1.1	You must maximise the thermal energy efficiency of the power plant and of the supply of heat for the associated PCC plant.	Not relevant in terms of power plant efficiency, however opportunities for maximising thermal energy efficiency will be explored and integrated in the design of the PCC Plant. For instance, the waste heat from the FCC Unit flue gas will be used to generate steam for use in the PCC Plant.
	For natural gas power plants, lower heating value efficiencies of 60% or above without CO_2 capture are reported in the LCP BRef to be achievable for large-scale new combined cycle gas turbine installations.	Not applicable as the PCC Plant is a retrofit to an existing FCC Unit, not a power plant.
Dispatchable Operation		
1.2	In line with the needs of a UK electricity system with a large amount of intermittent renewable generation, all thermal power plants, including those with CO_2 capture, are likely to be dispatchable. This means that the power plant operator can, within technical limits on rates of change in output and on minimum stable generation levels, operate the plant at any required output, up to its full load, at any time, and sustain this output indefinitely.	Not applicable to the FCC Unit.
2. Supplying Heat and Power for PCC Operation		
2.1	You will need to use low grade (for example 130°C) heat and electrical power to operate the PCC plant. You should work out the amounts needed based on factors that include the: • selected solvent • PCC plant configuration • CO_2 capture level • CO_2 delivery pressure	The overall performance of the PCC Plant depends on the integration, as far as practicable, of electrical power and steam circuits. The Cansolv DC-103 solvent and associated process configuration was selected to maximise this integration.
	You should supply this heat and electricity from the main power plant. Where not possible, this will need to be by fuel combustion in ancillary plants (with CO_2	The majority of heat and electricity will come from the adjacent VPI Immingham CHP Power Plant, as per the current site operations.

Ref.	BAT Requirement	Response
	capture) that are then also treated as a power plant system for performance calculations.	There will be no additional ancillary plants for the generation of electricity, however heat recovery and reuse will be applied where possible, as described in Section 4.10.
	Typically, the best heat supplied to lost power ratio will exceed 4:1 for regeneration heat supplied at 130°C. It follows that if you use electricity instead of steam in PCC heating, for example to compress the vapour produced from flashing lean amine so that it can be fed back into the amine stripper, you should aim to achieve a similar ratio. This will ensure that the overall impact on plant electricity output is no higher than for steam extraction. You will achieve the best use of any additional fuel inputs when as much electricity as possible is also generated from the energy in the fuel before supplying the low grade heat. You can assess this based on: • the thermal efficiency of a BAT baseload-capable power plant without capture using that fuel • the ratio between heat supplied for PCC and the reduction in electrical power output from the relevant unabated BAT power plant output in the LCP BREF, which should exceed 4:1 for a typical amine regeneration heat supply at 130°C.	Not applicable. The steam reboiler and MVR, which recompresses vapour from flashing the lean amine, will improve the energy efficiency of the PCC Plant. The MVR saves a third of the duty required from the reboiler and therefore improves the energy efficiency of the plant.
3. PCC Plant Design and Operation – Purpose		
3.1	The purpose of the PCC plant is to maximise the capture of CO_2 emissions for secure geological storage. You should aim to achieve a design CO_2 capture rate of at least 95%, although operationally this can vary, up or down.	The PCC Plant has been designed to capture approximately 95% CO_2 in the flue gas treated.
3.2	You should capture CO_2 during start-up and shutdown as part of using BAT.	There will be short periods on start-up, when the compression plant may not generate CO_2 of the required quality for delivering into the T&S Network. The deoxygenation, dehydration and cooling process during compression may take 15 – 30 minutes to meet the required specification. As such CO_2 may be vented to atmosphere during this time.
3.3	You will need to deliver CO_2: • at local transport system pressures (gas phase such as 35 bar or dense phase such as 100 bar), with levels of water, oxygen and other impurities as required for transport and storage such as that for the	The onsite compression will remove oxygen and water from the CO_2 to meet the requirements of the T&S Network. The quality of the CO_2 will be monitored for compliance with export specifications for the temperature, pressure, water content, oxygen content, hydrogen content, CO,

Ref.	BAT Requirement	Response
	system operator National Grid (NGC/SP/PIP/25 Dec.2019)	hydrogen sulphide, SOx, NOx and amines. In addition to quality monitoring, fiscal flow metering will be provided for custody transfer of CO_2 sent to the T&S Network. Onward transport of the captured CO_2 will be undertaken by a separate operator after the onsite CO_2 metering station.
3.4	The PCC plant must also have acceptable environmental risks through preventing or minimising emissions, or render them harmless. You must achieve environmental quality standards for air emissions from the PCC plant and their subsequent atmospheric degradation products (including, for example, nitrosamines and nitramines). You should confirm this using: • atmospheric dispersion and reaction modelling tools • specific site parameters which will define plant-specific ELVs	Dispersion modelling has been carried out to demonstrate that environmental quality standards for air emissions from the PCC Plant and their subsequent atmospheric degradation products will not be exceeded as a result of the PCC Plant operation. The Air Impact Assessment is provided in Appendix D of this document.
3.5	Your PCC system design should aim to minimise the overall electricity output penalty on the power or CHP plants from all aspects of PCC plant operation, as much as possible. It should do this while meeting the CO_2 capture requirements set out in this guidance.	The PCC Plant will be designed to maximise energy efficiency to ensure that CO_2 reductions for the project as a whole are as high as possible.
4. Solvent Selection		
4.1	While the process design for the PCC plant is likely to be generally similar for all solvents, the amine solvent you select will determine details of the design and performance. Solvent types and published performance figures are described in the BAT review. There is particular concern about impacts on the environment from nitrosamines and other potentially harmful compounds formed by reaction of the amines and their degradation products with nitrogen oxides (NOx) in the flue gases. You have a choice between: • solvents using primary amines that may require more heat for regeneration but will not readily form stable nitrosamines in the PCC plant, especially if a high level of reclaiming is used to remove degradation products • solvent formulations including secondary amines or other species that may have lower regeneration heat requirements	The PCC Plant will utilise the Cansolv DC-103 solvent, and the plant has been designed with the specific solvent and degradation characteristics in mind. The solvent regeneration and reclamation process will minimise solvent degradation, in order to minimise emissions and potential environmental impacts, as demonstrated in the Air Impact Assessment (Appendix D). This assessment has taken into account both the direct and indirect impacts of N-amines resulting from anticipated amine and N-amine releases.

Ref.	BAT Requirement	Response
	may readily form nitrosamines with NOx in the flue gases in the PCC plant - for controls, see section 3.3 on features to control and minimise atmospheric and other emissions The project-specific potential for absorber stack emissions and consequent environmental impacts will depend on the selected solvent. You should assess your plant design and operation, plus local environmental factors, based on: • direct emissions of solvent components • formation of additional substances in the PCC system and emissions of those substances • formation of further additional substances in the atmosphere from emissions from the PCC system	
4.2	The potential for solvent reclaiming and other cleaning methods is also an important factor in solvent selection. You should make sure it is practicable to remove all non-solvent constituents from the solvent inventory as fast as they are added during operation, to avoid accumulation. You should also make sure that you: • recover a high fraction of the solvent in the feed to the reclaimer during reclaiming • minimise reclaimer wastes and that they can easily be disposed of	The PCC Plant will include a solvent filtration unit which will take a slip stream of the solvent from the absorber for continual cleaning. Most of the filtered solvent is routed to the Lean Solvent Cooler for reuse in the Absorber, however a further slip stream of this will go to the Thermal Reclaimer, which will also operate continuously. The aim of solvent filtration and reclaiming is to ensure that a high proportion of solvent can be reused in the process, without compromising either the CO_2 capture rate or the potential for emissions of degradation products to occur. Until operation commences it is not possible to confirm how much solvent can be reclaimed, although it is anticipated that 82% of the feed to the thermal reclaimer will be returned to the solvent circuit 'clean'. In maximising solvent reuse on site, reclaimer wastes will be minimised as far as possible.
4.3	You must work out the solvent performance, including reclaiming requirements and emissions to atmosphere. Determine this through realistic pilot (or full scale) tests using fully representative (or actual) flue gases and power plant operating patterns over a period of at least 12 months.	As above. Although a pilot plant has not been carried out on the flue gases from the FCC Unit, the solvent provider has carried out numerous pilot trials of the Cansolv solvent on various different flue gas streams including Waste to Energy, natural gas-fired boilers, coal-fired boilers, blast furnaces and a cement kiln.

Ref.	BAT Requirement	Response
		In addition, Cansolv has been commercially deployed since 2012, with the first large scale capture of CO_2 from a coal-fired power station (Boundary Dam) commencing in 2014.
5. Flue Gas Cleaning		
5.1	Sulphur oxides (SOx) removal can be in the power plant flue gas desulphurisation unit or in the PCC direct contact cooler. SOx in the flue gas will readily react with amines to produce heat stable salts. These products are typically stable under reclaimer conditions, but the heat stable salt formation with SOx can be, at least partly, reversed by alkali addition in the solvent reclaiming process. SOx levels will therefore affect solvent consumption but are expected to have a limited effect on emissions. For most gas and biomass fuels that have intrinsically low S levels, adding more upstream SOx removal is likely to be primarily an economic decision. SOx levels in the exit flue gases from an amine PCC plant will be at extremely low levels.	DeSOx additive will continue to be used in the FCC to reduce the loading on the WGS. The WGS will further reduce SOx concentrations in the flue gas from the FCC unit prior to the PCC Plant. It is considered that SO_2 will be reduced to levels that will minimise the generation of heat stable salts.
5.2	The impact of NOx in the flue gas will vary significantly with the solvent composition. If the amine blend will form significant amounts of stable nitrosamines with NOx in the flue gas, then you must reduce NOx to as low a level as practicably possible using selective catalytic reduction (SCR).	An SCR is being installed to reduce NOx concentrations in the flue gas from the FCC Unit prior to the PCC Plant.
	If necessary, it is expected that ammonia (NH_3) slip from the SCR unit could be addressed in a suitably designed PCC unit. In all cases, you must assess the effects of NOx in the flue gas on atmospheric degradation reactions and this may also affect the need for SCR.	Ammonia was previously used in the existing ESP on site, and therefore ammonia slip was already emitted from the FCC Unit stack. The dispersion modelling assessment (Appendix D) included ammonia slip from the PCC Plant.
	If SCR is not fitted to a new build power plant, it is generally considered BAT to maintain space so it may be retrofitted in future, should this be considered necessary to meet ELVs.	Not applicable.
5.3	Sulphur trioxide (SO_3) droplets and fine particulates should not be present in the flue gas. If they arise in the PCC process they can cause significant amine emissions. The level of emissions (mainly solvent amines) are not directly related to aerosol measurements. Monitoring aerosols is difficult	The Wet ESP will remove aerosols and a mist eliminator will be located after the water wash section at the top of the Absorber Column to further minimise aerosol release.

Ref.	BAT Requirement	Response
	and aerosol quantities may also vary significantly over time. Aerosols might be present, for example, because of significant SOx in the flue gas. Where this is the case, you should carry out long-term testing on a pilot plant or the actual plant, with all planned countermeasures in place, to show satisfactory operation. You should also carry out regular isokinetic sampling in the operational plant to assess total vapour and droplet emission levels.	
5.4	You may need to remove materials in the flue gas that would accumulate as impurities in the solvent (such as metals, chlorine and fly ash) to lower concentrations than is required under the LCP BRef. This is to ensure satisfactory PCC plant operation. Whether you need to do this will depend on the specific solvent properties and the effectiveness of the solvent management equipment (such as filtering and reclaiming).	The WGS and Wet ESP will reduce particulates from the catalyst fines from the FCC Unit significantly over the current emissions. Correspondingly, emissions of metals will be very low and therefore will not impact on the solvent.
	You should assess the effects of flue gas impurities through realistic, long term pilot testing. In general, your PCC plant must abate these types of flue gas impurities before the residual flue gases are finally released to atmosphere.	Flue gas impurities have been considered in the plant design and it has not been deemed necessary to provide further abatement other than that discussed in this application.
6. PCC System Operation		
Operating Temperatures		
6.1	You must establish and maintain optimum temperature and appropriate limits in the solvent stripping process. Elevated temperatures can cause some thermal degradation of the solvent. But higher peak average temperatures during regeneration will also likely promote reduced energy requirements and higher CO_2 capture levels. You must balance both to ensure the right environmental outcome. Where feasible, you should avoid locally higher metal skin temperatures, such as from the use of superheated steam in heaters, as this provides no benefit and can result in degradation.	The PCC Plant design is such that it will operate at optimised conditions for the Cansolv DC-103 solvent. The steam supply to the CO_2 Stripper has been selected because it has a saturation temperature that is lower than the degradation temperature of DC-103.
Solvent Degradation		
6.2	You should minimise oxidative degradation of the solvent by reduced solvent residence times in the absorber sump and other hold-up areas. Direct O_2 removal from rich solvent	The PCC Plant design is such that it will operate at optimised conditions for the Cansolv DC-103 solvent.

Ref.	**BAT Requirement**	**Response**
	may be developed in the future but has not yet been proven at scale.	
7. Absorber Emissions Abatement		
Water Wash		
7.1	You must use one or two water washes or a scrubber to return amine and other species to the solvent inventory. Capture levels are limited by vapour or liquid equilibria, with volatile amines captured less effectively. Any aerosols present will also not be captured effectively. Water washes alone are ineffective in preventing NH_3 emissions, as concentrations will increase until the rate of release balances the rate of formation (and possibly addition from SCR slip).	There will be a single water wash section in place, which will enable solvent reuse. In addition, a mist eliminator will reduce aerosols present in the released flue gas. Ammonia emissions will be minimal from the operational PCC Plant and therefore no additional abatement is required.
Acid Wash		
7.2	An acid or other chemically active wash or scrubber after the water wash will react with amines, NH_3 and other basic species and reduce them to very low levels (for example, 0.5 to 5mg per m^3 per species or lower). You should implement an acid wash as BAT, unless: • emission levels are already at acid wash levels with a water wash • you can show that the need to dispose of the acid wash waste outweighs the benefits of the additional reduction in emissions to atmosphere Depending on PCC system configuration, an absorber acid wash can also counteract NH_3 slip from an SCR system. If an acid wash is not fitted, you should consider a second water wash as an acid wash if: • emission performance is worse than expected • you wish to change to a more volatile solvent An acid wash is not likely to trap aerosols.	An acid wash is not considered necessary to further reduce amine, NH_3 or other pollutants from the process, based on the anticipated emission concentrations. The low volatility of the Cansolv DC-103 solvent helps to minimise the amine emissions and ammonia slip from the SCR will be reduced to very low levels through the WGS. Additional space for increasing the packing within the water wash section has been included in the design, for in the event that amine emission concentrations are higher than those anticipated.
Droplet Removal		
7.3	You must prevent emissions of aerosols. To do this you could use standard droplet removal sections after washes. These will prevent droplet carryover from the wash. However, they are not effective against very fine	SO_3 and fine particulates in the flue gas that can lead to the formation of aerosols in the Absorber will be removed by the Wet ESP. In addition, a mist eliminator will be located at the top of water wash section to further

Ref.	BAT Requirement	Response
	aerosols arising from SO_3 or other aerosol mists.	prevent the entrainment of droplets and aerosols into the waste gases.
Stack Height		
7.4	Where modelling predicts that you may need to raise the temperature at the point of release to aid dispersion, you can: • increase the design stack height • add flue gas reheating Flue gas reheating can also reduce the plume visibility. Heat from cooling the flue gas before the PCC plant or waste heat from the PCC process should be used for flue gas reheating (see section on cooling).	Detailed dispersion modelling has shown that a stack height of at least 65m for the PCC Plant will ensure that pollutants released will not result in exceedance of any air quality standards. On the basis of the model results, it is not considered that flue gas reheating is required.
8.0. Process and Emissions Monitoring		
Role of Monitoring		
8.1	You must also carry out monitoring to show that resources are being used efficiently. This includes: • energy and resource efficiency • capture efficiency • verification that the CO_2 product is suitable for safe transport and storage Your permit application should include a monitoring plan for both a commissioning phase and routine operation. • During the commissioning phase you will need to optimise the operating envelope for the process. When you have achieved this, the process operation will then become routine, along with the monitoring	The Installation is required to monitor and report energy and resource efficiency figures. The PCC Plant operation will also be monitored continuously to report the resource and energy efficiency of the plant.
8.2	It is likely you'll need to do more extensive monitoring during commissioning than during routine operation. As PCC is an emerging technique, you will need to develop monitoring methods and standards. You should include proposals for this in your permit application.	It is anticipated the commissioning monitoring plan will be developed further into the detailed design process, and therefore it is envisaged that this can be provided to the EA through a Pre-operational Condition within the Environmental Permit. Proposed monitoring methods and standards are detailed in Section 6.2.
8.3	Compliance with ELVs in the permit will provide the necessary protection for the environment, by monitoring emissions at authorised release points. You must also show that you are managing the process to	Monitoring will be carried out in line with proposals in Section 6.1 of this document.

Ref.	BAT Requirement	Response
	prevent (or minimise) the formation of solvent degradation products.	
8.4	Where degradation products are formed (and may be released), you must reduce these and any solvent emissions to the appropriate level. This process control monitoring will also be part of the permit conditions.	Process control monitoring to ensure that degradation products do not build up in the PCC Plant will involve a weekly sampling and testing schedule for degradation products, as advised by the solvent supplier based on their operational experience.
9. Point Source Emissions to Air		
9.1	You must include monitoring to demonstrate compliance with the IED Chapter III ELVs and the LCP BRef BAT-AELs at normalised conditions.	LCP BRef BAT-AELs not applicable, but BAT-AELs for FCC units from the Refineries BATc will be met. CEMS for monitoring of flue gases from the PCC Plant will be installed. In addition, CEMS will be installed on the WGS for in the event that the FCC Unit is required to operate in CO_2 unabated mode. Extractive monitoring for particulates is proposed.
	Monitoring for: • Ammonia • Volatile components of the capture solvent • Likely degradation products such as nitrosamines and nitramines	It is intended that CEMs monitoring of these species will be included for the PCC Plant, however the exact specification of equipment to monitor the amines and degradation products is yet to be confirmed. If no suitable equipment is available, these will be monitored by periodic extractive monitoring.
	Your monitoring may be either: • Continuous emissions monitoring (on line) • Periodic extractive sampling (off line) – where aerosol formation is expected, this must be isokinetic	As described above.
10. Process Control Monitoring		
10.1	You should use process control monitoring or periodic sampling with off-line analysis to control the CO_2 capture and the quality of the solvent reclaiming. Parameters you can monitor include: • absorber solvent quality – percentage active solvent • CO_2 loading both rich and lean solvent • maximum solvent temperature • heat stable solvent content • solvent colour or opacity • soluble iron and other metals and degradation products	The PCC Plant will include instrumentation to monitor and record CO_2 capture rates and purity. Sampling points will be provided to collect fluid samples of the solvent to ensure the quality of solvent reclaiming.

Ref.	BAT Requirement	Response
	• in water or acid washes and scrubbers – pH, conductivity, loading of abated substances, flow rate	
Monitoring of CO_2		
10.2	To meet the required specification, include: • CO_2 mass balance • CO_2 in fuel combusted • total capture level (as a percentage) • CO_2 released to the environment • CO_2 quality	These parameters will be monitored as part of the PCC Plant operation.
Monitoring Standards		
10.3	The person who carries out your monitoring must be competent and work to recognised standards such as the Environment Agency's MCERTS scheme. MCERTS sets the monitoring standards you should meet. The Environment Agency recommends that you use the MCERTS scheme where applicable. You can use another certified monitoring standard, but you must provide evidence that it is equivalent to the MCERTS standards. There are no prescriptive BAT requirements for how to carry out monitoring. Monitoring methods need to be flexible to meet specific site or operational conditions.	Any extractive monitoring carried out on the emissions from the PCC Plant will be carried out by MCERTS accredited contractors.
	You must use a laboratory accredited by the UKAS to carry out analysis for your monitoring.	Where required and available, UKAS accredited labs will be used for analysis.
11. Unplanned Emissions to the Environment		
11.1	You should propose a leak detection and repair programme that is appropriate to the solvent composition. This should use industry best practice to manage releases, including from joints, flanges, seals and glands. Your hazard assessment and mitigation for the plant must consider the risks of accidental releases to environment. This should also consider the actual composition of the fluids, gases and vapours that could be released from the plant after an extended period of operation. (Not only fresh solvent as initially charged.)	The PCC Plant will be part of the Installation's maintenance and operations programme and LDAR programme and will include routine operator checks and portable analysers to detect and monitor any leaks, as appropriate. Any leaks identified will be repaired by licenced contractors. The current design is to provide the CO_2 Compression system with an unlit CO_2 vent stack for the safe disposal of CO_2 to atmosphere. This approach may be rationalised in the next phase of engineering design. Any venting of CO_2 will be in line with applicable Health and Safety Executive (HSE) guidelines. Suitable automated systems will be installed to provide for early detection and warning of

Ref.	BAT Requirement	Response
		CO_2 release or leak that will allow plant personnel to move to a place of safety in sufficient time to prevent harm from occurring.
12. Capture Level, Including During Flexible Operation		
12.1	Capturing at least 95% of the CO_2 in the flue gas is considered BAT. You can base this on average performance over an extended period (for example, a year). To achieve this, you should make sure the design capture level for flue gas passing through the absorber equates to at least 95% of the CO_2 in the total flue gas from the power plant. If you process less than the full flue gas flow, your capture rate will have to be correspondingly higher. Over the averaging period, your capture level may vary up or down. As the fraction of intermittent renewable generation in the UK rises, CCS power plants will need to start and stop more often, and possibly also operate at variable loads. It is therefore important that CO_2 can also be captured at high levels during these periods, including during start-up and shutdown, to maintain high average capture levels. A method to maintain capture at normal rates or higher at all times using solvent storage has been identified in the BAT Review. This, or alternatives that can achieve equivalent results, is considered BAT. If your PCC plant is not initially constructed with this capability, your permit application should show how you may retrofit it.	The expectation is that the PCC Plant will demonstrate approximately 95% capture rates are achievable. The intermittency of power generation is not applicable, the FCC runs at relatively rateable loads while online, and has planned unit outages at 6 year intervals.
13. Compression		
13.1	You should select CO_2 compressors based on the expected duty. You should consider how any waste heat arising may be used.	The type of compressor will not be confirmed until later in the detailed design process, however the intention is that integrally geared units will be employed if possible to maximise the efficiency and to minimised the number of compression trains.
13.2	For base load operation, you should use integrally geared units because they give the: • Maximum full-load efficiency • Minimum number of compression trains	As above.
13.3	For flexible and part-load operation, smaller compression trains (for example 2 at 50% compared to 1 at 100%) may be preferable. The use of different types of compressor or pump in series may also be preferable, to give	As above.

Ref.	BAT Requirement	Response
	greater flexibility at the expense of slightly lower full-load efficiencies.	
14. Noise and Odour		
14.1	Consider additional process steps in PCC technology that have high potential for noise and vibration. In particular, CO_2 compression could be an area of concern. Once you've identified the main sources and transmission pathways, you should consider the use of common noise and vibration abatement techniques and mitigation at source wherever possible. For example: • Use of embankments to screen the source of noise • Enclosure of noisy plant or components in sound-absorbing structures • Use of anti-vibration supports and interconnections for equipment • Orientation and location of noise emitting machinery Change of the frequency of the sound	A Noise Impact Assessment (Appendix F) has been undertaken in support of this Environmental Permit variation application, and includes an assessment of all potential sources of noise from the PCC Plant, including but not limited to the CO_2 compression. Considering the industrial setting of the PCC Plant within the boundary of an existing Installation, the relative noise generated by the compressors is considered to be not significant.
14.2	The handling, storage and use of some amines may result in odour emissions, so you should always use best practice containment methods. Where there is increased risk that odour from activities will cause pollution beyond the site boundary, you will need to send an odour management plan with your permit application.	Solvent will be stored appropriately to ensure minimal odour emissions. The Cansolv DC-103 solvent has very low volatility and therefore is not considered to represent a particular odour risk.
15. Cooling		
15.1	You will be able to achieve the best power and CO_2 capture plant performance by using the lowest temperature cooling available. You should use the hierarchy of cooling methods as follows: • direct water cooling (such as seawater) • wet cooling towers • hybrid cooling towers • dry cooling – direct air-cooled condensers and dry cooling towers	Cooling will be provided from the Installation's cooling water system and additional air cooling. The balance between water and air cooling will be managed within constraints of available water.
15.2	Power plants that are retrofitted with PCC using steam extraction, or are intended to be able to operate without capture, can share water cooling between the power plant and the PCC system. This is because the cooling load on the main steam condensers falls with increased steam extraction rate. This shift away from condenser cooling will not apply for systems with direct aircooled condensers.	Not applicable.

Ref.	BAT Requirement	Response
	It may also be possible to reuse cooling water after the main condensers for higher-temperature cooling applications in the PCC plant. However, site specific water discharge temperature limits may be an issue for direct cooling.	
15.3	A feature of PCC is that you have to remove heat from a flue gas stream that was originally not cooled. You can still achieve rejection of heat to atmosphere by heating the flue gas leaving the absorber, using heat from the incoming flue gas. You can do this either: • directly – such as using a rotary gas-gas heater • indirectly – such as using a heat transfer fluid or low-pressure steam	Heat from the FCC Unit will be used to generate steam for use in the PCC Plant. As it is not considered that flue gas reheating is required, the rejected heat will have beneficial use elsewhere in the PCC Plant.
15.4	Lean and rich solvent storage may also help you achieve satisfactory PCC performance during periods of high cooling demand.	Not relevant to the Refinery process.
15.5	You should refer to the Environment Agency's evidence on cooling water options for the new generation of nuclear power stations in the UK when considering options for cooling. This gives an overview of UK power station cooling water systems in use in the UK and abroad.	Due to the limited cooling load compared to a power station air cooling, it is not considered that this guidance is relevant. Air cooling is also considered to be BAT due to the constraints of water availability in the Humber region.
16. Discharge to Water		
16.1	For discharges to water, you should refer to the guidance on surface water pollution risk assessment for your environmental permit. For best practice in plume dispersal modelling, see the Joint Environmental Program report 'A protocol on projects modelling cooling water discharges into TrAC waters within power station developments'.	The potential impacts of sulphates from the WGS effluent stream have been discussed in the application. The use of DeSOx is assumed be employed to reduce the sulphate level in the effluent, however there is limited options for further treatment on site. Further work is being carried out to better understand the sensitivity of the receiving environment, and if required additional assessment will be carried out in agreement with the EA.
17. Climate Change Adaptation		
17.1	You need to integrate climate change adaptation into your management system.	The EA's Adapting to climate change: Refineries and fuel guidance has been consulted[21] and a Risk Assessment has been prepared and is provided in Appendix K.

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[21] Refineries and fuel: examples for your adapting to climate change risk assessment - GOV.UK (www.gov.uk)

Appendix D – Air Impact Assessment

See Appendix D Electronic File

Appendix E – CO_2 Venting Assessment

See Appendix E Electronic File

Appendix F – Noise Impact Assessment

See Appendix F Electronic File

Appendix G – Noise Management Plan

See Appendix G Electronic File

Appendix H – H1 Screening Tools

Access database files

Appendix I – AECOM Water Monitoring Report

Appendix J – Qualitative Risk Assessment

Assessment of Fugitive Emission Risks

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
Escape of odour from stored chemicals	Local residents/ businesses beyond the Installation Boundary	Vapours/ odour carried on wind	The PCC Plant will use and store chemicals, which will be managed in accordance with appropriate management procedures. All raw materials will be stored in suitable sized above ground tanks and containers, provided with sufficient spillage containment, in accordance with the relevant material specifications. Where necessary bulk storage tanks will have abated breather vents. Tanker deliveries of ammonia will be back vented to the delivery tankers.	Probability of exposure is considered to be very low due to management procedures.	Complaints of odours/ smells in vicinity of local receptors	Very low
Escape of amines/ odour during operation	Local residents/ businesses beyond the Installation Boundary	Vapours/ odour carried on wind	The PCC Plant will be designed to ensure fugitive emissions will be minimised as far as possible through detailed design.	Probability of exposure is considered to be very low due to plant design and management procedures.	Complaints of odours/ smells in vicinity of local receptors	Very low
Escape of raw materials including hazardous chemicals	Local surface water and/ or groundwater	Flow by gravity/ drainage systems/ unsurfaced areas	Storage arrangements appropriate to materials being stored; impermeable surfacing across the PCC Plant; bunded storage facilities; limited external storage facilities; high and low level tank alarm systems; segregated drainage systems for offloading areas with interceptors and isolation points; and inspection and maintenance at regular intervals. All raw materials stored will be stored in appropriate containers,	Fugitive releases could reach surface water and/ or groundwater but appropriate design and management actions should prevent this from happening. All chemical storage tanks will be bunded to provide sufficient containment in the event of a tank/ containment failure.	Localised pollution of surface water and groundwater	Low

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
			provided with sufficient spillage containment, in accordance with the relevant material specifications.	Site underlain by clay strata, protecting groundwater. Probability is therefore low.		
Escape of wastes from PCC Plant, including hazardous chemicals	Local surface water and/ or groundwater	Flow by gravity/ drainage systems/ unsurfaced areas	Storage arrangements appropriate to materials being stored; impermeable surfacing across the PCC Plant; bunded storage containers with closed drainage systems; and inspection and maintenance at regular intervals. All materials stored will be stored in appropriate containers, provided with sufficient spillage containment, in accordance with the relevant material specifications.	Fugitive releases could reach surface water and/ or groundwater but appropriate design and management actions should prevent this from happening. All chemical storage tanks will be bunded to provide sufficient containment in the event of a tank/ containment failure. Site underlain by clay strata, protecting groundwater. Probability is therefore low.	Localised pollution of surface water and groundwater	Low

Assessment of Visible Plume Risks

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
Operation of PCC Plant emission stack	Local residents/ businesses beyond the Installation boundary	Dispersion by wind	Visible plumes could potentially occur from the PCC Plant absorber stack due to the lower temperature of release and the water content of the flue gas. An assessment has been undertaken using ADMS modelling to predict visibility of plumes from the absorber stack. The results show that the plumes are predicted to be visible for 22% of the time, with average plumes only being very short (<12m). Occasional longer plumes are predicted (up to 241m), however these are predicted to occur for less than 1% of the time. Therefore, associated impact of visible plumes is considered to be low.	Very low given location of the Installation, and applied management procedures.	Nuisance – visible plume	Low

Assessment of Accident Risks

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
Fire	Local residents/ businesses beyond the Installation boundary. Site staff and infrastructure.	Emissions of smoke to the air and potentially firewater, foam, etc. to site drainage and soil/ groundwater and waters	Fire detection across all plant areas. Provision of a firefighting water supply with adequate flow and pressure to feed fire suppression systems. Use of sprinklers and/ or foam systems to protect all raw materials and plant areas; chemical tanks and bund areas and accommodation areas. Use of portable extinguishers plant wide and smoke vents in designated areas. Installation designed to contain contaminated firewater and spillages within the Installation boundary and site drainage system, with dedicated firewater storage tanks and drainage diversion and containment systems.	Appropriate design and management actions should allow the early detection of/ minimisation of the risk of fire spreading. Containment infrastructure is in place for firewater management.	Complaints of smoke/ smells in vicinity from local residential receptors. Localised pollution of surface water and soil/ groundwater.	Low
Flooding of the Installation and associated contamination of flood waters with chemicals/ fuel stored on site	Local surface water and/ or groundwater	Flow by gravity/ drainage systems/ unsurfaced areas	The flood defences in proximity to the Installation are considered to be in fair condition. Based on the information provided by the EA, it has been determined that the Installation is at a 'low' risk of flooding from tidal and fluvial sources risk of flooding (at the defence) up to the 0.5% AEP (1 in 200-year return period) flood event. The Environment Agency inspects these defences routinely to ensure potential defects are identified. Flood mitigation measures will be implemented on the PCC Plant, a system would be put in place to safeguard the site occupants. Measures will include, but not be limited to, implementation of a Flood Response Plan.	Low The EA Flood Maps illustrate that the Installation (including the PCC Plant area) is mainly located within Flood Zone 1 (i.e. a Low risk of flooding from tidal and fluvial sources). In addition, defences are in place and additional mitigation measures will be implemented.	Localised flooding of the PCC Plant and neighbours. Potential pollution of surface water and groundwater from escape of chemicals.	Low
Vandalism to plant, equipment and infrastructure	Local residents/ businesses beyond the	Emissions resulting from failure/ reduced	Security fence, appropriate intruder alarms and CCTV cameras to be located at numerous locations on Site, with restricted entry; relevant	Negligible. Appropriate design and management	Complaints of odours in the vicinity of local receptors.	Low

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
and associated loss of fuel/ chemicals from site	Installation boundary, air, land and water. Site staff and Infrastructure.	performance of vandalised plant, equipment and infrastructure	signage; building envelope around a significant proportion of the operation/ process.	actions should prevent vandalism happening.	Localised pollution of surface water and groundwater. Potential for injury, damage to plant/ equipment.	

Appendix K – Climate Change Risk Assessment

Ref.	Requirements	Response
Summer daily maximum temperature This may be around 7°C higher compared to average summer temperatures now, with the potential to reach extreme temperatures as high as over 40°C with increasing frequency based on today's values.		
Impact 1	Increased potential for non-methane volatile organic compound (NMVOC) emissions from storage tanks with atmospheric vents, with associated odour impacts.	The Cansolv DC-103 solvent has low volatility and odour potential. Storage tanks will be suitably designed.
Impact 2	There would be a greater likelihood of activation of pressure relief systems on sealed storage systems leading to increased routine flaring.	Pressure relief systems will be suitably designed to take into account potential increasing ambient temperatures.
Impact 3	There could be an increased risk of fire on adjacent facilities, woodland and common ground, which could spread to the refinery or impede local fire and rescue services (FRS) from accessing site.	Prolonged periods of extreme heat and dry conditions could increase the risk of fires on site which can cause damage to infrastructure assets and become a potential safety hazard. Mitigation for this includes: - Vegetation cleared around the Site. - Fire detection and protection built into the design of the PCC Plant area e.g. fire hydrants, ring main of water. Site Emergency Response Plans & team to manage and control fire risk.
Impact 4	There could be a risk of wildfires affecting power supply to key areas of plant.	Mitigation for this includes: - Engagement with VPI CHP Power Plant to help manage fire risks. - Vegetation cleared around the Sites. - Fire detection and protection built into the design of the PCC Plant e.g. fire hydrants, ring main of water. Site Emergency Response Plans & team to manage and control fire risk.
Impact 5	Increased energy and water consumption due to added load on cooling systems.	The PCC Plant is designed to ensure that the cooling systems will not limit cooling in warmer ambient temperatures and the VPI CHP has the capacity to provide additional energy, if required.
Impact 6	Risk of overloading vacuum systems.	There is only one vacuum system on the PCC Plant (Thermal Reclaimer). The thermal reclaimer has a larger design margin than any other part of the plant in order to ensure solvent quality is maintained. Given the large design margin, should feed rates need to be reduced in order to maintain vacuum this could be achieved whilst still maintaining the required solvent quality.
Impact 7	Increased potential for odour generation from effluent treatment systems, including storage tanks and lagoons.	Effluent from the PCC Plant will enter the existing site drainage systems. The operation of the ETP is monitored and maintained in line with the existing Environmental Permit and site EMS.
Winter daily maximum temperature This could be up to 4°C more than the current average with the potential for more extreme temperatures, both warmer and colder than present.		

Ref.	Requirements	Response
Impact 1	In extreme cold weather, the risk of: failure of trace heating systems freezing of cooling water, resulting in blockages – particularly on long pipelines and storage in exposed areas This could also lead to process failures and flaring events.	Extreme cold temperatures result in freezing of instrumentation and lines. Mitigation for this includes: - Regularly inspect and maintain insulation. - Good plant design, heat tracing of any lines susceptible to freezing. - Winterisation of plant instruments (good instrument design).
Impact 2	Increased risk of water pipework ruptures, affecting: • boiler condensate • process water • cooling water • effluent systems This in turn may lead to process interruption and flaring.	As above.
Impact 3	Failure of pH control due to caustic systems solidifying (for example, effluent treatment)	As above.
Impact 4	Extremes of hot and cold temperatures are likely to affect the performance of biological treatment facilities and may kill the biological organisms.	As above.
Impact 5	Viscous materials such as crude oil, crude distillation unit (CDU) and vacuum distillation unit (VDU) residues become immobile in cold weather causing process interruptions and damage to pumping equipment.	As above. Amine storage will have trace heating.
Impact 6	Frozen on-site roadways may restrict access for staff and emergency vehicles.	Controls in line with existing site procedures for such occurrences will be put in place for the PCC Plant.
Impact 7	Damage to site infrastructure from snow-loading over extended periods.	Mitigation for this includes: - Regularly inspect and maintain insulation. - Good plant design, heat tracing of any lines susceptible to freezing. Winterisation of plant instruments (good instrument design).
Daily extreme rainfall Daily rainfall intensity could increase by up to 20% on today's values.		
Impact 1	Flooding could lead to: • power failure • process disruption • infrastructure damage • restrictions on site access for staff and emergency services	Extreme rainfall events lead to surface water flooding and can cause damage to infrastructure, building surfaces and exposed utilities. Mitigation for this includes: - Protection and raising of critical equipment. - Suitable storage and bunding of pollutants to protect from high rainfall events. Supported by a Site Emergency Response Plans. - Installation of a suitable sustainable surface water drainage network and management

Ref.	Requirements	Response
		system (SuDS) to protect from high rainfall events. - Flood Resistance and Resilience Measures will be implemented as required, including: i. pipelines and storage tanks designed to withstand the water pressures associated with high return period event flooding; ii. tanks securely tethered in such a way to ensure the infrastructure remains secure should flooding occur; iii. electrical supply entering the PCC Plant from height and down to required connections; iv. flood proofing including the use of water resistant coatings, use of galvanised and stainless steel fixings and raising electrical sockets and switches; v. suitable waterproofing measures to development located below ground i.e. tanking below ground storage areas etc. vi. make use of EA flood warnings and alerts; and vii. define emergency access and egress route. - The Flood Risk Assessment (FRA) carried out for the TCPA application has considered climate change within its assessment. It has assessed the PCC Plant based on a 'high emissions' future scenarios including increases in extreme rainfall, flood flow and flash flood times. - All buildings will be designed to UK standards and specifications. - Maintenance inspections planned for operation.
Impact 2	Bunded areas could get flooded, reducing their capacity.	Bunds will be suitably designed, taking into account potential rainfall scenarios at detailed design stage. Consideration to bund level detection systems will also be given at detailed design. Bunds will be subject to frequent inspections, and in the event of extreme rainfall, the frequency of inspections will be increased.
Impact 3	Roof drains on floating roof tanks could become overwhelmed.	No floating roof tanks are proposed for the PCC Plant.
Impact 4	Potential for contaminated floodwater or surface water run-off from the site, causing pollution.	New, separate foul and surface water drainage system will be constructed for the PCC Plant area. Further details on the design of the drainage system, including attenuation, restricted discharge to South Killingholme Drain and accounting for climate change (factor of 25%) is provided in the Drainage Strategy presented as Annex C in the FRA within Appendix 9A in ES Volume II (Appendix B).

Ref.	Requirements	Response
Impact 4	Potential for increased site surface water and flooding.	As response for Impact 1 above.
Impact 5	Effluent treatment facilities overwhelmed with storm water, leading to direct discharge of untreated effluent to controlled water.	Further details on the design of the drainage system, including attenuation, restricted discharge to South Killingholme Drain and accounting for climate change (factor of 25%) is provided in the Drainage Strategy presented as Annex C in the FRA within Appendix 9A in ES Volume II (Appendix B).
Impact 6	Heavy precipitation falling as snow in winter could result in damage to equipment and collapse of old fragile roofs. Access around the site may also be hampered by snow on roads.	As response for Impact 1 above.
Average winter rainfall Average winter rainfall may increase by over 40% on today's averages.		
Impact 1	Erosion of earth bunds by prolonged heavy rainfall, reducing containment capability.	No earth bunds proposed for the PCC Plant area.
Impact 2	On-site flooding leading to: • power failure • process disruption • infrastructure damage • restrictions on site access for staff and emergency services	As above for Daily extreme rainfall response to Impact 1.
Impact 3	Prolonged saturation of unmade ground resulting in soil movement and erosion and subsidence of cross-country pipelines leading to loss of containment.	Not applicable to the PCC Plant area.
Impact 4	Bunds and tertiary containment fill up with rainwater, reducing the capacity for containing a spillage of a hazardous material.	Bunds will be suitably designed, taking into account potential rainfall scenarios at detailed design stage. Consideration to bund level detection systems will also be given at detailed design. Bunds will be subject to frequent inspections, and in the event of extreme rainfall, the frequency of inspections will be increased.
Impact 5	Potential for contaminated floodwater or surface water run-off from the site, causing pollution.	New, separate foul and surface water drainage system will be constructed for the PCC Plant area. Further details on the design of the drainage system, including attenuation, restricted discharge to South Killingholme Drain and accounting for climate change (factor of 25%) is provided in the Drainage Strategy presented as Annex C in the FRA within Appendix 9A in ES Volume II (Appendix B).
Impact 6	Effluent treatment facilities could be overwhelmed with storm water, leading to direct discharge of untreated effluent to controlled water.	Further details on the design of the drainage system, including attenuation, restricted discharge to South Killingholme Drain and accounting for climate change (factor of 25%) is provided in the Drainage Strategy presented as Annex C in the FRA within Appendix 9A in ES Volume II (Appendix B).
Sea level rise		

Ref.	Requirements	Response
Sea level rise which could be as much as 0.6m higher compared to today's level.		
Impact 1	Increased risk of flooding of refinery process areas and associated impacts as previously identified.	Sea level rise results in coastal flooding causing inundation of the PCC Plant (or parts of the PCC Plant) causing damage to infrastructure. Mitigation for this includes: - Suitable storage and bunding of pollutants to protect from high rainfall events. Supported by a Site Emergency Response Plans. - Installation of a suitable sustainable surface water drainage network and management system (SuDS) to protect the PCC Plant area from high rainfall events. - Flood Resistance and Resilience Measures will be implemented as required for the PCC Plant area, including: i. pipelines and storage tanks designed to withstand the water pressures associated with high return period event flooding; ii. tanks securely tethered in such a way to ensure the infrastructure remains secure should flooding occur; iii. electrical supply entering the PCC Plant from height and down to required connections; iv. flood proofing including the use of water resistant coatings, use of galvanised and stainless steel fixings and raising electrical sockets and switches; v. suitable waterproofing measures to development located below ground i.e. tanking below ground storage areas etc. vi. make use of Environment Agency flood warnings and alerts; and vii. define emergency access and egress route. - The Flood Risk Assessment (FRA) has considered climate change within its assessment. It has assessed the PCC Plant based on a 'high emissions' future scenarios including increases in extreme rainfall, flood flow and flash flood times. - All buildings will be designed to UK standards and specifications. - Maintenance inspections planned for operation.
Impact 2	Jetties become inaccessible (tide and wave height) or inoperable so raw materials cannot be delivered by ship.	There are multiple entry points of raw materials into the UK to ensure continuity of supply.
Drier summers Summers could see potentially up to 40% less rain than now.		

Ref.	Requirements	Response
Impact 1	Drought restrictions on direct and indirect abstraction, affecting the availability and quality of incoming water for cooling, boiler and process services.	The PCC Plant area has been designed to use mainly air cooling, to minimise additional water use. The PCC Plant has also been designed to maximum water reuse within the process where appropriate.
River flow The flow in the watercourses could be 50% more than now at its peak, and 80% less than now at its lowest.		
Impact 1	Longer periods of low water in estuaries, restricting access for shipping.	There are multiple entry points of raw materials into the UK to ensure continuity of supply.
Impact 2	Poorer dispersion in receiving waters of large effluent streams.	South Killingholme Drain feeds into the Humber Estuary and therefore dispersion is not anticipated to be affected at this receptor.
Impact 3	Potential for inability to discharge when a watercourse is at high level, leading to effluent treatment inundation and failure.	Further details on the design of the drainage system, including attenuation, restricted discharge to South Killingholme Drain and accounting for climate change (factor of 25%) is provided in the Drainage Strategy presented as Annex C in the FRA within Appendix 9A in ES Volume II (Appendix B).
Storms		
Impact 1	Stability of tall and exposed structures such as tanks is at risk in stronger winds along with jetties with higher sideways loadings due to wave and wind action.	Storm results in damage to structures/ equipment and resulting in repairs costs or reduced functionality, and/or unacceptable safety risks. Mitigation for this includes: - Wind loadings will be considered within the detailed design of plant. - Quality control during construction and maintenance to secure at risk lagging. - The Flood Risk Assessment (FRA) considers climate change considerations of the 'high end' future scenarios including increases in extreme rainfall, flood flow and flash flood times. - Maintenance inspections planned for operation. - Procedures in place for extreme weather events (including wind) e.g. minimise maintenance during high wind events. - Lightning protections (rods) built into structures. Structures are also earthed. - In built protection measures to allow for safe shut-downs (fail-safe). Storm event or heat event results in local power outage (power outage of VPIs CHP Plant) causing disruption to carbon capture facility operations and reduced efficiency. Mitigation for this includes: - Redundancy in power supply from grid connection as back-up. - Further redundancy included in electrical expansion design.

Ref.	Requirements	Response
		- In built protection measures to allow for safe shut-downs (fail-safe).
Impact 2	Increased risk of damage during major maintenance, such as to lifting equipment.	Risk assessments are carried out on site for all such work in line with existing site procedures. Weather conditions is taken into account during these risk assessments.

Appendix L - Company Information and Directors

Company name – Phillips 66 Limited

Registered office address – 7th Floor, 200–202 Aldersgate Street, London, England, EC1A 4HD

Company number – 00529086

Details of Company Secretaries

Secretary Name (Last name, First name)	Appointed on
Gennings, Sarah	12 January 2018
Janaszek, Anna	12 January 2018
Price, Elaine Marie	30 April 2012
White, Ruth Maretta	30 April 2012

Details of Directors (Active only)

Director Name (Last name, First name)	Date of Birth	Appointed on
Fursey, Paul Matthew		1 January 2023
Holland, Neal Andrew		18 November 2020
Love, Chad Ray		9 January 2023
McKnight, Nina Elizabeth		18 November 2020
Sherwell, Robin Edwin		31 December 2018
Taylor, Gary Stuart		14 May 2012
Turner, Rupert Justin		2 September 2022