5 Emissions, discharges and wastes

5 EMISSIONS, DISCHARGES AND WASTES

5.1 Introduction

Over the lifetime of the Ichthys Gas Field Development Project (the Project) a range of emissions, discharges and wastes will be produced that will have the potential to effect the environment.

This chapter describes the air, light and noise emissions, the liquid discharges to the marine environment, and the non-discharged liquid and solid wastes that will be produced through the different phases of the Project.

The data in this chapter have been used as the basis for a number of technical studies, including air-quality modelling, noise modelling and water-dispersion modelling. These studies are discussed in subsequent chapters of this draft environmental impact statement (Draft EIS) and are provided in full as separate technical reports in the appendices.

5.2 Greenhouse gas emissions

Development of the Ichthys Field will result in greenhouse gas (GHG) emissions over the life of the Project. These emissions and their management are discussed in Chapter 9 *Greenhouse gas management*.

5.3 Air emissions

Combustion emissions will be generated from the offshore and onshore facilities over the 40-year life of the Project. Other air emissions of lower volume or magnitude will be non-combustion hydrocarbons released from vented and fugitive sources and nuisance emissions such as dust, smoke and odour.

An air-quality assessment has been conducted to determine predicted ground-level concentrations of key air pollutants produced by the Project. This is discussed in detail in Chapter 8 *Terrestrial impacts and management*.

5.3.1 Combustion emissions

Significant gaseous emissions from the production of gas and condensate will be generated by the combustion of fuel gas in the compressor turbines and power generation turbines at the offshore and onshore facilities. Other combustion sources include the flares, acid gas removal unit (AGRU) incinerators, hot-oil furnaces and supplementary steam boilers.

The most significant non-GHG pollutants from combustion emissions, in terms of volumes produced, are nitric oxide (NO) and nitrogen dioxide (NO_2) (together known as "NO_x") and carbon monoxide (CO). Small quantities (trace amounts) of methane (CH_4) and sulfur dioxide (SO_2) will also be present in the emission streams.

Emissions data for the priority pollutants NO_2, ozone (O_3), SO_2 and particulates (PM_{10}) have been modelled at the onshore location to predict ground-level concentrations in the Darwin region. Model outputs are provided and discussed in Chapter 8 and have been compared with Australian ambient air quality standards.

5.3.2 Non-combusted emissions

Non-combusted emissions, consisting primarily of volatile organic compounds (VOCs), will be produced from the onshore and offshore facilities. The main sources include vented emissions released from storage and loading facilities and fugitive emissions from compressor seals, valves, flanges and pumps.

VOCs are organic chemical compounds with a high enough vapour pressure under normal conditions to vaporise and enter the atmosphere. Benzene, toluene, ethylbenzene and xylenes (known collectively as BTEX) are examples of VOCs.

5.3.3 Ozone

Gas processing can generate the precursors required to initiate the generation of O_3, a colourless gas naturally found in the upper atmosphere. It is produced photochemically by the reaction of NO_x and VOCs in sunlight.

The generation of O_3 from photochemical smog is a localised phenomenon; it is produced relatively slowly, over several hours, after exposure to sunlight has been sufficient for a series of chemical reactions to be completed.

5.3.4 Particulates

Particulates will be generated during onshore construction and decommissioning in the form of dust, and during the operation of the onshore and offshore facilities in the form of smoke. Particulates of interest are those less than 10 μm in diameter (known as PM_{10} for particulate matter <10 μm) as these can remain airborne and can be spread by winds over wide areas and long distances.

Emissions of PM_{10} from the operation of the onshore processing plant have been quantified and included in the air quality modelling.

Dust

Dust emissions during the construction phase will result from the following:

- vegetation clearing and site preparation
- earthworks (e.g. site levelling and excavation)
- cut-and-fill activities
- wind erosion of stockpiled materials
- traffic movements on unsealed roads
- loading and transport of loose soil, aggregate and/or other dust-generating material
- the operations of crushing and screening plant
- the operations of concrete batching plant.

The quantification of dust emissions is problematic as they can vary substantially according to the effectiveness of the dust-control measures employed, the physical characteristics of the soil, the prevailing weather conditions and the level of construction activity being undertaken.

Dust emissions during the operations phase of the Project will be minimal as most earth movement will have been completed and all roads and permanent work areas will have been sealed. Activities similar to those of the construction phase will be undertaken during the decommissioning phase, but this is expected to generate lower volumes of dust.

Smoke

The main potential source of PM_{10} from the operation of the onshore processing plant will be from the shielded ground flare and the enclosed tankage flare. Particulates can be released during the incomplete combustion of hydrocarbons, which can occur when the flares are too cold or there is insufficient oxygen in the flames. These particulates are often visible as smoke and contain PM_{10}.

The flares will be designed to burn efficiently, thereby minimising smoke production. Flaring of gases will be significant in the few months of commissioning and during the subsequent and occasional 1-hour to 5-day events when:

- warm or inert liquefied natural gas (LNG) tankers are being loaded
- shutdowns and start-ups are taking place
- process upset conditions occur
- there is a real threat or perceived danger to personnel or the facility.

During these events, high-pressure gas sent to the flares will periodically produce smoke. The likelihood of smoke production will be increased when propane and butane are sent to the flares. This is because propane and butane are longer-chain hydrocarbons than methane and require more oxygen to burn; they are therefore more likely to produce particulate matter.

5.3.5 Odour

Potential odours associated with offshore and onshore gas processing during the Project may originate from sulfurous compounds such as hydrogen sulfide (H_2S) in the reservoir gas. The H_2S content in the Brewster and Plover reservoirs is predicted to be around 25 ppm (parts per million) by volume.

The H_2S needs to be removed from the natural gas to ensure that the LNG and other products meet buyers' specifications. Its removal is achieved by treating the gas in the AGRUs (which also remove carbon dioxide (CO_2)). The emissions from the AGRUs are directed to incinerators where residual H_2S is converted to the non-odorous sulfur oxides (SO_x) prior to release to atmosphere.

In the unlikely event that the AGRU incinerators are shut down, exhaust gases will be hot-vented through gas turbine exhaust stacks to facilitate safe dispersion. Potential odour impacts are discussed in Chapter 8.

5.3.6 Summary of air emissions

The following assumptions were made in estimating annual emissions from Project operations:

- The emissions are based on 365 days of production per year.
- The central processing facility (CPF) at the Ichthys Field will use gas turbines for export gas compression and power generation from the start of the Project, with additional turbines being employed for inlet compression from Year 11.
- The floating production, storage and offtake (FPSO) facility at the Ichthys Field will also use gas turbines to provide electrical power. Supplemental fired heating will be required for monoethylene glycol (MEG) regeneration when waste heat from the gas turbine stacks is not sufficient to fully regenerate all of the MEG.
- The onshore process will use nine open-cycle industrial gas turbines for power generation, with an operating philosophy of eight running and the ninth available from cold start.
- The onshore process will use gas turbine drivers for refrigerant compression loops, which will be operating continuously at 100% design load.
- The onshore process will include one incinerator and one hot-oil furnace on each LNG train.
- Waste-heat recovery systems will be installed on gas turbines on the FPSO and at the onshore facilities.

Table 5-1 provides estimates of the Project's key combustion emissions for the offshore and onshore facilities in tonnes per annum.

Table 5-1: Estimated annual combustion emissions from routine operations of the Ichthys Project

Ichthys Project emissions* (t/a)		
Air emission	Offshore facilities	Onshore processing plant
NO_x (as NO_2)	5000	2700
CO	5800	Not calculated
SO_x (as SO_2)	16	950
CH_4	8500	10 500
PM_{10}†	Not calculated	150
VOCs	1100	500

* Values are based on normal operating conditions and do not include fugitive or vented emissions.

† PM_{10} from dust is not included in this calculation because quantification of a non-point-source emission is difficult.

5.4 Light

The generation of artificial light from the construction and operation of the offshore facilities, the onshore processing plant and other Darwin Harbour infrastructure has the potential to result in light spill to the environment.

5.4.1 Offshore lighting

To provide safe working conditions, lighting will be required from the commencement of drilling and through the installation of the CPF and FPSO facilities to production. Lighting will be designed in accordance with the relevant Australian and international standards to ensure that worker safety is not compromised. For this purpose, lighting levels are required to be 150 lx at 1 m above the decks of the CPF and FPSO (note that 1 lx is equal to 1 lm/m^2).

Additional lighting will be required periodically on cranes and on portions of the CPF, the FPSO and the mobile offshore drilling unit (MODU) to allow safe loading and unloading of support vessels and export tankers. The purpose of these additional lights will be to minimise the potential for safety and environmental hazards and they will not be intentionally focused into the water. Light spill from these sources is expected to be of low intensity.

5.4.2 Onshore and nearshore lighting

Construction of the onshore facilities at Blaydin Point will primarily be conducted during daylight hours. Where night-time activities are required, lighting will be generated by white metal halide, halogen and fluorescent bulbs directed on to working areas to allow the safe movement of personnel.

General vessel movement around Blaydin Point and the construction of the module offloading facility and the product loading jetty will also primarily occur during daylight hours. Again, situations may arise where work is required at night. For example, modules may be transported from the module offloading facility at night to prevent delays and allow for the correct sequencing of deliveries to site. Vessels moored during construction, dredging and pipe-laying operations in the vicinity of Blaydin Point will also require lighting for safe operation at night.

From the commencement of commissioning, work will be conducted on a 24-hour-a-day basis on the site for the entire 40-year life of the Project. Lighting will be designed to ensure that worker safety is not compromised and will be in accordance with the relevant Australian and international standards. Typical lighting will consist of white metal halide, halogen and fluorescent bulbs and tubes. Lighting will also be designed in consultation with the Darwin Port Corporation (DPC) and will aim to minimise navigational hazards. Product tanker lighting will also be subject to consultation with the DPC.

During the commissioning of the two LNG trains, flaring will be continuous for extended periods. However, as described in Chapter 4 *Project description*, the ground flare will be shielded and will be designed to accommodate all the flaring emissions, thereby avoiding direct light emissions from this source.

5.5 Noise and vibration

Sources of noise and vibration associated with activities undertaken offshore and in Darwin Harbour and the onshore environment are identified and described in this section. Modelling of onshore and offshore noise is detailed in Chapter 7 *Marine impacts and management* and Chapter 10 *Socio-economic impacts and management*.

5.5.1 Marine noise and vibration

Marine noise will primarily be generated through construction activities in both the nearshore and the offshore environment. As with light, noise is characterised by how it is propagated through different media and how it is received. Noise is therefore measured in a different way in water from that on land.

Offshore activities

Noise will be emitted through the activities associated with drilling, installation and operation on the offshore facilities. The primary sources of noise will be the following:

- operation of vessels and equipment, including the CPF, the FPSO, condensate tankers, support vessels, supply vessels, the pipelay barge, the production drilling MODU and support vessels
- vertical seismic profiling (VSP).

Operation of CPF, FPSO, maritime vessels and MODU

Noise generated from offshore facilities and vessel operations will occur during the construction, installation and subsequent phases of the Project. Most noise associated with vessel traffic will be from rig tenders and other associated support vessels, particularly those using dynamic positioning systems. Vessels will likely include module transfer barges; pipelay barges; heavy-lift-crane barges; smaller, faster-moving support and survey vessels; pipe supply vessels; and condensate offtake tankers. The main noise source during the exploration and production drilling programs will be from the rig tenders, rather than from the drilling rig or from the drilling operation itself.

Noise from maritime vessel traffic and drilling vessels is generally low- to medium-frequency broadband noise up to 186 dB re 1 µPa at 1 m.

Vertical seismic profiling

The VSP technique is used to correlate the subsurface geological layers identified through pre-drilling seismic surveys with those identified through cuttings returns and other data acquired during the drilling process (e.g. wireline logging data). It will be utilised for production drilling activities at the Ichthys Field.

Because of the water depth at the field, VSP will be conducted with a two- or three-airgun cluster; approximately 150 cubic inches (*c*.2.5 L) in capacity per airgun. The operating pressure of each airgun will be approximately 2000 psi, with the cluster positioned near the ocean's surface (approximately 5–10 m deep). The airgun cluster will typically be fired at intervals of 6–10 s, generating a sound-pressure level of around 190 dB re 1 µPa at the standard reference distance of 1 m, with a frequency typically centred around 200 Hz.

The airgun cluster is generally hung from a support vessel, which can be positioned near the drilling rig or can move away from the rig during the profiling of directionally drilled wells. These operations generally only last for 8 to 12 hours and will typically occur only once per production well drilled.

Vertical seismic profiling using this same technique can be used during operations to monitor the decline of hydrocarbons in a reservoir. However, at this stage this is not a planned monitoring technique for the Ichthys Project.

Nearshore activities

Noise will be generated by the activities associated with the installation and operation of the nearshore facilities and the dredging of the shipping channel. Primary sources of noise will include the following:

- drilling and blasting of rock in the shipping channel
- dredging of the shipping channel, approach area, turning basin and the berthing areas for the product loading jetty and module offloading facility
- piledriving for the jetty and module offloading facility.

Drilling and blasting

A marine drilling and blasting program is likely to be implemented to fracture around 170 000 m^3 of rock at Walker Shoal prior to removal by backhoe or grab dredging vessels. The rock material has been assessed as being too hard to remove by cutter-suction dredger. Detailed methods have not yet been confirmed, but it is likely that each round of blasting will detonate a total charge weight of 300 kg, separated into six approximately 50-kg charges set on micro-delays, contained in six pre-drilled holes in an area between 3 and 5.5 m^2 in extent.

Alternative techniques to drilling and blasting are being investigated to remove the hard rock material within the shipping channel. At this stage, however, it is not possible to confirm whether there are any viable alternatives.

The impact of the resultant shock waves is discussed in Chapter 7.

Dredging

The level and characteristics of noise will vary between the different types of dredging equipment. The characteristics of the four types of dredgers that may be used are considered below: cutter-suction, trailing suction hopper, backhoe, and grab (also referred to as clamshell).

Cutter-suction dredger

Measurements of underwater noise radiated from the *Queen of the Netherlands*, a giant trailing suction hopper dredger, are comparable to cutter-suction dredges. Measurements were taken during a trial dredging program in the Port of Melbourne which found that underwater sounds were primarily in the low frequencies with high-frequency tones also present. The total sound-power level for the *Queen of the Netherlands* was calculated to be in the order of 169 dB re 1 µPa at 1 m (root mean square).

Trailing suction hopper dredger

Direct measurements of underwater noise emitted from trailing suction hopper dredgers show that the level of noise fluctuates depending on operating status (Richardson et al. 1995). The noise emitted is predominantly in the low frequencies and they can be a strong source of continuous noise. A hopper dredger under load in previous studies had higher broadband source levels than other dredging equipment (Richardson et al. 1995).

Backhoe dredger and grab dredger

Noise levels from backhoe and grab-bucket dredging are highly variable depending on the phase of the operation. The strongest noises are in low frequencies centred about 250 Hz with peak measurements reported to be in the order of 150–162 dB re 1 µPa at 1 m. The strongest sounds in one study were associated with the winch motor pulling the grab bucket back to the surface (Richardson et al. 1995).

Piledriving

Piledriving operations involve hammering piles into the seabed. Piles will be required for the construction of the product loading jetty and potentially also for the module offloading facility. The action of driving a pile into the seabed will generate compressional waves along the length of the pile and radiate acoustical energy into the water column and seabed.

There is a substantial body of literature describing the characteristics of noises generated during piledriving operations. The noise generated by a pile during driving operations is a function of its material type and its size. The resultant noise is likely to be of high intensity (around 180–215 dB re 1 µPa at 1 m) and low frequency and will be generated intermittently. Typically, during piledriving activities the physical driving of piles will occur for 30–40% of each daily shift. There may be more than one piledriving spread working in the nearshore area at any one time.

General shipping and vessel traffic

Noise generated from vessel traffic associated with the Project will occur during both the construction and operations phases of the Project. The Port of Darwin contains well-established trading and recreational facilities that host a wide variety of vessels ranging from small pleasure boats to large commercial tankers. Noise is therefore currently being generated around the Project area from already present (and increasing) vessel movements.

Additional sources of noise from maritime traffic will include the following:

- the operation of vessels and equipment, including the dredging and pipelay vessels and supporting vessels and tugs during the construction phase
- the operation of tankers and associated tugs during the operations phase
- the operation of maintenance dredgers and other maintenance vessels during the operations phase.

The noise characteristics and noise levels generated by the vessels that will be present in the Ichthys Field and near Blaydin Point will vary considerably and will depend on the type of vessel being considered. The particular activity being conducted by the vessel also greatly influences the noise characteristics.

Large commercial tankers have powerful engines primarily designed to drive the vessel at a steady cruising speed. These vessels produce high sound levels, mainly at low frequencies. At these frequencies the noise is dominated by propeller cavitation noise combined with dominant tones arising from the propeller blade rate.

Noise from maritime vessel traffic will generally be low- to medium-frequency broadband noise, at levels up to 186 dB re 1 µPa at 1 m.

Discussion of the impacts of noise in the marine environment is provided in Chapter 7.

5.5.2 Airborne noise

This section describes the sources of airborne noise from construction and operation of the onshore gas-processing plant.

Onshore and nearshore construction

Project activities that will contribute to noise levels during site preparation and construction at the Blaydin Point site will include the following:

- geotechnical boring and excavation
- clearing of vegetation using, for example, bulldozers and dumper trucks
- construction traffic and equipment movement
- earthworks
- rock-armouring works
- crushing and screening plant operations
- concrete batching plant operations
- piledriving for jetty construction
- onshore blasting (if required)
- equipment erection using heavy-duty trailers and cranes
- assembly and welding work
- piping work
- compressors operation for dewatering of the pipeline
- surface protection and sand-blasting of vessels and pipework
- transport movement around the site.

With the exception of blasting and piledriving, general construction noise emissions at Blaydin Point are likely to be lower than those generated during the normal operations of the processing plant.

Operational noise

General noise sources associated with the onshore processing plant and utility areas during normal operations will include the following:

- pumps
- refrigerant compressors
- fin-fan coolers
- turbines
- motors
- flares
- general utilities.

Estimates of cumulative sound power levels for equipment during normal plant operation is estimated to be approximately 127 dB(A) at source. For the emergency flaring case, a single noise source has been identified with a cumulative sound power level of 140 dB(A) at source. This source is located 4 m above ground level and is enclosed by a 12-m-high barrier. The flare systems will be designed to mitigate noise emissions.

Airborne noise modelling has been undertaken for key noise sources—plant operations, emergency flaring, and piledriving during construction—and is presented along with a discussion on potential community impacts in Chapter 10.

5.6 Liquid discharges

Liquid discharges will be produced throughout the various activities of the Project, including offshore drilling and pipelay, installation and construction, commissioning, operations and decommissioning. The source of each discharge and its characteristics are described in this section, with dispersion modelling and a detailed assessment of selected impacts provided in Chapter 7.

5.6.1 Offshore discharges

A summary of the discharges for the various offshore components of the Project at different stages of development is presented in Table 5-2. Dredge spoil disposal is discussed in Chapter 7.

Table 5-2: Summary of liquid discharges from the offshore components of the Project

Discharge stream	Drilling (intermittently over c.20 years)	Pipelay (c.1 year)	Construction and commissioning (4–5 years)	Operations (c.40 years)	Decommissioning (c.1 year)
Drilling discharges	✓	–	–	–	–
Subsea completion and control fluids	–	–	✓	✓	–
Hydrotest water	–	–	✓	–	–
Produced water	–	–	✓	✓	–
Cooling water	–	–	✓	✓	–
Sewage and grey water	✓	✓	✓	✓	✓
Desalination reject water	✓	–	✓	✓	–
Deck drainage	✓	✓	✓	✓	✓
Ballast water	✓	✓	✓	✓	✓

Drilling discharges

Drilling will occur from the commencement of the Project through to the operations phase as more wells are drilled, up to around 50 wells in total. During drilling, the drill bit produces cuttings which become entrained in the drilling muds that will be discharged to the marine environment.

In addition to their primary function of lubricating and cooling the drill bit, drilling muds serve a number of other purposes. These include the following:

- the removal of cuttings from the bottom of the well
- the deposition of an impermeable cake on the well-bore wall to seal the formation being drilled
- the prevention of contaminants entering the mud and/or of the fluid entering the formation
- the maintenance of the structural stability of the well bore.

Drilling mud consists of the base fluid, weighting agents and chemical additives used to give the mud the required characteristics to ensure that drilling is as safe and as efficient as possible. Since well design and substrate will vary from one well to another, the composition of the drilling muds will also vary.

Drilling muds required as part of the Project's drilling activities will include both synthetic-based mud (SBM) and water-based mud (WBM). The SBM will generally be used at greater well depths with smaller drill bits where greater lubrication and other technical performance capabilities are required. SBMs will typically consist of low-toxicity muds with additives such as polymers, caustic soda, barite and starches.

For the greater part of the drilling operation, the muds and their contained cuttings will be returned to the surface where they will be separated and the muds recycled for reuse in the well. Cuttings are continuously discharged during the drilling operations. Following completion of the drilling operations, the WBMs will be discharged to the marine environment and the SBMs will be recovered and returned to the supplier onshore for reuse or disposal.

Drill cuttings are inert pieces of rock, gravel and sand removed from the well during the drilling process. The characteristics of the cuttings to be discharged can be predicted from the lithology of other wells drilled in the permit area, but are expected to consist of calcarenite, shale and sandstone. The cuttings are expected to range in size from very fine to very coarse particles, with a mean diameter of around 10 mm.

Cuttings will be continuously discharged during drilling operations in the offshore development area. Typically, drilling at the Ichthys Field will produce around 700 m^3 of drill cuttings per well. As around 50 wells will be developed, there will be approximately 35 000 m^3 of cuttings across the 800 km^2 (80 000 ha) area of the Ichthys Field.

Toxicity effects of the drill muds and cuttings are well understood and are discussed further in Chapter 7.

Subsea completion and control fluids

Once a well has been drilled, subsea well completion fluids will be required to ensure that the surface is clean and to prevent blockage in the reservoir. The type of fluid used will depend on the drilling fluid used. This may be brine when WBMs are used and a low-weight fluid such as diesel when SBMs are used. The management of completion fluids is described further in Chapter 7.

After a well has been drilled and the subsea systems have been installed, hydraulic fluids will be required to control the subsea tree valves. An open-loop system is likely to be employed; this will release hydraulic fluids to the sea when operated. These fluids are water-based and contain additives such as hydrate inhibitors, lubricants, corrosion inhibitors, biocides and surfactants.

The volumes of hydraulic fluids to be discharged over the Project's 40-year lifetime will be proportional to the level of Project activity. The volumes of hydraulic fluid used will range from 100 to 4500 m^3/a in the first year of drilling to approximately 300 m^3/a through the remainder of the Project's life.

Further discussion of the impacts of control fluid discharge can be found in Chapter 7.

Hydrotest water

During the precommissioning of the offshore facilities, pressure-testing will be required to ensure the integrity of the subsea flowlines, pipework, process vessels and the MEG service line from the facilities to the well manifold. This will be done using treated sea water or potable water, which will then be discharged to the marine environment after hydrotesting has been completed. Hydrotest water will consist of chemically treated water containing biocides, corrosion inhibitors and oxygen scavengers to prevent internal pipe corrosion, and bacterial formation and scale inhibitors to prevent the build-up of scale.

The volumes of hydrotest water required during the initial subsea installation of infield flowlines and export flowlines (one to two years into the Project's construction phase) will be approximately 19 000 m^3 with approximately 700 m^3 for transfer flowlines. Subsequent drilling campaigns will require the discharge of approximately 3000 m^3 of hydrotest water per well installation.

During precommissioning of the gas export pipeline it will be flooded with approximately 1 000 000 m^3 of filtered and chemically treated sea water sourced from Darwin Harbour. The pipeline will then be hydrotested twice using approximately 10 000 m^3 of treated water (for each operation). At the end of each hydrotest operation, the 10 000 m^3 of treated water will be discharged from the offshore facilities to return the pipeline to ambient pressure. In the highly unlikely event of mechanical failure or a cyclone passing Darwin during the hydrotest operation, this 10 000 m^3 may need to be discharged from the onshore facility into the Harbour. This scenario is discussed in Section 5.6.3 *Darwin Harbour discharges* below.

On completion of the hydrotesting, the pipeline will be dewatered and then dried and purged using nitrogen. During dewatering, the approximately 1 000 000 m^3 of treated water in the pipeline will be discharged at the offshore end. It is possible that MEG (monoethylene glycol) or TEG (triethylene glycol) will be introduced during the dewatering and drying stage to ensure that all traces of water are effectively removed from the pipeline.

Produced water

"Produced water" is water extracted from the gas reservoirs and separated from the hydrocarbon gases and liquids through a series of processes usually conducted at offshore facilities. It has two sources: one is the saline "produced formation water" found as a liquid in the geological formation along with the gas, and the other is the water vapour commingled with the gas which is condensed out during the processing phase. Produced water is the combination of produced formation water and the condensed water. Figure 5-1 shows the volumes of produced water that will be discharged from the offshore facilities over the 40-year life of the Project.

Low flow rates of produced water are expected from the Brewster Member reservoir, while significantly higher volumes are predicted from the Plover Formation reservoir. The total volumes of produced water discharged from the offshore facilities are therefore dependent on the relative proportions of gas extracted from the two reservoirs. The averaged volumes of produced water to be discharged to the marine environment will range from 480 m^3/d in the first year of production to a maximum of approximately 3200 m^3/d.

Produced water typically contains small volumes of hydrocarbons, traces of minerals, production chemicals, dissolved salts and some solid particles such as sand.

In order to comply with Clause 29 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth), the concentration of oil in any produced water discharged to sea will be limited to not greater than an average of 30 mg/L over any period of 24 hours.

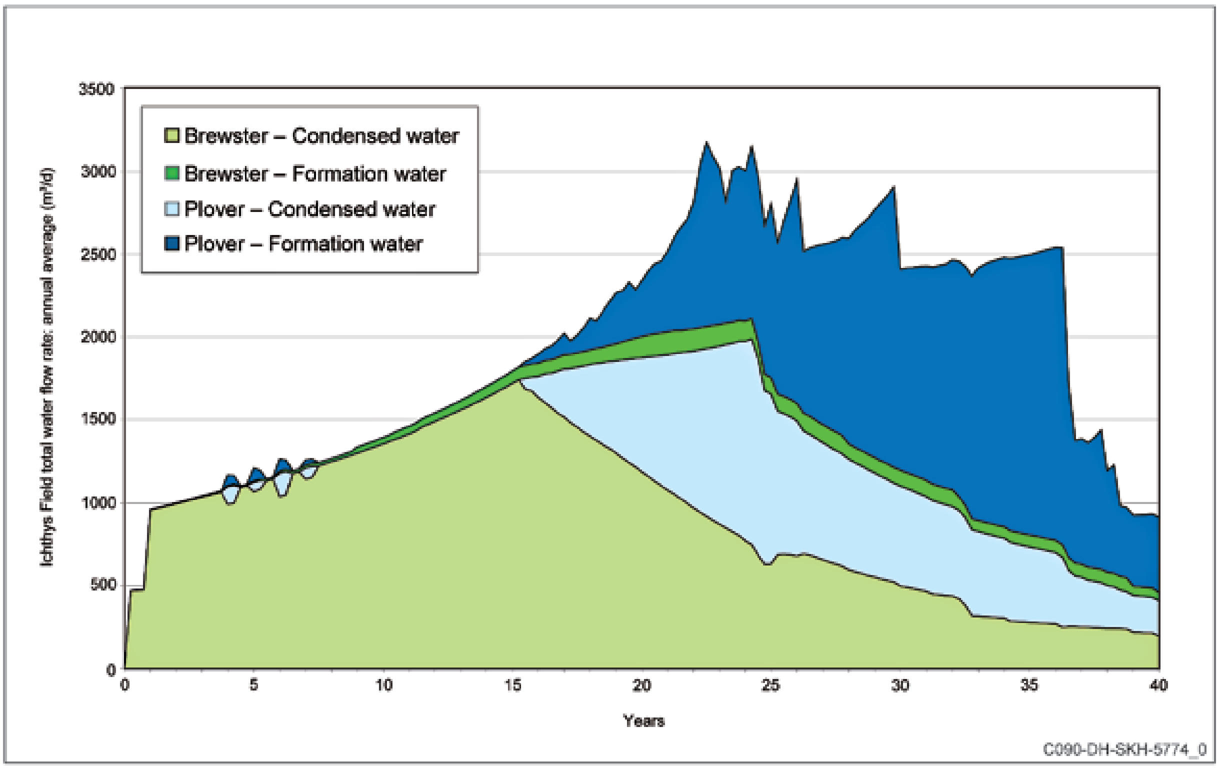

Figure 5-1: Average volumes of produced water discharged from the offshore facilities over the 40-year life of the Project

The produced water will be discharged from the FPSO through a submerged caisson in line with standard practice for offshore installations. The temperature of the water will be in the range 45–50 °C.

Chemicals added to the produced water during the extraction process will also be present in the produced water discharge. These include MEG, corrosion inhibitors, scale inhibitors and biocides.

MEG will most likely be required on a continuous basis for management of hydrate formation in the flowlines from the wells. Most of the MEG will be removed by the MEG regeneration unit on the FPSO prior to discharge.

Concentrations of MEG in produced water from the offshore development area will vary across the Project's operational life cycle depending on the amount of formation water associated with the gas extracted from the reservoirs. The Brewster reservoir, which will be developed early in the life of the Project, contains very little formation water, resulting in low concentrations of MEG (approximately 100 mg/L) in the associated produced water. The Plover reservoir contains more significant volumes of formation water and it is estimated that during years 28–33 of the Project, MEG concentrations in produced water from the offshore facilities could rise to 15 000 mg/L.

Corrosion inhibitors are intended to limit the rate of corrosion of the inner surfaces of the production process equipment. Corrosion inhibition is based on the formation of a film on the internal surface of the vessel or piping. Although a wide variety of corrosion inhibitors are available, they are mostly carboxylic acids that have had nitrogen-containing chemicals substituted. Black et al. (1994) identify four generic types of corrosion inhibitor as follows:

- imidazoline derivatives
- amines and amine salts
- quaternary ammonium salts
- nitrogen heterocyclic compounds.

Of these generic types, only imidazoline derivatives are water-soluble. The other three are all oil-soluble and therefore would not be discharged with the produced water to any significant extent. Imidazoline derivatives are normally produced from the reaction of fatty acids with amines and are readily biodegradable (Madsen et al. 2001). The maximum concentration range of corrosion inhibitor in the discharge is expected to be 7.5–30 ppm.

Scale inhibitor is used to prevent carbonate or sulfate salts of calcium, strontium, barium or radium from the reservoir water precipitating and forming scale on the inner surfaces of the production process equipment. The active ingredient of scale inhibitor is usually either a phosphate or a phosphonate ester. These chemicals are strongly water-soluble. The expected concentration range of scale inhibitor in the discharge would be 3–10 ppm.

Biocides are used to prevent or control the growth of sulfate-reducing bacteria. (A by-product of the action of sulfate-reducing bacteria is hydrogen sulfide, which is both corrosive and toxic in high concentrations.) To improve performance and avoid the potential for development of biocide-resistant bacteria, biocides are generally applied in short doses of a relatively high concentration rather than by continuous dosing. Typical active ingredients in biocides include aldehydes or amine salts: both of these types of biocide are soluble in water and would be discharged with the produced water within an expected concentration range of 10–200 ppm.

The produced water discharged from the FPSO is estimated to contain dissolved hydrocarbons and production chemicals within the ranges presented in Table 5-4.

Modelling of the produced water discharge has been conducted and is discussed in detail in Chapter 7.

Cooling water

Cooling water will be required on the offshore facilities to reduce the temperature of the gas coming from the reservoir and to provide cooling for gas compression and power generation facilities. For this purpose, sea water would be treated, used, and discharged back into the marine environment. Cooling water is sea water that has been passed through a heat exchanger and discharged to the sea at a higher temperature, in this case at approximately 45–50 °C. The cooling water will also be dosed with hypochlorite at approximately 5 ppm.

The maximum volumes of cooling water discharged from the CPF and FPSO are expected to be approximately 250 000 m^3/d and 80 000 m^3/d respectively.

Sewage and grey water

Throughout each phase of the Project, sewage waste and grey water will be produced and discharged in the offshore marine environment. Sources of sewage waste include the offshore processing and storage facilities, transport barges and support vessels.

All discharges of sewage from maritime support vessels are required to comply with the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) (IMO 1978) and the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth).

All sewage waste discharged from the permanent CPF and FPSO will be macerated to fragments less than 25 mm in diameter prior to discharge and will not be disposed of within 12 nautical miles (approximately 22 km) of land (the Australian territorial sea). This is a requirement of Clause 222 of the Petroleum (Submerged Lands) Acts Schedule (DITR 2005).

During the construction phase, additional sources of sewage waste will include the MODU and maritime construction, transport and support vessels. During operations, product tankers and other vessels supporting operations in Darwin Harbour will be required to dispose of their sewage waste offshore, that is, beyond the 12-nautical-mile territorial sea limit, or alternatively to pump out the sewage at a port facility.

During the operations phase it is estimated that up to 100 m^3/d of sewage waste and grey water will be discharged offshore from the permanently moored CPF and FPSO (up to 50 m^3/d each).

Desalination brine

Potable water will be necessary for both process and personnel needs on the CPF and FPSO. It will be produced by reverse osmosis and will result in the discharge of saline water (brine). Offshore brine discharges are expected to be in low volumes—approximately 100 m^3/d from each facility.

Deck drainage

Deck drainage consists mainly of washdown water and rainwater. Rainwater runoff from non-contaminated areas will generally be directed overboard without treatment. The drain system will be designed so that no pollutants or contaminants will be routinely discharged by deck washdown.

Areas on the MODU and construction barge(s) that could potentially be subject to small oil spills will be drained to a sump that will in turn be directly connected to an oily-water separation system. This separation system on maritime vessels such as the MODU will be configured and monitored to ensure that any discharge has an oil-in-water concentration of less than 15 mg/L in accordance with Annex I of MARPOL 73/78 (IMO 1978).

Ballast water

Ballast water is sea water that unladen ships, drilling rigs and some offshore oil- and gas-producing facilities carry to provide stability and then discharge when their cargo is loaded.

Ballast water will be discharged from the MODU (on arrival at the offshore site), from the CPF (on arrival) and FPSO (on arrival, and then regularly during the life of the Project) and from the condensate cargo tankers (on arrival).

The use of fully segregated ballast-water tanks and other requirements for how and when ballast water can be discharged are set out in MARPOL 73/78 (IMO 1978). Tankers that do not meet these requirements are not permitted to operate in Australian offshore waters.

5.6.2 Summary of offshore liquid discharge characteristics

Liquid discharges from the offshore facilities and vessels will either be discharged directly (e.g. deck drainage) or will be directed to submerged caissons for discharge into the ocean (e.g. produced water and cooling water). Tables 5-3 and 5-4 summarise the likely volumes and characteristics of the offshore discharge streams.

5.6.3 Darwin Harbour discharges

A summary of liquid discharges into Darwin Harbour at different stages of development is presented in Table 5-5. Wastewater discharge modelling has been conducted for the onshore and offshore facilities in order to determine the dispersion characteristics of key pollutants. This is detailed in Chapter 7.

Table 5-3: Volumes of liquid discharges from the offshore facilities (CPF and FPSO)

Liquid	Estimated discharge volumes
Hydrotest water (pipeline, flowlines and risers)	Up to 2 Mm^3.
Treated produced water	Between 1000 and 5000 m^3/d. (3000 bbl/d in the first year of production to approximately 22 000 bbl/d.)
Cooling water	250 000 m^3/d (CPF) and 80 000 m^3/d (FPSO).
Treated sewage and grey water	Up to 50 m^3/d each for the CPF and FPSO.
Desalination brine	Up to 100 m^3/d each for the CPF and FPSO.
Deck drainage	Variable depending on rainfall.

Table 5-4: Characteristics of the liquid discharges from the offshore facilities (CPF and FPSO)

Parameters	Unit	Estimated wastewater characteristics (excluding hydrotest water)
Oil in water (as per OPGGS(Environment) Regulations 2009)*	mg/L	0–30
Temperature	°C	Ambient to 50
pH	–	6–9
Monoethylene glycol	mg/L	100–15 000
Corrosion inhibitor	ppm	7.5–30
Scale inhibitor	ppm	3–10
Biocide	ppm	10–200

* Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth).

Table 5-5: Summary of liquid discharges from the onshore facilities

Liquid discharge	Pipelay, dredge and other construction vessels	Construction and commissioning (4–5 years)	Operations (*c*.40 years)	Decommissioning (*c*.1 year)
Hydrotest water	–	✓	–	–
Demineralisation reject water	–	✓	✓	–
Sewage and grey water	✓	✓	✓	✓
Process water	–	–	✓	–
Drainage and stormwater runoff	✓	✓	✓	✓
Ballast water (dependent on MARPOL 73/78* requirements)	✓	✓	✓	✓

* IMO 1978.

Hydrotest water

As with the offshore facilities, hydrostatic pressure-testing is required for all onshore process and storage vessels, tanks and pipework. Some hydrotesting may occur at the fabrication yards during module construction. Hydrotest water will be discharged during precommissioning as well as during the early stages of operation of the onshore facilities. In most cases potable water will be used, no chemicals will need to be added, and the water may be reused several times (e.g. to leak-test one tank after another).

If the hydrotest water is chemically treated, this may include adding biocides to prevent bacterial formation, scale inhibitors to prevent the build-up of scale, and corrosion inhibitors and/or oxygen scavengers to prevent internal pipe corrosion. Soda ash solution may also be added to the hydrotest water for some process vessels such as the AGRU. The chemicals to be used in hydrotesting have not yet been decided upon, but will be pre-approved by the regulatory authorities as is current industry practice.

The intention is to hydrotest and dewater the pipeline from onshore to offshore. In the highly unlikely event that hydrotest depressurisation cannot be undertaken offshore, as a result, for example, of a cyclone or of mechanical failures, a scenario exists where it may be necessary to discharge approximately 10 000 m^3 of hydrotest water into Darwin Harbour. During dewatering, the 1 000 000 m^3 of treated water in the pipeline will be discharged at the offshore facility.

Hydrotest water from the onshore gas-processing facilities will be discharged at either the combined outfall on the product loading jetty or through inspection pits, or similar structures, to the open-drain systems. The discharge location will be dependent on the quality of the water. Total hydrotest discharges from the onshore facility are likely to peak at 7200 m^3/d when the tanks are being hydrotested. The average discharge volumes will be substantially lower than this for the duration of the six-to-nine-month precommissioning period.

Demineralisation reject water

A demineralisation plant will be required to supply the onshore processing plant with demineralised water.

The raw water for the demineralisation plant will come from Darwin's potable water supply. Treatment will include appropriate filtering and chlorination to remove biological components and particulates. Approximately 7–16 m^3/h of demineralisation reject water will be discharged to the Harbour. Cleaning and descaling of the filtration system will also be required and this will generate small volumes of liquid wastes. These small volumes of descaling wastes will also be discharged to the Harbour.

Sewage and grey water

Sewage waste and grey water will be generated throughout the life of the Project. Approximately 20–25 m^3/h of treated sewage will be produced during the construction phase and around 2–20 m^3/h will be produced during the operations phase (allowing for fluctuations in personnel numbers during maintenance shutdowns every six years). This number is directly related to the number of people on site. The sewage treatment requirements for the different stages of the Project are likely to be met by packaged sewage treatment plants, self-contained septic-tank systems and/or ablution blocks. Sewage will either be stored on site and disposed of to existing sewage treatment facilities in the Darwin area or it will be treated and discharged to the marine environment. Ground infiltration of treated wastewater is also an option being considered, but this will depend upon its being found to be environmentally acceptable.

During the operations phase, a sewage treatment plant will be installed to produce high-quality treated wastewater suitable for discharge and for irrigation or infiltration to a designated area. The plant will be designed to meet the following discharge quality parameters:

- total nitrogen: <40 mg/L
- total phosphorus: <10 mg/L
- biochemical oxygen demand (BOD) <20 mg/L
- faecal coliforms <400 cfu/100 mL.

Treated sewage will be commingled with other wastewater streams that are directed to the jetty outfall (as shown in Figure 5-2). Temporary discharge facilities may also be required during construction prior to the completion of jetty construction.

Sewage sludge will not be discharged but will be managed as solid waste as discussed in Section 5.7.2 *Wastes generated onshore*.

Process wastewater

Various process wastewater streams will be produced from the onshore processing plant at Blaydin Point.

For example, process water is likely to be produced intermittently by the stabiliser feed separator and the warm-flare knockout drums, as well as from condensate storage tank drawdowns, the amine units during maintenance, and the gas turbines during cleaning. Wastewater from these streams will either be directed to the oily-water treatment facilities or to the neutralisation unit depending on the characteristics of the streams. The volume and concentration of contaminants entering the treatment facilities will fluctuate depending on the intensity of maintenance activities.

If a combined-cycle system is chosen as the preferred technology for power generation, steam will be required as a heating medium. A proportion of the potable water circulating in the steam system will be released through a "steam loop bleed" on a continuous basis. This steam will condense to form a wastewater stream at an estimated rate of 8–13 m^3/h and with a temperature of approximately 26–35 °C; it will have low oxygen levels.

The wastewater generated will be treated in a neutralisation unit prior to being commingled with the treated process wastewater stream. It will have a pH between 5 and 9 after treatment, prior to commingling.

The treated process wastewater stream will be discharged at the combined outfall on the product loading jetty.

Stormwater and runoff

Onshore construction stormwater and runoff

During construction and prior to final surfacing, runoff from the construction site will contain sediment and will contribute to the total suspended solids (TSS) load reaching the Harbour. The quantification of predicted sediment runoff is problematic as there are several variables to take into account, such as levels of construction activity and rainfall patterns.

Stormwater that will be discharged to Darwin Harbour during the construction phase will likely be controlled by silt fences and sedimentation ponds around the site. These will be designed to decrease the sediment load in the discharged water.

Operations stormwater and runoff

Permanent drainage systems from areas exposed to possible hydrocarbon and/or chemical contamination will be isolated and treated through separate drainage systems. Wastewater from areas that could potentially be contaminated by hydrocarbons will be directed to the oily-water treatment system. Wastewater from areas that could potentially be contaminated with other chemicals will be sent to a neutralisation unit.

The stormwater runoff will be commingled with other wastewater streams and directed to the combined outfall on the product loading jetty. Runoff from the site will fluctuate in volume from zero during the dry season to around 110 m^3/h in the wet season.

Non-contaminated runoff will include drainage from non-process areas such as paved areas and roads. These non-contaminated flows will be directed through multiple open-channel drains with suitable control devices such as inspection pits or similar structures. Where appropriate, these structures will be designed to remove settleable solids, floating litter and other debris.

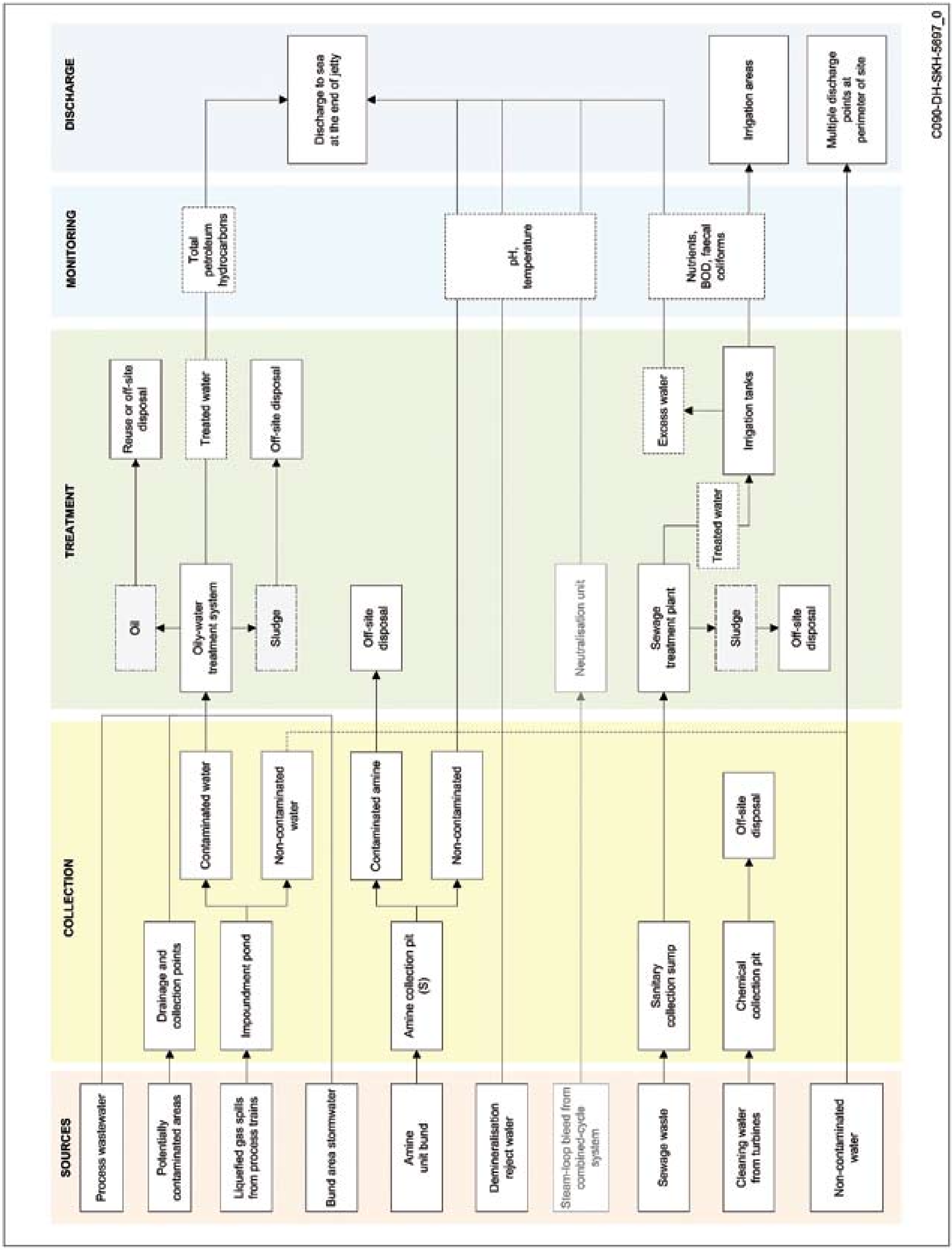

Figure 5-2: Wastewater streams and discharge or disposal points

Ballast water

Ballast water is sea water that unladen ships carry to provide stability and then discharge when their cargo is loaded. However, as ballast water pumped into a ship at a given port will contain a wide variety of marine organisms, from plankton and larvae to fish and seaweeds, there is clearly a risk of bringing marine pests to the port where the ballast water is discharged. The Australian Quarantine and Inspection Service (AQIS) deems all salt water from ports and coastal waters outside Australia's territorial sea to present a high risk of introducing exotic marine pests into Australia and has laid down mandatory ballast-water management requirements enforceable under the *Quarantine Act 1908* (Cwlth) (DAFF 2008).

In consequence, ballast water from vessels such as the larger support vessels, module transport vessels, pipelay barges, dredging vessels and product tankers, will be required to exchange ballast in accordance with AQIS requirements prior to arrival at Darwin Harbour.

The use of fully segregated ballast-water tanks and other requirements for how and when ballast water can be discharged are set out in MARPOL 73/78 (IMO 1978). Tankers that do not meet these requirements are not permitted to operate in Northern Territory waters.

The management of ballast water and potential impacts are discussed in Chapter 7.

5.6.4 Summary of nearshore discharge characteristics

Onshore, wastewater from the process water streams and the potentially contaminated drainage system, together with the continuous flow of treated water from the demineralisation plant and sewage treatment plant, will be treated, commingled and discharged at the end of the product loading jetty. Figure 5-2 above presents the wastewater streams and discharge or disposal points. The likely volumes and characteristics of the combined discharge stream are presented in Table 5-6 and Table 5-7.

The combined discharge point on the jetty, shown in Figure 5-3, will be designed to disperse potential contaminants. The quality of the discharge will also be subject to a monitoring and verification program as described in Chapter 11 *Environmental management program*.

Potential impacts on water quality are discussed in Chapter 7.

Table 5-6: Volumes of liquid discharges from the outfall on the product loading jetty

Source	Maximum discharge volumes at outfall (m^3/h)	
	Typical (continuous)	Maximum (intermittent)
Process water	0	1
Water from accidentally oil-contaminated drains	0 (dry season)	110 (wet season peak rainfall events)
Treated sewage and grey water	3	20
Demineralisation reject water	7	16
Combined-cycle steam loop bleed	8	13
Total	**18 (dry season)**	**160 (wet season peak rainfall events)**

Table 5-7: Characteristics of the liquid discharges from the outfall on the product loading jetty

Parameters		Unit	Estimated wastewater characteristics (excluding hydrotest water)
Total petroleum hydrocarbons		mg/L	≤10
Temperature		°C	26–35 °C
pH		–	5–9
Nutrients	Total nitrogen	mg/L	≤40
	Total phosphorus	mg/L	≤10
BOD		mg/L	≤20
Faecal coliform bacteria		cfu/100 mL	<400

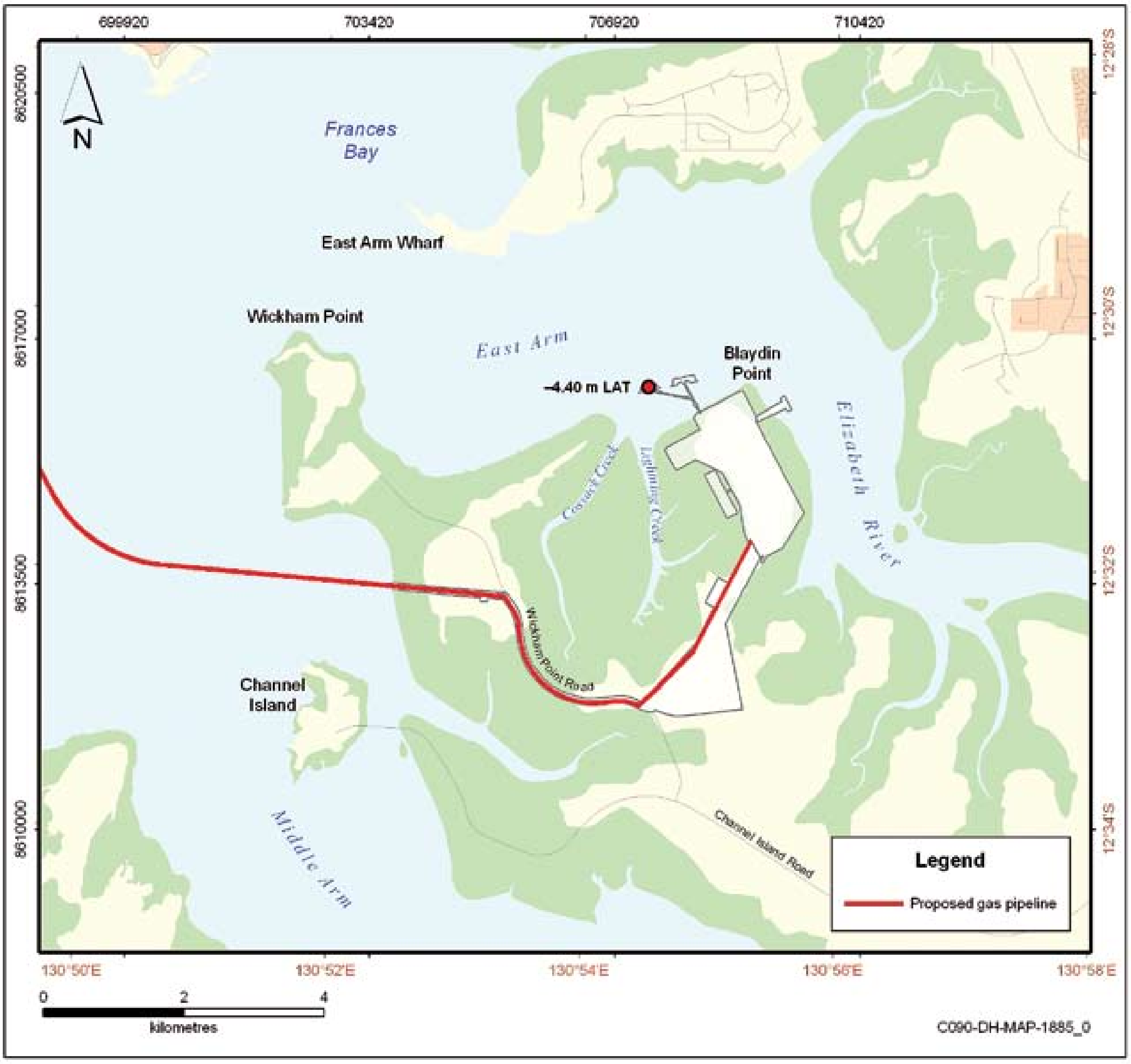

Figure 5-3: Onshore outfall location at the end of the product loading jetty

5.7 Liquid and solid wastes

Solid and liquid wastes will be produced from the construction phase of the Project through to decommissioning. Waste produced during the different stages of the Project will require treatment, storage, transport and, if necessary, disposal to licensed disposal facilities. In particular, hazardous wastes will have specific transport, disposal and/or treatment requirements as they are composed of or contain materials that may pose a threat or risk to public health, safety or the environment.

This section identifies the types and volumes of the wastes that will be generated during the course of the Project. As the Project moves into the detailed-design phase, these estimates will be refined and appropriate waste-disposal pathways will be identified and documented in INPEX's waste-management documentation.

A discussion on the potential impacts of waste handling and transport is provided in chapters 7 and 8. A detailed description of waste-management controls is provided in Chapter 11.

5.7.1 Wastes generated offshore

Non-hazardous and hazardous solid wastes will be generated during the installation, commissioning and operation of the offshore facilities, and also by drill rigs, supply and construction vessels, and pipelay barges.

General non-hazardous solid wastes will be transported to a mainland disposal facility, with the exception of food scraps and other putrescibles at the CPF and FPSO which will be macerated to fragments less than 25 mm in diameter and disposed of offshore.

Sands, sludges and scale may be generated through the well-drilling process and from the offshore processing facilities. Scale may contain naturally occurring radioactive materials (NORMs). Their disposal will be determined on a case-by-case basis in discussion with the relevant designated authority.

Other hazardous materials likely to be produced will be segregated, packaged and directed to waste transfer areas at the maritime supply base. From there they will be transported to approved waste-disposal facilities. The location of the maritime supply base is yet to be determined.

5.7.2 Wastes generated onshore

Construction waste

Large volumes of waste will be produced during the construction phase of the Project because of the level of activity and the number of personnel on site.

Most of these wastes will be non-hazardous as shown in Table 5-8. In addition, during site preparation, large volumes of plant material waste and inert material (rock, soil, etc.) will also be generated. Some of this will be reused on site for reinstatement and rehabilitation. Disposal of excess plant material will be conducted by chipping and mulching where possible.

Construction waste will include domestic and packaging waste, the volume of which will correlate directly with the number of personnel. The construction workforce will be accommodated off site at the accommodation village and elsewhere within the greater Darwin area.

Table 5-8: The types and quantities of waste likely to be produced during the Project's 60-month construction phase onshore

Waste material	Indicative total quantity (t)
General construction waste	35 000
Accommodation domestic waste	7 500
Untreated wood	3 500
Kitchen mess waste	3 500
Waste oils	950
Recyclables (commingled)	750
Scrap metal	550
Administration domestic waste	400
Recyclable packaging	350
Concrete	200
Cooking oils and grease-trap waste	170
Cardboard	70
Cable	3
Aluminium cans	1

Hazardous wastes such as fluorescent tubes, spent batteries, biological waste from medical facilities, and pickling fluids from commissioning will be produced in smaller quantities but will require specific handling and transportation controls.

Dredge spoil and acid sulfate soil waste are described in chapters 7 and 8.

Operations wastes

Solid wastes from the operations phase will include common general waste streams and process waste streams. Common waste streams will include food, domestic and packaging wastes, maintenance wastes, oily rags, clean drums and paint tins. These will be packaged and disposed of at a licensed disposal facility.

Pipeline pigging wastes and wastes accumulated in the slug catcher will consist of a slurry of removed scale, sand, rust, potential scale and possibly NORMs. The means of disposal of NORMs will be determined on a case-by-case basis in discussion with the relevant designated authority.

Other hazardous materials likely to be produced from the facility will require specialist handling; activated carbon from the mercury removal unit, for example, is sent to specialist contractors for disposal or is returned to the supplier for recycling.

Indicative types and quantities of wastes likely to be produced during the operations phase of the Project are presented in Table 5-9.

5.7.3 Decommissioning wastes

Major sources of decommissioning wastes (in addition to those likely to be produced during the operation of the facilities) will include large volumes of solid wastes derived from the dismantling of the infrastructure. The philosophy to be employed will be based on the waste hierarchy with a view to maximising reuse and/or recycling opportunities. These will include, for example:

- assessing whether there could be alternative uses for various structures such as the administration buildings, accommodation facilities, workshops, jetty and module offloading facility
- maximising opportunities to reuse materials or, where that is not feasible, to recycle them (e.g. scrap steel).

Where materials cannot be reused or recycled, steps will be taken to ensure that there are appropriate disposal pathways as part of the environmental management program.

Table 5-9: The types and quantities of waste likely to be produced during the Project's 40-year operations phase onshore

Potential hazardous waste	Estimated annual average (t/a)	Estimated maximum during maintenance shutdowns every 6 to 12 years
Liquid process wastes		
Process water contaminated with hydrocarbons, detergents and/or miscellaneous chemicals	2500	5000
Spent lube oil, seal oil and engine oils	30	200
Oil-contaminated wastes (e.g. spill equipment, rags)	50	100
Water contaminated with aMDEA*	4	32
Scale (potentially containing NORMs)	–	20
Water contaminated with chemicals from neutralisation unit	1	6
Solid process wastes		
Carbon filters, membranes, guard beds, etc.	1	350
Molecular sieves	–	200
Mercury filters and adsorbent materials	–	100
Hydrocarbon sludge	–	5
Sewage and medical wastes		
Sewage sludge	200	–
Untreated sewage and detergents from maintenance activities	6	–
Medical waste	5	–
General non-hazardous wastes		
General waste (e.g. wood from packing crates, other packaging materials, expended consumables, cable offcuts)	240	500
Metal waste	100	–
Gasket materials (e.g. silicone, rubber, neoprene)	50	–

* aMDEA = activated methyldiethanolamine. Methyldiethanolamine is a compound which absorbs the acid gases carbon dioxide (CO_2) and hydrogen sulfide (H_2S) at lower temperatures and releases them at higher temperatures. It is used to separate CO_2 and H_2S from natural gas streams.

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