Imperial Oil & Gas

EP 187

Appendix 06

Waste and Wastewater Management Plan

IMP 5-1

Date	Rev	Description	Author(s)	Reviewed	Approved
05/02/24	1	Issued as an Appendix of EMP IMP 5-1	Damian O., Pete S., Nicholas F.	Trent S., Vic F., Jon B., Kelvin W., Spiros K.	Robin P.

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1 Introduction

Part C of the *Code of Practice: Onshore Petroleum Activities in the Northern Territory* establishes a framework governing wastewater management in petroleum activities, encompassing storage, handling, transport, reuse, recycling, treatment, and disposal.

The preferred requirement in Section C.4.2.3 (a) of *the Code* is that recycling and re-use of all fluids should be maximised, and the off-site transport and disposal of fluids should be minimised.

Section B.4.16.2 (h) of *the Code*, requires the use, storage, and handling of materials on site be conducted in accordance with section A.3.8 and Part C of *the Code*.

2 Waste Hierarchy

Section C.3.1 of *the Code* requires interest holders to implement the Waste Hierarchy outlined in the *National Waste Policy* 2018, when developing their Waste and Wastewater Management Plan (WWMP).

The waste hierarchy involves the following:

1. <u>Avoid</u>: eliminate or substitute an activity that results in wastewater.
2. <u>Reduce</u>: lower the generation of wastewater as part of a process or activity.
3. <u>Reuse</u>: use of wastewater for the same or alternative petroleum activity without treatment, or with minimal treatment.
4. <u>Recycle</u>: beneficial re-use of wastewater for another purpose without treatment, or with minimal treatment.
5. <u>Treat</u>: bring wastewater back into use through treatment to improve water quality or to make quality suitable for disposal.
6. <u>Dispose</u>: using licensed contractors to dispose in accordance with relevant regulations.

3 Waste and Wastewater Sources

The Activity will generate both wastewater, as defined in the Code, and other waste. **Table 3—1** details the potential sources and types of waste and wastewater from the Activity.

Section C.2.1 of *the Code* defines the water and wastewater to which the requirements of the Code apply. Section C.2.2 defines the water and wastewater to which the requirements of *the Code* do not apply.

Table 3—1 Waste Sources and Types

Waste Source	Example Waste Types
Domestic Activities: • Camp • Offices	• Treated sewage effluent • Putrescible and municipal waste • Greywater (laundry, showers, sink wastes, etc.) • Recyclables (glass and cans)
Construction Activities	• General waste (i.e. batteries, plastics, cardboards) • Chemical bags and cardboard packaging materials • Scrap metals • Timber pallets (skids) • Vehicle tyres • Oily rags, filters
Drilling	• Drilling fluids • Drilling cuttings • Cement returns
Hydraulic Fracture Stimulation	• Flowback fluid • Produced water (potential)
Appraisal Testing	• Flowback fluid • Produced water (not anticipated)

Waste Source	Example Waste Types
CGP Operation	• Chemical bags and cardboard/plastic packaging materials • Scrap metals • Timber pallets (skids) • Vehicle tyres • Oily water • Chemical wastes
Ancillary Works associated with: • Drilling • Hydraulic Fracturing • Production Testing • CGP Operation	• Chemical bags and cardboard packaging materials • Scrap metals • Used chemical containers and fuel drums • Chemical wastes • Timber pallets (skids) • Vehicle tyres • Oily rags, filters

Table 3—2 details wastewater types and sources from the Activity. **Table 4—2** details strategies for effective management and the fate of wastewater and waste. Considering the waste management hierarchy, the overall objective is to reduce consumption, enhance recycling and minimise offsite disposal.

For the purposes of **Figure 4—1**, the risk rating is derived considering the impact on the receiving environment from an uncontrolled loss, the potential contaminants of concern, and projected volumes. Given the volumes generated during the development of each well, hydraulic fracture (HF) flowback fluid poses the greatest risk to the receiving environment.

Table 3—2 Wastewater Source Summary

Wastewater	Source	Risk (Low, Medium, High)	Projected Volume
Condensed Water Vapour	Low point drains (LPD's)	Low	~100 L/Week/LPD
Drilling, Workovers, and Completion By-products	Drilling, completions, and workovers	Medium	~1,500 kL/Well
Grey Water	Ablutions	Low	~100-200 L/person/day
Flowback Fluid	HF process in the development of a well	High (based on volume generated)	~35 ML/Well
Produced Water	During well testing	Low	Not anticipated
CGP Water	Wastewater generated at the Carpentaria Gas Plant (CGP)	Low	~1 kL /Week

4 Wastewater Management

A summary of wastewater storage for the Activity is outlined below in **Table 4—1** and detailed further in the following sections. Details on how the waste hierarchy will be implemented for each waste stream is outlined in **Table 4—2**.

Table 4—1 Wastewater Storage Summary

Storage	Max Capacity	Indicative Configuration	Details
Above Ground Tank(s) (Contingency)	Up to 13 ML (per contingency tank)	Up to one per well pad and WHS	Further detailed in **Section 4.1** and **4.3**.
Primary Above Ground Tank(s) (Water Handling Station)	Up to 110 ML	Two 55 ML tanks	Further detailed in **Section 4.3**.
Sump(s)	≥ 4.5 ML (per sump)	Minimum of two per well pad	Further detailed in **Section 4.1**.
CGP Oily Water	100 kL (total wastewater storage for CGP area)	Multiple	Further detailed in **Section 4.6**.
LPD	1,000 L (per IBC)	1 per LPD	Further detailed in **Section 4.5**.

Table 4—2 Waste Management

Waste Stream	Avoid	Reduce	Reuse	Recycle	Treat	Dispose
Greywater / Sewage Effluent	Cannot avoid	Not proposed	Not proposed	Not proposed	Treated on-site and irrigated	Greywater and treated sewage effluent irrigated. Solids will be transferred to a licensed disposal facility.
Residual Drilling, Completions and Workover Fluid	Cannot avoid	Evaporation from sumps	Not anticipated	Not proposed	Evaporation	Remaining fluid will be transported off-site of disposed of on-site as per clause C.4.1.2 and C.5.2 of *the Code*.
Drilling and Completions By-products	Cannot avoid	Mud volumes are designed specifically for the size wellbore, therefore minimising excess fluid requirements. During drilling a well the mud is re-used multiple times. The mud is screened for solids and recirculated down the well.	Reuse mud when drilling multiple wells on the same pad.	Not proposed	Not proposed	Drilling By-products buried on-site pending sampling results and certification from an independent EPA-accredited auditor. Disposal will comply with Clause C.4.1.2(f) of *the Code*. Cuttings disposed off-site if on-site disposal is not available. Off-site disposal will comply with Clause C.5.2 of *the Code*.
HF Flowback / CGP Flowback	Cannot avoid	Evaporation from enclosed and potentially open-topped treatment above-ground tanks.	Transferred via flowlines and/or trucks and potentially re-used for HF operations.	Not proposed	Evaporation	Any sludge or fluid remaining to be transported off-site by licenced contractors to a licensed facility.
CGP Oil/Sludge	Cannot avoid	Not proposed	Not proposed.	Not Proposed	Separate oil from wastewater to reduce volumes	Regularly collected and disposed of at a licenced facility by an appropriately licenced contractor.
Chemical Additives	Cannot avoid	Reusing drilling and completion fluids can lead to a significant reduction in chemical consumption, thereby minimizing waste production.	Surplus chemicals will be either returned to the supplier or repurposed for future operations.	Not proposed	Not proposed	Chemicals that are unused and cannot be returned or repurposed will be transported to a licensed facility for proper disposal.
Contaminated Rainwater	Inspect and ensure the maintenance of leak-free secondary containment systems or bunds.	Manage stormwater run-on and runoff using Erosion and Sediment Control (ESC) measures approved in **Appendix 05**, the Erosion and Sediment Control Plan (ESCP).	Not proposed	Not proposed	Not proposed	Rainwater that has been contaminated by wastewater will be disposed/managed in accordance with the specific requirements applicable to the wastewater.
Other Waste (Including Listed Waste)	Cannot avoid	Reduce the quantity of single use plastics in campsite where practicable.	Not proposed	Recyclable materials separated from general waste	Not proposed	Regularly transported off-site to a licensed disposal/recycling facility. Collected in designated area for disposal, following the *Waste Management and*

Waste Stream	Avoid	Reduce	Reuse	Recycle	Treat	Dispose
• General and Food • Empty IBCs • Metals and Plastics • Batteries and Tyres • Used Fuel Drums						*Pollution Control Act* [WASTE MANAGEMENT AND POLLUTION CONTROL ACT, 1998 (NT)]. Listed waste transported by a licensed company will carry out transportation and disposal following relevant regulations.

4.1 Well Pad Design

An indicative well pad design that has been developed for the well pads is shown in (**Figure 4—1**).

To manage the risks posed by wastewater, the CPP well pad will:

- Be located out of potential 1 in 100-year flood zones.
- Be located outside of riparian buffer zones.
- Have diversion berms on the upslope side of the pad and around sumps and any above ground tanks to divert rainwater around the pad, sumps, and tanks.
- Be designed so rainwater on the well pad will be diverted to erosion and sediment control measures.
- Have a minimum of two fully lined (HDPE or similar) sumps:
    - One for the collection of drilling and completion by-products.
    - One for storage of freshwater (turkey nest) and also to act as a contingency for drilling and completion by-products.
    - Where more wells are constructed on one well pad, more drilling and completion by-products can be expected. Therefore, the sump for wastewater by-products may be constructed larger or more than two sumps per pad constructed.
- Contingency above ground tank(s) installed up to the max capacity outlined in **Table 4—1**
- Above ground tanks will be installed as per **Section 4.8.1**.

A 13 ML above ground tank is currently storing flowback fluid on the Carpentaria 2 and 3 well pad. The fluid in this tank may be re-used for the Activity and the tank may be used as part of the contingency tanks outlined in this EMP.

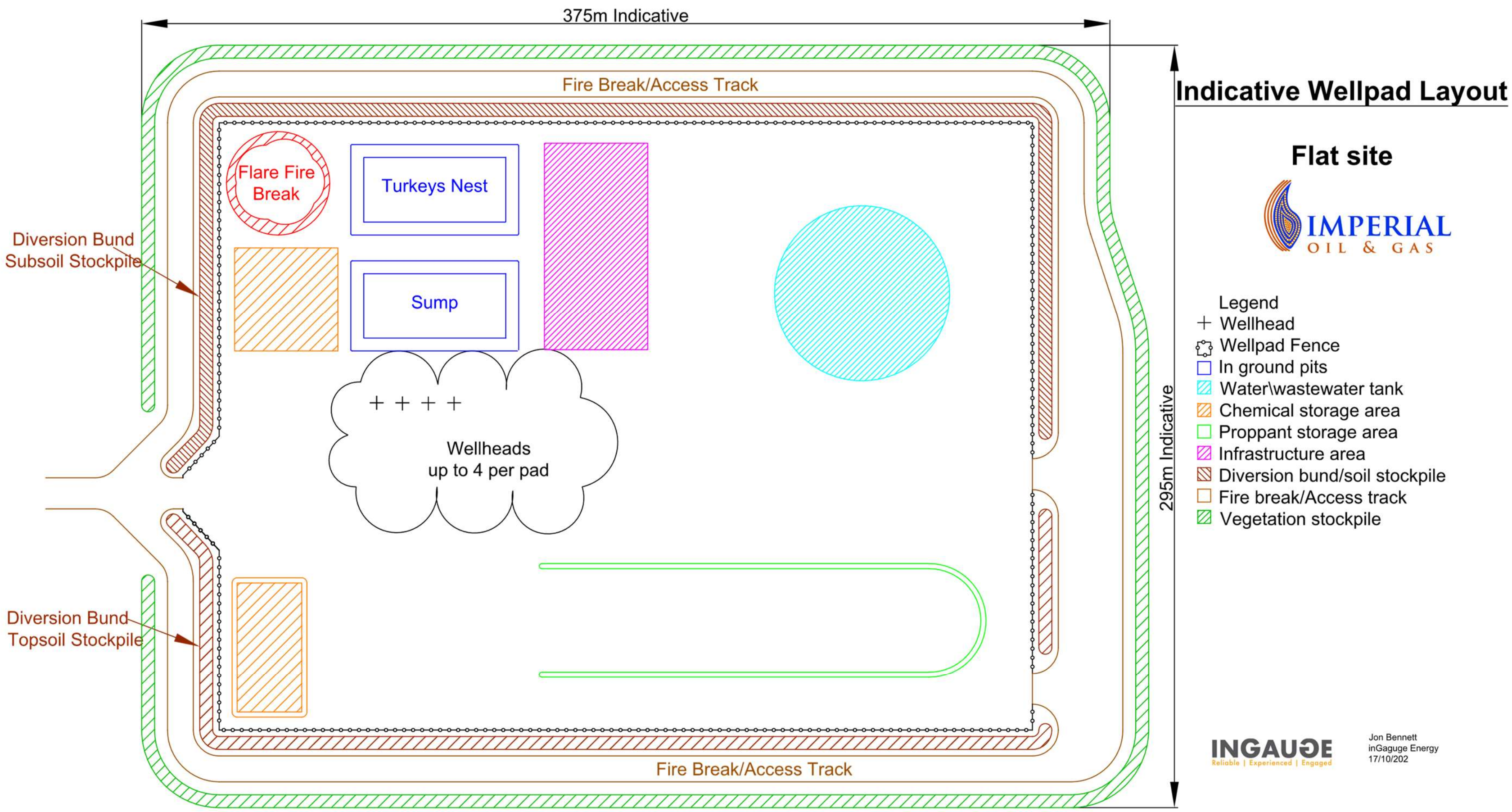

Figure 4—1 Indicative Well Pad Layout

4.2 Flowline Design

Flowline design is based on the Australian Pipelines and Gas Association (APGA) *Code of Practice for Upstream Polyethylene Gathering Networks, 2019* (*PEGN Code*) [APGA, 2019]. The *PEGN Code* provides guidance on the design, construction and operation of upstream polyethylene gathering networks in the Australian gas industry.

No traffic impacting works are anticipated to be carried out on the Carpentaria Highway. Flowlines that cross the Carpentaria highway will be installed utilising horizontal directional drilled (HDD).

Flowline installation will be carried out in a manner to reduce the risks of loss of containment with the following controls:

- All operators carrying out welded pipe jointing will be trained by registered training organisations (RTOs) and be qualified to PMBWELD 301 standard.
- The flowlines will be installed in a trench excavated to a depth that will give 750 mm Depth of Cover (DOC). Where the flowline crosses an access track or watercourse, DOC will be increased to at least 1,200 mm. If the trench bottom cannot be cleared of angular material, bedding material will be applied in the trench.
- The flowline networks will be subject to testing to validate mechanical strength and to detect leaks before commissioning. Safety precautions will be implemented during testing.
- A survey will be carried out to locate the flowlines and related infrastructure relative to permanent marks and benchmarks that conforms to Mapping Grid of Australia (MGA 94) or other approved datum. All buried flowlines will have a detectable tracer wire installed.
- Commissioning will ensure that both the PE pipes and all associated facilities are checked and verified by a competent and qualified inspector to ensure that they are fit for the nominated operating envelopes.
- The flowline network will be fitted with manifolds and valves so they can be isolated into sections. These valves will be locked to prevent unauthorised operation where they are not inside a fenced facility.

4.3 Water Handling Station Design

A centralised water handling station (WHS) for the Activity is proposed. The WHS will be the primary flowback storage location for the Activity. The indicative layout for the WHS is shown in **Figure 4—2**. The capacity of the primary tank(s) at the WHS will equal 110 ML (assumed configuration is two 55 ML tanks) the primary tank(s) will be enclosed with a floating lid.

Credible environmental and operational risks have been assessed in the design of the WHS with consideration given to:

- The WHS pad will be compacted to reduce infiltration and bunded to manage rainwater and risk of overtopping of tanks. Pad fall is away from tanks into designed erosion and sediment control (ESC) measures to manage stormwater runoff.
- Rainwater collected on tank lids may be left to evaporate when it does not pose a risk to the raised floating vents. Otherwise, it will tested prior to pumping to level spreaders / ESC measures at the WHS installed in accordance with the ESCP. See **Table 6-1** for details of the test parameters for water accumulated on tank lids.
- Contingency above ground tank(s) installed up to the max capacity outlined in **Table 4—1**.

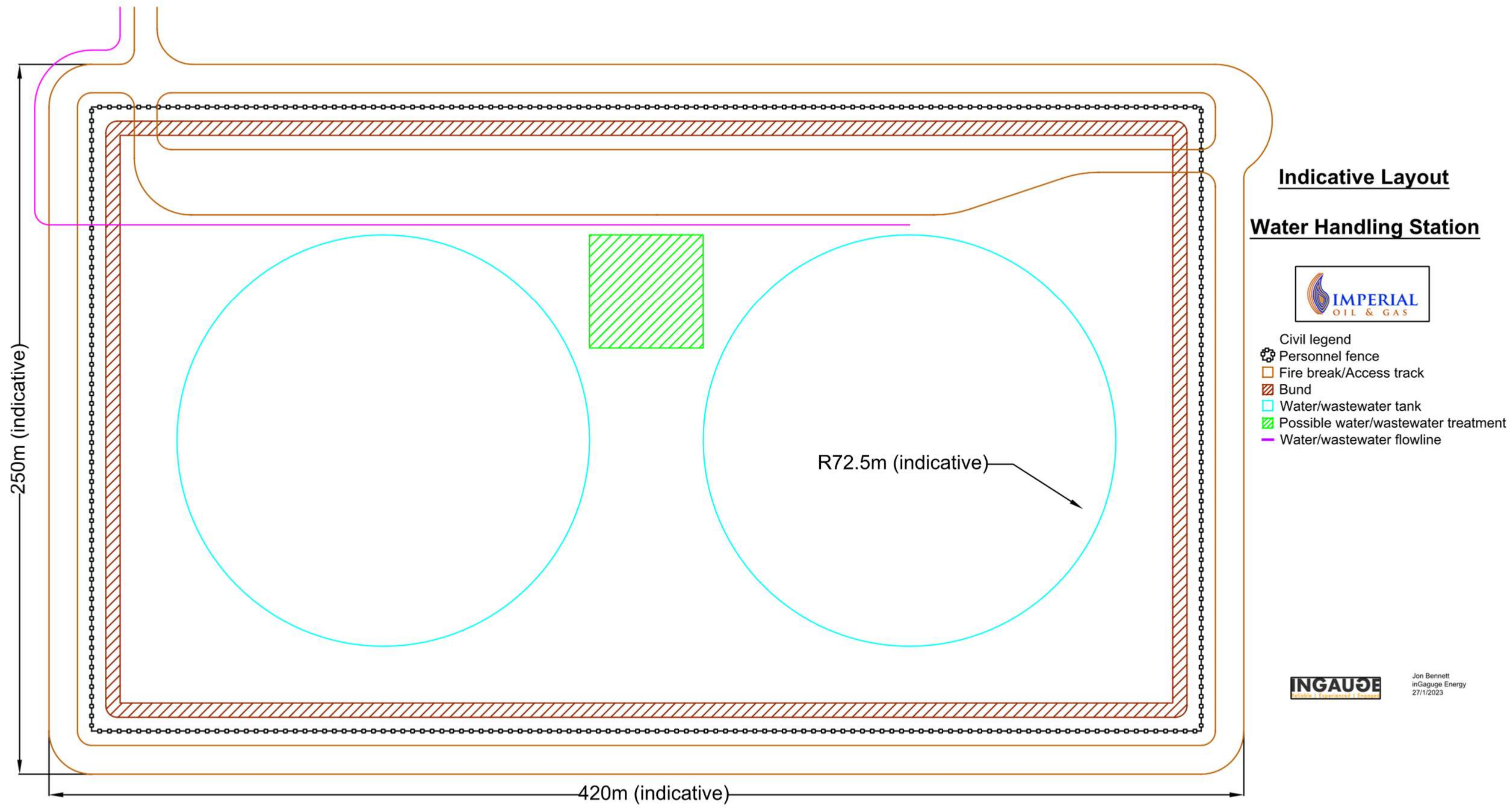

Figure 4—2 Indicative Water Handling Station Layout

4.4 Camp Greywater

Accommodation and messing facilities will be provided at the campsite and on well pads as required. All camp Greywater will be processed by Sewage Treatment Systems, with water irrigated once treated. The treatment system and irrigation area design will meet the requirements of the *Code of Practice (COP) for Wastewater Management 2020* (NT) and will be fenced to manage access by livestock.

4.5 Low Point Drain Water

Condensed water vapor in the gas gathering network will be directed to Low Point Drains (LPDs) for manual discharge into 1,000 L Intermediate Bulk Containers (IBCs). A shallow rubble pit will be constructed adjacent to the LPD discharge point. Subject to the following paragraph, this trench may be used to evaporate the water in the future and it is considered adequate given the expected volume of condensed water be ~100 L/week/LPD.

During monthly inspections, on-site personnel will either transport the IBC to the Water Handling Station for addition to an above-ground tank or assess the water quality by measuring its pH and Electrical Conductivity (EC) and record the results. If the water quality exceeds the thresholds outlined in **Table 6—1** they will transport the IBC to the Water Handling Station for addition to an above-ground tank. If the water quality is below the thresholds outlined in **Table 6—1**, the water will be released for evaporation in the rubble pit. The testing protocol will only be conducted for the first 12 months, to verify that the average water quality does not exceed the thresholds outlined in **Table 6—1**. If after 12 months average water quality is below the thresholds outlined in **Table 6—1,** the water will be sent to the rubble pit for evaporation. Alternatively, if after 12 months, average water quality exceeds the thresholds outlined in **Table 6—1** it will be transferred to the WHS.

Both the LPD system and adjacent evaporation rubble pit will be fenced to prevent livestock access.

4.6 Carpentaria Gas Plant (CGP) Wastewater

Rainwater runoff from the CGP skid will be collected in the rainwater runoff sump then pumped to the oil/water separation tank. Waste oil will be disposed offsite by licensed contractors. The water from the separation tank will be transferred to the oily water treatment package.

The liquids removed from the gas stream at the CGP inlet and compressor scrubbers will be drained into a process water tank and then transferred to the oily water treatment package. The oily water treatment package will remove oils and greases, suspended solids, and surfactants. The treated water will be pumped to the treated water storage tanks and then to the WHS. The oily waste will be removed for offsite disposal by a licensed contractor.

4.7 Drilling and Completion Waste

Drilling waste (cuttings and drilling fluid) will be contained in a lined and bunded drilling sump at the well pad in compliance with *Code* specifications. A description of an indicative well pad layout and design is provided in **Figure 4—1**. Each petroleum well will produce drilling and completion by-products.

4.7.1 Drilling and Completion Waste Management

The sumps will be:

- Constructed with a 500 mm high perimeter bund to prevent overland flow from entering pit/s.
- Lined with an impermeable membrane (Aquacon 345, HDPE or equivalent) as per Section C.4.1.2 (b) i of *the Code*.
- Marked with dry season and wet season freeboard limits (as outlined in **Table 5—2**) and fitted with fauna ladders (as per *Section C.4.1.2 (g)* of *the Code*).

Wastewater sumps will be equipped with a remote telemetry system. This will be either a water level sensor and/or a camera. If only a camera is setup, the sump must have water level markers that provide accurate water level estimates.

As a contingency, in the event that freeboard needs to be managed in the sumps, wastewater may be transferred between sites to other wastewater sumps using trucks.

4.7.2 Drilling Waste Assessment

Sampling and analysis of the drilling waste from past campaigns followed analyte testing standards for drill cuttings and drilling mud. Total and leachability concentration testing, in accordance with Table 9 of *the Code*, was performed to assess and classify the waste. The summarised analysis results are presented in **Table 4—3**.

Results of sampling and analysis provided the foundation for two drilling waste reports completed by suitably qualified third-party consultants. Of note, elevated chloride/TDS/EC levels were identified in the waste stream, most likely due to potassium chloride (KCl) added to drilling fluid (to inhibit clay expansion) during drilling.

The reports concluded that the risk posed by pH, chloride and associated cation and beta activity migration from the drilling waste to the water table at ~ 65 m BGL, "*Is considered negligible based on infiltration modelling, the high clay content of the CPP soil; and the low permeability properties of the drilling fluid*" [Kleinfelder, 2022].

Both reports confirmed the classification of the drilling sump material, which includes cuttings and residual WBM drilling fluid, as General Solid Waste (inert), with no listed elevated contaminants of potential concern (CoPC).

Table 4—3 Summary of Activity Drilling Waste Analysis

Analyte	Cuttings Concentration (Total mg/kg & Leachate mg/L)	Background Soil Concentration (Total mg/kg & Leachate mg/L)	Comment	Adverse Impact?
Electrical Conductivity (μS/cm)	7,600 ± 4,000	300 ± 340	EC is a measure of dissolved salts within a 1:5 cuttings – DI water mixture, high EC suggests highly soluble components are present (likely adhered to the rock chips) potential for migration to groundwater.	Requires review
Total Organic Carbon	1.9 ± 0.8	0.8 ± 0.2	Higher carbon content of cuttings is likely due to adhered cellulose from the additives.	No
Iron (%)	2.0 ± 0.4	7.6 ± 0.9	Higher iron in background samples reflects iron concentrations in surface and near surface soils.	No
Phosphorous (Total)	450 ± 190	-	Total phosphorous not measured in background samples. Reactive phosphorous in cuttings samples was below LOR (< 0.5 mg/kg) indicating phosphorous is not available.	No
Chloride†	43,000	40 ± 41	Higher chloride concentrations are likely related to mud additives. Potential for migration to groundwater at concentrations higher than background.	Requires review
Combined Cations† (Na, K, Ca, Mg)	60,000	2,140 ± 220	All cations have higher concentrations than those in the background soil, with the elevated concentration indicative of mud additives.	Requires review
Nitrogen (Total)	340 ± 35	380 ± 50	Comparable total nitrogen in cuttings and background soil, it is notable that nitrate concentrations are higher in background soil (1.0 vs < 0.5 mg/kg in cuttings).	No
Aluminum†	4,100 3.7 ± 0.9	7,100 ± 680 0.3 ± 0.2	Background soil has higher total aluminium concentration than estimated final cuttings concentration, but cuttings aluminium is more leachable. Not considered to pose significant risk.	No
Barium†	795 5.7 ± 2.5	85 ± 70 0.4 ± 0.2	Barium derived from the barite mud additive, generally considered non-toxic. Leachate concentrations are higher in the cuttings but are not considered to pose a risk.	No
Chromium† (Total)	25 0.1 ± 0.1	63 ± 6 < LOR	Chromium concentrations are higher in background soil (similar process to iron enrichment). Chromium is slightly more mobile from cuttings.	No
Manganese†	122 0.1 ± 0.0	74 ± 37 0.1 ± 0.1	Cuttings and background soil essentially indistinguishable. Low toxicity at observed concentrations.	No
Strontium†	22 < LOR	7.5 ± 1.9 < LOR	Strontium likely impurity in carbonate (either natural or within mud additive). Not leachable. Non-toxic at low concentrations.	No
Vanadium†	13 < LOR	170 ± 20 < LOR	Concentrations are higher in background soils than cuttings (similar enrichment process to iron).	No
Thorium†	1.1 < LOR	7.1 ± 1.0 < LOR	Concentrations considered to represent background in cuttings.	No

Analyte	Cuttings Concentration (Total mg/kg & Leachate mg/L)	Background Soil Concentration (Total mg/kg & Leachate mg/L)	Comment	Adverse Impact?
Uranium†	0.3 2 ± 0	1.0 ± 0.1 1 ± 0	Concentrations considered to represent background in cuttings.	No
Gross Alpha (Total Bq/kg & Leachate Bq/L)	1,450 ± 20 0.2 ± 0.0	1,230 ± 350 0.10 ± 0.04	Similar for cuttings and background soil.	No
Gross Beta (Total Bq/kg & Leachate Bq/L)	860 ± 140 7.1 ± 5.8	< 500 0.3 ± 0.0	Total and leachable levels from cuttings are higher than background.	Requires review
Gross Beta Potassium 40 Leachate Bq/L	< LOR	0.2 ± 0.0	Leachate only. Not observed above the laboratory LOR in the majority of samples.	No

Notes:

Concentrations are mg/kg and mg/L except for electrical conductivity (µS/cm), carbonate (%), iron (%) and alpha and beta activity (Bq/kg & Bq/L).

Concentrations are arithmetic means; Error is standard deviation.

† Estimated final cuttings concentration after water evaporation.

4.8 HF Flowback

Up to 85 ML is required to develop a well as part of the HF process, with up to 40% of the fluid potentially recovered for beneficial reuse. The fracturing process is designed to improve permeability in the Velkerri shale target, facilitating the release of economically viable gas volumes.

4.8.1 HF Flowback Management

The primary storage location for flowback fluid will be the enclosed above-ground storage tanks on the WHS. However, smaller open-topped above-ground treatment tanks may be utilised for the initial storage of flowback prior to pumping to the WHS and to facilitate evaporation during the Activity A summary of wastewater containment structures that are in use is:

- Above-ground tanks that will be:
  - Placed on a compacted tank pad with an overland flow bund.
  - Resistant to physical, chemical, and other failure during handling, installation, and use.
  - Designed and operated to prevent the uncontrolled discharge of connected tanks should one tank fail.
  - Able to withstand localised meteorological conditions (storms, wind loading etc.).
  - Built to ensure no access for terrestrial fauna (excluding avifauna).
  - Constructed to include adequate freeboard (dry and wet season) to prevent overtopping.
  - Constructed to contain a loss of primary containment through the installation of a secondary liner and leak detection system.
- Enclosed above-ground tanks will have the additional following controls:
  - Equipment available to pump rainwater that collects on the lid, as required, to ESC installed in accordance with the ESCP. Collected rainwater on the lid must be tested for pH and EC and meet the criteria outlined in **Table 6—1** before being pumped to the ESC. If the collected rainwater exceeds the limits in **Table 6—1,** it will be pumped into an above-ground tank with sufficient freeboard to safely take the extra water.
  - The enclosed above-ground tank lid is purpose built and has been designed:

   - With venting (top fitted) to reduce the likelihood of gas buildup when installed.
   - With vented floats and buoyant covers to prevent sinking and manage rainwater accumulation.

- Contingency above-ground open topped treatment tanks may be required, and are designed with the same requirements as enclosed above-ground tanks but will either have a removable lid available or be able to be connected to the WHS in the event of an SRE.
  - The above-ground tank lid is purpose built and has been designed:
    - With venting (top fitted) to reduce the likelihood of gas buildup when installed.
    - With vented floats and buoyant covers to prevent sinking and manage rainwater accumulation.
    - To be easily installed prior to rain events and removed to assist in evaporation during the dry season.

Remote telemetry systems will be installed to allow for remote monitoring and response to alarm activation. These will include a water level sensor, a leak detection sensor and possibly a camera.

HF fluid will be transferred to above ground tanks at the WHS for re-use. Above ground tanks at the well pads will typically be interconnected through the HF flowline (subsurface HDPE pipework) to the WHS.

As an additional contingency measure, if it becomes necessary to manage wastewater in the above-ground tanks, wastewater fluid may be transferred between on-site above-ground tanks or off-site for disposal, using trucks.

4.8.2 HF Flowback Monitoring

During the flowback period, fluid will be monitored in accordance with section C.5.4 (b) ii of *the Code* by field testing for EC until results stabilise.

Stabilisation will be achieved when the average EC measurements from three consecutive weeks fall within a range of +/- 5% of the median value of these three results.

4.8.3 HF Flowback Quality Assessment

Assessment of HF chemicals that may be used downhole in the Activity did not identify any Persistent, Bio-accumulative, and Toxic (PBT) chemicals that may be harmful to human health.

HF chemicals that may be used downhole are risk assessed in **Appendix 08** (Human Health and Environment Chemical Risk Assessment) of the EMP.

The HF flowback contains chemicals used in the fracturing process, principally guar gum, friction reducers and residual biocide. It may also contain trace levels of geogenic constituents of potential concern (COPC).

Laboratory analysis of HF flowback quality from previous Imperial wells constructed in the CPP Area (Carpentaria 1, 2, 3) and was undertaken in accordance with *the Code* requirements for HF flowback analysis [KLEINFELDER, 2021]. Results for analytes above the Limit of Reporting (LoR), average across all samples and the 95% Upper Confidence Level (UCL) are presented in **Table 4—4**.

The analysis suggests that the range of CPP HF flowback brine (e.g. chloride) content is technically feasible for re-use of HF flowback in subsequent HF operations. This in part is due to recent industry innovations in brine tolerant friction reducers [J. PAKTINAT et al., 2011].

An analysis of constituents of potential concern that have reported above the LOR in the HF Flowback assessment [KLEINFELDER, 2022] is provided below. Results are seen as typical across the CPP site.

Lithium UCl = 20 mg.L^{-1}: A naturally occurring metal that tends to accumulate in water systems due to its high solubility in water and mobility characteristics. The health-based screening level of Li in drinking water is 10 µg.L–1 (ppb). The elevated Lithium in HF flowback is primarily from geogenic sources in the target shale formation.

Manganese UCl = 14 mg.L^{-1}: A naturally occurring metal that has relatively low solubility in water. The health-based screening level of Mn in drinking water is 10 µg.L^{-1} (ppb). The elevated Manganese in HF flowback is primarily from geogenic sources in the target shale formation.

Total Organic Carbon UCl = 1248 mg.L^{-1}: Residue from the guar gum used in the HF fluid at approximately 1,000mg.L^{-1}. The health-based screening level of TOC in drinking water is 2 mg.L^{-1} (ppm). High organic load in HF flowback will biodegrade rapidly in open tanks.

Phosphorus UCl = 7 mg.L^{-1}: A naturally occurring element found in soil, water, and rock. The health-based screening level of P in drinking water is 20 µg.L^{-1} (ppb). The elevated P in HF flowback is both from geogenic sources in the target shale formation.

Alpha UCl = 166 Bq.L^{-1}: A naturally occurring radionuclide particle commonly found in soil, water, and rock. The health-based screening level of Alpha particles in drinking water is 0.5 Bq.L^{-1}. The elevated Alpha in HF flowback is from geogenic sources in the target shale formation. Alpha particles are not soluble in water, but they may be suspended. Analyses of NORM from many different oil and gas fields show that produced water may contain 224 Ra, 226 Ra and 228 Ra in concentrations of up to a few hundred becquerels per litre [INTERNATIONAL ATOMIC ENERGY AGENCY, 2003].

Table 4—4 Summary Results of HF Flowback Analysis [Kleinfelder, 2021]

Analyte	Unit	Average	95% UCL Value
Electrical Conductivity	µS/cm	14,556	34,301
Total Dissolved Solids	mg/L	12,596	29,646
Chloride	mg/L	5,497	13,967
Sodium	mg/L	8,569	16,520
Total Organic Carbon	mg/L	855	1,248
Alkalinity	mg/L	584	885
Bromide	mg/L	243	470
Strontium	mg/L	318	409
Barium	mg/L	390	523
Phenol	mg/L	48	109
Sulfate	mg/L	58	110
Boron	mg/L	46	62
Nitrogen	mg/L	145	239
Iron	mg/L	24	51
Phosphorus	mg/L	5	7
Lithium	mg/L	13	20
Manganese	mg/L	9	14
C10-C40	µg/L	1,698	2,840
Total BTEX	ug/L	9	25
Alpha	Bq/L	96	166
Beta	Bq/L	69	139
Sodium Absorption Ratio	N/A	32	52
pH	unit	6	7

Barium UCI = 523 mg.L^{-1}: A naturally occurring metal that that has relatively low solubility in water. The health-based screening level of Ba in drinking water is 2 mg.L^{-1} (ppm). The elevated Ba in HF flowback is primarily from geogenic sources in the target shale formation. Barium sulphate is a common additive to drilling fluid used to increase the weight of the fluid to maintain bottom hole pressure. Barium sulphate is insoluble in water as is evident in the low ASLP values of barium.

Strontium UCI = 409 mg.L^{-1}: A naturally occurring metal that that has relatively low solubility in water. The health-based screening level of Sr in drinking water is 4 mg.L^{-1} (ppm). The elevated Sr in HF flowback is primarily from geogenic sources in the target shale formation.

Bromide UCI = 470 mg.L^{-1}: A naturally occurring element found in underground brines that has relatively high solubility in water and mobility characteristics. The health-based screening level of Br in drinking water is 6 mg.L^{-1} (ppm). The elevated Br in HF flowback is primarily from geogenic sources in the target shale formation.

Beta UCI = 139 Bq.L^{-1}: A naturally occurring radioactive material found in soil, water, and rock. The health-based screening level of Beta particles in drinking water is 0.5 Bq.L^{-1}: The elevated Beta in HF flowback is from geogenic sources in the target shale formation. Beta particles are not soluble in water but they may be suspended.

C10:C40 UCI = 2,841 μg.L^{-1}: These longer chain hydrocarbons occur naturally in petroleum. They are biodegradable. They have low solubility in water. The health-based screening level of C10:C40 in drinking water is 50 μg.L^{-1} (ppb)

Chloride UCI = 13,967 mg.L^{-1}: Chloride contamination of soil is the most frequently reported pollution problem occurring at shale oil well pads in North America due to spills of HF flowback. The health-based screening level of Cl in drinking water 250 mg.L^{-1} (ppm). The elevated chlorides in HF flowback are primarily from geogenic sources in the target shale formation.

Phenol (hydroxy-benzene) UCl = 109 mg.L^{-1}: A naturally occurring aromatic hydrocarbon which is biodegradable. Among the various microorganisms, *Pseudomonas putida* is the most common soil gram-negative bacteria that degrades phenol; this species has been widely used in hydrocarbon bioremediation in saline and non-saline environments. The health-based screening level of Phenol in drinking water is 2 mg.L^{-1}.

Total BTEX = 25 μg.L^{-1} (ppb): These volatile organic compounds (VOC) occur naturally in petroleum. They are highly volatile and biodegradable. They are moderately soluble in water. The health-based screening level of BTEX in drinking water is 1 μg.L^{-1} (ppb)

TTPC = < 28 mg.L^{-1}: An industrial biocide that is particularly effective at low concentrations in managing gram-negative bacteria; a key biocide characteristic needed to manage bacterial communities in CPP due to high organics (TOC = 0.1%) from the use of HF gels. It is stable over a wide pH range, is not susceptible to photodegradation, and is of comparatively low toxicity to non-aquatic life. TTPC is biodegradable, but not readily biodegradable. It will be strongly absorbed by soil and sediment. TTPC is not expected to bioaccumulate. TTPC concentration in the CPP is significantly lower (5-fold) than observable effects on drinking water for birds. However, TTPC is very toxic to aquatic life with long-lasting effects. Drinking water is TTPC < 150 mg/L^{-1}, which is much higher than predicted maximum concentration in the CPP Area.

4.9 Separated Sand

Flowback fluid will be processed via atmospheric and then low pressure separators as the wells are brought online. This is to separate the gas, the fluid, and the sand.

Once separated, sand will be reused in stimulations, transported off-site or cleaned via washing and used as construction sand or fill. The water used to wash the sand will be transferred to the WHS after use. The sand will be washed until the returned water has an EC less than 5,000 uS/cm.

The gas that is separated during this process will be managed in accordance with the Methane Emissions Management Plan (**Appendix 13**).

5 Freeboard Management

5.1 Rainfall

Australian tropical savannahs extend from the Gulf of Carpentaria in north Queensland, across the northern half of the Northern Territory and Western Australia and include the Beetaloo and CPP Area.

The CPP Area is located within a uniquely seasonal bioregion, where ~ 85% of the rainfall occurs between the months of December and March. Climate statistics for rainfall design were derived from BOM station daily weather records at Daly Waters and McArthur River Mine, east and west of the Activity, and are presented in **Figure 5—1** and **Figure 5—2**.

The Code defines the Wet Season as the months of October to April. This seasonality is driven by the annual movement of the Intertropical Convergence Zone, which drives the Australian summer monsoon.

An assessment of available data indicates:

- Total annual rainfall is highly variable within the bioregion, resulting in a conservative approach being used in storage freeboard calculations for reliability.

- On average considering the last 66 years of available data, a 7-day accumulative average rain event > 100 mm only occurred in the months of December – March and has not occurred in July-September (see **Figure 5—2**).

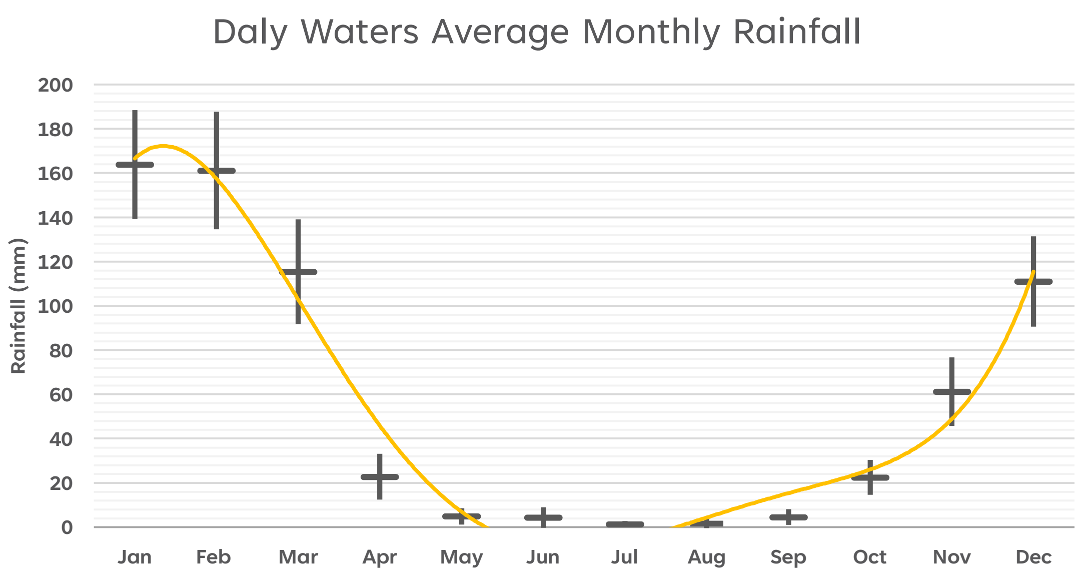

Figure 5—1 Monthly Average Rainfall (± CI 95%) at Daily Waters Since 1880

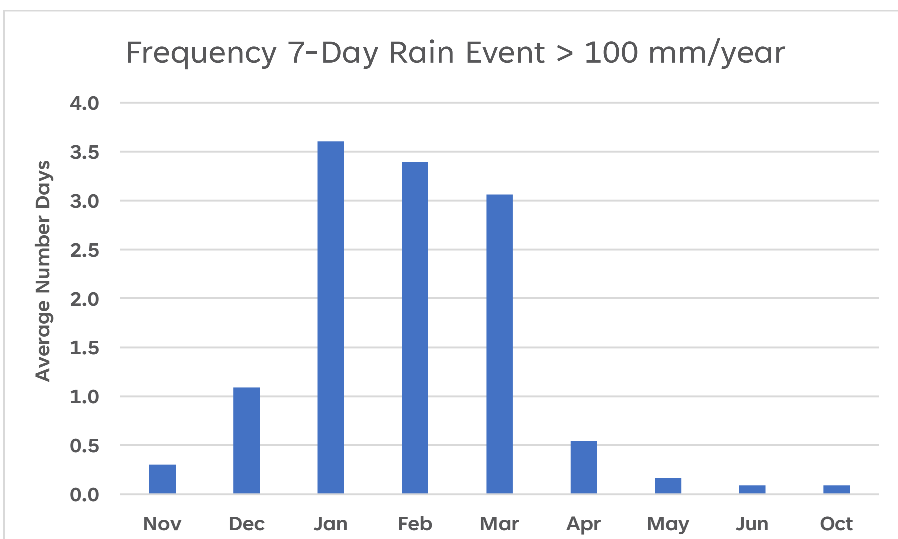

Figure 5—2 Average Number of Days in Months in which > 100 mm 7 Day Rain-events Occurred During Last 66 years at McArthur River Mine

5.2 Evaporation

Daily evaporation at Sturt Plateau averages 7.5 mm/day with a significant increase towards the end of the dry season and during the build-up phase late in the year (see **Figure 5—3**).

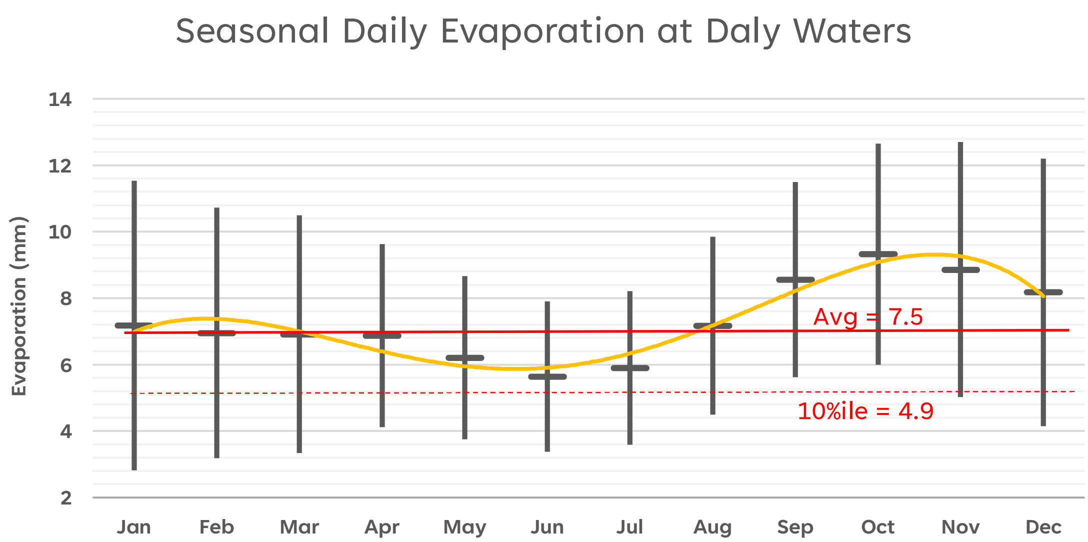

Figure 5—3 Average Daily Evaporation (± CI 95%) by Month at Daly Waters Since 1880

5.3 Freeboard

The Code requires estimates for the 1 in 1,000 (0.1%) average recurrence interval (ARI) rainfall rate using Australian Rainfall and Runoff methodologies for the critical period during which there would be greatest risk of overtopping of any structures holding wastewater which are not enclosed.

The preferred statistical approach for projecting Probable Maximum Precipitation (PMP) estimates, crucial for designing high-consequence infrastructure like CPP tanks in the Australian tropical savanna region, is the Generalised Tropical Storm Method (GTSMR) [BOM, 2023]. According to this method, the maximum duration considered is 120 hours during summer in the coastal zone and 96 hours (equivalent to 4 days) for all other zones and seasons.

However, for compliance with this EMP, regulatory standards require operators employ a 0.1% Probable Maximum Precipitation (PMP) estimate over a 90-day period. The extension of the GTSMR PMP estimate to this prolonged duration introduces considerable statistical uncertainty in predicting extreme rainfall. This uncertainty arises from the inherent variability in rainfall and storm patterns within the savanna region.

As a result, utilising probability methods that leverage historical daily rainfall datasets emerges as a viable approach to reasonably forecast a 0.1% PMP estimate for 90 days. This method, though accompanied by a wide range of uncertainties, provides for a conservative prediction of an extreme event within the CPP Area.

The analysis results from the daily records of the Daly Waters (west of EP 187) and McArthur River Mine (east of EP 187 CPP) weather stations are presented in **Table 5—1**. To calculate the minimum required reserved space to handle a 1 in 1,000-year rainfall event the following formula has been utilised:

Minimum Amount of Reserved Space Required	**=**	**Dry or Wet Season PMP_90 days** (0.1%0_Cumulative Rainfall) **–** **Corresponding Season Evaporation_90 Days** (10th percentile)

Notably, no maximum observed tropical storm events (3-day and 7-day cumulative events) measured at Daly Waters (120 years) or McArthur River Mine (66 years) exceeded 60% of the proposed wet season freeboard which demonstrates the conservative reliability of this analysis.

Table 5—1 Climate Statistics East and West of CPP [BoM, 2023]

Climate Statistic	Daly Waters BOM14618	McArthur River Mine BOM14704
Number Years Daily Observations	140 years	60 years
Annual Total Average Evaporation (E)	2,650 mm	2,600 mm
Annual Total Average Rainfall (P) ± 95% Confidence Interval	650 ± 430 mm	880 mm ± 670 mm
Total Annual Rainfall Coefficient of Variation	33%	38%
Annual Average Period No-Rain ± 95% Confidence Interval	195 ± 171 days	190 ± 160 days
Wet Season 1 In 1,000 (0.1%) Year AEP_90-Day Cumulative Rainfall	1,100 mm	1,400 mm
Dry Season 1 In 1,000 (0.1%) Year AEP_90-Day Cumulative Rainfall	200 mm	220 mm
10%ile Evaporation_90 Days	440 mm	450 mm
Theoretical Minimum Required Reserved Space - Wet Season 90-day Net Precipitation 0.1% AEP	660 mm	950 mm
Theoretical Minimum Required Reserved Space - Dry Season 90-day Net Precipitation 0.1% AEP	300 mm	300 mm
Maximum 72 Hour Total	270 mm	330 mm
Maximum 7 Day Total	380 mm	600 mm
Maximum Annual Recorded Total Rainfall	1,323 mm (2011)	1,606 mm (2011)
Minimum Annual Recorded Total Rainfall	203 mm (1900)	250 mm (1961)

Sec C.7.1.1 (a) iv. of *the Code* requires the following for freeboard management:

Specify minimum freeboard for treatment infrastructure to accommodate total rainfall anticipated (based on 1:1,000-year average recurrence interval rainfall estimates, for the period that treatment infrastructure contains wastewater.

Based on the seasonal rainfall design analysis provided above although the theoretical minimum required reserve space has been calculated as 950 mm in the wet season and 300 mm in the dry season, Imperial has opted to use higher values to both, mitigate the potential risk of overtopping due to wind events, and to align with the freeboard utilised in past operations within the CPP Area. Consequently, the freeboard to be adopted for open-topped above-ground tanks and sumps during the dry and wet seasons has been established at 500 mm and 1,100 mm, respectively. For enclosed above-ground tanks, the freeboard is set at 500 mm. The freeboard values are shown in **Table 5—2**.

Table 5—2 Minimum Freeboard for Wet Season and Dry Season

Seasonal Freeboard	Freeboard for Wastewater Sumps and Open Topped Above-ground Tanks	Freeboard for Enclosed Above-ground Tanks
Wet Season (October - April)	1,100 mm	500 mm
Dry Season (May – September)	500 mm	500 mm

5.3.1 Forecast Significant Rain Event

Section C.7.1.1 (a) of *the Code* requires for open-topped tanks:

ii. *Include a plan to transfer produced water and flowback fluid into above-ground enclosed tanks (see section C.4.2.2) at least 8 hours in advance of any predicted significant rainfall event as specifically defined based on local weather conditions and other site-specific risks.*

iii. *Include a strategy (including environmental performance standards and measurement criteria) for detecting and responding to predicted significant rainfall events, with a focus on the wet season.*

For the purposes of this section of *the Code*, a significant rainfall event is defined as an event where > 300 mm rainfall occurs over four days. The three historical SREs for McArthur River Mine Airport are shown in **Figure 5—4**. If the Bureau of Meteorology (BOM) 7-day forecast predicts a "significant rainfall event" exceeding 300 mm over four days for the CPP Area, Imperial plans to ensure that freeboard will be maintained as follows:

- Monitor the stored volume and available freeboard of all open-topped treatment tanks in line with condition C.5.5(b) of *the Code*.
- Subtract the SRE forecast rainfall volume from the current freeboard of all open topped treatment tanks; this will become the "calculated post significant event freeboard".
- If the "calculated post significant event freeboard" is less than the season freeboard requirement in any open topped tank, Imperial will transfer water using the flowline network to a tank at the WHS with sufficient freeboard. If no tank at the WHS has sufficient freeboard, tanks on the well pads may be used.
- Imperial will install engineered tank covers on open-top treatment tanks at least 8 hours before the forecast SRE (*the Code* C.7.1.1 (a) ii and iii) if the freeboard cannot be managed by transferring water as described above.

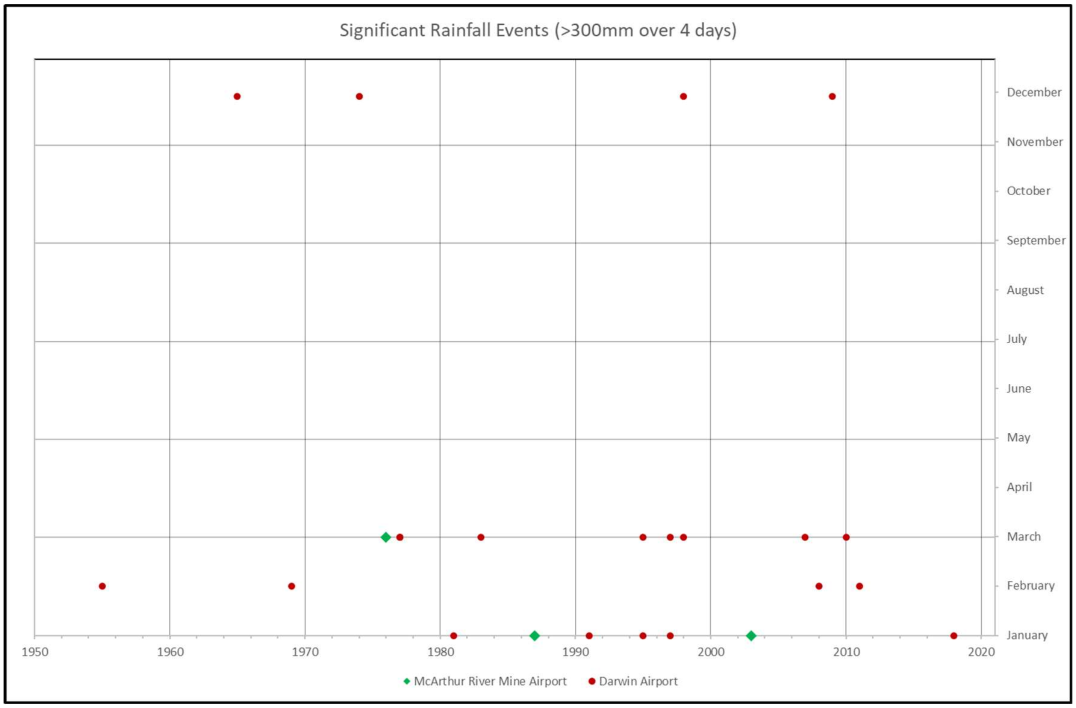

Figure 5—4 Significant Rainfall Events

6 Monitoring

Below sections outline *the Code* monitoring requirements for drilling materials, flowback fluid and produced water. These monitoring requirements are summarized in **Table 6—1**.

6.1 Drilling Materials

Section C.5.2 of *the Code* details the monitoring requirements for drilling materials:

(a) *The quality and quantity of drilling fluid and drill cuttings shall be recorded while within the area in which the petroleum activity is approved to occur.*

(a) *Interest holders must analyse the composition of drill cuttings and residual drilling fluids as it is identified to determine whether it is consistent with assumptions used for the assessment of environmental hazards and the design of proposed disposal methods made in accordance with section C.4.1.2.*

(b) *Prior to off-site management, disposal or transport, residual drilling waste shall be tested:*

i. *for radioactivity from NORMs to determine if the waste is classified under the Radiation Protection Act 2004 (NT); and*

ii. *as required by the Waste Management and Pollution Control (Administration) Regulations 1998 (NT), which may require testing to classify the waste.*

6.2 Flowback Fluid and Produced Water

Section C.5.4 of *the Code* details the monitoring requirements for flowback fluid as follows:

(a) *For hydraulic fracturing, the interest holder must implement a flowback fluid monitoring program must be established and implemented to characterise the quality and quantity of flowback fluid generated during flowback activities.*

(b) *The monitoring program must characterise flowback fluid quality through the following measures:*

i. *continuous monitoring (sampling frequency of at least once per 24 hours) of electrical conductivity, pH and temperature*

ii. *monitoring at least weekly for a duration long enough that the quality of the flowback fluid is sufficiently stabilised against criteria described in the WWMP, and tested for the analytes listed in section C.8.* (see Section 4.8.2 above)

iii. *monitoring of the flowback fluid storage, as required by C.5.5 (c).*

(c) *The monitoring program must measure flowback fluid volume by recording the cumulative flowback fluid volume for each well at one month, 3 months, 6 months, and 12 months after flowback has commenced.*

Section C.5.5 of *the Code* details the monitoring requirements produced and flowback water storages (Note: no produced water is anticipated from the Activity) as the following:

(a) *The quantity and quality of produced water and flowback fluid must be recorded while within the area in which the petroleum activity is approved to occur, in accordance with the methods specified in an approved WWMP or SMP.*

(b) *Stored volume and available freeboard for all produced water and flowback fluid storage facilities must be monitored at least weekly, unless being operated through the wet season during which they should be monitored daily.*

(c) *A sample from all produced water and flowback fluid storages must be taken at least once every 6 months and tested for the analytes listed in section C.8.*

Table 6—1 Monitoring Plan for Wastewater in the CPP Area

Wastewater	Location	Frequency	Analysis/Limit (Code/Legislation Reference)	Requirements
Drilling Materials	Well pad	Once	C.4.1.3. Table 9: Analytes and method for drilling waste assessment.	Suitably qualified personnel NATA Laboratory
		Prior to offsite disposal	Tested as per C.5.2.(c).	
		Prior to onsite disposal	Third-party certification as per C.4.1.2.(f).	
HF Flowback	Well pad or WHS	During flowback, field test until results stabilize as described in **Section 4.8.2** above.	C.5.4 (b) ii Electrical conductivity	Suitably qualified personnel*
		At one month, 3 months, 6 months, and 12 months after flowback has commenced.	C.5.4 (c) cumulative flowback fluid volume for each well.	Remote telemetry or suitably qualified personnel*
		During flowback, once every 24 hours during flowback activities.	C.5.4 (b) i Electrical conductivity, pH and temperature.	Remote telemetry or suitably qualified personnel*

Wastewater	Location	Frequency	Analysis/Limit (Code/Legislation Reference)	Requirements
Wastewater Sumps	Well pad	Daily during drilling otherwise weekly while operational.	Available freeboard	Visual inspection and/or remote telemetry
HF Flowback Water Storage	Water Handling Station and/or well pad	Weekly in dry season and daily in wet season while operational.	C.5.5 (b) Stored volume and available freeboard.	Visual inspection and/or remote telemetry
		Continuous, while operational	Leak detection	Remote telemetry with alarm and and/or visual inspection for permanently staffed sites
		Every 6 months	C.5.5 (c) tested for the analytes listed in section C.8.	Suitably qualified personnel* NATA Laboratory
LPD Water	LPD IBC (multiple locations)	Conditionally sampled monthly for 12 months as discussed in **Section 4.5**.	Electrical Conductivity (EC) < 1,500 µs/cm pH 6-9 pH units and Volume (Litres) (field measurement).	Suitably qualified personnel*
Water Accumulated on Tank Lids	Water Handling Station	As required before release to Erosion and Sediment Control.	Electrical Conductivity (EC) < 1,500 µs/cm pH 6-9 pH units (field measurement).	Suitably qualified personnel*

*A person who has professional qualifications, training or skills or experience relevant to the nominated subject matters or tasks.

7 Transport on Unsealed Access Tracks

The transport of chemicals or wastewater during the wet season is subject to conditions as outlined in section A.3.8 (b) of *the Code*. Transport on unsealed road networks will only be undertaken once the risk has been assessed, has been reduced to ALARP and is acceptable.

Where practicable, transport will be scheduled to align with the extended dry season to reduce potential for wet weather disruption. Transport of chemicals or wastewater on unsealed roads during the wet season will only be approved by the Site Supervisor when the road is assessed using the Wet Season Transport of Chemicals/ Wastewater Checklist to be in suitable condition, and when no significant rainfall events are forecast. A record of this Wet Season Transport of Chemicals/ Wastewater Checklist undertaken by the Site Supervisor will be kept.

8 Waste and Wastewater Offsite Disposal

Section C.6.1 (b & c) of *the Code* imposes requirements for the tracking of wastes considering the *Waste Management and Pollution Control Act 1998* (NT), subordination regulations and relevant Codes of Practice (CoP's). Any liquid waste generated as part of the Activity would likely be considered a *"controlled waste"* as defined under regulation for the purpose of transport and disposal.

Waste and wastewater disposal will be managed only by licensed contractors.

The requirements for waste tracking include:

- A controlled waste consignment authorisation (CA) must be completed for all controlled waste transported into, within or out of the Northern Territory (NT).
- For controlled waste leaving the NT to another State or Territory, a CA must also be obtained from the destination jurisdiction.
- For every movement of a controlled waste, within, into or out of the NT, a Waste Transfer Certificate (WTC) must be completed.

9 Wastewater Movement Tracking

The mandatory recording and reporting of water and wastewater movements is required under section C.6.1 (a) of *the Code*. Wastewater tracking documentation must be reported to the Minister at least annually in accordance with the mandatory reporting requirements as per *the Code* (referenced below).

Section C.6.1 Water and wastewater tracking and reporting requirements:

(a) *the movement of water and wastewater must be tracked and include:*

- ii. *Volumes of produced water and flowback fluid from each well;*
- iii. *Volumes of water transferred into each tank;*
- iv. *Estimates for evaporation rates from each tank;*
- v. *Volumes of water planned to be, and ultimately, reused in petroleum operations including drilling and hydraulic fracturing;*
- vi. *Volumes of water and wastewater used for other purposes including dust suppression and construction water;*
- vii. *Volumes of water and wastewater removed from site and its destination (whether by vehicle or pipeline) including details of the licence number of the any licensed waste transporters; and*
- viii. *Volumes of any spills of water or wastewater.*

(b) *Wastewater tracking must be documented in an auditable chain of custody system.*

(c) *Wastewater tracking must be in accordance with other legislative requirements such as those imposed under the Waste Management and Pollution Control Act 1998 (NT) and the Radiation Protection Act 2004 (NT).*

(d) *Wastewater tracking documentation must be reported to the Minister at least annually in accordance with the framework provided in the EMP.*

To meet compliance outcomes, flow meters, tank level indicators and weigh scales on waste transport vehicles will be installed or required by transport contractors to provide an accurate annual water balance report for regulatory review.

10 Wildlife, Stock, and Human Interaction

Controls will be implemented to minimise the risk of wildlife, stock, and human receptors interacting with stored waste. Stock proof fencing will be installed around all well pads, water handling system and low point drains, with access to each area controlled.

Above ground tanks have been designed with sheer outer walls/framework to minimise access for fauna. Fauna ladders will be installed in all open storage sumps to provide exit points for any terrestrial fauna should it be required.

Contractors, visitors, adjacent landowners, and the general public will have limited and restricted access points to enter well pads and the WHS but will have access to the surrounding land leased by the Activity. Signage will be installed at the entryway to each well pad and the WHS and will include contact information for the site supervisor.

Full access to the site will be restricted to those inducted, where hazards and risks will be identified, and controls established. All other persons will require an inducted host as escort to ensure exposure to waste and wastewater hazards are minimised.

The CPP Area will be routinely monitored during operations to ensure signage is legible, controls are maintained, remain effective, and are repaired as required.

11 References

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