2022 Groundwater Summary Report

Kearl Oil Sands Mine

Imperial Oil Resources Limited.

15 April 2023

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DESIKA

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Executive Summary

Imperial Oil Resources Limited's (Imperial) Kearl Oil Sands Mine (the Site) is an open-pit oil sands mine and bitumen processing facility located in the Regional Municipality of Wood Buffalo, Alberta, approximately 70 kilometres (km) north of Fort McMurray. The Site covers an area of approximately 197 km^2 within Townships 95 to 97 and Ranges 7 to 8, west of the 4^{th} Meridian (Figure 1).

The Kearl Mine became operational with the onset of oil production and first oil in April 2013. In 2022, the Kearl Mine was in various stages of design, construction, and operation, and will continue to cycle through these stages over the lifespan of the mine.

Groundwater activities at Kearl in 2022 included the following:

- The Athabasca Field Program (AFP) and Western Canada Wells (WCW) Field Program (Section 3.2).
- Regulatory Groundwater Monitoring Program (Section 5).
- Internal Tailings Area 1 (ITA1) Monitoring Program (Section 6).
- External Tailings Area (ETA) Seepage Interception System (SIS) Monitoring Program (Section 7).
- Iron Precipitate Investigation (Section 8).
- Basal Depressurization Program (Section 9).
- Devonian Depressurization Program (Section 10). and
- Operation of the ETA SIS pumping system including activation of eight SIS pumping wells to capture process affected water (PAW) seepage and return it to the ETA (Section 7.6).
- Activation of Quaternary dewatering wells in North Pit South Advance and East Pit mining areas.
- Other on-going groundwater-related activities were conducted by on-site hydrogeologists on an as needed basis, including inspections, abandonments, and maintenance of Kearl Mine groundwater monitoring wells.

Predevelopment, the groundwater flow direction in the Quaternary sediments was generally interpreted to follow surface topography, predominantly towards the west and northwest, towards the Muskeg and Firebag rivers (Imperial 2005). Following development of North Pit and the ETA, flow regimes have been altered in the northern portions of the Mineral Surface Lease (MSL). Flow interpretations for 2022 are outlined below:

- Radial flow away from the ETA, in particular the West ETA (WETA), was interpreted based on evidence supporting a hydraulic connection between the ETA and the Quaternary sediments, including borehole logs, groundwater chemistry changes, and increasing groundwater elevations in the area. Groundwater flow north of the ETA was generally towards the north and northwest, toward the Firebag River and a large wetland complex northwest of the Site.
- To the west and south of the ETA, Quaternary groundwater flow was generally towards the North Pit, where discharge into the pit enters the Industrial Wastewater System. However, at the northwest portion of WETA, groundwater flowed towards the west, beneath the North Overburden Disposal Area (NODA), and then towards the wetland complex northwest of the Site.

- West of the North Pit and in the southern portion of West Overburden Disposal Area (WODA), the Quaternary groundwater flow direction was generally northwest.
- Southeast of the plant and northeast of Central Overburden Disposal Area (CODA), groundwater flow through the East Pit footprint and CODA was generally towards the Muskeg River in the southeast and the south advance dewatering area to the southwest.
- In the southern portion of the Site, groundwater flow was generally from the higher topography of Muskeg Mountain in the southeast towards the lower Muskeg River Plain to the northwest.

The average linear flow velocity in the Quaternary deposits across the Site ranged from about 5 to 62 m/year. Two areas of higher velocity were identified near the ETA as result of the hydraulic gradient created by the ETA and local areas within the Quaternary deposits with higher hydraulic conductivity. An average linear flow velocity of approximately 270 m/yr was estimated within the Quaternary sediments beneath the dyke on the north side of WETA and upgradient of the seepage interception system, and an average linear flow velocity of approximately 300 m/yr was estimated along a flow path at Centre Dyke near KH11-179.

In 2022, the Regulatory Groundwater Monitoring Network increased by 14 monitoring wells and the ETA SIS Monitoring Network increased by 30 monitoring wells to increase coverage of the monitoring networks, respond to triggers of the Groundwater Response Plan, and investigate shallow groundwater seepage to surface where iron precipitate was present downgradient of the ETA.

Groundwater key indicator parameter (KIP) concentrations with statistically significant upward trends and/or exceedances of assessment criteria were generally interpreted to be caused by one or more of:

- Natural variation;
- Hydrogeochemical reactions, predominantly sulphide mineral oxidation (SMO);
- Seepage of process affected water (PAW) from the ETA; and/or
- Connections to deeper Basal and Devonian aquifers in the Kearl Channel.

Within the Regulatory Groundwater Monitoring Network, multiple monitoring wells indicated increasing KIP concentrations and/or location-specific assessment criteria exceedances that were interpreted to be the result of hydrogeochemical reactions related to SMO. Impacts attributed to, or potentially attributed to SMO, occurred across multiple areas of the Site, mainly near overburden disposal areas and the ETA, but also at Muskeg Lake and potentially Reclamation Material Stockpile 8. Assessment criteria exceedances were due to an unknown source at one location in the Regulatory Groundwater Monitoring Network.

Within the ETA SIS Monitoring Network, PAW seepage and impacts from SMO were detected on the north and east sides of the ETA with most control objective (CO) exceedances reported north of WETA in ETA SIS Zones 1 and 2 and east of the East ETA (EETA) near Waterbody 3 in ETA SIS Zone 5. PAW seepage detection triggered the activation of eight new SIS pumping wells north of WETA in 2022, with a total of 12 active pumping wells by the end of 2022. Downgradient of the ETA SIS, assessment criteria exceedances attributed to SMO and/or PAW seepage were reported at ETA Compliance monitoring wells on the north Site boundary and approximately 540 m north of the Site at two Regional monitoring wells. Assessment criteria exceedances were also attributed to an unknown hydrocarbon source in two ETA zones.

As part of investigations into shallow groundwater seepage to surface where iron precipitate was present downgradient of the ETA, a groundwater sampling and monitoring program was completed in 2022. A total of 46 existing monitoring wells not routinely sampled as part of the existing groundwater monitoring programs were used to measure water levels and collect samples at select locations. Most locations sampled reported KIP concentrations within Alberta Tier 1 (ABT1) Groundwater Remediation Guidelines for natural land use and both fine- and coarse-grained sediment, aside from total ammonia (as N) which naturally exceeded the ABT1 guideline historically at multiple wells. Four locations, north of WETA or NODA, reported potentially elevated concentrations compared to historic data for at least one KIP, including inorganic parameters sulphate and/or total dissolved solids (TDS), which may suggest emerging impacts.

A total of six new ITA1 source wells were installed and baseline data were collected in 2022, prior to the deposition of tailings in the planned ITA1. The six ITA1 source monitoring wells are still in the baseline data collection phase and a complete baseline dataset will be collected prior to analyzing the groundwater quality data. The baseline data collection period is expected to be completed in the fourth quarter of 2024.

The Basal Aquifer depressurization pumping well system operation continued in 2022. Water level data were continuously analyzed by Imperial for trends in aquifer drawdown and comparison to the base of feed elevation. Basal Aquifer water chemistry was monitored throughout 2022. A total of six vibrating wire piezometers (VWP) were installed in the Basal Aquifer as part of the Basal depressurization monitoring and pumping networks. One pumping well was commissioned in October 2022.

In 2022, Imperial operated one Devonian Aquifer depressurization well. The purpose of the Devonian depressurization program for the Keg River-Prairie Evaporite Aquifer Complex (also referred to as the Devonian Aquifer) is to manage the risk of water influx to the mine pit, which could impact safety and productivity. Imperial collected groundwater quality samples from the operating Devonian depressurization well as part of the monitoring program. The results were reviewed regularly to understand potential changes in water quality that might affect the setup and operation of the Devonian Aquifer depressurization system.

Groundwater quality changes noted at Kearl and implemented mitigation measures continued to be managed through the Groundwater Response Plan (GRP; Advisian 2018a), the ETA SIS Monitoring and Response Plan (Imperial 2015), and the Lined Ponds Monitoring and Response Plan (Imperial 2020) in 2022.

1 Introduction

Desika Limited Partnership (Desika) was retained by Imperial Oil Resources Limited (Imperial) to prepare the 2022 Groundwater Summary Report for the Kearl Oil Sands Mine (the Kearl Mine; the "Site"). Work was conducted under Imperial's contract A4003976. The report was prepared as per the terms and conditions of Sections 2.1.9 and 4.5.8 of Approval No. 46586-01-00 (the "Approval") under the Alberta *Environmental Protection and Enhancement Act* (EPEA). Sections of this report addressing the conditions outlined in the Approval are identified in Table 1. Limitation of Liability, Scope of Report, and Third-Party Reliance are provided in Appendix 1.

This report (Sections 3 through 10) provides a summary of the groundwater-related activities completed at the Site in 2022. Groundwater-related activities at the Site in 2022 were generally guided by the Groundwater Monitoring Plan (GMP; Advisian 2018a).

1.1 Site Description

The Kearl Mine involves the development of an open-pit oil sands mine and the construction and operation of a plant for bitumen extraction from the oil sands. The Site is located within the Wood Buffalo region of Alberta, approximately 70 kilometres (km) north of Fort McMurray. The Site covers the project lease area of approximately 197 km^2, within which the Kearl mineral lease covers approximately 132 km^2. The Kearl Mine is located within Townships 95 to 97 and Ranges 7 to 8, west of the 4^{th} Meridian (Figure 1). The subsurface bitumen ore deposit straddles multiple leases owned by Imperial (Figure 1).

The Kearl Mine became operational with the onset of oil production in April 2013. In 2022, the Kearl Mine was in various stages of design, construction, and operation and will continue to evolve through these stages over the lifespan of the mine. Key industrial activities that occurred in 2022 are listed in Section 2 of this report. A map of Site facilities/areas with the potential to affect groundwater quality or levels/flow is provided on Figure 2.

A detailed report on the pre-development setting of the Site, including maps, figures, cross-sections, surface water drainage patterns, topography, geology, and hydrogeology, was provided as an appendix to the GMP (Advisian 2018a). Updates to cross-sections, topography, surface water drainage patterns, and Quaternary deposit thicknesses are provided in Appendix 3 and Figures 3, 4, and 5, respectively. Surface water and groundwater users within a 5 km radius of the Site are identified in Figures A2-1 and A2-2 and are summarized in Tables A2-1 and A2-2 (Appendix 2).

1.2 Background

Geological and hydrogeological field investigations have been conducted at the Site since 1996; investigations have included groundwater characterization and monitoring (including groundwater level and quality monitoring), aquifer tests, and geophysical investigations (WorleyParsons 2013).

Groundwater monitoring data up to 2006 were presented in Kearl Oil Sands Project (KOSP) – Mine Development Regulatory Application (Vol. 3, Section 3; Imperial 2005). Groundwater monitoring was completed by AMEC from 2007 to 2011 (AMEC 2008, 2009, 2010, 2011 and 2012).

WorleyParsons/Advisian/Mikisew Advisian Environmental (MAE) has conducted groundwater monitoring programs at the Site since 2012 (WorleyParsons 2013, 2014, 2015, 2016; Advisian 2017, 2018b; MAE 2019, 2020, 2021, 2022a).

Evidence of sulphide mineral oxidation (SMO) and/or gypsum dissolution in groundwater was first reported at some monitoring locations in the 2018 Groundwater Summary Report (MAE 2019). Evidence of SMO and/or gypsum dissolution in groundwater continued to be reported at the Site from 2019 through 2021 (MAE 2020, 2021, 2022a). SMO is a chemical reaction that occurs when sulphide-containing minerals are exposed to oxygen, such as when mined materials are exposed to the atmosphere, resulting in the generation of hydrogen ions and sulphate. Iron and other metals may be mobilized, depending on mineralogy and water chemistry (Price 1998). While SMO is a natural weathering process, it can be accelerated by disturbances during construction and mining. During these activities, previously buried sulphide-containing minerals are exposed to factors, including oxygen and precipitation, that promote weathering. In the absence of sufficient natural buffering capacity these reactions can lead to acidification which will frequently promote the mobilization of metals (Price 1998). Sulphide mineral (specifically pyrite) oxidation has been documented in the coarse sand tailings (CST) dykes of the ETA (MAE 2022b). SMO products within the unsaturated portion of the CST dykes are transported by infiltration, seepage of process affected water (PAW) from the tailings ponds and a rising water table resulting in a mixture of PAW, SMO products and natural groundwater (Okane 2022).

Evidence of PAW seepage, or tailings water seepage, from the External Tailings Area (ETA) was first detected in 2020 at Compliance monitoring well KH11-179, located north of the ETA centre dyke, a few metres (m) north of the lease boundary (MAE 2021). Since then, PAW arrival has been detected at numerous ETA Seepage Interception System (SIS) and Compliance monitoring wells (MAE 2022a). Imperial activated four ETA SIS pumping wells in June and July 2021 to capture and return PAW to the ETA (MAE 2022a).

In May 2022, several areas where groundwater was discharging to surface (seeps) were observed along the northern lease boundary and near Waterbody 3. The seeps were initially identified by discoloured trees visible on aerial imagery and/or orange discolouration on the ground surface, assumed to be caused by iron precipitate associated with the surface discharge. The off-lease area to the north of the Site and the area surrounding Waterbody 3 were investigated, resulting in the field verification of four areas with groundwater seeps in 2022. The seeps were generally identified on- and off-Site, in the area surrounding Waterbody 3, north of the West ETA (WETA), north of Drainage Pond 4 (DP4) and north of the North Overburden Disposal Area (NODA). Further investigation and delineation were completed in 2022, including surface water, groundwater, soil monitoring and sampling (Paragon 2023), preliminary risk assessment and geochemical assessment (Okane 2022).

2 Industrial Activities in 2022

Key mining and industrial activities at the Kearl Mine during 2022 (Imperial 2023b) included:

- overburden and interburden disposal to the following areas:
  - ex-pit disposal areas, including; NODA, Central Overburden Disposal Area (CODA) and West Overburden Disposal Area (WODA);
  - in-pit disposal areas, including; In-pit Disposal Area (IPDA) 1, IPDA 2, and IPDA 3; and
  - in-Pit Tailings Area 1 Dyke 1 Starter Dyke.
- bitumen mining and stockpiling at the Ore Stockpile (OSP);
- bitumen processing through two Ore Preparation Plants (OPP) and extraction plants;
- tailings disposal in the ETA;
- cell construction of the ETA dyke;
- water recycle to OPP1 and OPP2 from the ETA for use in bitumen processing;
- overburden and interburden in-pit water management and removal from the North Pit area;
- overburden dewatering in the North Pit and East Pit mine advance areas;
- depressurization of the Basal Aquifer in the North Pit;
- depressurization of the Devonian Keg-Prairie Evaporite Aquifer Complex in the North Pit;
- operation of the closed-circuit water drainage system and release water drainage system;
- tree clearing activities in support of the mine advance in North Pit and East Pit;
- early site works associated with In-Pit Tailings Area 1 (ITA1) construction;
- salvaging and stockpiling of soil resources (reclamation material) from cleared areas in North Pit and East Pit in reclamation material stockpiles (RMS);
- construction of infrastructure works (roads, power lines, pipelines);
- operation of supplemental crushers; and
- production operation of autonomous haul trucks.

3 Groundwater Activities in 2022

Site groundwater monitoring continued in 2022 as outlined in the Kearl GMP (Advisian 2018a) to comply with the requirements of the Approval. Various groundwater-related activities occurred at the Site in 2022 supporting mine design, construction, and operation. These activities included new well installations, groundwater sampling, groundwater level measurements, well abandonments, and dewatering/depressurization. Specifically, groundwater-related activities and monitoring programs at Kearl in 2022 included the following:

- The Athabasca Field Program (AFP) and Western Canada Wells (WCW) Field Program (Section 3.2).
- Regulatory Groundwater Monitoring Program (Section 5).
- Internal Tailings Area 1 (ITA1) Monitoring Program (Section 6).
- External Tailings Area (ETA) Seepage Interception System (SIS) Monitoring Program (Section 7).
- Iron Precipitate Investigation (Section 8).
- Basal Depressurization Program (Section 9).
- Devonian Depressurization Program (Section 10).
- Operation of the ETA SIS pumping system including activation of eight SIS pumping wells to capture process affected water (PAW) seepage and return it to the ETA (Section 7.6).
- Activation of Quaternary dewatering wells in North Pit South Advance and East Pit mining areas.
- Other on-going groundwater-related activities were conducted by on-site hydrogeologists on an as needed basis, including inspections, abandonments, and maintenance of Kearl Mine groundwater monitoring wells.

In 2022, there were no new intrusive investigations related to the Kearl Channel geological feature. Desika continued to download and analyze transducer data from existing monitoring wells in this feature. These data have been retained on file by Imperial.

The total volume of water diverted from groundwater sources in 2022 was 3,468,343 m^3, meeting the criteria for groundwater diversion outlined in the Kearl Water Diversion Licence 00222199-01-00.

3.1 Participation in Regional Monitoring Initiatives

Imperial participates in regional groundwater management through the following initiatives on an as-scheduled basis. Imperial represents industry on the groundwater technical advisory committee for the Oil Sands Monitoring (OSM) Program and Canada's Oil Sands Innovation Alliance (COSIA). The OSM program is managed by Alberta Environment and Protected Areas (AEPA) on behalf of the Government of Alberta and Environment and Climate Change Canada (ECCC) on behalf of the Government of Canada.

Regional groundwater monitoring wells within and outside of the Kearl Mineral Surface Lease (MSL) boundary are monitored and sampled as part of this program with results reported in Section 5.1.3.

3.2 Athabasca and Western Canada Wells Field Programs

Well installation/abandonment and groundwater testing and sampling occurred as part of the 2021/2022 Athabasca Field Program (AFP) and Western Canada Wells (WCW) field program. The 2021/2022 AFP/WCW programs (Imperial 2022) included the following.

Quaternary Deposits

- Drilling and installation of 10 vibrating wire piezometers (VWPs) in the mine advance overburden.
- Drilling and installation of 31 monitoring wells in the mine advance overburden, 10 monitoring wells in the Kearl Channel, and eight monitoring wells in the ETA Seepage Interception area.
- Drilling and installation of 14 pumping wells in the mine advance overburden and two pumping wells in the ETA Seepage Interception area.

Basal Aquifer

- Drilling and installation of seven VWPs in the Basal Sand deposit.

Devonian Aquifer

- Abandoning two pumping wells in the North Pit (KGD17_001 and KGD17_003).

4 Physical Hydrogeology

Groundwater elevations, well installation details, and hydraulic conductivities are presented in Table 3, and groundwater elevation hydrographs are provided in Appendix 5. Discrepancies between surveyed monitoring well stickup heights and stickup heights measured during sampling events were noted at many off-Site wells to the north of the MSL. As a result, vertical hydraulic gradients at many locations were not able to be calculated. Most groundwater elevation data were considered acceptable for the purposes of flow mapping and are discussed herein.

In 2022, pressure transducers collected water pressure data at select monitoring wells at the Site (Table 2). Additionally, electrical conductivity (EC) was continuously monitored at a subset of these locations (Table 2). The purpose of the transducers is to monitor for seasonal variations and/or long-term trends in physical and chemical indicators along anticipated groundwater flow paths between potential source areas and Site boundaries. Data loggers are downloaded during each monitoring event and the results are stored and referenced on an as-needed basis.

4.1 Quaternary Deposits

4.1.1 Groundwater Elevations and Flow

Consistent with historic reports, the Quaternary sediments were generally mapped as a single unit while excluding wells installed at the base of the Quaternary deposits and, in some cases, at the water table where groundwater elevations were not consistent with the overall flow pattern. Predevelopment, the groundwater flow direction in the Quaternary sediments was generally interpreted to follow surface topography, and was predominantly towards the west and northwest, towards the Muskeg and Firebag rivers (Imperial 2005). Following development of North Pit and the ETA, flow regimes have been altered in the northern portions of the MSL.

Radial flow away from the ETA, and in particular WETA, was interpreted in 2022 based on evidence supporting a hydraulic connection between the ETA and the Quaternary sediments, including borehole logs, groundwater chemistry changes, and increasing groundwater elevations in the area. The WETA and East ETA (EETA) tailings surface water elevations in 2022 were approximately 400 and 387 metres above sea level, respectively (Imperial 2022a). In 2022, ETA surface water elevations were approximately 50 to 60 m higher than the predevelopment Quaternary deposits groundwater elevations in the area (Imperial 2005). This change has induced higher groundwater elevation gradients at the ETA and has likely reversed the local predevelopment gradient and groundwater flow direction southeast of the ETA.

Groundwater elevations at most monitoring wells along the north of the ETA had been rising for several years following construction of the ETA and tailings deposition within the ETA. However, following the activation of multiple ETA SIS pumping wells in 2021 and 2022, groundwater elevations at many of these monitoring wells have begun to decrease. Off-site to the north of the ETA, and outside of the ETA SIS capture zone, the potentiometric surface elevation has increased in many areas, with groundwater elevations increasing at multiple monitoring wells and artesian conditions emerging at new locations. At monitoring wells north of the Site where groundwater elevations have increased from historic levels measured prior to 2015, the average increase in groundwater elevation was at least 2 m at locations where the increases were not attributed to natural variation.

Groundwater flow north of the ETA is generally towards the north and northwest towards the Firebag River, and towards a large wetland complex northwest of the Site. East of the ETA, groundwater flow is initially towards Waterbody 3 and then to the north past Waterbody 3. Southeast of the ETA is a topographic high, which is likely a north-south drainage divide and represents a potential groundwater recharge area.

To the west and south of the ETA, Quaternary deposits groundwater flow was generally towards the North Pit, where discharge into the pit entered the Industrial Wastewater System. At the northwest portion of WETA, groundwater flows towards the west, beneath NODA, and then towards the wetland complex northwest of the Site. Groundwater elevations south of the ETA were also increasing, as observed at KH12-126 and KH12-160 in the plant area since 2014 and 2015, respectively. The groundwater elevation increase at KH12-126 appears to have stabilized just below the ground surface elevation (Figure A5-2, Appendix 5). The groundwater elevation at KH12-160 has continued to rise with an increase of approximately 4 m between well installation in 2012 and 2022; however, levels may have stabilized since 2020 (Figure A5-3, Appendix 5).

South of North Pit, Quaternary deposit groundwater elevations were decreasing due to dewatering efforts in support of the south advance of North Pit. A decreasing groundwater elevation trend began in 2020 at nearby Surveillance monitoring well KH10-082. Decreasing groundwater elevations at P04099707Q1 and KH12-161, located southwest of the K2 plant, were also attributed to dewatering due to mine expansion towards these well locations.

West of the North Pit and in the southern portion of WODA, the Quaternary groundwater flow direction was generally towards the northwest and the wetland complex. At the peripheral edges of WODA that are adjacent to the Muskeg River and North Pit, Quaternary groundwater appears to flow towards the Muskeg River to the west, and to North Pit to the east. In the northern portion of WODA, the hydraulic gradient decreases as groundwater flows towards the Muskeg River floodplain.

Southeast of the plant and northeast of CODA, dewatering of the East Pit has begun, which has resulted in a localized lowering of the Quaternary groundwater elevations. Groundwater flow through the East Pit footprint and CODA was generally towards the Muskeg River in the southeast and the south mine advance dewatering area to the southwest.

In the southern portion of the Site, groundwater flow was generally from the higher topography of Muskeg Mountain in the southeast towards the lower Muskeg River Plain to the northwest, generally reflecting pre-development flow patterns.

4.1.2 Average Lateral Groundwater Flow Velocity

The same methodology as outlined in the 2016 Groundwater Summary Report (Advisian 2017) was used to estimate the average linear groundwater flow velocity in the Quaternary deposits in 2022, with an update to the effective porosity estimate.

Average linear groundwater velocity estimates within the variably textured Quaternary deposits were made by assuming the effective porosity of the most conductive material (sand unit) as 0.2 (Woessner and Poeter 2020).

The average linear groundwater flow velocity in the Quaternary deposits in 2022 varied across the Site from approximately 5 to 300 m/year (Table 4-1). While the West, Plant Site, North, and South areas present average linear velocities across the Site, areas of higher velocity have been estimated near the ETA as a result of the higher hydraulic gradients created by the tailings ponds and local areas with higher hydraulic conductivity.

An average linear groundwater flow velocity of approximately 270 m/yr was estimated in the Quaternary deposits beneath the dyke on the north side of WETA and upgradient of the seepage interception system, based on a gradient of 0.1 m/m, geometric mean hydraulic conductivity of 1.7 x 10^{-5} m/s, and effective porosity of 0.2 (Woessner and Poeter 2020). The steep gradient is maintained by the drains built into the dyke and by SIS pumping at the toe of the dyke.

An average linear flow velocity of approximately 300 m/yr was estimated along a potential preferential flow path at Centre Dyke north of WETA, based on a gradient of 0.02 m/m, geometric mean hydraulic conductivity of 9.1 x 10^{-5} m/s (geometric mean of hydraulic conductivities measured at KH11-179, KH09-055, KH09-057, and KH10-022), and effective porosity of 0.2. A velocity of about 300 m/yr was supported by estimated contaminant transport rates between KH11-179 and KH09-055 and KH09-057 (Section 5.4.3).

The more conservative assumed effective porosity has resulted in groundwater velocity estimates that are greater than historic estimates, and that better align with measured contaminant transport timelines observed near the ETA.

Additionally, the estimated average lateral velocity north of the MSL and in the plant area were greater than historic estimates, in part due to improvements in the understanding of the flow regime to the north. Improvement to the understanding of the flow regime north of the site was facilitated by a greater distribution of groundwater elevation measurements in 2022. The higher lateral groundwater velocities were also due to the increasing gradient driven by the groundwater mounding effect the ETA is causing in the underlying Quaternary deposits.

A change in the area where the horizontal hydraulic gradient used for the velocity calculation was measured in the west area also contributed to an increase in the estimated groundwater velocity. Previously, hydraulic gradients were estimated across the south advance dewatering area, immediately south of North Pit, whereas the current hydraulic gradient was estimated across the WODA area.

Hydraulic gradients in the south area were characterized by a steep gradient at the toe of Muskeg Mountain, followed by a low gradient plateau, and an increasing gradient towards the Muskeg River floodplain near the Muskeg Lake Overburden Disposal Area (MLODA). The South area estimated lateral groundwater velocity was calculated using the hydraulic gradient measured near MLODA, rather than across the plateau as in previous years.

Table 4-1 Hydraulic Conductivities, Hydraulic Gradient and Average Linear Groundwater Flow Velocity by Area

Area	Geometric Mean (m/s)	Maximum K (m/s)	Minimum K (m/s)	Hydraulic Gradient, 2022 (m/m)	Average Linear Flow Velocity (m/yr)
West	2.3×10^{-5}	8.0×10^{-4}	5.4×10^{-9}	0.008	27
Plant Site	3.2×10^{-6}	6.6×10^{-5}	4.8×10^{-9}	0.01	5
North	1.7×10^{-5}	9.0×10^{-4}	1.0×10^{-9}	0.02	62
South	1.5×10^{-5}	2.3×10^{-4}	1.8×10^{-7}	0.01	23
Beneath WETA North Dyke	1.7×10^{-5}	9.0×10^{-4}	1.0×10^{-9}	0.1	270
Potential Preferential Flow Path North of Centre Dyke	9.1×10^{-5}	9.0×10^{-4}	9.1×10^{-6}	0.02	300

4.1.3 Vertical Hydraulic Gradients and Flow Potential

Vertical hydraulic gradients within the Quaternary deposits were calculated using paired monitoring wells screened across different depth intervals of the Quaternary deposits. The results, along with the interpreted potential vertical flow direction, are presented in Table 4.

A potential for downward flow was calculated at regional monitoring wells P14049607Q/P14049607Q1 located near the base of Muskeg Mountain.

A potential for downward flow in the Kearl Channel was calculated at well pair P10239708Q/P10239708Q1 and a potential for upward flow was inferred at well pair P13369608Q/P13369608Q1 but could not be reliably calculated due to the frost heaving of the deeper monitoring well.

Flow potential at well pairs installed on the north dyke of WETA was generally downward (KHY22_623/KHY22_624/KHY22_625 and KHY22_626/KHY22_627/KHY22_628). Along the ETA north dyke toe, vertical gradients were highly variable with upward and downward flow potential in close proximity. This irregularity was potentially due to pumping related to the ETA SIS. Along the EETA East Dyke toe, potential for vertical flow was primarily upwards where topography declines north of P09149707Q towards Waterbody 3.

While vertical gradients generally could not be calculated off-Site to the north of the ETA, 22 monitoring wells to the north and northeast of the ETA were noted as exhibiting hydraulic head elevations above ground surface (artesian) in 2022. Most of the artesian conditions observed in 2022 were at monitoring wells located at or near topographic lows, and potential for upward flow was assumed for these locations.

4.2 McMurray Formation Basal Aquifer

The McMurray Formation oil sands generally act as an aquitard between the Quaternary deposits and the Basal Aquifer. The potentiometric surface for the confined Basal Aquifer typically occurs within the upper Quaternary deposits or near ground surface; thus, the need for depressurization of the Basal Aquifer during Site development and mining.

Three monitoring wells (KH12-136, 3-22-96-8 [B], and 12-1-96-9 [B]) screened in the Basal Aquifer are part of the Regional Network. Two of these Basal Aquifer monitoring wells are located near the southwest corner of the Kearl MSL boundary (3-22-96-8 [B] and 12-1-96-9 [B]), and one is located outside the northwest corner of the MSL in the Kearl Channel footprint (KH12-136; Figure 6A).

The historically decreasing trend in groundwater elevations at 12-1-96-9 (B) was primarily due to Basal Aquifer depressurization at adjacent mine sites, while the response at 3-22-96-8 (B) may be due to depressurization activities at Kearl. The groundwater elevation at 12-1-96-9 (B) decreased slightly in 2022 compared to the previous year. Groundwater elevations at 3-22-96-8 (B) and KH12-136 remained stable in 2022 (Table 3 and Appendix 5).

5 Regulatory Groundwater Monitoring Program Summary

The Regulatory Groundwater Monitoring Program is an overarching monitoring program designed to enable the early detection of potential effects to groundwater across the entire Site.

The primary purposes of the Regulatory Groundwater Monitoring Program are to:

- Focus on groundwater in Quaternary sediments, which is most susceptible to quality effects from mining activities at the Kearl Mine.
- Assess groundwater quality along flow paths from potential source areas to potential receptors.

A description of the field methods used to monitor and sample groundwater monitoring wells is provided in the GMP (Advisian 2018a). Borehole logs for the active groundwater monitoring well network, as well as other pertinent logs, were included in the 2016 Groundwater Summary Report (Advisian 2017), with additional logs for newly installed wells provided in the 2017, 2018 2019, 2020, and 2021 Groundwater Summary Reports (Advisian 2018b; MAE 2019, 2020, 2021, and 2022, respectively). Borehole logs for new wells added to the Regulatory Groundwater Monitoring Program in 2022 are provided in Appendix 4, Boreholes logs for monitoring wells drilled in 2022 were not available at the time of writing this report and will be submitted as an addendum when available. Other borehole logs are available upon request.

All groundwater samples were submitted to Bureau Veritas (BV) Laboratories in Calgary, Alberta, for analysis as listed in the GMP (Advisian 2018a). A summary of the parameters within each analytical suite can be found in the GMP (Advisian 2018a).

5.1 2022 Regulatory Monitoring Well Network Overview

In 2022, the Regulatory Groundwater Monitoring Program consisted of 75 wells divided into the Surveillance, Compliance, ETA Compliance, and Regional Networks (Table 2 and Figure 6).

5.1.1 Surveillance Network

The Surveillance Network monitoring wells are typically located on-Site, typically within operating areas, downgradient of potential source areas along predicted flow paths and screened in shallow permeable deposits (Table 2 and Figure 6). The purpose of the Surveillance Network is to provide early detection of changes to groundwater quality near potential sources. In 2022, the Surveillance Network consisted of 21 monitoring wells.

A subset of Surveillance Network monitoring wells (KH13-004, KH13-005, KER18_001, KER18_002, KER18_003, and KER18_005) are located near higher-risk lined ponds, as indicated in the Lined Ponds Monitoring and Response Plan (LPMRP; Imperial 2020). The purpose of these wells is to detect and monitor potential interactions of the pond and subdrain systems with the local groundwater (Imperial 2020).

Surveillance Network monitoring wells were generally sampled annually, except for those located near higher-risk lined ponds, which were sampled semi-annually in spring and fall 2022, with the following exceptions:

- Two monitoring wells (KHY22_618 and KHY22_619), which were installed in 2022 as part of the Iron Precipitate investigation (Section 1.2 and 8), were sampled monthly in September, October and November.
- An additional sample was collected from KER18_002 as part of the Iron Precipitate Investigation.

5.1.2 Compliance Network

The Compliance Network monitoring wells are typically located near Site boundaries along anticipated groundwater flow paths between potential source areas and Site boundaries (Table 2 and Figure 6). All Compliance Network monitoring wells are located on Site, with the exception of KH11-179 and KH10-013, which are located approximately 4 m and 200 m off Site, respectively. The purpose of the Compliance Network is to monitor and evaluate the quality of Quaternary deposits groundwater potentially leaving the Site.

Compliance monitoring wells near the ETA have been grouped into an ETA Compliance Network. Wells within the ETA Compliance Network continue to be considered Compliance locations under the Regulatory Groundwater Monitoring Program and are managed and assessed as such.

In 2022, the Compliance Network consisted of 38 monitoring locations, with 20 of these locations near the ETA.

Wells in the Compliance Network with an established baseline dataset were generally sampled semi-annually in the spring and fall, while Compliance monitoring wells without an established baseline were generally sampled quarterly (Table 2), with the following exceptions.

- KER14-004 and KER22_689 were dry and not sampled in 2022.
- KH09-076 and KH09-077 were sampled more frequently to investigate trends and/or upper control limit (UCL) exceedances.
- Data were collected at an accelerated rate at the following locations as part of response under the Groundwater Response Plan (GRP; Advisian 2018a).
  - KH11-179;
  - P13369608Q;
  - KH12-132A;
  - KER22_673;
  - KER22_674; and
  - KER22_676.
- Newly installed wells KER22_680, KER22_681, and KER22_682 were scheduled to be sampled quarterly in 2022; however, due to elevated H_2S concentrations at some of these locations, sampling frequencies were lower due to time required to manage health and safety risks.

- Only one sample was collected from KH12-117 due to the well being frozen during the spring sampling event.
- KH12-132A was sampled three times instead of four due to a scheduling issue.

5.1.3 Regional Network

The Regional Network monitoring wells are located near the periphery of the Site lease boundary, both upgradient and downgradient of the Site (Table 2 and Figure 6). The intent of the Regional Network is to collect groundwater quality and level data that are representative of off-Site conditions. In 2022, the Regional Network consisted of 17 wells, 14 of which are screened within Quaternary deposits and three of which are screened in the Basal Aquifer.

Wells in the Regional Network were sampled annually, with the following exceptions:

- KH09-057 was sampled twice as part of response under the GRP.
- P14259607Q was not sampled in 2022 as it was inaccessible due to the inability to cross a Muskeg River tributary.
- Due to elevated H_2S, a representative sample could not be collected from 3-22-96-8 (B) in 2022.

Regonal Network monitoring wells are typically located outside of the project lease, the following five of the 17 Regional Network monitoring wells were located on lease:

- 97-20 (Q);
- KH09-105;
- P14049607Q;
- P14049607Q1; and
- P14259607Q.

5.2 Changes to the Regulatory Groundwater Monitoring Program in 2022

One change to the requirements presented in the GMP (Advisian 2018a) was implemented in 2022 as follows.

- Transducer data obtained from the monitoring wells are not presented herein but will be retained on file and available upon request. Data loggers remain installed at selected groundwater monitoring locations at Site, are downloaded regularly, and used to aid interpretation, as needed (Table 2).

The following changes to monitoring networks and routine sampling frequencies were made in 2022.

Surveillance Network

- P12359607Q1 was moved from the Regional Network to the Surveillance Network. Due to the development of East Pit, the well better suits the purpose of the Surveillance Network (Figure 6).

- Two monitoring wells, KHY22_618 and KHY22_619, were installed and added to the Surveillance Network as part of the Iron Precipitate Investigation.
- Surveillance monitoring well KER18_004 no longer serves a purpose under the LPMRP (Imperial 2020) since CODA Runoff Pond 2 is no longer considered a higher risk lined pond. KER18_004 remains part of the Surveillance Network, but the sampling frequency decreased from semi-annual to annual.
- KER14-003 was abandoned and removed from the regulatory program due to CODA expansion.

Compliance Network and ETA Compliance Network

- Two monitoring locations, P10239708Q and P10239708Q1, were returned to the Compliance Network to improve monitoring coverage along the west Site boundary. P10239708Q and P10239708Q1 were monitored as part of the Compliance network from 2005 through 2015 but were removed from the program in 2016 as they were within the planned mine footprint. The wells are no longer within the planned mine footprint so they were returned to the program in 2022.
- KH11-179 was returned to the ETA Compliance Network as it better suits this purpose.
- Three monitoring wells (KER22_680, KER22_681, and KER22_682) were installed and added to the Compliance Network to improve monitoring coverage along the west Site boundary.
- Compliance monitoring location KER22_689 was added to the program to delineate the impacts reported at P13369608Q.
- Six ETA Compliance monitoring wells were added to the network (KER22_671 through KER22_676) to improve coverage along the Site boundary north of WETA and to delineate upgradient impacts.
- The sampling frequency was increased to monthly at three ETA Compliance monitoring wells (KER22_673, KER22_674, and KER22_676) as part of response under the GRP.

Regional Network

- KH09-057 was added to the Regional Network as an interim sampling location north of Site to delineate the impacts at upgradient ETA Compliance monitoring location KH11-179.
- KH09-055 was added to the Regional Network to investigate impacts reported at KH09-057.
- Regional monitoring locations 3-5-96-8 (B) and 3-5-96-8 (Q) were removed from the program as they were destroyed.

5.3 Assessment Criteria

Alberta Tier 1 Soil and Groundwater Remediation Guidelines (AEP 2022; "ABT1 guidelines") cannot be formally applied to the site due to inconsistency with Tier 1 model assumptions, including the presence of coarse-grained materials with Darcy velocities greater than 3×10^{-7} m/s and a contaminant source size greater than 10 m in length or volume of 300 m^3. Additionally, some chemical parameters occur naturally above ABT1 guidelines. While not directly applicable to the Site, ABT1 guidelines were used as a contaminant screening tool where other criteria were not available, as detailed below.

The ABT1 groundwater remediation guidelines for some parameters, including key indicator parameters (KIPs) sulphate and total ammonia (as N), refer to the respective Environmental Quality Guidelines for

Alberta Surface waters and are dependent on parameters in the receiving water body (AEP 2018). Sulphate depends on the hardness of the receiving water body, while total ammonia (as N) depends on temperature and pH of the receiving waterbody.

To compare with guidelines that are environmentally conservative, the historic maximum temperature and pH of each waterbody was used to select the associated total ammonia ABT1 guideline. Similarly, the historic minimum hardness was used to select the associated sulphate ABT1 guideline, with a similar approach for some metals parameters and nitrite (as N), which also depend on certain parameters in the receiving water body. Four water bodies were considered as potential groundwater receptors at the Site: Firebag River and its tributaries, Waterbody 3, Waterbody 4, and Muskeg River. While data were unavailable for the Firebag River tributaries, data from the Firebag River were used instead.

Data were available across all seasons for most potential receiving water bodies, with the exception of Waterbody 4, where data were limited to three data points. The guidelines presented in this report, with consideration to Waterbody 4 as a potential receptor, should be updated in 2023 when more data are available. Additionally, further investigation into groundwater/surface water interactions is needed to identify which water bodies and wetlands near the Site are potential receptors of Site groundwater.

Regulatory Groundwater Monitoring Program (Regulatory) data were primarily assessed for impacts due to Site operations based on the procedures detailed in the Groundwater Monitoring Plan (Advisian 2018a), which was developed in consideration of the Lower Athabasca Region Groundwater Management Framework (ESRD 2012). Piper plots were employed to assist in the interpretation of potential sources of impacts to groundwater. Groundwater quality was primarily evaluated relative to control limits and trend analysis for a select list of KIPs (Advisian 2018a).

The following KIPs were used as primary indicators of change in groundwater quality (Advisian 2018a).

- chloride;
- sodium;
- sulphate;
- boron;
- total ammonia (as N);
- calculated total dissolved solids (TDS);
- petroleum hydrocarbon (PHC) fraction (F)1 (C6-C10)-Benzene, Toluene, Ethylbenzene, Xylenes-Total (BTEX);
- PHC F2 (C10-C16);
- naphthenic acids; and
- pyrene.

Control limits define the range of expected natural variation in KIP concentrations. KIP concentrations above or below the control limits potentially indicate changes in groundwater quality. Control limits were developed and implemented for KIPs at Regulatory Network wells using methods outlined in the GMP (Advisian 2018a).

Trend analysis was also conducted on KIPs following the methodology in the GMP (Advisian 2018a). Increasing trends in KIP concentrations may indicate changes to groundwater quality and may trigger the GRP (Advisian 2018a). Decreasing trends in KIP concentrations, except for pH, are currently considered to be protective of the environment and are therefore not discussed herein.

While control limits are calculated and trend analysis is completed at Regional and Surveillance Network wells, exceedances of these limits or increasing trends may not trigger the GRP (Advisian 2018a).

Some Regulatory groundwater monitoring wells have insufficient baseline data or data that may be impacted by Site operations; therefore, baseline data sets cannot be established and control limits cannot be calculated. In these cases, data were compared to:

- historic data collected from the monitoring well prior to the potential for impacts from Site operations, where available; and/or
- Alberta Tier 1 Groundwater Remediation Guidelines for natural land use and fine- and coarse-grained sediment (AEP 2022); and/or
- control limits or historic data established at nearby wells installed in a similar geologic interval.

5.4 Results and Discussion

A subset of 20 monitoring wells within the Compliance Network are geographically grouped along the northern and eastern perimeter of the ETA and herein referred to as the ETA Compliance Network. While wells in the ETA Compliance Network are considered part of the Regulatory Groundwater Monitoring Program, these results are presented in Section 7 to provide a comprehensive summary of groundwater quality near the ETA.

Field-measured parameters (temperature, pH, and EC) were measured at the time of groundwater sampling and are presented on Table 5. Laboratory analytical results are presented on Tables 6A to 11A. Laboratory analytical reports and data quality checklists have been retained on file and are available on request.

Table A6A-1 (Appendix 6) summarizes the results of the statistical analyses, including basic statistical analysis, lower control limit (LCL) and UCL exceedances, and trend analysis for wells in the Regulatory Groundwater Monitoring Program. KIP hydrochemical control charts, including control limits where available, are provided in Appendix 7A. Assessment criteria exceedances at Regulatory Network monitoring wells are presented on Figure 9A.

Natural variability in groundwater quality is expected to occur due to a combination of geological, hydrological, spatial, and temporal variations in the environment. Specifically, Quaternary groundwater monitoring wells may be screened across naturally occurring, bitumen-stained sands that resulted from glacial erosion and incorporation of Cretaceous-aged deposits into the Quaternary deposits (Andriashek 2002). Evidence of bitumen-stained sands from borehole logs and notes of bitumen odours during sampling and well development signify that groundwater samples may be affected by the surrounding bituminous sediments. Groundwater samples collected from these locations may exhibit upward trends and/or UCL exceedances in organic KIPs, which are interpreted to be naturally occurring.

The trends and control limit exceedances may also be related to varying sediment content in groundwater samples as bitumen fragments may be included in the sediment.

5.4.1 Surveillance Network Groundwater Quality Summary

In 2022, all trends and CO exceedances reported at Surveillance groundwater monitoring wells were attributed to hydrogeochemical processes or natural variation as detailed below, except the following:

- An upward trend in sodium at Surveillance monitoring well KH12-161, located beside a mine road in the centre of the Site, has been present since it was installed in 2012 and has not been attributed to a specific cause. The sodium concentration increased from 7.6 mg/L in 2012 to about 60 mg/L in fall 2016 and has since decreased (Figure A7-A-14A, Appendix 7). A UCL has not been calculable for sodium at this location due to the increasing trend since installation. The sodium concentration remains within the ABT1 Groundwater Guideline (Table 6; AEP 2022). Based on the well location, immediately upgradient of the mine pit, it is expected that any potentially impacted groundwater in this area would ultimately be captured in the closed loop system.
- In 2022, UCL exceedances for sodium and sulphate were recorded at KH12-126 and KH12-160, respectively. Concentrations remained below ABT1 guidelines at KH12-126 and KH12-160. KH12-126 and KH12-160 are located immediately adjacent to the Plant Site and downgradient of WETA (Figure 6). The monitoring well locations and corresponding increases in groundwater levels suggested that the increase in sulphate and sodium may have been caused by PAW seepage from WETA; however, more data are required to confirm the exceedances and determine the source.

Natural Variation

Within the Surveillance Network, a sulphate UCL exceedance was reported at P12359607Q1, consistent with previous exceedances from 2013 through 2018. The exceedance may be attributed to natural variation given the monitoring well's location upgradient of CODA and lack of potential sources upgradient of the monitoring well. Site operations near the monitoring location, specifically the development of East Pit, did not commence until 2022, suggesting the repeated exceedance may not have been caused by East Pit development. Except for sulphate, all KIPs have remained generally stable below their UCLs since monitoring began in 2003. Additionally, sulphate concentrations remain relatively low, less than 15 mg/L. The exceedance may be attributed to natural variation given the low concentration and timing relative to development in the area; however, further monitoring is required.

One Surveillance monitoring well (KER18_002) located near EETA Drainage Pond 4 reported an upward trend in boron concentrations in 2022 that was attributed to natural variation (Table A6A-1, Appendix 6). UCLs were not able to be calculated for this parameter at this location due to the presence of the trend.

Hydrogeochemical Processes

A total of seven locations within the Surveillance Network reported upward trends, ABT1 guideline exceedances, and/or UCL exceedances (Table 5-1) that may be attributed to hydrogeochemical reactions.

Decreasing trends in sodium, sulphate, and TDS-c concentrations present at KER18_004 since late 2018 continued to be statistically significant in 2022; however, trends visually appear to have stabilized in 2021 and 2022. Due to evidence of impacts interpreted to be caused by SMO at the time of installation, UCLs could not be calculated for these parameters at this location. In 2022, all KIP concentrations were below the ABT1 guideline (Muskeg River Receptor), except for TDS-c.

A statistically significant upward sulphate trend and UCL exceedance at lined ponds surveillance monitoring well KER18_001 located near Drainage Pond 1A may be a result of hydrogeochemical processes, natural variation, or leakage from Drainage Pond 1A. Sulphate concentrations remain low (less than 10 mg/L) and further monitoring is required to determine the cause of increasing concentrations (Table 5-1; Figure A7A-3A, Appendix 7).

KIP UCL exceedances and trends were reported at two Surveillance monitoring wells (KH13-004 and KH13-005) located near NODA Runoff Pond in 2022 (Figure 9A and Table 5-1). KIP UCL exceedances and upward trends reported in groundwater in this area may be due to hydrogeochemical processes, specifically SMO, occurring in the area and/or leakage of NODA Runoff Pond. Chloride, sodium, sulphate, and TDS concentrations in NODA Runoff Pond and the associated sub-drain were similar and pond sub-drain pumped volumes have increased in recent years, suggesting the pond may be the source (Appendix 7D). However, the sub-drain could be receiving impacted groundwater, reflecting the chemistry of surface run off which is collected in NODA Runoff Pond making it difficult to determine a potential source of exceedances and trends in groundwater near NODA Runoff Pond (Appendix 7D). Further investigation under the LPMRP (Imperial 2020) and GMP (Advisian 2018a) is required to understand the source of elevated KIPs at KH13-005 and KH13-004.

Sulphate and TDS-c concentrations greater than seven and five times the referenced ABT1 guidelines (Table 5-1), respectively, were reported at shallow Surveillance monitoring location KHY22_618, located north of NODA, in 2022 (Figure 9A, Table 6A). Total ammonia (as N) and multiple dissolved metals (aluminum, iron, manganese, and nickel) also exceeded the referenced guidelines (Table 11A and 8A). The installation of KHY22_618 was for the Iron Precipitate Investigation (Section 1.2 and 8) to help identify the source of iron precipitate in surface water in the area and understand the spatial distribution and quality of any potentially impacted groundwater upgradient of the groundwater seeps.

Sulphate and TDS-c concentrations exceeding thier respective ABT1 guidelines have been reported at KER18_005, located downgradient of NODA near the Pilot Wetland, since well installation in 2018 (Table 5-1; Figures 2 and 9A). Elevated TDS-c and sulphate concentrations at this location were attributed to SMO. Delineation sampling was completed at KH09-003, located to the west of KER18_005, with sulphate and TDS-c concentrations reported within ABT1 guidelines.

Consistent with previous years, the TDS-c concentration exceeded the UCL, and sulphate continued to increase at PCL3-Q, located on the western perimeter of Muskeg Lake (Table 5-1; Figure 9A; Figures A7A-17A, Appendix 7). In 2022, all KIP concentrations were below the ABT1 guideline except for TDS-c (Tables 6A through 11A).

Table 5-1 Groundwater Quality Potentially Affected by Hydrogeochemical Reactions (Surveillance Network)

Well ID	Parameters Exceeding Assessment Criteria in 2022 and Maximum Concentration (mg/L)	Assessment Criteria (UCL or ABT1) (mg/L)	Parameters with Upward Trend	Previously Identified Trends/ Exceedance	2022 GRP Stage
KER18_001	Sulphate: 9.5 (Sep)	UCL: 5.00	Sulphate	N/A	Evaluation
KER18_004	TDS-c: 600 (Apr)	ABT1: 500	N/A	Decreasing Trends: TDS-c	Evaluation
KH13-004	TDS-c: 580 (Aug)	UCL: 465	Sulphate* (potential trend stabilization)	Upward Trends: Sulphate UCL Exceedance: TDS-c	Evaluation
KH13-005	Sodium: 12 (Aug)	UCL: 9.37	Sodium[V] Sulphate*	Upward Trends: Sulphate UCL Exceedance: Sodium	Evaluation
KHY22_618**	TDS-c: 2,700 (Oct)	ABT1: 500	N/A	N/A	Evaluation/Delineation
	Sulphate: 1,600 mg/L (Oct)	ABT1: 218			
	Total Ammonia (as N): 4.5 (Oct)	ABT1: 0.045			
PCL3-Q1	TDS-c: 810 (Sep)	UCL: 611	Sulphate*	Upward Trends: Sulphate UCL Exceedance: TDS-c	Evaluation

Well ID	Parameters Exceeding Assessment Criteria in 2022 and Maximum Concentration (mg/L)	Assessment Criteria (UCL or ABT1) (mg/L)	Parameters with Upward Trend	Previously Identified Trends/ Exceedance	2022 GRP Stage
KER18_005**	TDS-c: 1,100 (May and Sep)	ABT1: 500	Sodium	N/A	Delineation
	Sulphate: 420 (Sep)	ABT1: 218			
	Total Ammonia (as N): 0.62 (Sep)	ABT1: 0.045			

Notes:
N/A – Not applicable
[V] Visual Trend
* UCL not calculated for sulphate due to trend in baseline data set.
** Assessed using ABT1 guidelines in the absence of a baseline dataset.

5.4.2 Compliance Network Groundwater Quality Summary

This subsection provides a summary of groundwater quality at Compliance monitoring wells in 2022, excluding those located around the ETA. Groundwater quality results for the ETA Compliance network are presented in Section 7 to provide a comprehensive summary of groundwater quality near the ETA.

In 2022, all elevated KIP concentrations, trends, and UCL exceedances reported at Compliance groundwater monitoring wells were attributed to natural variation, connections to deeper aquifers in the Kearl Channel, SMO, and unknown source, or natural variation as detailed below, except the following.

- Sodium, sulphate, and TDS-c UCL exceedances were recorded in July 2022 at KH09-093, located at RMS 8 (Figure 9A; Table A6A-1; Figure A7A-27A, Appendix 7). Sodium, sulphate, and TDS-c concentrations remained within their respective ABT1 guidelines (Table 6A). The exceedances were confirmed in September 2022, however, the source contributing to the UCL exceedances at this well is not understood. Currently, two potential sources contributing to UCL exceedances are being investigated, including PAW seepage from the ETA and/or surface water infiltration from RMS 8. Given the low hydraulic gradient in area and KHY14-050 (upgradient monitoring well) recording lower KIP concentrations, groundwater impacts may not be exclusively sourced from the ETA. Because RMS 8 construction began in 2021 and UCL exceedances were reported in 2022, surface water infiltration influenced by the RMS stockpile cannot be ruled out as a potential source at KH09-093. Further investigation is required to determine the source of potentially impacted groundwater at KH09-093.
- Sodium and sulphate concentrations exceeded UCLs at P10239708Q in 2022 but remained within the ABT1 guidelines. Sodium and sulphate concentratons at this location remained low relative to the ABT1 guideline and are potentially decreasing, but additional sampling is required to confirm.

Natural Variation

An increasing trend in one KIP was attributed to natural variation at Compliance monitoring wells KH09-002 (sodium) and P10239708Q1 (naphthenic acids; Table A6B-1, Appendix 6). These locations were interpreted to exhibit natural variations in groundwater quality because:

- the upward trends were identified for a single KIP;
- the concentrations of the KIP exhibiting the trend were within the UCL, where available, and similar to baseline/historical range; and
- increasing trends were independent of spatial location.

Increasing trends and variability of PHC F2 and pyrene concentrations were observed at P13369608Q1, near WODA, beginning in 2015 (Figure 9A; Table A6A-1, Appendix 6; Figure A7A-33B,). PHC F2 and pyrene are considered naturally occurring at this location given detections in the baseline dataset and indications of rafted oil sands and oil sheen on the borehole logs. Elevated PHC F2 and pyrene concentrations were interpreted to be caused by a change in sampling method as detailed in the 2021 Groundwater Summary Report (MAE 2022a).

Potential Connections to Deeper Aquifers in the Kearl Channel

Two new Compliance monitoring wells (KER22_680 and KER22_681), installed along the western lease boundary within the Kear Channel, reported elevated KIP concentrations of sodium, chloride, sulphate and TDS-c relative to nearby monitoring wells and, in some cases, ABT1 guidelines. No statistical trends or UCLs have been calculated for these monitoring wells due to limited sampling events.

Based on review of preliminary borehole logs and water chemistry, these wells were interpreted to reflect a mixing with groundwater from deeper aquifers and may reflect natural chemistry for these monitoring locations and depths.

Changes in some KIP concentrations continued at Compliance monitoring well KH09-076 in 2022, installed in the Kearl Channel (Figure 9A), as detailed below.

- Increasing trends and/or UCL exceedances in select KIP concentrations (sulphate, dissolved boron, PHC F2, and naphthenic acids) were reported in 2022 (Table A6A-1).
- An increase in variability of chloride and sodium beginning in 2017 has been observed, resulting in fluctuations below and above their respective UCLs; however, chloride and sodium remained below their respective UCLs in 2022 (Table A6A-1 and Figure A7A-25A).
- An increase in H_2S measured in the well headspace has been reported in recent years suggesting a change in the water type and resulting in a change to a high-risk sampling procedure involving no-purge sampling beginning in fall 2021. Recent increases in sulphate and naphthenic acids in fall 2021 and 2022 may be a result of the change in sampling method or increased mixing with deeper aquifers.

Chemistry and field H_2S concentration changes at KH09-076 were interpreted to be caused by mixing with water from a deeper aquifer (i.e. Basal or Devonian Aquifer) which may be caused by a change in the groundwater regime in the area. Changes to the groundwater regime in the area may be caused by:

- overburden dewatering, including the construction of a large drainage ditch 30 m west of KH09-076;
- depressurization of the Devonian and Basal aquifers; and/or
- mine expansion towards the west and north.

Similar changes in several KIP parameters (chloride, sodium, dissolved boron, PHC F2, and pyrene) have previously been observed at nearby Compliance monitoring well KH09-077 (MAE 2022a). In 2022, KIP concentrations generally returned to concentrations within or similar to baseline range at KH09-077 (Figures A7A-26A and A7A-26B).

Sulphide Mineral Oxidation

In 2022, UCL exceedances of sodium, sulphate, and TDS-c were reported at Compliance monitoring location P13369608Q, located downgradient of WODA approximately 100 m from the Muskeg River (Table A6A-1; Figure A7A-32A; Figure 9A). Additionally, a statistically significant upward trend in sulphate concentrations and a visually identified upward trend in TDS-c concentrations were reported (Table A6A-1 and Figure A7A-32A).

Sodium concentrations at P13369608Q remained within the referenced ABT1 guideline in 2022, but sulphate and TDS-c concentrations were reported at concentrations greater than three times their respective referenced guideline. Additionally, dissolved iron, manganese, and nickel concentrations were elevated in 2022 compared to historic data and exceeded the referenced ABT1 guidelines. Upward trends, UCL and ABT1 guideline exceedances at this location may be attributed to SMO potentially associated with WODA construction/operation, however, further investigation is required. Vertical delineation of impacts has been achieved at P13369608Q1; however, lateral delineation is incomplete. Efforts to achieve lateral delineation at downgradient monitoring well KER22_689 were unsuccessful in 2022 due to dry well conditions.

While Compliance monitoring well KER14-004, located downgradient of WODA, has been dry since 2021, an upward trend in sulphate concentrations and a sodium UCL exceedance were reported in 2020.

5.4.3 Regional Monitoring Groundwater Quality Summary

The naphthenic acids concentration at KH10-022, located north of the Site, was elevated relative to the baseline in 2020, and the well was not sampled in 2021 due to access issues. In 2022, naphthenic acids concentrations were reported below the reportable detection limit (RDL) at KH10-022.

The KIP chemistry reported at Quaternary and Basal Regional monitoring wells continued to reflect baseline conditions and upward trends in KIP concentrations and/or UCL exceedances were attributed to natural variation except at KH09-057 and KH09-055, located approximately 540 m north of the Site boundary.

KH09-057 was sampled in 2022 to delineate impacts reported at KH11-179 (Section 7.5.2). As UCLs were not available for this location, groundwater KIP concentrations were screened for impacts using ABT1 guidelines (Firebag River potential receptor) and comparison to historic data at KH09-055. TDS-c and sulphate concentrations exceeded the referenced ABT1 guidelines (Table 6A). In response, KH09-055, located on the same well pad as KH09-057 but screened at an interval that does not extend as deep as KH09-057, was sampled and compared to ABT1 guidelines. Similar to the results reported at KH09-057, TDS-c and sulphate concentrations exceeded the referenced ABT1 guideline (Table 6A). Compared to historical (2009) groundwater quality data collected at KH09-055, multiple KIPs have increased in 2022. Notably, elevated chloride and sodium concentrations were measured at KH09-057 in 2022 compared to historic results, while at KH09-055 these KIP concentrations were similar to historic data.

Initial groundwater chemistry results suggested impacts at KH09-057 and KH09-055 may be predominately caused by SMO products that have migrated off Site in groundwater at KH09-055 and a mixture of SMO and PAW seepage at KH09-057, which is screened across a deeper interval. Assuming impacts from PAW seepage arrived at KH11-179 by spring 2020 and at KH09-057 by fall 2022, a contaminant transport rate of at least 270 m/year was inferred, supporting groundwater velocity estimates of 300 m/year in this area (Section 4.1.2).

5.5 Regulatory Monitoring Well Network Conclusions

In 2022, changes to groundwater quality within the Regulatory network, excluding ETA Compliance monitoring wells, were attributed to natural variations in groundwater, PAW seepage or hydrogeochemical processes.

An upward trend in sodium at Surveillance monitoring well KH12-161, located beside a mine road in the centre of the Site, has been present since it was installed in 2012 and cannot be attributed to a specific cause. Based on the location of this well, immediately upgradient of the mine pit, decreasing trends, and KIPs within ABT1 guidelines, it is expected that any potentially impacted groundwater in this area would ultimately be captured in the closed loop system and further investigation was not completed.

UCL exceedances of sodium and sulphate were recorded at two surveillance monitoring locations (KH12-126 and KH12-160) located immediately adjacent to the Plant Site and downgradient of WETA. The well locations and corresponding increases in groundwater levels suggested the increase in sulphate and sodium may have been caused by PAW seepage from WETA; however, more data are required to confirm the exceedances and determine the source.

Increasing trends and/or UCL exceedances in select KIP concentrations continued at Compliance monitoring well KH09-076, installed in the Kearl Channel, in 2022. Chemistry changes at KH09-076 were interpreted to be caused by mixing with water from a deeper aquifer (i.e. Basal and/or Devonian Aquifer) which may be caused by changes in the groundwater regime in the area related to overburden dewatering, depressurization of the Devonian and Basal aquifers and or mine expansion.

UCL exceedances of sodium, sulphate, and TDS-c recorded at KH09-093, located at RMS 8, may be a result of PAW seepage from the ETA and/or surface water infiltration from RMS 8. UCL exceedances of sodium and sulphate at P10239708Q are the result of an unknown source.

At one Compliance (P13369608Q) and seven Surveillance monitoring wells (KER18_001, KER18_004, KER18_005, KH13-004, KH13-005, KHY22_618, and PCL3-Q1) located across the Site, increasing KIP concentrations and/or UCL exceedances, or ABT1 guideline exceedances were reported that may be the result of hydrogeochemical reactions, including the following notable results:

- Sulphate and TDS-c concentrations at Compliance monitoring well P13369609Q, located downgradient of WODA approximately 100 m from the Muskeg River, were reported at concentrations greater than three times their respective referenced ABT1 guidelines. Additionally, some dissolved metals concentrations were elevated in 2022 compared to historic data and exceeded the referenced ABT1 guidelines.
- Sulphate concentrations greater than seven times and TDS-c concentrations greater than five times the referenced ABT1 guideline were reported at shallow Surveillance monitoring location KHY22_618, located north of NODA, in 2022. Total ammonia (as N) and multiple dissolved metals also exceeded the referenced ABT1 guideline.

ABT1 guideline exceedances reported at two Regional Network monitoring wells (KH09-055 and KH09-057) located approximately 540 m north of the Site boundary were interpreted to be caused by SMO and/or PAW seepage.

All other ABT1 guideline exceedances, UCL exceedances, or upward trends were interpreted to be related to natural variation.

6 Internal Tailings Area 1 (ITA1) Program Summary

The Internal Tailings Area 1 (ITA1) is a proposed tailings sequestration area that is planned for the North Pit area following reserve exhaustion. The ITA1 is intended to receive Tailings Solvent Recovery Unit (TSRU) and Coarse Sand Tailings tailings streams.

ITA1 Monitoring Network is a new network, currently consisting of six monitoring wells located along the west side of the northern portion of Kearl's North Pit (Table 2; Figure 6). The ITA1 monitoring wells were installed in winter 2021/2022 to allow for collection of baseline data prior to tailings deposition.

Current ITA1 source monitoring wells are located downgradient and in proximity to the proposed barrier/slurry wall, west of the future ITA1. The purpose of ITA1 source monitoring wells is to monitor the effectiveness of proposed ITA1 mitigation (i.e. the barrier/slurry wall), identify changes in water quality directly downgradient of the future seepage management system (SMS), and inform the management of potential future PAW seepage as detailed in the proposed ITA1 Monitoring and Response Plan (Imperial 2022c, pending approval from the Alberta Energy Regulator).

In 2022, ITA1 source monitoring wells were in the baseline data collection phase and were scheduled for quarterly sampling in 2022. However, due to elevated H_2S at some new Compliance locations installed in the same area, sampling frequency was lower at most locations due to the time required to manage the potential for health and safety risks (Table 2).

A description of the field methods used to monitor and sample groundwater monitoring wells is provided in the GMP (Advisian 2018a). Field-measured parameters (temperature, pH, and EC) were measured at the time of groundwater sampling and are presented in Table 5. Laboratory analytical results are presented in Tables 6A to 11A. Laboratory analytical reports and data quality checklists have been retained on file and are available on request.

Since all ITA1 source monitoring wells are currently in the baseline data collection phase, control limits could not be calculated and trend analysis was not completed. Control limits will be calculated and trend analysis will be completed and reported in future reports once baseline is established. The baseline data collection period is expected to be completed in the fourth quarter of 2024.

7 External Tailings Area (ETA) Groundwater Summary

Monitoring, assessment, and response associated with the ETA (EETA and WETA) SIS Monitoring and Response Program was conducted as detailed in the ETA SIS Monitoring and Response Plan (Imperial 2015) and associated amendments/additions (Advisian 2018a). The ETA SIS monitoring and response scope of work in 2022 included the following:

- Manually collecting groundwater levels and quality data for operational monitoring (Desika responsibility).
- Telemetrically recording groundwater field parameters (e.g. groundwater levels, temperature, and EC) to help detect potential PAW seepage (Imperial responsibility).
- Identifying deviations from natural variability in groundwater quality that trigger the ETA SIS Response Plan and Groundwater Response Plan as required (Desika responsibility; Imperial 2015; MAE 2018).
- Activation, maintenance, performance evaluation, and associated adjustments of existing pumping wells and drilling and installation of new pumping wells as needed (Imperial responsibility).

Monitoring wells within the ETA SIS Monitoring Network are grouped into geographical zones (ETA SIS Zones) to improve efficiency and manage large volumes of analytical data. To date, seven water quality zones have been established along the northern and eastern perimeters of the ETA, each with assigned zonal control objectives (COs) and LCLs for ETA SIS KIPs (Figure 7; Imperial 2015).

A description of the field methods used to monitor and sample groundwater monitoring wells is provided in the GMP (Advisian 2018a). Results are reported in the following sections, except for telemetrically collected data, which are stored and maintained in a database by Imperial. Borehole logs for new wells added to the ETA SIS Monitoring Program in 2022 are provided in Appendix 4. Boreholes logs for monitoring wells drilled in 2022 were not available at the time of writing this report and will be submitted as an addendum when available.

A total of eight ETA SIS pumping wells were activated in 2022. The installation and activation of these wells is discussed further in Section 7.6. A total of 12 pumping wells were active in 2022 (Figure 7).

7.1 2022 ETA SIS Monitoring Network Overview

In 2022, the ETA SIS Monitoring Network consisted of 65 monitoring wells (Figure 7 and Table 2). Monitoring and sampling frequencies were semi-annual, quarterly, and/or monthly depending on the status and purpose of the monitoring well (Table 2).

Deviations from the original sampling schedule include the following:

- One or more samples were not collected from KHO10-015, KHO10-017, KHY22_603, and KHY22_620 due to scheduling, weather, or safety considerations (Table 2).
- KHY22_616 was dry and was not sampled.
- Additional samples were collected from KHO10-007 in July and September to investigate anomalous results.

- An additional sample was collected from KHY14_047 in November to confirm a CO exceedance.

7.2 Changes to the ETA SIS Monitoring Program in 2022

In 2022, ETA zonal control objectives (COs) were updated based on ABT1 Groundwater Remediation Guidelines with consideration to the nearest potential receiving water body for each ETA SIS Zone (Appendix 8). Details on the selected guidelines are provided in Section 5.3.

Potential receiving water bodies were assigned to ETA Monitoring Zones as follows.

- ETA Monitoring Zones 1, 3, and 4: Firebag River and its tributaries.
- ETA Monitoring Zone 2: Both Waterbody 4 and Firebag River and its tributaries were considered potential receiving water bodies and the most conservative resulting guideline was used.
- ETA Monitoring Zone 5: Both Waterbody 3 and Firebag River and its tributaries were considered potential receiving water bodies and the most conservative resulting guideline was used.
- ETA Monitoring Zones 6 and 7: Waterbody 3.

The following changes to the ETA SIS Monitoring Network and sampling frequencies were made in 2022:

- ETA SIS Monitoring well KHS13-017 was changed from a monitoring location to an active SIS pumping well in October.
- 30 monitoring wells were added to the ETA program as follows:
  - 14 monitoring wells, KHY22_604 through KHY22_617, were installed and added to the ETA Monitoring Program as part of the Iron Precipitate Investigation (Section 1.2 and 8).
  - Eight monitoring wells (KHY22_620, KHY22_621, KHY22_623, KHY22_624, KHY22_625, KHY22_626, KHY22_627, and KHY22_628) were installed and added to the ETA SIS Monitoring Program for the purpose of vertically delineating PAW seepage and SMO impacts at the source.
  - KHY22_603 was installed on the northwest corner of WETA as a replacement for damaged monitoring well P14209707Q1 and the sampling frequency was increased to monthly in response to CO exceedances.
  - Seven monitoring wells (KHO10-015 KHY16_002, KHY16_003, KHY16_005, KHY16_006, KHY16_008, and KHY16_013) were added to the ETA SIS Monitoring Program to enhance the lateral coverage within the network .
- The sampling frequency was increased to monthly at four ETA Seepage monitoring wells (KH13-008, KHY14_018, KHY14_025, and P15219707Q1) as part of response under the GRP.

7.3 External Tailings Area Hydrogeological Numerical Model Update

A numerical model was completed by Golder Associates Inc. for the northern half of the ETA in 2022. The objective of the numerical model was to simulate groundwater pathways from the ETA to estimate the volume of water pumped from the ETA SIS and number of pumping wells required.

Once the numerical model was complete, a geology review was completed by Imperial for the southern half of the ETA and included a review of data from 206 boreholes (Imperial 2023a). The objective of the geology review was to confirm aquitard and aquifer facies and refine the Pfsa unit (Quaternary outwash sand) into different groups based on the percent of fine-grained material calculated using lab and field data (Imperial 2023a).

7.4 Assessment Criteria

ETA Compliance monitoring data presented in Section 7.5 were assessed as detailed in Section 5.3.

ETA SIS Monitoring Network groundwater chemistry data were assessed as detailed in the ETA SIS Monitoring and Response Plan (Imperial 2015). KIP concentrations were compared to COs developed for each ETA SIS Zone and trend analysis was completed where sufficient data were available, using the methodology presented in the ETA SIS Monitoring and Response Plan (Imperial 2015) with further details included in the Groundwater Monitoring Plan (Advisian 2018a).

The following scenarios triggered investigation under the GRP (Imperial 2015) and are presented in the following sections.

- KIP concentrations/values remained within the CO but trended upward (statistically significant result) or, in the case of pH, upward or downward (statistically significant result).
- KIP concentrations/values exceeded the CO or, in the case of pH, exceeded the CO or zonal LCL.

Decreasing trends in KIP concentrations, except for pH, are currently considered to be naturally occurring and protective of the environment and are therefore not discussed herein. One-time, single parameter exceedances may represent natural variation and may not be discussed further herein but will be confirmed during the next sampling event in accordance with the ETA SIS Monitoring Plan (Imperial 2015).

The ABT1 Groundwater Remediation Guidelines for natural area land use and coarse-grained soil (AEP 2022) were used for reference purposes and to define COs (Section 7.2; Appendix 8), as described in the ETA SIS Monitoring and Response Plan (Imperial 2015) and associated amendments/additions (Advisian 2018a).

A list of the 16 ETA SIS Monitoring KIPs, used as primary indicators of change to groundwater quality, is provided below (Imperial 2015).

- pH;
- EC;
- TDS calculated (TDS-c);
- chloride;
- sodium;
- sulphate;
- total ammonia (as N);
- dissolved boron;
- pyrene;

- benzene;
- toluene;
- ethylbenzene;
- xylenes - total;
- PHC F1 (C6-C10) - BTEX;
- PHC F2 (C11-C16); and
- naphthenic acids.

7.5 Results and Discussion

Field-measured parameters and laboratory analytical results are presented in Table 5 and Tables 6A to 11A, respectively. The statistical analyses undertaken in 2022 for the ETA Compliance Network, including UCL exceedances, values lower than LCL, and trend analyses, are summarized in Table A6A-1 (Appendix 6). The statistical analyses undertaken in 2022 for the ETA SIS Monitoring Network, including values lower than the Zonal LCL, CO exceedances, and trend analyses are summarized in Table A6B-1 (Appendix 6). KIP control charts are provided in Appendix 7.

A total of eight new monitoring wells (KHY22_620, KHY22_621 and KHY22_623 through KHY22_628) were installed upgradient of the ETA SIS pumping wells, on the north dyke of WETA, to assist with the vertical delineation of contaminants. Since these monitoring wells were located upgradient of the SIS pumping network, the GRP was not triggered for CO exceedances or upward trends at these monitoring wells and results are not discussed further in the following subsections. The highest concentrations of EC, TDS-c, and sulphate were reported at KHY22_627. The highest sodium and chloride concentrations were reported at KHY22_626, which also had elevated EC, TDS-c, and sulphate concentrations. The highest naphthenic acids concentration at these vertical delineation wells was reported at KHY22_625.

CO exceedances in ETA SIS Monitoring Network monitoring wells and UCL exceedances in ETA Compliance Network monitoring wells and/or upward trends identified within both networks were generally attributed to one or a combination of the following factors: natural variation in groundwater quality, SMO (occurring in CST deposits), or PAW seepage.

Monitoring wells with reported exceedances and/or upward trends attributed to natural variations in groundwater chemistry included ETA Compliance Network wells KHY14_022 and P16239707Q and ETA SIS Monitoring Network wells KH13-006, and KHY14_037. These locations were interpreted to exhibit natural variations in groundwater quality because upward trends were identified for a limited number of KIPs and were independent of spatial location. Additionally, the KIP concentrations with increasing trends were generally within their respective UCLs or COs and in some cases, may have been related to naturally occurring bitumen within the well screen (Section 5.4). Exceedances due to natural variations in groundwater quality did not trigger the GRP and are not included in the following subsections.

Indicators of hydrogeochemical processes, such as SMO, were generally increasing sulphate, TDS-c, and dissolved metals concentrations. The parameters that typically indicated the presence of PAW seepage were increasing naphthenic acids, chloride, sulphate, EC, TDS-c, sodium, and dissolved boron. PAW seepage and SMO often occurred in the same locations and groundwater chemistry may represent impacts from both processes. Piper plots were used as an aid in interpretation of source/potential source of groundwater impacts. Interpretations presented in the following sub-sections may present an apparent dominant source; however, it is possible that both processes are occurring simultaneously.

The following subsections summarize groundwater chemistry results and/or actions associated with monitoring locations within the ETA SIS Monitoring and ETA Compliance Monitoring Networks currently being investigated under the Groundwater Response Plan (Advisian 2018a; Imperial 2015), including follow up from triggers identified in 2021.

7.5.1 ETA SIS Network Zone 1

In 2021, an upward trend in sulphate concentrations was identified at KHY14_006; however, concentrations decreased in 2022 to concentrations representative of baseline and no trends or exceedances were identified in 2022.

Samples collected from KHO10-007 in April and June of 2022 reported CO exceedances of pH and EC The results were subsequently considered outliers due to data quality issues (Section 11). Subsequent samples collected in 2022 were within baseline concentrations. High ion balances and pH associated with high hydroxide concentrations in some samples may have been caused by cement grout entering the well through a casing failure. Further investigation into well integrity is required.

CO exceedances and upward trends at multiple ETA SIS Zone 1 Monitoring wells (Figure 9B) were interpreted to be caused, or potentially caused, by SMO and/or PAW seepage in 2022 (Table 7-1). Confirmatory sampling is required at two locations to confirm elevated KIP concentrations, so these were interpreted as potentially caused by PAW seepage and/or SMO in 2022 as follows.

- An upward trend in sulphate concentration was reported at KHS10-009 and may be attributed to SMO and/or PAW seepage, but data were limited and the elevated sulphate concentration above the baseline range reported in fall 2022 has not been confirmed (Table 7-1 and A6B-1).
- Visually increasing trends in sodium and sulphate, as well a new naphthenic acids detection at KHO10_019, may suggest the arrival of PAW seepage at this location (Figures A7B-7A and A7B-7B).

No KIP UCL exceedances or statistically significant upward trends were reported at ETA Compliance wells downgradient of the ETA SIS Monitoring Network. However, a visually increasing trend in naphthenic acids concentrations at ETA Compliance monitoring location KER22_671, located near the northern Site boundary, may indicate PAW seepage. Most KIPs remained within ABT1 guidelines at KER22_671 in 2022, except for total ammonia (as N; Table 11A; Figures A7A-52A and A7A-52B). As most KIPs were within ABT1 guidelines and the trend in naphthenic acids was visual, the GRP was not triggered at KER22_671 in 2022. Multiple visually increasing KIP trends and a ABT1 guideline exceedance of TDS-c triggered the GRP at KER22_672 in 2022, which is located on the same well pad as KER22_671 but installed at a shallower depth (Figure A7A-53A and A7A-53B).

Table 7-1 ETA SIS Zone 1 Groundwater Monitoring Locations Investigated under the GRP in 2022

Well ID	Parameters Exceeding Assessment Criteria in 2022 and Maximum Concentration	Assessment Criteria (CO or ABT1)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/ CO Exceedance	2022 GRP Stage
ETA SIS Monitoring Network							
KH13-008	TDS-c: 860 mg/L (Nov)	CO: 845 mg/L	TDS-c, sodium, sulphate, boron	EC	PAW/SMO	Upward statistical trends: EC, TDS-c, sodium, and sulphate.	Mitigation*
	Sulphate: 280 mg/L (Oct)	CO: 185 mg/L					
KHO10-017	Naphthenic acids: 8.1 mg/L (Sep)	CO: 5.00 mg/L	TDS-c, chloride, sodium, sulphate, and boron	EC	PAW	CO exceedances: naphthenic acids. Upward statistical trend: EC, TDS-c, sodium, sulphate, and boron.	Mitigation
KHS10-009	N/A	N/A	Sulphate	N/A	Potential PAW	N/A	Verification
KHY14_008	N/A	N/A	Sulphate	EC and TDS-c	Potential SMO	Upward statistical trend – sulphate.	Evaluation
P14209707Q1	EC: 1,800 µS/cm (Sep)	CO: 1352 µS/cm	EC, TDS-c, chloride, sodium, sulphate, pyrene and PHC F2	Naphthenic acids	PAW/SMO	CO Exceedances: EC, TDS-c, sulphate, pyrene, PHC F2 and naphthenic acids. Upwards statistical trends: EC, TDS-c, chloride, sodium, sulphate, and pyrene.	Delineation/Evaluation
	TDS-c: 1,400 mg/L (Sep)	CO: 845 mg/L					
	Sulphate: 760 mg/L (Sep)	CO: 185 mg/L					
KHY22_603	EC: 1,700 mg/L (Oct)	CO: 1352 µS/cm	N/A	EC, TDS-c, sulphate	SMO, Potential PAW	N/A	Delineation/Evaluation
	TDS-c: 1,300 mg/L (Nov)	CO: 845 mg/L					
	Sulphate: 670 mg/L (Nov)	CO: 185 mg/L					
	Pyrene: 0.0035 mg/L (Aug)	CO: 0.0014 mg/L					
	PHC F2: 11 mg/L (Aug)	CO: 3.78 mg/L					
	Naphthenic Acids: 7.2 mg/L (Aug)	CO: 5.00 mg/L					
KHY22_614	EC: 1,400 mg/L (Nov)	CO: 1352 µS/cm	N/A	EC, TDS-c, and sulphate	SMO	N/A	Evaluation

Well ID	Parameters Exceeding Assessment Criteria in 2022 and Maximum Concentration	Assessment Criteria (CO or ABT1)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/ CO Exceedance	2022 GRP Stage
	TDS-c: 880 mg/L (Nov)	CO: 845 mg/L					
KHY22_615 mg/L	EC: 1,900 µS/cm (Nov)	CO: 1352 µS/cm	N/A	Sodium	PAW/SMO/Unknown potential hydrocarbon source	N/A	Delineation/Evaluation
	TDS-c: 1,500 mg/L (Nov)	CO: 845 mg/L					
	Sulphate: 690 mg/L (Sep)	CO: 185 mg/L					
	Benzene: 0.16 mg/L (Aug)	CO: 0.0043 mg/L					
	Toluene: 0.092 mg/L (Aug)	CO: 0.018 mg/L					
	Ethylbenzene: 0.0056 mg/L (Aug)	CO: 0.0020 mg/L					
	Xylenes-total: 0.039 mg/L (Aug)	CO: 0.017 mg/L					
ETA Compliance							
KER22_672	TDS-c: 550 mg/L (Oct)	ABT1: 500 mg/L	N/A	Chloride, sodium, boron, TDS-c	Potential PAW	N/A	Mitigation
	Total Ammonia (as N): 0.35 mg/L	ABT1: 0.045 mg/L					

* ETA SIS mitigation is designed to capture seepage of process affected water (PAW) and the effectiveness in capturing other impacts (i.e. SMO) is not currently understood

7.5.2 ETA SIS Network Zone 2

CO exceedances and upward trends that triggered the GRP were identified in KIP concentrations/values at a total of eight ETA SIS Zone 2 Monitoring Network locations (Table 7-2; Figure 9B). The exceedances and upward trends were interpreted to be caused by PAW seepage or a combination of PAW seepage and SMO (Table 7-2).

The highest KIP concentrations within the ETA SIS Monitoring Network were measured at KHY14_025 and KHY14_026, which are near active ETA SIS pumping wells KHS13-022, KHS13-023, and KHY15_008 (Figure 7). Due to the proximity of the monitoring wells to the pumping wells, concentrations were highly variable.

UCL or ABT1 guideline exceedances and/or upward trends at five ETA Compliance wells located along the north Site boundary at ETA SIS Zone 2, suggested impacts from PAW seepage or a combination of PAW seepage and SMO (Table 7-2; Figure 9A).

Table 7-2 ETA SIS Zone 2 Groundwater Monitoring Locations Investigated under the GRP in 2022

Well ID	Parameters Exceeding Assessment Criteria in 2022 and Maximum Concentration	Assessment Criteria (CO/UCL/ABT1)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/Exceedances	GRP Follow-Up
ETA SIS Monitoring							
KH13-014	N/A	N/A	Sulphate	Sodium, Naphthenic Acids	PAW	Upward visual trends - EC, TDS (measured), chloride, sodium, and sulphate.	Evaluation
KHY14_018	EC: 1,200 µS/cm (Jul)	CO: 972 µS/cm	TDS-c, sodium, sulphate, boron	EC	PAW	CO Exceedance – EC, TDS-c and sulphate. Upward statistical trends – TDS (measured), chloride, sodium, sulphate, and naphthenic acids.	Mitigation
	TDS-c: 730 mg/L (Nov)	CO: 608 mg/L					
	Sulphate: 240 mg/L (Nov)	CO: 109 mg/L					
KHY14_023	EC: 1,400 µS/cm (Mar)	CO: 972 µS/cm	N/A	N/A	PAW/SMO	CO Exceedance – EC, TDS-c, sodium, sulphate, Naphthenic acids. Upward statistical trend – TDS-c, sodium, and sulphate.	Mitigation*
	TDS-c: 960 mg/L (Feb)	CO: 608 mg/L					
	Sulphate: 430 mg/L (Mar)	CO: 109 mg/L					
	Naphthenic acids: 8.6 mg/L (Feb)	CO: 5.38 mg/L					
KHY14_025	EC: 1,800 µS/cm (Sep)	CO: 972 µS/cm	TDS-c, sulphate and boron	EC	PAW	CO Exceedances - EC, TDS-c, sodium, sulphate, and naphthenic acids.	Mitigation
	TDS-c: 1,300 mg/L (Sep)	CO: 608 mg/L					
	Sodium: 220 mg/L (Aug)	CO: 170 mg/L					
	Sulphate: 610 mg/L (Sep)	CO: 109 mg/L					
	Boron: 1.4 mg/L (Sep)	CO: 1.28 mg/L					
	Naphthenic Acids: 12 mg/L (Dec)	CO: 5.38 mg/L					
KHY14_026	EC: 1,700 µS/cm (Dec)	CO: 972 µS/cm	EC, TDS-c, chloride, sodium, sulphate, boron and naphthenic acids	N/A	PAW/SMO	CO Exceedances - EC, TDS-c, sodium, sulphate, boron, and naphthenic acids.	Mitigation*
	TDS-c: 1,200 mg/L (Dec)	CO: 608 mg/L					
	Sodium: 210 mg/L (Dec)	CO: 170 mg/L					
	Sulphate: 610 mg/L (Dec)	CO: 109 mg/L					
	Naphthenic Acids: 11 mg/L (Dec)	CO: 5.38 mg/L					
KHS13-017**	EC: 1100 µS/cm (Sep)	CO: 972 µS/cm	EC, TDS-c, chloride, sodium, sulphate, and naphthenic acids	N/A	PAW	CO Exceedances – Naphthenic acids. Upward statistical trend: Sulphate.	Mitigation
	TDS-c: 690 mg/L (Aug)	CO: 608 mg/L					
	Sulphate: 240 mg/L (Sep)	CO: 109 mg/L					
	Naphthenic acids: 11 mg/L (Sep)	CO: 5.38 mg/L					
KHY21_631	EC: 1,200 µS/cm (Sep)	CO: 972 µS/cm	N/A	N/A	PAW/SMO	CO Exceedances - EC, TDS-c and sulphate.	Mitigation*
	TDS-c: 820 mg/L (Sep)	CO: 608 mg/L					

Well ID	Parameters Exceeding Assessment Criteria in 2022 and Maximum Concentration	Assessment Criteria (CO/UCL/ABT1)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/Exceedances	GRP Follow-Up
	Sulphate: 280 mg/L (Sep)	CO: 109 mg/L					
P15219707Q1	Naphthenic acids: 9.9 mg/L (Oct)	CO: 5.38 mg/L	N/A	N/A	PAW	N/A	Mitigation
	Sulphate: 120 mg/L (Oct)	CO: 109 mg/L	N/A	N/A	PAW	N/A	Mitigation
ETA Compliance							
KHY14_021	TDS-c: 550 mg/L (Aug and Jun)	ABT1: 500 mg/L	N/A	Chloride, sodium, sulphate, boron, TDS-c, naphthenic acids	PAW/Potential SMO	N/A	Mitigation*
KER22_673	TDS-c: 530 mg/L (Nov)	ABT1: 500 mg/L	N/A	Chloride, sodium, sulphate, boron, TDS-c	PAW	N/A	Mitigation
	Total Ammonia (as N): 0.12 mg/L (Apr)	ABT1: 0.045 mg/L					
	Naphthenic Acids: 9.6 mg/L (Oct)	CO: 5.38 mg/L					
KER22_674	TDS-c: 630 mg/L (Dec)	ABT1: 500 mg/L	N/A	N/A	PAW	N/A	Mitigation
KER22_676	Sodium: 240 mg/L (May)	ABT1: 200 mg/L	Chloride, boron, total ammonia (as N), and naphthenic acids	N/A	PAW/SMO	N/A	Mitigation*
	Sulphate: 880 mg/L (Sep)	ABT1: 128 mg/L					
	TDS-c: 1700 mg/L (Sep)	ABT1: 500 mg/L					
	Naphthenic Acids: 9.4 mg/L (Dec)	CO: 5.38 mg/L					
KH11-179	Chloride: 15 mg/L (Nov)	UCL: 5.14 mg/L	Sodium, sulphate, boron and TDS-c	Chloride	PAW/SMO	UCL – Chloride, sodium, sulphate, boron and TDS-c. Upwards statistical trend - Chloride, sodium, sulphate, boron and TDS-c.	Mitigation*
	Sodium: 140 mg/L (Nov)	UCL: 7.89 mg/L					
	Sulphate: 950 mg/L (Jan)	UCL: 29.1 mg/L					
	Boron: 0.76 mg/L (Sep)	UCL: 0.16 mg/L					
	TDS-c: 1,800 mg/L (June)	UCL: 608 mg/L					

* ETA SIS mitigation is designed to capture seepage of process affected water (PAW) and the effectiveness in capturing other impacts (i.e. SMO) is not currently understood
**Pumping began at KHS13-017 in October 2022.

7.5.3 ETA SIS Network Zone 3

CO exceedances were identified at one ETA SIS Network monitoring well in Zone 3 in 2022 (Figure 9B; Table 7-3 and Table A6B-1).

In 2022, CO exceedance for EC, TDS-c and sulphate were recorded at KHY16_002. Similar KIP concentrations were reported following well installation in 2016. The initial groundwater sample collected at KHY16_002 in 2016 may have indicated SMO influence. Similar sulphate, TDS-c, and EC values were reported at nearby KHY14_029 from 2014 to 2017 and were followed by a decrease in 2018. The source of sulphate, EC, and TDS-c concentrations above CO at KHY16_002 is unknown but may indicate impacts from SMO.

CO exceedances and trends were not identified at ETA SIS Zone 3 monitoring well KHY14_029, but there was an increase in sulphate, TDS-c, and total ammonia (as N) in the latest sample (Fall 2022).

ETA Compliance monitoring well KH12-130 is downgradient from KHY16_002 and their screened intervals overlap potentially providing lateral delineation of suspected SMO impacts at KHY16_002 The screened interval at KH12-130 is much longer than at KHY16_002 and results may be diluted when compared to KHY16_002. Statistically significant increasing trends in boron at ETA Compliance well KH12-130 and a potentially monotonic increasing trend in sodium may suggest potential PAW seepage; however, the water type did not indicate PAW influence.

Table 7-3 ETA SIS Zone 3 Groundwater Monitoring Locations Investigated under the GRP in 2022

Well ID	Parameters Exceeding Assessment Criteria in 2022 and Maximum Concentration	Assessment Criteria (CO or UCL)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/Exceedances	GRP Follow-Up
ETA SIS Monitoring Network							
KHY16_002	EC: 1,300 µS/cm (Nov)	CO: 927 µS/cm	N/A	N/A	Potential SMO	N/A	Evaluation
	TDS-c: 810 mg/L (Nov)	CO: 511 mg/L					
	Sulphate: 200 mg/L (Nov)	CO: 185 mg/L					
ETA Compliance							
KH12-130	Boron: 0.14 mg/L (Sep)	UCL: 0.10 mg/L	N/A	Sodium and boron	To be determined	UCL - Boron	Evaluation

7.5.4 ETA SIS Network Zone 4

CO exceedances were identified at a single ETA SIS Zone 4 monitoring well (KHY22_613) in 2022 (Table 7-4; Figure 9B).

Observed CO exceedances at KHY22_613 could be attributed to PAW seepage or an unknown potential hydrocarbon source. In 2022, pH was recorded below the zonal LCL and CO and exceedances of EC, TDS-c, and total ammonia (as N) were recorded. Elevated concentrations of sodium, chloride, sulphate, PHC F2, and naphthenic acids relative to the nearby Surveillance lined pond monitoring well KER18_002 and deeper ETA SIS Zone 4 monitoring well KHY22_612 were also reported. Additionally, an increasing trend in toluene concentrations and detections of ethylbenzene were reported which were not considered naturally occurring at the Site or an indication of PAW seepage, suggesting an alternate source. Vertical delineation has been achieved at KHY22_612 and potential impacts appear limited vertically to the fill in the area south of EETA Drainage Pond 4.

ETA Compliance monitoring well KH12-131, located downgradient of KHY22_613 on the north side of EETA Drainage Pond 4, reported UCL exceedances of boron and ammonia (as N) and visually increasing trends of sodium and boron. This well continues to be sampled, but uncertainty in the results exists until a new monitoring well can replace this sampling location due to the inability to purge the well completely. The source of boron and sodium exceedances and trends at KH12-131 is unknown but may be related to well condition, a potentially unknown hydrocarbon source in the area, or PAW seepage.

Table 7-4 ETA SIS Zone 4 Groundwater Monitoring Locations Investigated under the GRP in 2022

Well ID	Parameters Exceeding Assessment Criteria in 2022 and Maximum Concentration	Assessment Criteria (CO or UCL)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/Exceedances	GRP Follow-Up
ETA SIS Monitoring Network							
KHY22_613	pH: 6.87 (Sep)	Zonal LCL: 7.17	N/A	Toluene	Potential unknown hydrocarbon source/ Potential PAW	N/A	Evaluation
	EC: 1,400 (Aug, Sep, Oct) µS/cm	CO: 1133 µS/cm					
	TDS-c: 960 (Sep) mg/L	CO: 670 mg/L					
	Total Ammonia (as N): 5.2 mg/L (Aug)	CO: 1.45 mg/L					
ETA Compliance							
KH12-131	Boron: 0.72 mg/L (Sep)	UCL: 0.56 mg/L	N/A	Sodium and boron	Potential unknown hydrocarbon source/ Potential PAW	UCL - Boron	Evaluation
	Total Ammonia (as N): 1.3 mg/L (Sep)	UCL: 1.22 mg/L					

7.5.5 ETA SIS Network Zone 5

CO exceedances and/or upward trends attributed to SMO and/or PAW seepage were identified at four ETA SIS Zone 5 monitoring wells (Table 7-5) and seven drive point piezometers west of Waterbody 3 (Table 7-5; Table A6B-1). KIP CO exceedances and upward trends were only present in the shallow monitoring wells (approximately 3.5 to 7.0 mbgs) at each well cluster, with vertical delineation achieved by a deeper well paired at each location.

Elevated naphthenic acids (relative to baseline) have been investigated since 2020 at KHY14_036. In 2021, delineation samples collected at KHY14_035 and KHY14_037 indicated that naphthenic acids may be naturally occurring in the cluster of wells. While a source of PAW seepage cannot currently be eliminated for KHY14_036, KIP concentrations at this well cluster (other than naphthenic acids and sulphate) remain generally consistent with baseline, and naphthenic acids concentrations appear to be stable since 2021. However, an unconfirmed increase in sulphate concentration was reported in November 2022. Continued monitoring under the evaluation phase of the GRP will help determine if elevated naphthenic acids, and potentially sulphate concentrations, at KHY14_036 may be due to PAW seepage.

Notable increases and/or visual upward trends for one or more KIPs were recorded at KHY16_005 and KHY16_008 in 2022 compared to historic results. When compared to samples collected following installation, KHY16_005 reported elevated EC and TDS-c concentrations in 2022 and a visual upward trend for naphthenic acids (Figures A7B-46A/46B). Additionally, at KHY16_008, naphthenic acids was recorded below the reportable detection limit in 2016 and subsequently recorded potentially increasing concentrations in 2022 (Figure A7B-48B). With exception of the notable KIP increases previously mentioned, all other KIPs appear to be stable and similar to initial concentrations recorded after installation at KHY16_005 and KHY16_008.

KIP UCL exceedances and upward trends were reported at two ETA Compliance monitoring wells (KH12-132A and KH12-116; Table 7-5; Figure 8A) in 2022, as follows.

Changes in TDS-c and sulphate concentrations at KH12-116, located on the south side of Waterbody 3, are presently attributed to an unknown cause.

In 2020, notable changes in chemistry were reported at ETA Compliance monitoring well KH12-132A, located north of the East ETA. Low concentrations (relative to baseline) of total ammonia (as N), dissolved boron, PHC F2, pyrene, fluoride, dissolved iron, and dissolved manganese were reported in August 2022. Additionally, relatively high concentrations (relative to baseline) of sulphate, TDS-c, calcium, and nitrate (as N) were reported. Decreased PAW KIP concentrations suggested the source of changes was not ETA seepage, but rather hydrogeochemical processes (potentially including SMO). Fall 2021 monitoring results indicated that KIPs and other parameters mentioned above generally returned to baseline concentrations at KH12-132A, except for TDS-c. The April 2022 results were generally within baseline ranges, but the subsequent two sampling events in 2022 reported increasing concentrations for chloride, sulphate, and TDS-c and decreasing concentrations for sodium, boron, and total ammonia (as N).

Table 7-5 ETA SIS Zone 5 Groundwater Monitoring Locations Investigated under the GRP in 2022

Well ID	Parameters Exceeding CO in 2022	Assessment Criteria (CO or UCL)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/Exceedances	GRP Follow-Up
ETA SIS Monitoring Network							
KHY14_036	N/A	N/A	N/A	Naphthenic acids	To be determined	Upwards statistical trend - Boron and total ammonia (as N)	Evaluation
KHY22_604	EC: 1,200 µS/cm (Nov)	CO: 817 µS/cm	N/A	TDS-c and sulphate	PAW	N/A	Delineation/Evaluation
	TDS-c: 800 mg/L (Nov)	CO: 451 mg/L					
	Total ammonia (as N): 2.5 mg/L (Nov)	CO: 2.06 mg/L					
	Naphthenic acids: 12 mg/L (Nov)	CO: 7.80 mg/L					
KHY22_606	EC: 2,600 µS/cm (Nov)	CO: 817 µS/cm	N/A	EC, TDS-c, sulphate, total ammonia (as N) and boron	PAW/SMO	N/A	Delineation/Evaluation
	TDS-c: 2,100 mg/L (Nov)	CO: 451 mg/L					
	Sodium: 260 mg/L (Nov)	CO: 170 mg/L					
	Sulphate: 1,200 mg/L (Nov)	CO: 185 mg/L					
	Boron: 2.0 mg/L (Nov)	CO: 128 mg/L					
	Naphthenic acids: 11 mg/L (Oct)	CO: 7.80 mg/L					
KHY22_608	EC: 1,600 µS/cm (Nov)	CO: 817 µS/cm	N/A	Boron and naphthenic acids	PAW/SMO	N/A	Delineation/Evaluation
	TDS-c: 1200 mg/L (Nov)	CO: 451 mg/L					
	Sodium: 230 mg/L (Nov)	CO: 170 mg/L					
	Sulphate: 480 mg/L (Nov)	CO: 185 mg/L					

Well ID	Parameters Exceeding CO in 2022	Assessment Criteria (CO or UCL)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/Exceedances	GRP Follow-Up
	Total ammonia (as N): 3.7 mg/L (Nov)	CO: 2.06 mg/L					
	Boron: 1.3 mg/L (Nov)	CO: 128 mg/L					
	Naphthenic acids: 14 mg/L (Nov)	CO: 7.80 mg/L					
KHY22_610	EC: 1,800 µS/cm (Nov)	CO: 817 µS/cm	N/A	N/A	PAW/SMO	N/A	Delineation/Evaluation
	TDS-c: 1,300 mg/L (Nov)	CO: 451 mg/L					
	Sodium: 230 mg/L (Oct)	CO: 170 mg/L					
	Sulphate: 630 mg/L (Nov)	CO: 185 mg/L					
	Total ammonia (as N): 2.4 mg/L (Sep)	CO: 2.06 mg/L					
	Boron: 1.3 mg/L (Nov)	CO: 128 mg/L					
	Naphthenic acids: 19 mg/L (Nov)	CO: 7.80 mg/L					
WB3-GW-10	EC: 1,000 µS/cm (Sep/Oct)	CO: 817 µS/cm	N/A	N/A	PAW	N/A	Delineation/Evaluation
	TDS-c: 590 mg/L (Oct)	CO: 451 mg/L					
WB3-GW-11	EC: 1,300 µS/cm (Sep/Oct)	CO: 817 µS/cm	N/A	N/A	PAW	N/A	Delineation/Evaluation
	TDS-c: 770 mg/L (Oct)	CO: 451 mg/L					
	Naphthenic acids: 8.7 mg/L (Oct)	CO: 7.80 mg/L					
WB3-GW-12	EC: 1,500 µS/cm (Sep/Oct)	CO: 817 µS/cm	N/A	N/A	PAW	N/A	Delineation/Evaluation

Well ID	Parameters Exceeding CO in 2022	Assessment Criteria (CO or UCL)	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/Exceedances	GRP Follow-Up
	TDS-c: 960 mg/L (Oct)	CO: 451 mg/L					
	Sulphate: 250 mg/L (Sep/Oct)	CO: 185 mg/L					
	Naphthenic acids: 11 mg/L (Oct)	CO: 7.80 mg/L					
WB3-GW-16	EC: 960 µS/cm (Sept)	CO: 817 µS/cm	N/A	N/A	PAW	N/A	Delineation/Evaluation
	TDS-c: 550 mg/L (Sept)	CO: 451 mg/L					
WB3-GW-17	EC: 1,700 µS/cm (Sep/Oct)	CO: 817 µS/cm	N/A	N/A	PAW/SMO	N/A	Delineation/Evaluation
	TDS-c: 1,200 mg/L (Sep/Oct)	CO: 451 mg/L					
	Sulphate: 470 mg/L (Oct)	CO: 185 mg/L					
WB3-GW-19	EC: 960 µS/cm (Oct)	CO: 817 µS/cm	N/A	N/A	PAW	N/A	Delineation/Evaluation
	TDS-c: 560 mg/L (Oct)	CO: 451 mg/L					
	Total ammonia (as N): 3.0 mg/L (Oct)	CO: 2.06 mg/L					
WB3-GW-20	EC: 1,200 µS/cm (Oct)	CO: 817 µS/cm	N/A	N/A	PAW	N/A	Delineation/Evaluation
	TDS-c: 690 mg/L (Oct)	CO: 451 mg/L					
ETA Compliance							
KH12-116	TDS-c: 330 mg/L (Sep)	UCL: 293 mg/L	N/A	TDS-c	To be determined	N/A	Confirmation
KH12-132A	Sulphate: 120 mg/L (Aug)	UCL: 28 mg/L	Sodium and sulphate	N/A	Potential SMO/Hydrogeochemical Processes	N/A	Evaluation
	TDS-cc: 440 mg/L (Aug)	UCL: 372 mg/L					

7.5.6 ETA SIS Network Zone 6

No CO exceedances or upward trends (statistical or visual) were identified in KIP concentrations/values at ETA SIS Network Zone 6 monitoring wells in 2022 (Figure 9B; Table A6B-1). ETA Compliance well KH10-013 continued to reflect baseline conditions in 2022 (Figure 9A; TableA6A-1).

7.5.7 ETA SIS Network Zone 7

In 2022, EC and TDS-c CO exceedances were reported at KHY14_047 in addition to a statistically significant upward sulphate trend (Table 7-6, Table A6B-1; Figure A7B-68A). TDS-c and EC above COs and elevated sulphate concentrations were subsequently confirmed in a sample collected in November 2022. All other KIPs were generally consistent with baseline data. Observed CO exceedances and upward trends were interpreted to be caused by SMO but may also represent arrival of PAW. Lateral delineation of groundwater impacts is currently achieved towards the south at PET2-Q but lateral delineation to the north and downgradient to the east is incomplete.

A CO exceedance for total ammonia (as N) was recorded in October 2022 at KHY14_052. Except for total ammonia (as N), all other KIPs were within baseline range and remained stable. Total ammonia (as N) concentrations were also elevated (compared to baseline) at the shallower monitoring well KHY14_050 nearby but concentrations remained below the zonal CO. Confirmation of the elevated total ammonia (as N) concentrations reported in ETA SIS Zone 7 is required.

Table 7-6 ETA SIS Zone 7 Groundwater Monitoring Locations Investigated under the GRP in 2022

Well ID	Parameters Exceeding CO in 2022	Control Objective	Parameters with Statistically Significant Upward Trends in 2022	Parameters with Visual Upward Trends	Interpreted Source of Impact	Previously Identified Trends/Exceedances	Current GRP Follow-Up
ETA SIS Monitoring Network							
KHY14_047	EC: 820 µS/cm (Nov)	672 µS/cm	Sulphate	N/A	SMO	N/A	Confirmation
	TDS-c: 510 mg/L (Nov)	425 mg/L					
KHY14_052	Total ammonia (as N): 0.33 mg/L (Oct)	0.25 mg/L	N/A	N/A	To be determined	N/A	Confirmation

7.6 External Tailings Area Seepage Interception System Pumping Wells

As outlined in the ETA Monitoring and Response Plan (Imperial 2015), CO exceedances at ETA SIS monitoring wells trigger the installation and activation of pumping wells to capture and return PAW back to the ETA. In 2022, eight pumping wells were activated and a total of 2,350,000 m^3 of water was diverted (Imperial 2023a). Certain parameters may not have been reported as exceeding COs in 2021 but are now exceeding due to the recalculation of the zonal COs in 2022. Active ETA SIS pumping well groundwater chemistry is provided in Tables 6B through 8B, 10B and 11B. The following list summarizes the pumping wells that were activated in 2022:

- Due to PAW seepage resulting in CO exceedances at KH13-008, pumping wells KHS13-013, KHS13-014, KHS13-015, KHY14_002 and KHY14_003 were activated in July 2022 (except for KHY14_003 which was activated in August 2022).
- Pumping wells KHS13-022 and KHS13-023 were activated in July 2022 due to PAW seepage resulting in elevated concentrations of TDS-c, sodium, sulphate, boron, and naphthenic acids at KER22_676 (ETA Compliance grouping) when compared to the ETA SIS Zone 2 CO.
- Due to PAW seepage resulting in a CO exceedance for naphthenic acids and elevated concentrations of other KIPs at P15219707Q1, pumping well KHS13-017 was activated in October 2022.

7.7 External Tailings Area Groundwater Conclusions

The ETA SIS Monitoring network was expanded by 30 monitoring wells in 2022 to increase coverage of the monitoring network and investigate discoloured groundwater seepage to surface downgradient of the ETA.

Groundwater chemistry results reported for the ETA SIS Monitoring Network indicated impacts or potential impacts from Site operations at one or more monitoring wells in all ETA SIS Zones, except Zone 6, as follows.

- Changes in groundwater chemistry in ETA SIS Zones 1, 2 and 5 were attributed to PAW seepage and SMO, with an unknown hydrocarbon source in Zone 1.
- KIP CO exceedances reported in ETA SIS Zone 3 may be caused by SMO.
- KIP CO exceedances and upward trends in ETA SIS Zone 4 may be caused by PAW seepage and/or an unknown hydrocarbon source.
- KIP CO exceedances and upward trends in ETA SIS Zone 7 were attributed to SMO but PAW seepage could not be eliminated.

Groundwater chemistry collected at ETA Compliance wells continued to reflect baseline conditions, including natural variation, except for the following.

- UCL and/or ABT1 guideline exceedances reported at ETA Compliance locations were attributed to PAW seepage and/or SMO in ETA SIS Zones 1 and 2.
- KIP UCL exceedances at one Compliance well in ETA SIS Zone 4 may be a result of well condition, unknown hydrocarbon source or PAW seepage and further investigation is required.

- In ETA SIS Zone 5, UCL exceedances and trends at ETA Compliance monitoring wells were attributed to hydrogeochemical processes (potentially including SMO) at one location and were potentially related to an unknown source at another location near Waterbody 3.

As a result of CO exceedances attributed to PAW seepage, eight pumping wells were activated in 2022 to capture and return PAW back to the ETA. These pumping wells are in ETA Zone 1 or 2 and were activated in July, August and October 2022.

8 2022 Iron Precipitate Investigation Sampling

In response to the identification of orange coloured surface water in some areas surrounding Waterbody 3, north of WETA, DP4 and NODA (Section 1.2), a groundwater investigation was completed as detailed below with results presented in the following sections. The sampling and monitoring schedule for the groundwater monitoring wells and drive point piezometers included in the Iron Precipitate Investigation is provided in Table 2.

A discussion of groundwater elevations, flow patterns, vertical gradients, and estimated flow velocity, including wells monitored under the Iron Precipitate Investigation, is included in Section 4.1.

A total of 46 existing monitoring wells, not routinely sampled as part of the existing groundwater monitoring programs, were visited to measure water levels with samples collected at select locations, generally in summer 2022 (Table 2; Figure 10). The purpose of this investigation was to understand changes in groundwater levels and quality in the areas surrounding the seeps. In total, 15 monitoring wells were sampled and 31 monitoring wells were visited to measure groundwater levels only in 2022 (Table 2).

An additional 16 monitoring wells and eight drive point piezometers were installed in summer 2022 in support of the Iron Precipitate Investigation (Table 2; Figure 10). The purpose of the additional monitoring wells and drive point piezometers was to investigate the source of discoloured surface water and understand the spatial distribution and quality of any potentially impacted groundwater upgradient of the groundwater seep areas. The newly installed monitoring wells and drive point piezometers were subsequently added to an existing groundwater monitoring network (ETA SIS Monitoring or Surveillance Monitoring Networks) and are discussed within Section 5 and 7 of this report as follows.

- KHY22_614 through KHY22_617 were included in ETA SIS Zone 1 with results presented in Section 7.5.1.
- KHY22_612 and KHY22_613 were included in ETA SIS Zone 4 with results presented in Section 7.5.4.
- KHY22_604 through KHY22_611 and all drive point piezometers are included in ETA SIS Zone 5 with results presented in Section 7.5.5.
- KHY22_618 and KHY22_619 are included in the Regulatory Surveillance Network with results presented in Section 5.4.1.

Section 8.2 provides an assessment of the results collected at Iron Precipitate Investigation sampling locations that are not included in an existing groundwater monitoring network.

8.1 Assessment Criteria

The same list of KIPs used to evaluate data collected under the Regulatory Groundwater Monitoring Program was used to evaluate chemistry data collected during the Iron Precipitate Investigation (Section 5.3).

The locations included in the Iron Precipitate Investigation do not have enough data to establish a baseline dataset that could be used to calculate UCLs and perform trend analysis.

Although ABT1 guidelines cannot be formally applied to groundwater data collected at the Site (Section 5.3) and some KIPs naturally exceed ABT1 guidelines, they are still considered a useful screening tool for potential impacts relating to the Iron Precipitate Investigation. As such, the ABT1 guidelines for natural land use and both fine- and coarse-grained sediments were applied with consideration to the appropriate potential Freshwater Aquatic Life (FAL) receptor where ABT1 defaults to the Environmental Quality Guidelines for Alberta Surface Waters (AEP 2018; Section 5.3).

Groundwater quality was also compared with historic data from each monitoring well where available, or from nearby comparable monitoring wells if historic data was not available.

8.2 Results

Field-measured parameters (temperature, pH, and EC) were measured at the time of groundwater sampling and are presented in Table 5 and laboratory analytical results are presented in Tables 6C, 7C, 8C, 9B, 10C, and 11C.

Total ammonia (as N) exceeded the applied guideline at multiple locations, but may represent natural background concentrations as historic samples also reported total ammonia (as N) concentrations above the applied ABT1 guideline. Where total ammonia (as N) exceeded the applied guideline, but all other KIPs were within the ABT1 guideline and consistent with historic results, the exceedance was considered naturally occurring.

KIP concentrations that were similar to historic or ABT1 exceedances were considered naturally occurring at all locations except for those listed in Table 8-1.

Evidence of reworked oil sands, bitumen (trace or nodules), and/or bitumen odour during drilling was noted at KH09-050, KH10-009, KH10-018 and P07289707Q1, suggesting that PHC F2, naphthenic acids, and pyrene may occur naturally at these locations. Additionally, historic detections (2005 to 2010) of naphthenic acids, PHC F2, or pyrene at KH10-018, P07289707Q1 and P05-025Q suggested these parameters occur naturally at these locations.

A total of four locations (KH09-050, KH10-015, KH10-018 and KHO10-008a) reported potentially elevated concentrations for at least one KIP, including inorganic parameters, sulphate and/or TDS, which may suggest emerging impacts. KH09-053 and KH09-063 reported increased, although similar, sulphate concentrations when compared to historical samples and additional samples are required to further assess whether the increases were due to potential impacts or natural variation. The chloride concentration reported at KH09-053 in 2022 may also be elevated compared to historical results, but further data are required.

Table 8-1 Iron Precipitate Investigation: Summary of Groundwater Quality Assessment

Well ID	Well used for historic data comparison	All KIP concentrations within guideline but some elevated relative to historic data	Some KIP concentrations exceeding guidelines and elevated relative to historic data	KIPs with concentrations within guideline but potentially elevated relative to historic data	KIPs with concentrations exceeding guideline and elevated compared to historic data
KH09-050	KH10-019 and KH09-049		X	Sulphate, Naphthenic Acids	TDS-c, PHC F2, Pyrene
KH09-053	KH09-052	X		Chloride, Sulphate	
KH09-054A	KH09-054A		X	Pyrene	Total Ammonia as N
KH10-009	KH10-009		X	Naphthenic Acids	Total Ammonia as N
KH10-015	KH10-025	X		Sulphate	
KH10-018	KH10-018		X	Sulphate, Naphthenic Acids	PHC F2, Pyrene
KHO10-008a	KH09-009		X	Sulphate	TDS-c, Total Ammonia as N
P05-025Q	P05-025Q		X		PHC F2, pyrene
P07289707Q1	P07289707Q1	X		Naphthenic Acids	

9 Basal Aquifer Depressurization Summary

The Basal Aquifer depressurization system aims to lowers the hydraulic head in the mine area below the base of feed to improve trafficability and minimize water influx to the pit. Operation of the Basal Aquifer depressurization system continued in 2022 with five active Basal depressurization pumping wells (BDP-007, BDP-016, BDP-017, BDP-018, BDP-019; Figure 11).

9.1 Monitoring

In 2022, Imperial continued the Basal Aquifer monitoring and surveillance plan (Advisian 2018a), that was initiated in 2013. A network of VWPs and monitoring wells are maintained around the Site and monitored at regular intervals. The monitoring data are continuously analyzed by Imperial for trends in aquifer drawdown and for comparison to the base of feed elevation. A snapshot of groundwater surface elevations and inferred groundwater elevation contours in the Basal Aquifer depressurization and monitoring network from December 2022 is provided in Figure 11.

Basal Aquifer water chemistry was monitored throughout 2022. Groundwater samples were collected semi-annually (except at BDP-017 and BDP-018, where samples were generally collected monthly) at the pumping wells and shipped to BV Laboratories for analysis. The analytical results from the sampling programs were reviewed by Imperial through the established Basal Aquifer monitoring program in 2022 for changes in water quality that might affect operation of the Basal depressurization system.

The groundwater volume diverted from the Basal Aquifer was reported monthly in 2022 to the Alberta Energy Regulator (AER) and AEPA under the Kearl Water Diversion License 00222199-01-00 (as amended).

9.2 Development

BDP-019 was commissioned in October 2022 and six additional VWPs were installed in the Basal Aquifer during the 2021/2022 AFP as follows (Figure 11):

- KHY22_164
- KHY22_409
- KHY22_389
- KHY22_538
- KHY22_408
- KHY22_551

9.3 Planning

In 2023, Imperial plans to continue the operation of the existing Basal Aquifer depressurization system. Two horizontal Basal depressurization wells are planned for installation in 2023.

To monitor the growing depressurization footprint, additional VWPs and monitoring wells will be installed. The system performance will be monitored continuously, and this information will inform the need for system modifications.

9.3.1 Numerical Modelling of Basal Aquifer Depressurization

An updated numerical groundwater flow model was developed in 2019 by Imperial using FEFLOW software to include the Basal Aquifer and Devonian aquifer-aquitard system, since Kearl is actively depressurizing both aquifers.

The model was bounded by hydrological features (e.g. water bodies) and has been vertically discretized into 18 layers. According to Imperial, it has been calibrated and verified to field-measured hydraulic heads and drawdown data, respectively. The 2019 model was updated with the latest hydrogeological data from the Basal and Devonian aquifer systems in 2022.

9.4 Results

9.4.1 Groundwater Quantity

The cumulative volume diverted from the Basal Aquifer in 2022 was 2,053,164m^3. Figure 11 shows the inferred groundwater surface elevation contours in the Basal Aquifer based on data collected in December 2022.

9.4.2 Groundwater Quality

Laboratory analytical results are presented in Tables 6D to 8D, 9C and 11D. Table A6C-1 (Appendix 6) summarizes the results of the statistical analyses undertaken in 2022, including values lower than the LCL, UCL exceedances, and trend analyses. Shewhart control charts for Basal depressurization KIPs are provided in Appendix 7C.

2022 Trends Observed

Although control limit development and trend analyses are not required for the Basal Aquifer depressurization wells as per the GMP, they were completed for reference purposes to help identify potential changes to groundwater chemistry. Potential control limit exceedances or trends identified in the Basal depressurization wells would not initiate the GRP (Advisian 2018a).

KIP concentrations at BDP-017 have decreased since the first sample in 2021 for chloride, sulphate, calcium, magnesium, sodium, EC, and TDS-c. KIP concentrations in 2022 have stabilized and no statistically significant trends were present. No statistically significant increasing trends or UCL exceedances were observed at active Basal Aquifer depressurization wells in 2022.

10 Devonian Aquifer Depressurization Summary

The purpose of the Keg River-Prairie Evaporite Aquifer Complex (also referred to as the Devonian Aquifer) depressurization system is to manage the risk of water influx to the mine pit, which could impact safety and productivity. Pumping wells are used to drawdown the hydraulic head below the base of feed in the North Pit area, where the risk of inflow from the Devonian Aquifer is deemed high.

In 2022, Imperial operated one horizontal Devonian depressurization well (DEV-004; Figure 12).

10.1 Monitoring

In 2022, Imperial continued to monitor the Devonian Aquifer pressure data regularly via a network of multi-level VWPs installed in the North Pit area. The monitoring data were continuously analyzed by Imperial for trends in aquifer drawdown and for comparison to the current mine pit elevation. A snapshot of groundwater surface elevations and inferred groundwater elevation contours in the Devonian Aquifer depressurization and monitoring network from December 2022 is provided in Figure 12.

Imperial collected groundwater quality samples from the operating Devonian depressurization well as part of the established monitoring program. The samples were collected from the pumping well and shipped to BV Laboratories for analysis. The results were reviewed regularly by Imperial for changes in water quality that might affect the setup and operation of the Devonian Aquifer depressurization system.

The groundwater volume diverted from the Devonian Aquifer was reported monthly in 2022 to the AER and AEP under the Kearl Water Diversion License 00222199-01-00 (as amended).

10.2 Development

In 2022, Imperial installed three nested VWPs (KGD22_011, KGD22_012, and KGD22_013) to characterize the Devonian aquifer-aquitard system in Kearl's East Pit and for long term pressure monitoring.

10.3 Planning

In 2023, Imperial plans to continue operating the existing Devonian depressurization system. There are plans to drill and complete additional Devonian depressurization and monitoring wells in future mine advances. These plans are based on geologic modelling and operational experience with the current system.

A total of six nested VWPs, each with five tips, installed within the Devonian strata are planned for installation in winter 2022-2023 to continue monitoring the Devonian Aquifer pressures as the mine expands.

The system performance will be monitored continuously, and this information will inform future development of the system.

10.3.1 Devonian Aquifer Modelling

An updated numerical groundwater flow model has been developed by Imperial using FEFLOW software and includes both the Basal Aquifer and Devonian aquifer-aquitard systems (see Section 9.3.1).

10.4 Results

10.4.1 Groundwater Quantity

The cumulative volume diverted from the Devonian Aquifer in 2022 was 777,467 m^3. Figure 9B shows the inferred groundwater surface elevation contours from the Devonian Aquifer based on data collected in December 2022.

10.4.2 Groundwater Quality

Laboratory analytical results are presented in Tables 6D to 8D, 9C and 11D . Table A6C-1 (Appendix 6) summarizes the results of the statistical analyses undertaken in 2022. Shewhart control charts for Devonian depressurization KIPs are provided in Appendix 7C.

Statistically significant upward trends were reported for sulphate, calcium, magnesium at DEV-004 in 2022.

11 Quality Assurance/Quality Control

A Quality Assurance/Quality Control program was completed for all groundwater samples collected in 2022, as outlined in Appendix 9. The following notable QA/QC issue was identified:

- Groundwater samples collected from KHO10-007 in April and July were reported as outliers due to data quality issues identified by high ion balance differences and anomalous groundwater chemistry results. Subsequent samples collected in 2022 were within baseline concentrations. High ion balances and pH associated with high hydroxide concentrations in some samples may be caused by cement grout entering the well through a casing failure. Further investigation into well integrity is required.
- TDS-c and EC reported at KHY14_052 on June 23, 2022 were flagged as outliers due to suspected data quality issues. The ion balance percent difference was 50% and TDS-c and EC were elevated compared to historic and not confirmed in the subsequent sampling event.

Sample handling, preservation, storage and transportation had no material effects on overall sample quality and therefore did not affect interpretations. Full details from the 2022 QA/QC program can be found in Appendix 9A and associated statistical summary, control charts and field duplicate relative percent difference summaries are provided in Appendix 9B through 9D.

12 Recommendations

Desika makes the following recommendations for Imperial's consideration:

- Proposed 2023 monitoring schedule and locations are provided in Table 12 and Figure 10. However, the monitoring well network groupings were completed in 2022, prior to the Environmental Protection Order issued for Kearl by the AER (AER 2023), and are expected to change during the 2023 reporting period. The final network groupings will be presented in the 2023 Groundwater Summary Report.
- Implement the updated GMP pending approval from AER (MAE 2022b).
- Continue to investigate any monitoring locations currently listed under the GRP.
- Abandon regional monitoring well 3-5-96-8 (B) as a representative sample can no longer be collected due to damage and safety issues. Evaluate the need for replacement in 2023.
- Evaluate the need for a replacement of 3-5-96-8 (Q) in 2023, as the well was abandoned due to damage.
- Classify wells into vertical monitoring zones based on hydrostratigraphic units, to enable improved groundwater flow mapping and plume mapping.
- Remove KH09-002 from the Compliance Program as it is installed in oil sands and not fit for purpose as a compliance monitoring well.
- Replace monitoring wells with long screened intervals with a cluster of monitoring wells with discrete screened intervals, as needed.
- Replace inaccessible Regional monitoring well P14259607Q.
- Evaluate the Regulatory monitoring network in relation to mine planning to ensure new wells are installed and baseline data sets are collected in advance of development.
- Continue to monitor and investigate sulphide mineral oxidation that may be affecting the hydrochemistry at some monitoring locations across the Site.
- Continue to mitigate PAW seepage as detailed under the ETA SIS Monitoring and Response Plan (Imperial 2015) and updates.
- Investigate changes to groundwater quality at lined ponds WETA Drainage Pond 1A and NODA Runoff Pond as per the Lined Ponds Monitoring and Response Plan (Imperial 2020) and GMP (Advisian 2018a).
- Abandon KER14-004 and KER22_689 from the program as there is not enough water in the wells to collect a representative sample, and replace with shallow monitoring wells within the Kearl Channel footprint near P13369608Q.
- Conduct well maintenance as needed including the following.
  - Cut down the PVC casing and resurvey frost heaved monitoring wells and plan to replace with new monitoring wells, as needed.
  - Install protective casings on all existing and new monitoring wells as required.
  - Redevelop monitoring wells that may have filled with sediment.

  - Resurvey monitoring wells without recent surveys (i.e. greater than five years old) or monitoring wells with suspected changes in ground elevation and/or top of casing.
- Confirm total depth measurement at P13369608Q1 in 2023 and address potential well maintenance issue if required.
- Conduct hydraulic conductivity testing strategically to increase the data set and better understand groundwater flow velocity at the Site.
- Install compliance monitoring wells along the lease boundary to the east of the ETA, downgradient of EETA.
- Decommission and replace damaged well KH09-093 with a well cluster and install additional wells for vertical and lateral delineation and to improve understanding of groundwater flow in this area.
- Continue to establish new ITA1 monitoring wells to establish a baseline dataset downgradient of the future proposed ITA1.
- Install compliance monitoring wells east of East Pit prior to mining to collect baseline data.
- Update the Kearl Channel outline, particularly to the west of WODA.
- Continue to develop the CSM for the site and conduct a site-specific risk assessment to understand the risks associated with sulphide mineral oxidation and PAW seepage observed at the Site.
- Adjust the sampling methodologies used at P13369608Q1 and P16239707Q to a method with low agitation to align with those used during baseline data collection and return to routine monitoring.
- Install monitoring wells west of WODA, drive point piezometers strategically located in the Muskeg River floodplain, and sample existing MRMW-4 to delineate impacts from potential SMO at P13369608Q.
- Sample the Muskeg River at strategic locations to identify potential changes to water quality due to groundwater discharge near P13369608Q.
- Conduct sampling and monitoring at Surveillance monitoring locations KH12-126 and KH12-160 , south of the ETA, in spring to verify KIP exceedances.
- Evaluate the current regulatory network to ensure adequate coverage laterally and vertically on and off-Site.
- Investigate the integrity of KHO10-007 using a downhole camera and replace if the well is damaged.
- All wells with potential impacts from Site operations should be sampled at an accelerated rate (i.e., quarterly or monthly) to ensure timely response.
- Remove damaged P14209707Q1 from the ETA SIS Monitoring Program.
- Evaluate the current ETA SIS monitoring and pumping well network to ensure adequate coverage laterally and vertically around the perimeter of the ETA.
- Follow up on monitoring wells sampled under the Iron Precipitate Investigation with KIPs elevated above background (KH09-050, KH10-015, KH10-018 and KHO10-008a).
- Implement the updated ETA SIS Monitoring and Response Plan, pending AER approval (Imperial 2022b).
- Investigate groundwater/surface water interactions downgradient of the Site at Waterbody 3 and 4 to understand which wetlands and surface water bodies may be receiving groundwater from the Site.

- Evaluate the Alberta Tier 1 Groundwater Remediation Guidelines selected with consideration to Waterbody 4 as a potential receptor, once more data are available for the water body in 2023.

13 Closure

We trust that this report satisfies your current requirements and provides suitable documentation for your records. If you have any questions or require further details, please contact the undersigned at any time.

Report Prepared by

[redacted]

[redacted]

[redacted]

PERMIT TO PRACTICE
Desika Limited Partnership
RM Signature________________

RM APEGA ID# ______53315______
PERMIT NUMBER: P14787
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

[redacted]

[redacted]

Desika Limited Partnership

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