12.0 Groundwater

Alcan Gove operations have the potential to affect groundwater at the refinery and the residue disposal area (RDA).

This section reviews current groundwater conditions at the refinery and RDA, assesses the potential impacts from the operations on groundwater conditions, and outlines actions that will be taken to mitigate any impacts of the proposed expansion.

Drinking water for the operations as well as for Nhulunbuy, Yirrkala and the surrounding communities is obtained from a groundwater source near Gove Airport. This groundwater source is separate from those at the refinery and the RDA. Details of the water supply groundwater source and related infrastructure are given in Section 5.1.

12.1 Refinery

12.1.1 Background

The peninsula on which the refinery is located is comprised of marine sediments that contain an unconfined aquifer which is recharged by rainfall infiltration. A mound of fresh to brackish groundwater is located under the peninsula, and radial groundwater flow occurs towards the coast. Groundwater discharge occurs at the saltwater interface with the ocean. At the beach to the north of the refinery this discharge is dark in colour due to the naturally occurring iron rich organic materials beneath the ground. The tide and variations in rainfall-recharge also influence the water table.

12.1.2 Monitoring Program

Alcan Gove undertakes regular groundwater monitoring at the refinery. The monitoring program includes measurement of groundwater depth, analysis of samples taken directly from bores, and interpretation of trends in groundwater quality (URS (2003c). The objectives of the monitoring program are to:

- Determine the characteristics and trends of contaminated groundwater migrating offsite;
- Identify whether any known plumes are varying in concentration or extent; and
- Identify whether any new contaminant plumes may be forming.

There are 128 monitoring bores at the refinery. Sampling is undertaken at a range of intervals for various parameters at each bore, depending on the location of the bore and the contamination risk associated with its location. Details of the groundwater monitoring program are given in Appendix H1. A summary of the results of the monitoring program is given in Section 12.1.4. The locations of the main monitoring bores are shown on Figure 12.1.1.

12.1.3 Standards

The Australian and New Zealand Environment and Conservation Council fresh and marine water quality guidelines (ANZECC, 2000) are part of the Australian National Water Quality Management Strategy to help assess and manage ambient water quality in natural and semi-natural water resources. They provide a framework for water quality management that is based on policies and principles that apply nationally. The ANZECC guidelines offer “default trigger values” for “toxicants and physical stressors” that signal the need to carry out detailed investigations on the effect (if any) of the toxicants and physical stressors. These trigger values are derived from previous scientific investigation, predictive modelling, and professional judgement. There are no relevant default trigger values for groundwater around the refinery and RDA because the groundwater is not currently used and not likely in the future to be connected with any human use. Since any potential environmental effects of groundwater contamination in these areas would be limited to the impacts on the marine environment, the trigger values for marine waters might be used as a reference point from which site-specific trigger values for groundwater might be developed. However, the low contaminant levels and low flows of groundwater to the marine environment significantly limit the potential for marine environment impacts. The ANZECC guidelines have a preference for the development of site-specific trigger levels and, despite the low potential for marine impacts in current circumstances and the lack of default trigger values, Alcan Gove will develop, by December 2004, groundwater quality trigger values taking account of:

- Seasonal and tidal variations in groundwater flow;
- Groundwater discharge quality;
- Neutralisation capacity and dilution rates in the receiving environment;
- Default trigger values for the marine environment; and
- Site-specific trigger values for the marine environment to be developed by Alcan Gove.

12.1.4 Existing Environment

12.1.4.1 Geology and Hydrogeology

The refinery is located on a peninsula comprised of marine sediments, predominantly quartz and calcareous sands, deposited between small outcrops of granitic/gneissic bedrock. On top of the bedrock is a weathered zone, comprising a clayey oxide regolith of variable thickness. Overlying the regolith is generally a layer of sandy marine sediments. In areas towards the north of the refinery the bedrock outcrops on the surface and the marine sands are absent. A cross section of the geology underlying the eastern side of the refinery is shown on Figure 12.1.2.

The marine sands comprise an unconfined aquifer, which is recharged by rainfall infiltration. A mound of fresh to brackish groundwater has formed under the peninsula, and radial groundwater flow occurs towards the coast. Groundwater levels at the refinery are generally between 1 m and 7 m below ground surface, with deeper groundwater under areas of elevated topography. Groundwater discharge occurs at the saltwater interface with the ocean. The water table is also influenced by the tide and variations in rainfall recharge.

12.1.4.2 Contaminant Sources

The main types of groundwater contamination at the refinery are contamination by alkaline process liquor and remnants of hydrocarbon contamination after recovery from a diesel pipe leak in 1994.

In the main operational areas, alkaline process liquors and mud can be spilt onto the ground. The primary sources of these discharge points have historically been the deep washer areas (Figure 12.1.1). Contaminants can migrate through the sub-surface and seep into the groundwater to form plumes of alkaline groundwater beneath the refinery. The plumes comprise saline groundwater which in some places is alkaline and contains trace elements including aluminium, arsenic, vanadium and molybdenum above local background concentrations. A number of mitigation measures are currently in place and will continue to be improved upon to minimise groundwater contamination from these areas (Section 11.3.1.2).

In the fuel storage areas, potential for hydrocarbon contamination of the groundwater from fuels leaks or spills is mitigated by regular tank inspection and testing programs and containment systems which are backed up by a groundwater monitoring program. The fuels are stored at the harbour tank farm (heavy fuel oil), the light fuel tank farm (petrol, diesel, aviation fuel, jet fuel lubes and greases), the drum yard (waste oils and greases), and the oily water containment pond (waste oils and a small amount of fuel). In some isolated areas of the refinery where groundwater has been affected by small spills or leaks, hydrocarbon concentrations in the groundwater are above background levels. Concentrations are not at a level that requires active remediation and will degrade naturally.

12.1.4.3 Groundwater Quality

Caustic

The chemical indicators for caustic contamination of the groundwater include pH, aluminium, arsenic, vanadium and molybdenum concentrations above local background concentrations. Caustic contamination of groundwater has been detected at the following locations:

- Northern Beach and Stockpile Creek;
- Southern Containment Pond;
- Deep Washers/Drum Yard; and
- Light Fuel Tank Farm.

Data collected over the period 1999-2003 indicate that in the deeper groundwater in clay regolith, the aerial extent of the alkaline groundwater, and the concentrations of the key indicators within these areas have remained reasonably constant.

In the more shallow groundwater in marine sands, the aerial extent of the alkaline groundwater has also remained reasonably constant for the same period. However, there has been a general decline in the concentrations of key indicators in some bores at the Light Fuel Tank Farm, Southern Containment Pond, Stockpile Creek, and Northern Beach.

The distributions of the concentrations of pH, alkalinity, aluminium, arsenic, vanadium and molybdenum in both the marine sands and the clay regolith are shown in Appendix H1.

As discussed in Section 12.1.1, groundwater discharges naturally along the Northern Beach. This discharge, which is naturally dark-coloured from the organic materials in the ground, has also been shown by the monitoring program to contain water with pH above background levels. Studies have been undertaken to investigate the likely environmental impact of this discharge. These investigations indicated that there was no measurable environmental impact occurring at Northern Beach as a result of the groundwater discharge (URS, 2001c).

Hydrocarbons

Hydrocarbons were detected floating (“free-phase”) on groundwater at the Light Fuel Tank Farm in 1996. Remediation was undertaken and a groundwater recovery system continues to remove the residual hydrocarbon (Section 12.1.4.4).

While no free phase hydrocarbon has been detected down-gradient of the Light Fuel Tank Farm, some bores have recorded hydrocarbon dissolved in the groundwater (“dissolved phase”) at concentrations slightly above the analytical detection limit. The bore located closest to the coast indicated concentrations below the analytical detection limit indicating that hydrocarbon contamination has not extended to the beach or marine areas.

Nutrients

Groundwater nutrient analysis undertaken in 2000 for selected monitoring bores indicated total phosphorous and/or total nitrogen concentrations above background levels.

Investigations undertaken where the groundwater discharges at Northern Beach did not identify nutrient impact (URS, 2001c).

12.1.4.4 Groundwater Recovery Program

In response to the presence of the contamination that has been identified in the groundwater under the refinery, Alcan Gove has implemented a number of mitigation strategies including a groundwater recovery program to intercept the contaminated groundwater before it flows off site. This program has been operating since 1994.

The current groundwater recovery system comprises recovery bores located in the areas to the north, east and south of the refinery as shown on Figure 12.1.1. The quantity of groundwater abstracted from each recovery bore is monitored by recording the number of pump cycles completed over time. The water levels in each recovery bore and the chemistry of the abstracted groundwater is also monitored. Extracted groundwater is neutralised with the refinery seawater and discharged.

The results of groundwater pumping measurements indicate that the estimated average groundwater through-flow to the northern and southern beaches is being intercepted by the recovery system. Combined with improved management practices in eliminating the placement of caustic contaminated materials on the ground (Section 11.3.1.2), the groundwater recovery program is expected to result in ongoing improvement in groundwater quality.

12.1.5 Expanded Refinery Groundwater Impacts

A number of improvements associated with the proposed expansion, combined with initiatives of the existing refinery, are expected to result in ongoing improvements to the groundwater quality.

12.1.5.1 Caustic

One of the main sources of caustic contamination of groundwater is the caustic scale and sludge from the cleaning of the thickeners being placed on the ground. Alcan Gove has committed to eliminate all significant sources of “caustic to ground” and to progressively implement site-wide bunding and containment (Sections 11.7.3 and 11.7.4). Previous operational practices of temporarily placing caustic contaminated materials on the ground during thickener descaling has been significantly reduced. Operational improvements, to be implemented as part of the strategic initiative to eliminate all significant sources of caustic to ground, include:

- Use of low loaders to directly transfer scale from tanks to trucks; and
- Ongoing improvements to a mechanical device which will return mud and scale from the descaling operation back to the process.

Because of the improved thickener design to be used as part of the proposed expansion, thickener descaling will still be required but only infrequently. When it does occur, it will be only within concrete bunded areas rather than on bare ground. The potential sources of caustic in groundwater under the refinery will be significantly reduced. Both the shallow and deeper aquifers will exhibit an improvement in water quality as a result of this improvement.

Complete elimination of all other existing operational sources of minor caustic impact on groundwater (eg. Stockpile Creek, Drum Yard and general minor spillages) may not be possible in the short term. Nevertheless, there will be a significant improvement in groundwater quality as a result of the implementation of the strategic initiative to eliminate all existing significant sources of caustic to ground, and as a result of the Third Stage expansion which will eliminate one of the main sources of current caustic contamination (thickener descaling).

As discussed in Section 24.4.3, Alcan Gove has an emergency response procedure in the event of a major chemical spill (emergency response for caustic and hydrocarbons) to back up all the control measures discussed above.

12.1.5.2 Hydrocarbons

Regardless of the fuel to be used in the expanded refinery, the current risk of hydrocarbon contamination to groundwater will not change as the existing tank facilities will continue to be used.

Sources of hydrocarbons at the Light Fuel Tank Farm and associated pipelines and smaller feed tanks will remain relatively unchanged as a result of the expansion. Other sources (eg. Drum Yard and Oily Water Containment Pond) will be improved or relocated prior to commissioning of the proposed expansion.

12.1.6 Refinery Groundwater Management

Alcan Gove has extensive management practices and plans in place to minimise groundwater contamination. These include:

- The remediation and improvement activities described above and including the continuation of the current groundwater recovery program;
- Monitoring and investigation programs to ensure the effectiveness of the improvement activities and identify potential new sources of contamination; and
- Review and update groundwater management programs.

The environmental management plan for groundwater at the refinery is summarised in Section 25.

12.2 Residue Disposal Area

12.2.1 Background

The RDA operations commenced in 1972 with initial disposal of a seawater-neutralised residue into Northern and Taylor's Ponds (see Figure 12.2.1). Disposal comprised the perimeter discharge of low-density material, a technique referred to as wet disposal[1]. Since 1992, the residue disposal system has been based on "dry stacking" methods to increase the density of the bauxite residue and maximise the storage efficiency of the disposal area. Further details of the RDA operations are provided in Section 3.6.

The pond embankments have been constructed from a low permeability clay regolith excavated from within each pond area. During the construction of embankments, the near-surface gravels and laterite were partially removed in some areas of the pond floors in order to source clayey borrow materials. When granular strata were located beneath proposed embankments, a key (trench) was excavated and backfilled with clayey material. This trench was designed to reduce the potential for lateral seepage from the pond.

[1] Wet disposal refers to the discharge of residue at a density of about 28% solids weight by weight. Dry disposal occurs at higher density (45% solids weight by weight) and deposition is typically subareas. Wet and dry disposal residue consolidates to densities of 55 and 60% solids, respectively.

The residue stored in the ponds primarily comprises chemically inert components of the bauxite (haematite, silica) that have passed through the alumina extraction process unaltered. However, it is alkaline because of the remnant caustic content from the refinery process. The RDA also contains the waste water leached from the residue after deposition, alkaline wastewater from the refinery, and rainfall runoff.

12.2.2 Monitoring Program

Alcan Gove carries out regular groundwater monitoring at the RDA. The program includes groundwater depth and groundwater quality measurement. The objectives of the groundwater monitoring program are to:

- Determine the characteristics and trends of contaminated groundwater flowing offsite;
- Identify whether any known plumes are varying in concentration or extent; and
- Identify whether any new contaminant plumes may be forming.

There are 128 monitoring bores at the RDA. The locations of the main monitoring bores are shown on Figure 12.2.1.

Sampling is conducted on a frequency depending on the predicted risk of contamination and the history of each site. Figure 12.2.2 indicates groundwater quality. A summary of the results of the monitoring program is given in Section 12.2.4. Further details of the groundwater monitoring program are given in Appendix H2.

12.2.3 Standards

The standards to be developed for the refinery groundwater (Section 12.1.3) will also apply groundwater at the RDA.

12.2.4 Existing Environment

12.2.4.1 Geology

The RDA is generally underlain by low permeability, fresh to weathered granitic bedrock. No major geological structures or faults in the bedrock are believed to be present.

The general geology comprises fresh to slightly weathered Archaean Bradshaw Granite bedrock - a gneissic rock comprising quartz, feldspar, garnet and biotite. The bedrock:

- Is generally within 10 m to 17 m of the natural surface;
- Outcrops at Dimbuka Rocks and Pond 6;
- Is at shallow depth to the east of the RDA; and
- Is at least 23 m deep to the west of Pond 5.

The bedrock is overlain by moderately to completely weathered Bradshaw Granite, comprising a clayey oxide regolith of sands, silts and clays that generally occur at 2 m to 3 m below ground surface and is about 10 m to 17 m thick. The weathered granite is overlain by:

- Surficial gravels and laterite up to 1 m thick; and/or
- Localised alluvial deposits in stream channels and estuaries, sometimes comprising organic material.

12.2.4.2 Groundwater

Original groundwater flow was generally southwards towards Melville Bay (Drimmie Arm) or northwards towards Northern Beach. Groundwater flow has been modified by the presence of the ponds and is currently radially away from the pond areas.

Hydraulic gradients are very steep through, under and at the toe of the embankments. This is due to:

- The low permeability of both the embankment walls and underlying sediments; and
- The large head differences between the stored residue/water and the groundwater level.

The rate of groundwater seepage through and under RDA embankments is low due to the generally low permeability of the embankments and underlying sediments.

The main chemical indicators of caustic groundwater contamination at the RDA include pH, total alkalinity and selected trace elements (aluminium, arsenic, and vanadium).

Monitoring data indicate that the clayey strata underlying the ponds naturally attenuate salts and trace elements that would originate from the caustic liquor stored in the RDA. It is likely that the clay minerals act to buffer high pH and adsorb (via cation exchange) many of the trace elements in any seepage from the ponds. In this situation, groundwater composition is affected by a major shift in ion distribution and total alkalinity, with no similar shift in trace element concentrations or pH. However, it is thought that as the buffering and cation exchange capacity of the clay minerals becomes fully utilised with ongoing waste water seepage, the pH and concentrations of trace elements in these areas may increase as contaminated groundwater moves out of the pond areas.

Plumes of contaminated groundwater may therefore have two chemical zones summarised below:

- Zone 1 is the least impacted contamination zone characterised by increased total alkalinity and only minor increases in pH or trace elements. It is likely that in this zone the natural attenuation and buffering capacity of the clay strata is being utilised to immobilise the migration of the trace elements. If the total leakage or groundwater movement is small, the groundwater impact is effectively immobilised.

  Areas of Zone 1 impact occur at Northern Pond, Taylor’s Pond and north-west, south and east of Pond 5.

- Zone 2 is the most highly contaminated zone characterised by increases in pH, total alkalinity and trace elements. It is likely that in this zone the natural ion exchange and the buffering capacity of the clay is fully utilised as a consequence of continuing/larger amounts of leakage or more permeable geology.

  Areas of Zone 2 contamination occur at parts of Northern Pond and Taylor’s Pond and historically at one bore north-west of Pond 5.

The areas where above-background alkalinity and pH have been measured are shown on Figure 12.2.2.

Compared to a review of groundwater data for the period 1995 to 1999, data from the groundwater review 1999-2002 indicate that most areas of contaminated groundwater have remained relatively constant. However, since the previous review, there has been a preliminary groundwater study of Northern Pond and Taylor’s Pond (URS, 2001a) which has shown that caustic contaminated groundwater occurs under this area and also extends to the north of the ponds towards the north coast.

Hydraulic loading (from the weight of the residue and stored water in the ponds) has resulted in rising water tables outside some RDA embankments. This rise has resulted in local areas of vegetation stress through water logging around the RDA embankments. This has resulted in some local changes to the vegetation communities near Dimbuka Rocks and Macassar Creek. A study conducted in 2000 on the mangrove communities adjacent to the RDA (LDM, 2000b) indicated the following:

- There was no evidence of widespread seepage of waste water into mangrove communities adjacent to the RDA;
- Impacts to mangroves are essentially historical with little or no evidence of current stress, ongoing defoliation of trees or expansion of mortality areas;
- A persistent elevated water table is the most likely and observable impact that has occurred to the mangroves since the impoundment of the northern arm of Macassar Creek; and
- Salinity increases or seawater encroachment were not immediately obvious from groundwater sampling in mangrove areas.

12.2.5 RDA Groundwater Impacts from Expansion

As a consequence of the waste water inventory reduction project (Section 4.5) and liquor purification project (Section 4.6), the operations at the RDA will result in:

- A reduction in the volume of waste water stored and hence a reduction in the risk of groundwater seepage due to lower hydraulic pressure (from the waste water inventory reduction project);
- A reduction of caustic concentration in residue and waste water (from the liquor purification project); and
- A gradual increase in the disposal of saline solid residue and waste water (from the waste water inventory reduction project).

Discharging of saline residue to the RDA will result in the new saline residue overlying the existing alkaline residue on some of the disposal areas. This will not result in any significant change to groundwater quality.

There are a number of groundwater impacts from the existing storage of residue at the RDA which are summarised below. These impacts will continue irrespective of the refinery expansion and the waste water reduction project. They are caused by the height (and hence weight) of the residue. The final height of the residue has been established in the long range residue disposal plan (RL 51 m) and this height will not increase as a result of the refinery expansion.

The potential impacts associated with the RDA facilities regardless of the expansion, are summarised below:

- Waterlogging – hydraulic loading associated with residue stacking that has caused some vegetation stress and change in vegetation structure.
- Caustic seepage - hydraulic head due to residue stacking will continue to create potential for seepage of waste water from the existing ponds.
- Increased hydraulic gradients - hydraulic loading associated with residue stacking will result in a local increase in hydraulic gradients. The RDA is upgradient of identified areas of caustic contaminated groundwater under Northern Pond and Taylor’s Pond. The increase in local hydraulic gradients could result in increased groundwater flow and faster flow of the caustic contaminated groundwater towards the northern coastline.

12.2.6 RDA Groundwater Management

12.2.6.1 Monitoring

The existing network of groundwater monitoring bores at the RDA and the current monitoring program is considered adequate for the expansion.

12.2.6.2 Northern and Taylor's Pond

The groundwater around Northern Pond and Taylor's Pond will be investigated to better characterise the extent and level of current contamination, the potential for increased migration as a result of increased hydraulic loading from the current operations, and possible methods for mitigating down-gradient impacts.

12.2.6.3 Remedial Actions

As the height of the residue in the RDA increases, groundwater levels and seepage under the embankments could also increase. If this occurs, remedial measures such as depressurisation bores and drains will be employed.

12.2.6.4 Environmental Management Plan

The environmental management plan for groundwater at the RDA is summarised in Section 25.

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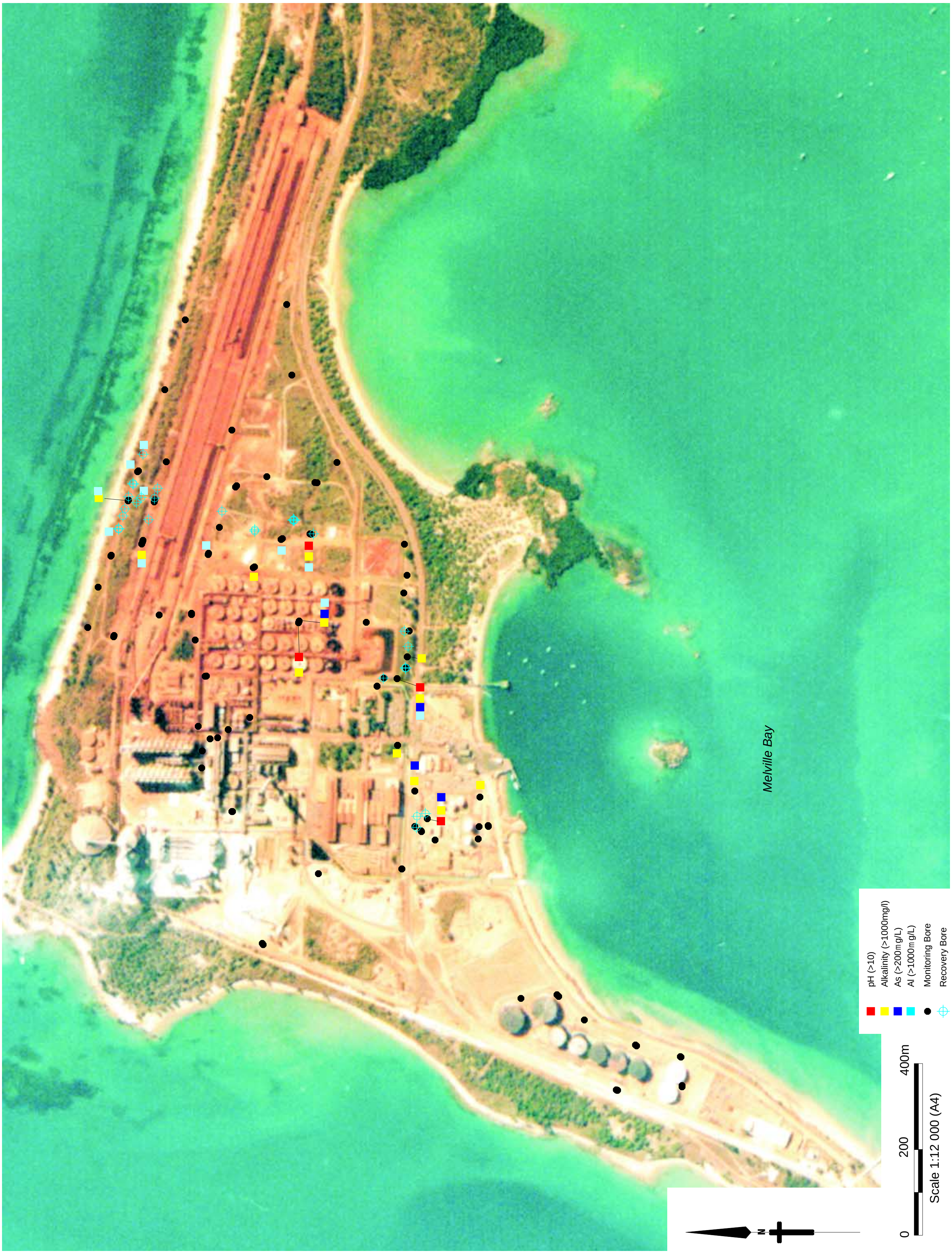
ALCAN GOVE REFINERY EXPANSION
ENVIRONMENTAL IMPACT STUDY

GROUNDWATER BORE NETWORK
REFINERY

Project No.	12373-021-559	Date : 13-01-04		Figure: **12.1.1**
MapInfo File No.	12373-021-g-052b.wor	Revision: B	A4	



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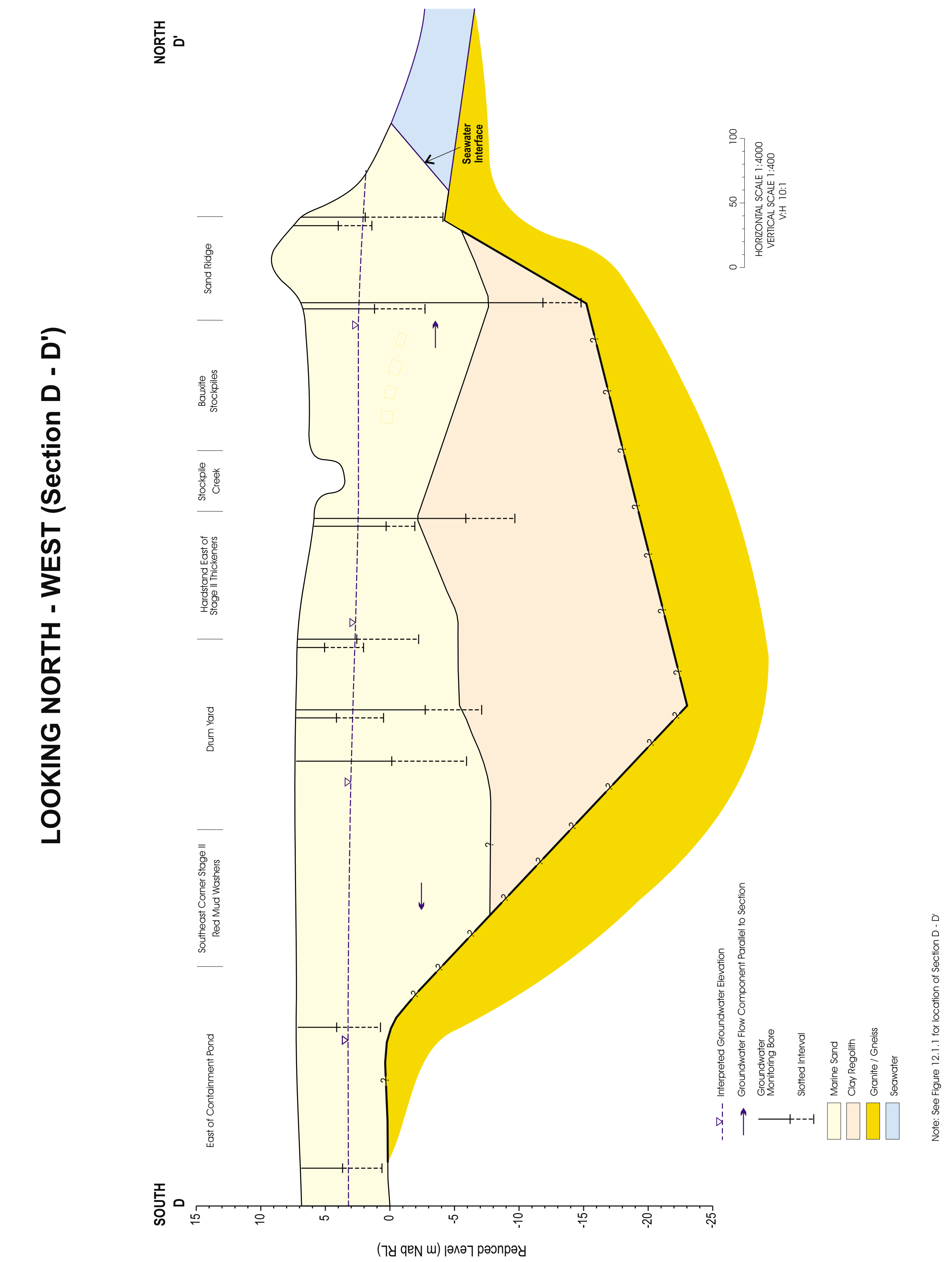
ALCAN GOVE REFINERY EXPANSION
ENVIRONMENTAL IMPACT STUDY

Project No.	12373-021-559	Date : 20-01-04	
MapInfo File No.	12373-021-g-072.wor	Revision: A	A4

DISTRIBUTION OF CONTAMINATED GROUNDWATER REFINERY

Figure: **12.1.2**



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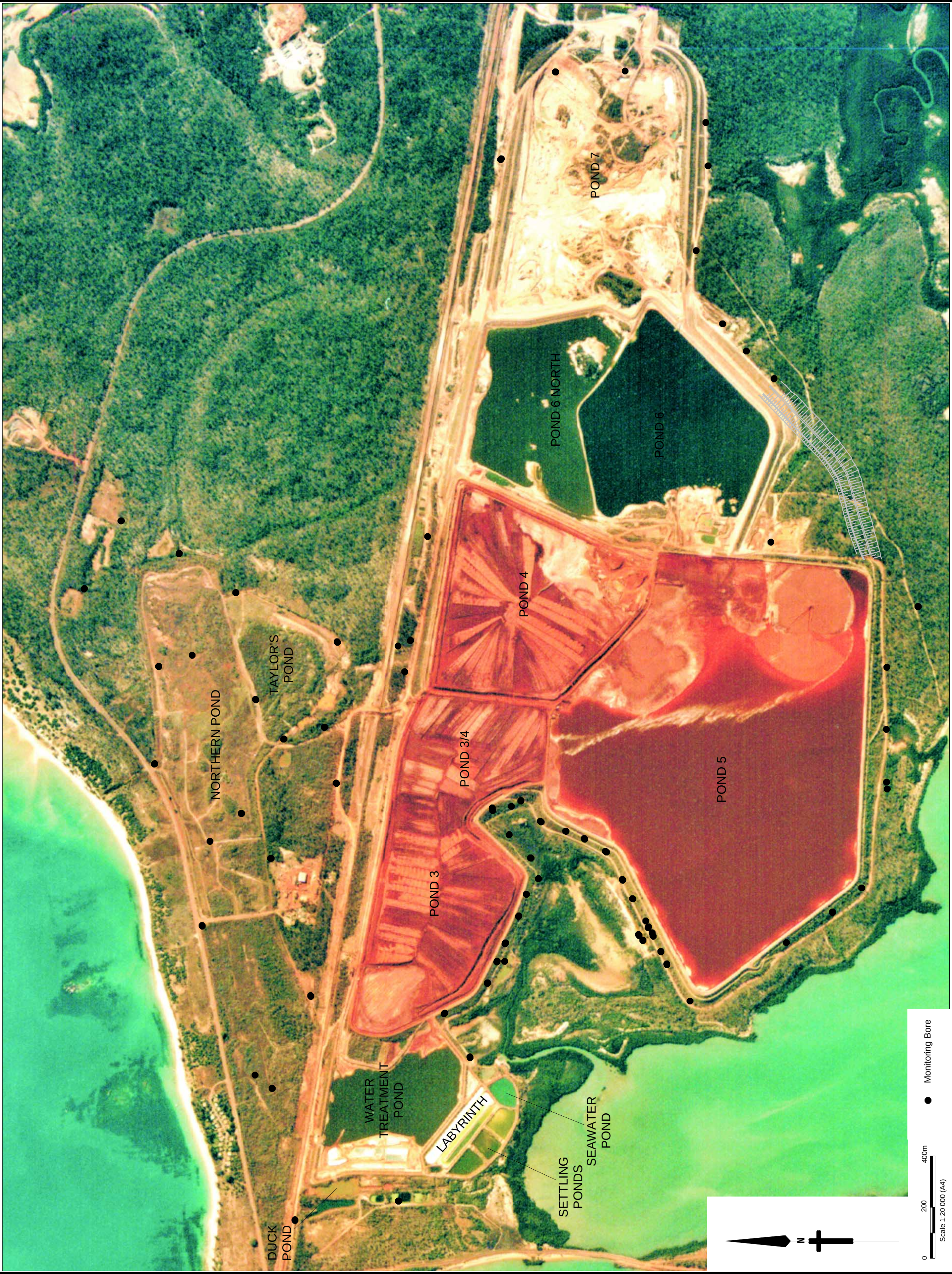
ALCAN GOVE REFINERY EXPANSION ENVIRONMENTAL IMPACT STUDY

REFINERY GEOLOGY

Project No. **12373-021-559**	Date 20-09-2003		Figure **12.1.3**
CAD File No. -g-053.cdr	Rev. A	A4	



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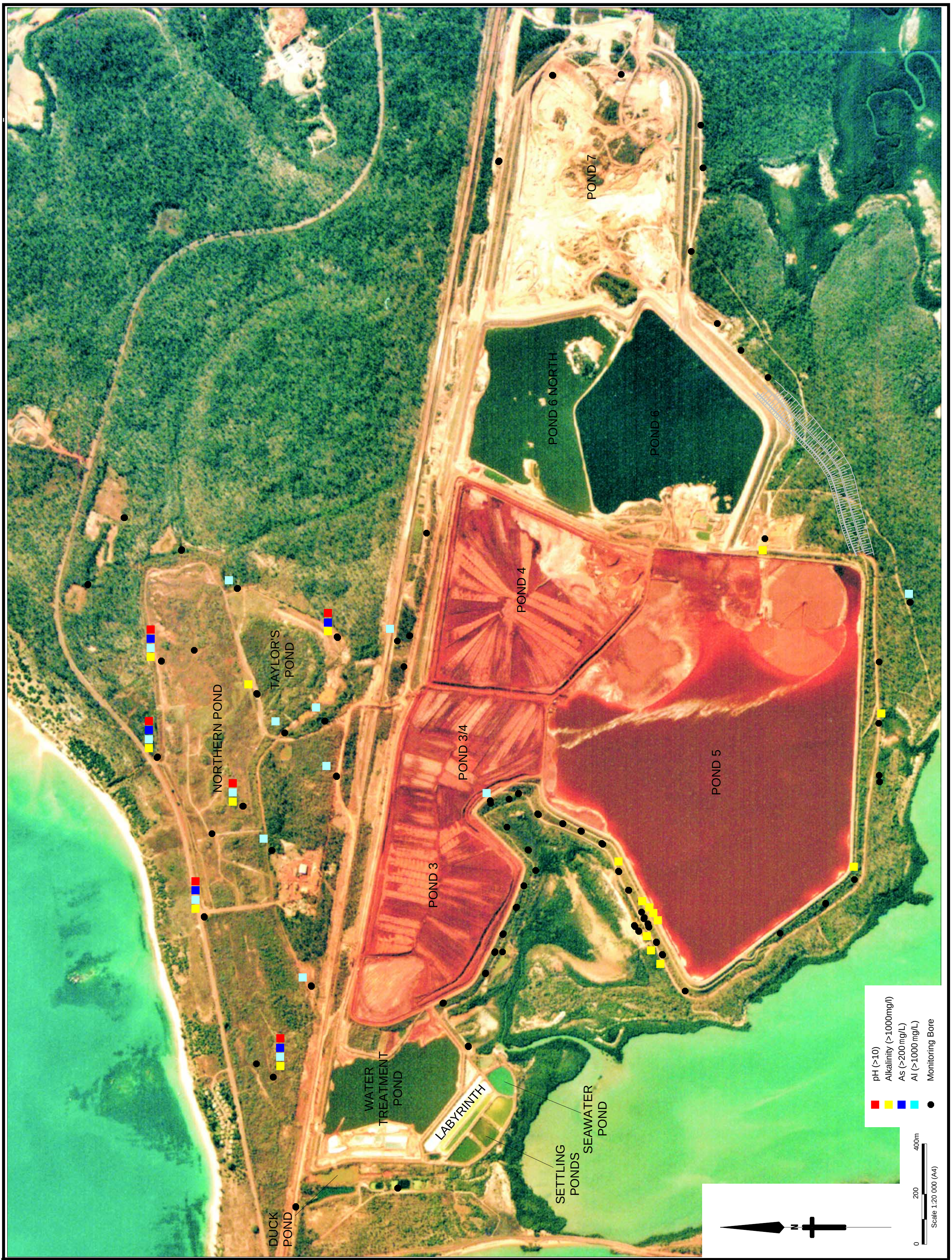
ALCAN GOVE REFINERY EXPANSION
ENVIRONMENTAL IMPACT STUDY

GROUNDWATER BORE NETWORK
RDA

Project No.	12373-021-559	Date :	19-11-03	
MapInfo File No.	12373-021-g-052b.wor	Revision:	B	A4

Figure: **12.2.1**



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ALCAN GOVE REFINERY EXPANSION ENVIRONMENTAL IMPACT STUDY			DISTRIBUTION OF CONTAMINATED GROUNDWATER RDA
Project No. 12373-021-559	Date : 20-01-04		Figure: 12.2.2
MapInfo File No. 12373-021-g-055c.wor	Revision: C	A4	