Government of **Western Australia**
Department of **Water**

# Murray hydrological studies: Surface water, groundwater and environmental water

Acid sulfate soil risk assessment and hydrochemistry
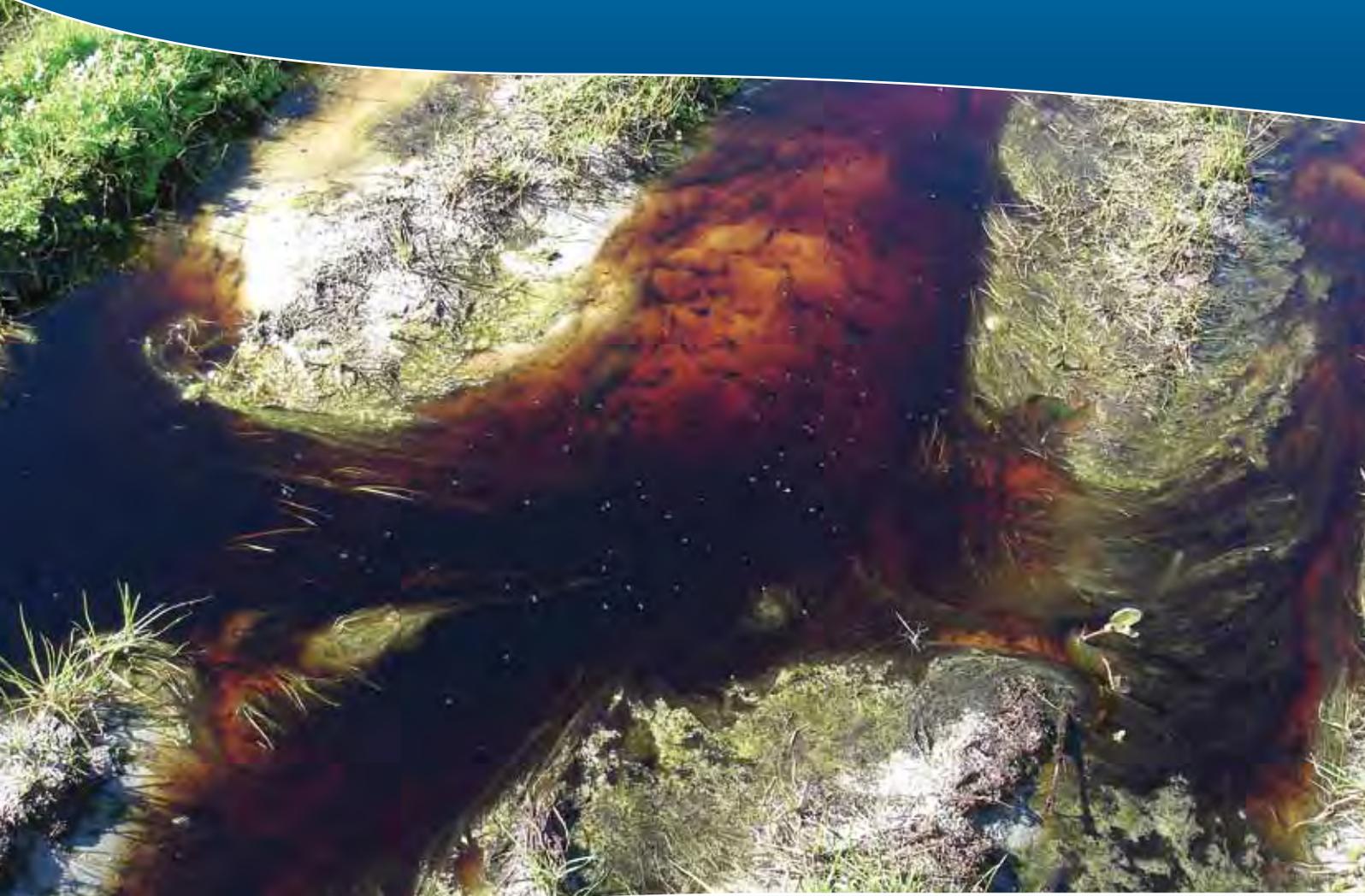


*Looking after all our water needs*

*Water Science*
*technical series*

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Acid sulfate soil risk assessment and hydrochemistry

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# Summary

This report focuses on two aspects of the *Murray hydrological studies*: a risk assessment of acid sulfate soil disturbance resulting from predicted changes to climate, topography and drainage, and an investigation of the groundwater and wetland hydrochemistry.

The results of the risk assessment are used to ascertain the likelihood of potential acid sulfate soils in the Murray–Serpentine region being converted to actual acid sulfate soils under different scenarios of climate, drainage and groundwater abstraction following urban development. This assessment incorporated the latest results from the groundwater–surface water modelling undertaken as part of the *Murray hydrological studies,* and used information on potential acid sulfate soils collected during the associated drilling program and from previous studies.

Assessment of acid sulfate soil risk and appropriate management, especially in areas of urban development, will help prevent water contamination and infrastructure damage.

Overall, the assessment identified little change in potential acid sulfate soil exposure risk due to shallow subsurface drainage and urban development alone, mainly due to predicted increases in groundwater recharge rates in urban areas and the effect of fill on vegetation root depth. However, the scenario modelling identified increased risk of potential acid sulfate soil exposure with drying climate and the use of garden bores.

The analyses revealed little change in risk between the 1945–1974 period and the drier 1975–2007 period. This indicates that the seasonally-full Superficial Aquifer has provided a buffer against the risk of potential acid sulfate soil oxidation in the past. However, a drying climate and garden-bore abstraction may decrease Superficial Aquifer groundwater levels, increasing the risk of potential acid sulfate soil exposure and oxidation.

The hydrochemistry investigation was undertaken to further understand groundwater hydrodynamics, determine regional patterns in groundwater quality and investigate water-rock interactions. Understanding the water quality is particularly important for determining the suitability of the groundwater for different purposes. A total of 64 bores and 9 wetland sites were sampled for this study.

The investigation identified two distinct water types, one dominated by silica weathering to the north of the Murray River, and the other dominated by carbonate dissolution south of the Murray River. The groundwater is generally suitable for irrigation, although in some areas uses will be limited due to poor water quality. Salinity was less than 1500 mg/L in all but four locations, with pH usually slightly acidic to neutral. High concentrations of iron, of the order of 4-6 mg/L, may limit groundwater use due to staining and clogging of irrigation systems. High total nitrogen and total phosphorus concentrations were also evident, the highest concentrations occurring in the Nambeelup region.

# 1   Introduction

## 1.1   Report context and objectives

This report combines the research of two parallel studies that have been completed for the *Murray hydrological studies*: an assessment of the risk of hydrological disturbance exposing potential acid sulfate soils to air; and an investigation of the Superficial Aquifer hydrochemistry. The study area referred to as the Murray–Serpentine region in this report, encompasses the *Murray Drainage and Water Management Plan* (DWMP) area from the *Murray hydrological studies* (Hall et al. 2010a) as shown in Figure 1-1. The methods for both the acid sulfate soil risk assessment and the hydrochemistry investigation are outlined in Section 2. The results of the risk assessment are outlined in Section 3 while the results from the hydrochemistry investigation are presented in Section 4. A discussion of both sets of results is presented in Section 5.

### Acid sulfate soil risk assessment

The risk assessment ascertains the likelihood of potential acid sulfate soils in the Murray–Serpentine region being converted to actual acid sulfate soils under different drainage, groundwater abstraction and climate scenarios. It incorporates the latest results from groundwater–surface water modelling, undertaken as part of the *Murray hydrological studies* and uses data on potential acid sulfate soils collected during the *Murray hydrological studies* and from other studies (Degens 2009; SKM 2008, RPS 2006, Douglas & Partners 2007, JDA 2009).

Knowing the location of potential acid sulfate soils (PASS) in the landscape is important for understanding the risk of oxidising potential to actual acid sulfate soils through soil disturbance or changes to the hydrology in a region. Acid sulfate soils contain sulfides which typically remain stable while they are kept saturated, that is when they are below the watertable. When the watertable drops the sulfides are exposed to air and their subsequent oxidation can result in the production of sulfuric acid and the release of arsenic and metals from the soil profile. Nitrate can also oxidise sulfides with similar results.

Urbanisation can disturb the lithology and modify the hydrology through the installation of subsoil drainage, the installation of deep reticulated sewerage and underground powerlines, modification of surface drainage, groundwater pumping, nutrient application and wetland and vegetation disturbance. The Murray–Serpentine region is currently undergoing urbanisation in several areas, with a significant portion of the region under investigation for urban development in the coming decades (WAPC 2010), as shown in Figure 1-2. There is a risk of potential acid sulfate soils being oxidised as a result of this development, potentially causing widespread damage with high remediation costs. The sulfuric acid and concomitant metal and metalloid release can cause environmental harm and damage infrastructure by killing vegetation, posing health risks to people and local ecosystems, and dissolving concrete or limestone structures (DERM 2009).

In the Murray–Serpentine region much of the future urban development is likely to be concentrated around low-lying land surrounding the Peel Estuary, Murray River, Serpentine

River and Nambeelup Brook floodplains and relatively flat seasonal wetlands. These sites are typical of the environments and lithology that are associated with potential acid sulfate soil materials (Degens 2009), and therefore it is important to understand the risks in this area.

Note that this report is not a substitute for local development scale investigations, but rather should be used as a guide for understanding regional risk patterns under possible future conditions.

The authors acknowledge that this acid sulfate soil study relies heavily on the extensive work of Degens (2009), and the reader is referred to this report for more information on acid sulfate soils in the Peel region. This report also relies on the groundwater modelling that is described in Hall et al. (2010a, 2010b, 2010c). The reader should refer to these reports for details regarding the groundwater modelling.

### Hydrochemistry

The primary objectives of the hydrochemistry investigation are to: determine groundwater recharge and flow dynamics; determine regional patterns in groundwater quality, and investigate water-rock interactions. To achieve this a hydrochemical survey of the Superficial Aquifer was completed over the period 2008 to 2009. A total of 64 groundwater bores and a further nine wetland locations were sampled for a range of field parameters, major ion species and nutrients. Including duplicates there was a total of 79 samples analysed. This information has been supplied to the Water Science Branch for analysis as part of the *Murray hydrological studies*.

This information can be used to inform groundwater users of likely concentrations and types of solutes in a particular area, including the source of the solutes, and inform groundwater managers of potential risks due to high levels of undesirable constituents or aquifer susceptibility to certain pollution sources.

## 1.2   Regional setting

### Geomorphology

The soils of the coastal plain in the Murray–Serpentine region are associated with the Quaternary superficial formations of the Perth Basin. Deeney (1989) divides the upper layers of the superficial formations into four geomorphic units: the Quindalup Dune System, the Spearwood Dune System, the Bassendean Dune System and the Guildford Formation. These approximately correspond to the geological formations of the Safety Bay Sand, Tamala Limestone, Bassendean Sand and Guildford Clay respectively. This work also extensively described the geology of the superficial formations south of the Murray River. The work of Hall et al. (2010a) has further investigated the superficial formations north of the Murray River to incorporate the rest of the Murray DWMP study area.

Most of the upper soil profile within the Murray DWMP study area is composed of the Bassendean Dune System, with estuarine and alluvial deposits located around the Peel Estuary and rivers (Figure 1-1). The Bassendean Sand is composed of pale grey to white, mainly fine to medium grained sub-rounded grains of mainly aeolian deposition. The

Bassendean unit tends to consist of a leached upper profile underlain by layers of iron stained or weakly cemented sand and silty sands which may contain variably decomposed humus material. In some areas the Bassendean Sand contains profiles of sandy clay that are likely of alluvial origin. Typically Bassendean Sand is leached of carbonates, has a low cation exchange capacity and therefore has poor acid buffering capacity. It is therefore highly prone to acidification (Degens 2009).

Silty sands and iron rich layers commonly found within the Bassendean Sand, colloquially known as 'coffee rock', are also reservoirs of highly reactive acid generating minerals that are oxidised when exposed to air (Degens 2009). Silty sands and iron rich layers were encountered in many locations during exploratory drilling conducted in 2009 (Hall et al. 2010a).

Current estuarine, swamp and alluvial deposits are often overlying the deposits of older, similar environments. The estuarine sediments which surround the Peel Estuary are mainly composed of silts and sandy silts (Degens 2009). The areas around the mouths of the rivers also contain relic channels, lakes and flats with sequences of silt and sand. These may contain accumulated sulfides such as pyrite which pose a significant acid sulfate soil risk (Degens 2009).

## Superficial aquifer hydrodynamics

Recharge to the Superficial Aquifer predominantly occurs via direct rainfall, particularly in areas with a sandy profile. Clay soils that occur in the eastern part of the study area may act as a minor aquitard and reduce recharge; however surface exposures of the sandier Yoganup Formation near the Darling Scarp may act as preferential recharge areas.

For the majority of the study area, recharge to the superficial groundwater is through free-draining sandy-soils. In most areas, the watertable is close to the surface (1–5 m BGL), and has small horizontal gradients. The water flux through the unsaturated zone is thought to be predominately vertical due to recharge and evaporative processes, while lateral movement is generally negligible due to the low hydraulic gradients.

The hydraulic head isopotentials indicate groundwater of the Superficial Aquifer flows from east to west across the study area, although the rivers dissecting the plain cause deviations of flow. The phreatic head reduces from over 60 mAHD along the Darling Scarp to sea level at the lower Serpentine River, lower Murray River, and Peel Inlet. In the central plain the hydraulic gradient is small. The study area incorporates two regional groundwater flow systems – the Waroona and Serpentine. The Waroona flow system flows north towards the Murray River and west towards the Peel-Harvey Inlet. The Serpentine flow system flows west from the scarp until it is intercepted by either the Murray or Serpentine Rivers (Davidson 1984, Deeney 1989). Nambeelup Brook is also an important conduit for groundwater discharge in the central areas of the Serpentine flow system (Hall et al. 2010c).

Groundwater discharge from the Superficial Aquifer occurs via several mechanisms; surface drains, rivers, downward leakage, evapotranspiration, wetland related pond evaporation, abstraction, and discharge to the ocean. Assuming a steady state condition, as water flows through the coastal plain the losses to these discharge points are offset by recharge, where the change in storage is zero over a full seasonal cycle.
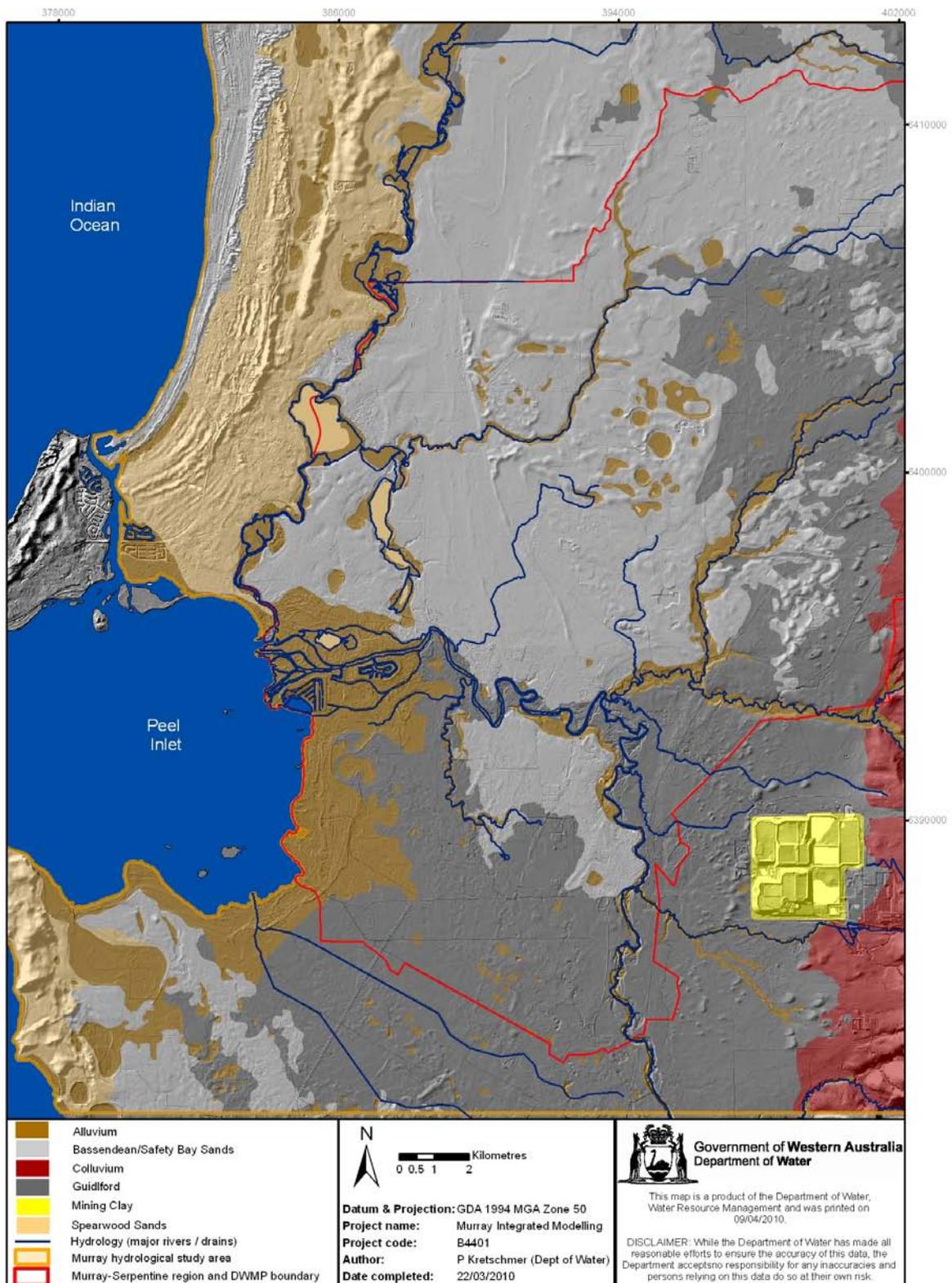
*Figure 1-1 Surface geology of the study area (based on DAFWA Soil-landscape map database 2002).*

# 2    Methods

## 2.1    Acid sulfate soil data collection and analysis

**Primary data collection**

Sampling for acid sulfate soil was carried out during the drilling phase of the *Murray hydrological studies*. A selection of 9 wetlands had a total of 23 monitoring bores constructed nearby, primarily to provide information on the interaction between surface water and shallow groundwater. Figures 2-1a and 2-1b show the location of the selected wetlands and all acid sulfate soil investigation sites including those used from other studies. The drilling program was contracted to GHD Pty Ltd who was responsible for logging core samples retrieved during the drilling process. The Department of Water was responsible for the acid sulfate soil data collection component of the program.

The push-probe drilling method was used to provide 38 mm diameter cores for logging and acid sulfate soil sampling. In instances of probe-refusal, where layers were consolidated or indurated, a hollow-stem auger was used and samples collected from the auger flight as cuttings reached the surface.

Field testing for acid sulfate soil was performed on site. Core samples were tested at 0.25 m intervals for field pH ($pH_f$) and pH after oxidation with a strong oxidising agent ($pH_{fox}$). Two equal volumes (2.5 mL) of core were sampled at each 0.25 m interval and placed into plastic vials. To one vial, 12.5 mL of deionised water was added, and 12.5 mL of 30% w/w hydrogen peroxide was added to the other. The hydrogen peroxide was buffered to a pH between 4.5 and 5.5. The pH of each vial was measured after 20 minutes had elapsed. The intensity of the material reaction to the $pH_{fox}$ test was also recorded.

Samples were collected at 0.5 m intervals for possible laboratory analysis. Samples were sealed in airtight zip-lock bags with the air expelled, and frozen on site. At the end of every sampling day, samples were transferred to freezers for storage. Any samples submitted to the laboratory were transported frozen in portable refrigerators.

The field acid sulfate soil testing, field lithological description and further core logging provided the basis on which samples were selected for laboratory analysis. Budget constraints precluded comprehensive laboratory testing of cored profiles. Of the 281 samples taken, 30 were submitted for laboratory analysis. The selection was based on a combination of field sampling results, lithology, and in some cases the formation of jarosite in stored core samples.

Samples submitted for laboratory analysis were tested using the 'chromium reducible sulfur' ($S_{CR}$) and the 'suspension peroxide oxidation combined acidity and sulfur' (SPOCAS) methods (McElnea et al. 2002; Latham et al. 2002). A more detailed explanation of the acid sulfate soil testing procedure can be found in DEC (2009).

For modelling purposes a depth to acid sulfate soil from ground level was interpreted for each site. The results for the sampling sites established for the *Murray hydrological studies* are included in Table 2-1, a list of all sites is presented in Appendix 1. Field tests, lithological

descriptions and laboratory analysis were assessed to provide a depth of occurrence of PASS. The paucity of laboratory data does detract from the confidence of this assessment. Hence, subsequent modelling outputs must be viewed with caution as the depth to acid sulfate soil may be underestimated.

*Table 2-1 Summary of interpreted depth to PASS horizon for sites sampled as part of the Murray hydrological studies.*

| Wetland ID | Bore ID | Depth to ASS (m bgl) | Comment |
|---|---|---|---|
| 5056 | HS80-1 | 4 | PASS |
| 5056 | HS80-2B | 3.7 | PASS |
| 5056 | HS80-3 | 4.3 | PASS |
| 3945 | HS87-1B | 2.9 | PASS |
| 3945 | HS87-2 | 1.5 | PASS |
| 3945 | HS87-3 | 2.5 | PASS |
| 5180 | HS96-1B | 2.8 | PASS |
| 5180 | HS96-2 | 2.5 | PASS |
| 5274 | HS99-1B | 4.5 | PASS |
| 4835 | HS104-1B | >5.5 | EOH at 5.5m. ASS horizon not encountered in core |
| 4835 | HS104-2A | >6.6 | EOH at 6.6m. ASS horizon not encountered in core |
| 4835 | HS104-2B | >3.8 | EOH at 3.8m. ASS horizon not encountered in core |
| 4835 | HS104-3A | >6.35 | EOH at 6.35m. ASS horizon not encountered in core |
| 4835 | HS104-3B | >4.5 | EOH at 4.5m. ASS horizon not encountered in core |
| 13305 | HS108-1B | >2.88 | EOH at 2.88m. ASS horizon not encountered in core |
| 13305 | HS108-2A | 4 | PASS |
| 13305 | HS108-2B | 3.6 | PASS |
| 5032 | HS109-1 | 5 | PASS |
| 5032 | HS109-2 | 4.2 | PASS |
| 7046 | T560S | 3.4 | Actual AAS? TAA value above trigger limit. |
| 7046 | T561 | 4.1 | PASS |
| 7046 | T563 | 4.4 | |
| 7046 | T564 | 2.7 | |

*Note: m bgl – metres below ground level. EOH = end of hole*

## Secondary data collection

In recent years, most large-scale urban development projects have been required to conduct detailed acid sulfate soil assessments prior to construction. These investigations have produced large amounts of data on the location, depth and volume of potential and actual acid sulfate soil materials within their respective study areas (RPS 2006, Douglas & Partners 2007, JDA 2009). This project has collated several of these assessment reports and used the data to increase understanding of where potential and actual acid sulfate soil is located.

Due to the volume of data, a simple system was devised where a single site for each development was mapped and the minimum depth found to potential or actual acid sulfate soil was ascribed to this point.

Although this could be seen as an over-simplification of the data, it was deemed suitable within the scope of this project for assessing whether a particular area has PASS materials at risk of being oxidised by a lowering of the watertable, or already has actual acid sulfate soil.

Further PASS data was gathered from a report prepared for the construction of a 10.8 km long mains water supply pipeline in Nambeelup Brook (SKM 2008). This comprehensive dataset incorporates 100 soil cores that were collected using the push-probe method to a depth of around 5.5 m unless refusal was reached prior to that depth. The east–west bore transect passes through several conservation category wetlands.

As acknowledged previously a primary data source is the recent acid sulfate soil survey completed by Degens (2009). The dataset titled "*2003–2005 acid sulfate soil site evaluation summary*" was obtained from the Department of Water spatial data store. This dataset contains 117 sample sites located within the Murray DWMP modelling area and all have been incorporated for analysis. The soil cores were collected to an average depth of 6 m using the push-probe method except where access or lithology precluded this method from being used. If this was the case then samples were collected using hand auguring (Degens 2009).

## 2.2   Acid sulfate soil risk modelling

### Risk assessment modelling scenarios

The *Murray hydrological studies* project has modelled a range of climate – land-use scenarios to assess likely watertable response (Hall et al. 2010c). Eight of these scenarios were selected for this study and are summarised in Table 3-1 below. Note that development changes were applied to the areas highlighted in Figure 1-2.

*Table 2-2  Modelling scenarios used in this study.*

| ID | Climate sequence | Drainage | Development |
|---|---|---|---|
| S36 | Historical wet | No drains | No development |
| S0 | Current | No drains | No development |
| S9 | Future Wet (MSL +0.2 m) | No drains | No development |
| S11 | Future Wet (MSL +0.2 m) | 1m fill, drains 1 m bgl | Development |
| S15 | Future Wet (MSL +0.2 m) | No fill, drains 1 m bgl | Development |
| S40 | Future Medium (MSL +0.2 m) | 1m fill, drains 1 m bgl | Development & garden bores |
| S27 | Future Dry (MSL +0.2 m) | No drains | No development |
| S33 | Future Dry (MSL +0.2 m) | No fill, drains 1 m bgl | Development |

*Note: MSL – mean sea level, m bgl – metres below ground level*

The output of the modelling process is a predicted watertable surface based on the different climate and land-use variables. In order to assess acid sulfate soil risks, the average annual minimum groundwater level (AAMinGL) was compared to the level (i.e. depth converted to mAHD) of potential acid sulfate soils. However, several scenarios have also been compared

to the absolute minimum groundwater level (AbMinGL) to assess whether this measurement greatly alters the risk of PASS oxidisation.

The scenario identification (ID) in Table 2-2 directly corresponds to the respective scenario's identification used in the Murray regional groundwater report (Hall et al. 2010c).

Several steps were required before the predicted groundwater levels could be compared to the levels of potential acid sulfate soils. The data collected from the supplementary sources did not contain the ground elevation at each sampling site and therefore the PASS levels, which were recorded as metres below ground level (m bgl), could not be directly compared to the water levels which were recorded relative to the Australian Height Datum (mAHD). To correct this, the location for each sampling site was intersected with the Department of Water's LiDAR raster image for the region, which gives the ground level accurate to within 0.15 m at each site. The PASS depth in m bgl was then subtracted from the LiDAR surface to give PASS level in mAHD at each sampling site.

The final step involved intersecting the sample sites with the water level surface from the modelling output. The difference between the PASS level and the groundwater level was then used to classify the risk of the potential acid sulfate soil becoming oxidised according to the risk assessment criteria outlined below.

## Risk assessment criteria

The *Murray hydrological studies* have modelled a range of climate and drainage scenarios to assess likely watertable responses. The resulting watertable surfaces were intersected with the known depth to potential acid sulfate soil to assess the risk of exposure.

There are a number of factors that cause a degree of uncertainty in the results. For example the regional groundwater model has a 200 m grid resolution. This level of resolution will produce errors in areas with large variations in topography. There are also localised areas where the groundwater model calibration process has not resolved errors in water level prediction. To account for this, the risk categories have incorporated modelling uncertainty. A statistical analysis of the Murray DWMP regional modelling revealed that 90% of the modelled groundwater levels were between +0.61 m and -0.95 m of the observed groundwater levels. These error values were used to set the risk category depths above or below the level of potential acid sulfate soil. Table 2-3 below shows the risk category criteria used.

*Table 2-3      Risk category criteria.*

| Risk category | Criteria |
| --- | --- |
| Low | Modelled AAMinGL is 0.61 m or more above the level of potential acid sulfate soil |
| Moderate | Modelled AAMinGL is between 0.00 and 0.61 m above the level of potential acid sulfate soil |
| High | Modelled AAMinGL is between 0.00 and 0.95 m below the level of potential acid sulfate soil |
| Extreme | Modelled AAMinGL is 0.95 m or more below the level of potential acid sulfate soil |

Investigation of the modelled results revealed that in the low-lying estuarine areas the minimum groundwater levels were below mean sea level (MSL). Following a review of the observed water levels and discussions with B. Degens (pers. comm. 2010) who conducted the regional acid sulfate soil study in the area (Degens 2009), it was deduced that minimum groundwater levels were unlikely to be below mean sea level. In these situations, the minimum predicted AAMinGL or AbMinGL was increased to mean sea level.

## 2.3   Hydrochemistry data collection and analysis

### Sampling sites

A total of 64 sampling bores were installed and sampled for the *Murray hydrological studies* during 2008 and 2009. In addition nine sampling points were established in wetlands at which surface water was collected in 2009. Depending on whether the bore was installed in 2008 or 2009, some sites were sampled in October and December 2008 and the remaining bores were sampled in early December 2009. Figure 2-2 illustrates the location of all sampled sites for this study and Appendix 2 provides the bore location, screen depth and sampling results. A bore completion report for the 2009 phase of drilling is being compiled and is likely to be published in late 2010. All bores were constructed using PVC casing. Screened intervals comprised slotted PVC casing. The annulus about the screened interval was gravel packed, with a bentonite seal above the screen. Deeper holes had cement grout filling the annulus to surface. A concrete pad and a galvanised standpipe were then installed at each site. In addition, surface water samples were taken from nine wetlands in November 2009 to compare against the groundwater samples.

### Field sampling

In 2008 samples were taken by pumping the bore using a 12 volt submersible pump at a rate of around 11 L/min. In 2009, water samples were collected from the bore using a 12 volt submersible Twister pump at a rate between 5 and 7 L/min. In some cases pumping rates were as low as 1 L/min (where there was little water in the well). At least three well volumes of water were evacuated prior to sampling to remove stagnant water from both within the bore and around the bore screen. The pump was located within the screen interval except in those bores where the screen depth was greater than 20 m (where samples were taken at

approximately 20 m, the maximum length of the sampling hose). The physical water quality parameters of pH, electrical conductivity, temperature and dissolved oxygen were recorded in water pumped to the surface into a 10L bucket. Note this method may have reduced the accuracy of the dissolved oxygen reading. The probes used in 2009 were WTW 330i handheld meters fitted with the appropriate probes. An Insite DO meter and probe combination was used in 2008 for physical water quality measurements. Where required the probes were calibrated daily using standards at the beginning and end of each day of sampling. The wetland samples were taken adjacent to the water level measurement point establish in each wetland as part of the *Murray hydrological studies*, with the sample bottles filled once fully submerged to avoid pond scum contaminating the sample. For the wetlands the physical water quality variables were measured in-situ.

## Laboratory analysis

Analysis of water samples was undertaken by National Measurement Institute (NMI), Western Australia. The standard laboratory methods are not discussed in detail in this report, however Appendix 3 lists the analytes measured, reference numbers for the relevant measurement method, and the limit of reporting for each analyte.

The ionic charge balance of each sample was calculated for quality assessment purposes. This resulted in the identification of a large number of samples that had an electrical balance difference of more than 5%, the recommended limit for analysis error (Hounslow 1995). Discussion with the NMI Laboratories and interrogation of the data indicates reported values for sodium and chloride was likely to be responsible for much of the error due to concentrations being rounded to the nearest 10 mg/L. This issue tended to be most prevalent but not limited to samples that had very low total dissolved solids.

# 3    Results: acid sulfate soil modelling

All scenarios discussed in this section were developed as part of the *Murray hydrological modelling* (Hall et al. 2010c). As each scenario has individual characteristics and responses, the results for each are discussed separately. Results for the scenarios modelled are presented in Figures 3-1a to 3-8, and Table 3-1. To allow more consistent identification of differences between each scenarios risk profile all scenarios are compared to S0 (current climate, no drains, no development) AAMinGL.

*Table 3-1 Number of sampling sites in each risk category for each scenario.*

Compared to average annual minimum groundwater level (AAMinGL)

| Scenario | Low | Potential acid sulfate soil risk | | | Total |
| | | Moderate | High | Extreme | |
| --- | --- | --- | --- | --- | --- |
| S0 | 126 | 40 | 77 | 17 | 260 |
| S09 | 116 | 49 | 77 | 18 | 260 |
| S11 | 137 | 45 | 63 | 15 | 260 |
| S15 | 129 | 42 | 72 | 17 | 260 |
| S27 | 116 | 43 | 76 | 25 | 260 |
| S33 | 121 | 46 | 73 | 20 | 260 |
| S36 | 130 | 42 | 71 | 17 | 260 |
| S40 | 118 | 49 | 73 | 20 | 260 |

Compared to absolute minimum groundwater level (AbMinGL)

| Scenario | Low | Potential acid sulfate soil risk | | | Total |
| | | Moderate | High | Extreme | |
| --- | --- | --- | --- | --- | --- |
| S0 | 116 | 39 | 80 | 25 | 260 |
| S11 | 118 | 51 | 73 | 18 | 260 |
| S15 | 120 | 42 | 76 | 22 | 260 |

## 3.1    Base case scenario (S0)

*Description: Current climate, no subsurface drains and no development*

The base case scenario (S0) was modelled to provide a baseline of current PASS exposure risk in the modelling area. Table 3-1 shows that there were a combined 94 sites classified as either high or extreme risk of exposure to air and 166 sites as either moderate or low risk of exposure to air. Of the 17 sites classified as extreme, 15 are classified as such in all subsequent scenarios. To avoid repetition, a separate discussion about these sites has been included in Table 3-2. All sites that have known actual acid sulfate soil were classified as either high or extreme risk. High risk sites were geographically interspersed with moderate and low risk sites, with 77 high risk sites to 40 moderate risk sites and 126 low risk sites (Table 3-1). Note that low risk sites included sample sites where no PASS was found. This means that many of the low risk sites have no known potential risk for the full depth of the core, and therefore did not change their risk category irrespective of the climate or land-use scenario applied.

Modelling using the absolute minimum water level, rather than the average annual minimum groundwater level, produced eight more extreme risk sites, three more high risk sites and ten fewer low risk sites. Most of the additional extreme risk sites occur along the Lakes Road

pipeline transect. This transect coincidentally runs along the edge of a paleochannel where the regional groundwater model had been difficult to calibrate, therefore the risk classification of these sites should be viewed with caution. Several sites south of the Murray River also changed to extreme risk which may be of concern for waterway health.

*Extreme sites*

Fifteen sampling sites were classified as extreme under all climate and development scenarios. Discussion about each of these sites is provided in Table 5-2 below. Some of the sites classified as extreme were due to actual acid sulfate soil being found in those locations. In other locations, under prediction of AbMinGL by the model may be the cause for the extreme risk, while some sites have potential acid sulfate soil recorded at a depth that would normally be expected to be above the groundwater level. This latter effect may be caused by elevation increases in areas that had been developed between acid sulfate soil sampling and the elevation data being collected.

*Table 3-2 The 15 locations classified as being at extreme risk in all scenarios.*

| Site | Description |
| --- | --- |
| ASS61401001 | Actual ASS located at 0.2 m bgl. Standing water level (SWL) located below ASS when sampled in September |
| ASS61401003 | Actual ASS located at 1 m bgl. SWL located below ASS when sampled in September |
| ASS61401403 | Actual ASS located 2.2 m bgl. SWL located below ASS when sampled in November |
| ASS61400401 | PASS located 1.5 m bgl. AAMinGL modelled at 6.54 mAHD, PASS located at 7.72 mAHD. Sample site located at a break in slope where the 200 m model cell size can lead to error |
| ASS61400211 | PASS located at 1.5 m bgl. AAMinGL located at 3.52 mAHD, PASS located at 4.68 mAHD. Model under predicts groundwater levels by approximately 0.6 m which if accounted for would place the bore in the 'high' risk category |
| ASS61400101 | PASS located at 0.25 m bgl which is within the normal seasonal unsaturated zone depth |
| MLB-2 | PASS located at 0.2 m bgl which is within the normal seasonal unsaturated zone. Data sourced from private investigation |
| SB04 | PASS located at 1.4 m bgl. This is generally within the seasonal unsaturated zone, however model may slightly under predict due to close proximity of the Murray River. Data sourced from private investigation |
| BH7 | PASS located 1.5 m bgl. This is generally within the seasonal unsaturated zone, however model may slightly under predict due to close proximity of the Murray River. Data sourced from private investigation |
| RH78, RH79, RH81, RH82 | PASS located between 1.5 and 3 m bgl. These sample sites are located close to calibration bore HS105A and HS105B which were under predicted in the regional modelling (mean error 2.8 m) |
| RH71, RH72 | PASS between 1.5 and 2 m bgl, generally within the seasonal unsaturated zone. The palaeochannel may influence groundwater model errors here |

## 3.2   Wet climate, no development (S09)

*Description: 'Wet' future climate prediction where mean annual rainfall is predicted to reduce by 1.6%, no subsurface drains and no development. It includes a sea level rise of 0.2 m.*

S09 incorporates the wettest future climate scenario that was modelled as part of the *Murray Hydrological Studies*. When compared to the S0 AAMinGL scenario the differences are small. There is one more extreme risk site adjacent to the Serpentine River (Figure 3-2), the number of moderate risk sites increases by nine, mostly around the Murray River, while the number of high risks sites is unchanged (Table 3-1).

## 3.3   Wet climate, subsurface drains at ground level (S11)

*Description: 'Wet' future climate prediction where mean annual rainfall is predicted to reduce by 1.6%, all urban development zones identified in WAPC (2010) fully developed and with 1.0 m of fill on top of the existing surface level with subsurface drainage installed 1.0 m below the top of the fill. It includes a sea level rise of 0.2 m.*

Despite the installation of subsurface drainage the risk of exposing PASS through a lowering of the watertable decreased in this scenario. When compared to the S0 AAMinGL scenario the number of sites in the extreme risk category decreased by two, both within the boundaries of the urban development. There were also 14 fewer high risk sites and five more moderate risk sites while low risk sites increased by 11 (Figure 3-3a).

There are two main reasons for the lower risk. Firstly, urban development marginally increases gross recharge, since recharge under pasture is approximately 45%, and as little as 10% under native vegetation (Hall et al. 2010c). This increases to approximately 50% in urbanised areas due to infiltration basins, soak wells, rain gardens and reduced areas of deep-rooted vegetation. Secondly, the change in aquifer thickness caused by imported fill may raise water levels in some areas. Fill of 1.0 m with subsurface drains set at the pre-development ground level means that the watertable will still rise to at least the previous ground level. In addition compared with pre-development, root depth of perennial vegetation relative to previous water levels is effectively raised by 1.0 m due to the fill height, therefore raising AAMinGL and lowering the risk of PASS exposure.

Note that abstraction via garden bores or municipal bores was not included in this scenario. The effect of these is discussed in scenario S40.

The scenario S11 AbMinGL illustrates the risk of PASS being exposed during the driest year in the modelling period (Figure 3-3b). There was a slight increase in risk compared to S11 AAMinGL, but it is considerably lower than the risk profile of S0 AbMinGL.

## 3.4 Wet climate, subsurface drains at 1.0 m bgl (S15)

*Description:* '*Wet' future climate prediction where mean annual rainfall is predicted to reduce by 1.6%, all urban development zones identified in WAPC (2010) fully developed, no fill and subsurface drainage installed 1.0 m below the existing surface. It includes a sea level rise of 0.2 m.*

The S15 AAMinGL scenario has a slightly lower risk profile compared to S0 AAMinGL, with an equal number of extreme risk sites, five fewer high risk sites, two more moderate and three more low risk sites (Figure 3-4a and Table 3-1). As explained in Section 5.3 urban development marginally increases recharge.

The S15 AbMinGL risk profile was similar to the risk profile of S0 AbMinGL. There are three fewer extreme sites, four fewer high risk sites and a slight increase in moderate sites and low risk sites. Again most of the risk reduction occurs within the immediate vicinity of proposed development areas (Figure 3-4b).

## 3.5 Dry climate, no development (S27)

*Description:* '*Dry' future climate with mean annual rainfall 16% less than current climate, no subsurface drains and no development. It includes a sea level rise of 0.2 m.*

The scenario S27 AAMinGL produced the lowest AAMinGL surface out of all the scenarios. Compared to S0 there were eight more extreme sites, five of which are located at the eastern end of the Lakes Road pipeline transect (Figure 3-5), where groundwater model calibration was difficult (refer discussion in Table 3-2).

Importantly there were 10 fewer low risk sites. The fact that the increase in risk has not been more significant may reflect the fact that the aquifer fills to the surface and the discharges to wetlands and surface drains in many areas under the current S0 base case climate. Therefore, the drier climate of S27 may tend to reduce this overflow component rather than the watertable height.

## 3.6 Dry climate, subsurface drains at 1.0 m bgl (S33)

*Description:* '*Dry' future climate with mean annual rainfall 16% less than current climate, widespread urban development, no fill and subsurface drainage installed 1.0 m below the surface. It includes a sea level rise of 0.2 m.*

The scenario S33 AAMinGL has three more extreme risk sites, four fewer high risk sites, six additional moderate risk site and five fewer low risk sites compared to S0 AAMinGL (Figure 3-6). As with scenario S27, the additional extreme sites again occur at the eastern end of the Lakes Road pipeline transect, where groundwater model calibration was difficult (refer discussion in Table 3-2).

Overall S33 has a lower risk profile than S27. Both were modelled with the same climate but S27 had no future urban development or drainage included. The diminished risk reflects the slight increase in gross groundwater recharge that occurs in urban development.

## 3.7   Historical wet climate (S36)

*Description: Represents a wet period in the historical rainfall record, in this case between 1945 and 1974. There was no urban development, no fill, no subsurface drainage and no sea level rise modelled.*

The scenario S36 AAMinGL was included to see how a previous increase in mean annual rainfall may affect watertable levels and therefore the PASS exposure risk. The results showed a slight decrease in risk compared to the current climate, with an equal number of extreme risk sites, six fewer high risk sites, two more moderate risk sites, and four additional low risk sites (Figure 3-7). The reduction in high risk sites occurs adjacent the Murray River, along the Lakes Road pipeline and near the Serpentine River.

The results indicate that AbMinGL is likely to have changed little between the current climate and historical wet climate. One reason for the broad similarity in AbMinGL across scenarios is because the aquifer fills to the surface in many areas during the current climate (S0), therefore the wet climate mainly increases the amount of runoff rather than the volume of water stored in the aquifer. Additionally, the similar results are also partially due to the root depth parameter which is not varied in the modelling except where the fill is incorporated (root depth is constant measured in depth below ground level, but raised measured relative to AHD due to the fill).

## 3.8   Garden bore abstraction (S40)

*Description: Medium climate change scenario with mean annual rainfall 8.7% lower than the current climate. All urban development zones identified in WAPC (2010) fully developed and with 1.0 m of fill on top of the existing surface level with subsurface drainage installed 1.0 m below the top of the fill. It includes a sea level rise of 0.2 m. Garden bores are added to the model, extracting water from October to May.*

Garden bores are particularly important in lowering the AbMinGL and potentially increasing PASS exposure because they can draw the water level below the root depth of vegetation during periods of low rainfall, when otherwise AbMinGL would generally reflect root depth. Evidence of the additional summer drawdown caused by bores screened in the Superficial Aquifer can be seen in other development areas such as Bartram Road (Hall 2010). Scenario S40 AAMinGL (Figure 3-8) has a higher risk profile than S0.

Increases in risk were mainly limited to the eastern half of the Lakes Road pipeline and near Murray and Serpentine Rivers. However the effects were reduced due to the fill raising root depth and urban development marginally increasing gross recharge. Figure 3-9 illustrates the drawdown caused by garden bores when compared to a matching scenario without garden bores (S20 was not analysed for acid sulfate soil risk as part of this report). It shows that garden bores could lower AbMinGL by up to 1.0 m (Hall et al. 2010c). Therefore if fill is not used or high levels of recharge in the urban environment are not achieved the risk profile may be much higher. Additionally the design of garden bores will affect the depth of watertable drawdown. Typically a single garden bore shared between multiple users will lead to deeper, more localised cones of depression in the watertable; therefore potentially

increasing the risk of exposing PASS. Distributed low-yield garden bores will minimise the cones of depression, reducing the risk of PASS exposure. For details regarding density and extraction rates of garden bores used for groundwater modelling please refer to Hall et al. (2010c).

## 3.9   Wetland bores

The wetlands sites discussed in Section 2.1 are of high environmental value (rated as conservation category wetlands by the Department of Environment and Conservation). For this reason a brief but separate outline of the risks faced by these wetlands in the scenarios is given.

The results indicate that none of these sites are either high or extreme risk, with most of them being of low risk. For scenario S0 there was one moderate risk site at Greyhound Road wetland (UFI 5032 from the DEC geomorphic wetlands database), one site at Scott Road wetland (UFI 5180), and two sites at Barragup wetland (UFI 3945). For the driest scenario, S27, there is an additional moderate risk site at Scott Road and Elliot Road wetlands (UFI 5056), otherwise there appears to be little alteration of the risk profile at these sites.

The sediments located directly in the wetland were not sampled. The profile of PASS in wetland sediments should be investigated if any urban developments are likely to reduce minimum groundwater levels in these areas.

# 4    Results: regional hydrochemistry

## 4.1    Total dissolved solids

Total dissolved solids (TDS) ranged between 80 mg/L (T680A) and 8080 mg/L (HS95) in the study area. The latter high value may be influenced by high clay content in the local lithology leading to increased evapoconcentration of solutes compounded by the bore being located amongst a stand of trees. Because samples were taken in different years at different times of year it is difficult to ascertain with a high level of accuracy the variation in TDS across the region; however some general conclusions can be made.

A total of 42 out of the 67 sites recorded a TDS of less than 500 mg/L, with 62 out of the 67 samples recording values below 1500 mg/L which is often used as a guiding limit on irrigation water quality. Where nested piezometers were sampled, typically salinities were slightly higher in the deeper portion of the Superficial Aquifer (Figure 4–1). To confirm this, samples taken from paired bores at the same time were analysed using a paired t-test, which confirmed that the shallow bores were statistically more likely to be fresh compared to deep bores (P=0.003). This is a common phenomenon due to the leaching of solutes from the tree root zone into the deeper Superficial Aquifer.

Bores located near the Murray River and between North and South Dandalup Rivers appear to have the highest salinities which may reflect higher rates of evapoconcentration and reduced flushing due to increased clay content in these regions. No sampling sites were located close to the estuarine reaches of the Murray and Serpentine Rivers; however it is likely that brackish water resides in the parts of the Superficial Aquifer in these regions.

Notably, none of the bores surrounding Barragup Lake (PLI 3945) recorded a TDS above 1250 mg/L, however the lake recorded a temperature compensated electrical conductivity of 15,700 µS/cm, approximately equivalent to 9420 mg/L (note the wetlands samples did not have TDS measured in the laboratory). The high lake salinity may reflect evapoconcentration or it could reflect interaction with an unmapped salt wedge extending from either the Peel Inlet or Serpentine River that was not intercepted by the installed bores.

## 4.2    pH, acidity and alkalinity

The pH of a solution is the measure of the activity of hydrogen ions ($H^+$), where 'activity' is the same as 'concentration' in dilute solutions. It is expressed as the negative logarithm of the hydrogen ion concentration.

$$pH = -\log_{10}[H+]$$

Most commonly, assessments regarding the acidity of groundwater are discussed solely in terms of pH. Lack of consideration of other components of groundwater acidity, can result in the under-estimation of acidity. Subsequently, any potential acidity-related risk to groundwater-receiving environments can be underestimated.

Contributions to acidity are protons (hydrogen ions) and dissolved metals which upon hydrolysis release $H^+$ ("metal acidity" of Kirby & Cravotta, 2005). Weak acids, such as organic acids from humic material, are not fully dissociated so the concentration of $H^+$

measured by pH underestimates the total acidity of a solution. Acidity can be counteracted by alkalinity. Alkalinity of water is its acid neutralising capacity and comprises bicarbonate, carbonate, hydroxide and weak bases.

Neutral pH is 7.0 by definition. Anything above this value is alkaline and any value below is acidic. A pH of range 6.5 to 8 specified as the guideline value for protection of slightly disturbed freshwater aquatic ecosystems of south-west Australia (ANZECC & AMMCANZ 2000). The ability of a system (includes sediment profile, surface water and groundwater) to resist changes in pH is referred to as the buffering capacity of the system. In the context of ASS, the buffering capacity is usually discussed in terms of a system's capacity to resist lowing of pH.

The buffering capacity of PASS is provided by minerals (e.g. carbonates, phosphates, and silicates), ion exchange sites (measured as cation exchange capacity), oxidation of organic matter and any alkalinity component of groundwater. Small increases in $H^+$ in groundwater (lowering of pH) may be buffered by the displacement of metal ions from cation exchange sites, resulting in the subsequent release of metal ions to groundwater. Low pH values can result in desorption of metals and metalloids, and if pH values are low enough, dissolution of minerals. Metal ions in groundwater can then release acidity by a series of hydrolysis reactions, one of which is shown below

$$Fe^{3+} + H_2O \leftrightarrow FeOH^{2+} + H^+$$
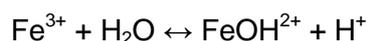
Once metals and metalloids are released into groundwater they can be taken up by flora and fauna (if acidic groundwater discharges to surface-water ecosystems), and potentially cycle through aquatic and terrestrial food chains.

Lowering of the watertable due to pumping can lead to the oxidation of PASS and subsequently a lowering of groundwater pH, similar to that seen near several pumping zones further north on the Swan Coastal Plain (Yesertner 2009).

Figure 4-2 illustrates that most sampling sites in this study had a pH of 5–7. This mildly acidic value is common in Bassendean Sands due to its lack of carbonate minerals and poor cation exchange capacity, and therefore poor pH buffering capacity (Yesertner 2009). South of the River Murray the pH tends to be near neutral to slightly basic (pH 6.5–8) which is likely to be a result of the greater carbonate content in the Ascot Formation.

Of some concern is the acidity in and around wetland PLI 5032. This wetland recorded a field pH of 4.16, and adjacent bores HS109-1 (pH 4.00), HS109-2 (pH 4.15) and HS108-2B (pH 3.96) recorded the three lowest values in the entire study area. It is unclear whether local disturbance and oxidation of acid sulfate soils has caused the acidification of groundwater in this area. Potentially the low pH is related to high concentrations of organic acids contributing to low pH. Given it's locality to properties potentially using groundwater, this site may warrant further investigation.

## 4.3   HCO₃ to SiO₂ ratio

When viewed regionally, the groundwater of the Superficial Aquifer can be split into two types based on the $HCO_3/SiO_2$ ratio. Figure 4-3 illustrates that the southern half of the study area has waters with a $HCO_3/SiO_2$ ratio typically above 8, while those in the northern half

tend to be more strongly dominated by silica dissolution with a $HCO_3/SiO_2$ of less than 4. The higher bicarbonate concentration in the south is likely to be a result of calcite dissolution in the seashell rich Ascot Formation. In the north, the Ascot Formation is absent and instead the Rockingham and Gnangara Sands are present. These formations are low in carbonates and therefore the $HCO_3/SiO_2$ ratio is much lower, and thus increased dominance of silicate weathering is seen in the water chemistry. It is not surprising to note the very similar regional patterns for pH and the $HCO_3/SiO_2$ ratio, as $HCO_3$ plays an important role in buffering acidity.

## 4.4 Hardness

Hardness is the sum of the Ca and Mg concentrations expressed as mg/L equivalents of calcium carbonate ($CaCO_3$). Calcium carbonate that has precipitated out of solution is often seen in kettles and hot water services. Table 4-1 contains a hardness scale that was established by the Chemistry Centre of Western Australia suitable for use in the Perth region (Davidson 1995). In much of the Murray study area, the Superficial Aquifer contains water that is very soft to moderately soft, being less than 100mg/L in nearly all sampling locations north of the Murray River. The dissolution of calcium carbonate in the Ascot Formation south of the Murray River results in increased hardness (HS79A has the highest at 360 mg/L) (Figure 4-4). Two additional sites between the North and South Dandalup Rivers displayed very hard water where the water is also slightly saline. Typically a concentration of less than 100 mg/L is preferred for domestic purposes other than potable water (Yesertner 2009).

*Table 4-1  Hardness scale suitable for West Australian groundwater (Davidson 1995)*

| Hardness scale (mg/L as CaCO3) | |
|---|---|
| <50 | very soft |
| 50-100 | moderately soft |
| 100-150 | slightly hard |
| 150-200 | moderately hard |
| 200-300 | hard |
| >300 | very hard |

## 4.5 Iron

Iron is commonly found in the groundwater of the Swan Coastal Plain. Sources of iron include the iron-indurated sands known colloquially as 'coffee rock', pyrite ($FeS_2$) and the mineral illminite. Untreated groundwater which is high in iron can clog irrigation systems and cause unsightly staining of infrastructure. Under certain conditions hydrolysis of iron rich groundwater can also result in an increase in acidity and the precipitation of ferrihydrite as shown in the reaction below.

$$2Fe^{2+} + 0.5O_2 + 5H_2O \rightarrow 2Fe(OH)_3(s) + 4H^+$$

In the Murray study area iron concentrations ranged from 0.07 to 87 mg/L. In an investigation of the central Swan Coastal Plain, Yesertner (2009) noted that most samples recorded concentrations of less than 10 mg/L. In the Murray study area concentrations were quite varied, with nearly half having concentrations between 1 and 10 mg/L, and several much

higher. HS102B, located on the far eastern plain recorded a concentration of 87mg/L, more than 14 times the study area average concentration of 6 mg/L. This site also recorded the second highest TDS (4420 mg/L) and therefore this may be indicative of evapoconcentrated groundwater, however, HS97A also recorded a high iron concentration of 59 mg/L and had an TDS of just 240 mg/L. Excluding these two anomalous sites, the average concentration of iron in groundwater in the region is 4 mg/L. There does not appear to be a spatial relationship for iron concentration such as across the region, or between shallow and deep nested bores.

## 4.6 Nitrogen

Nitrogen in groundwater most commonly exists as either nitrate ($NO_3^-$), ammoniacal nitrogen ($NH_3/NH_4^+$), or dissolved organic nitrogen (DON). Nitrate is naturally occurring in the soil where it is a product of mineralisation and is then used for plant growth. However, in cultivated areas the concentration of nitrogen can be significantly above natural levels due to the application of fertilisers and manure from grazing animals. The additional nitrate and ammoniacal nitrogen is mainly sourced from animal wastes and fertilizers, while dissolved organic nitrogen is derived from the decay of vegetation and animal wastes. Nitrogen from urban and agricultural areas is leached from the upper soil profile into the groundwater from where it is transported into rivers, wetlands and estuaries where it can lead to excess algal growth, deoxygenating events and potentially trigger fish kills.

Total nitrogen (TN) is frequently used to sum the main nitrogen species into one figure for ease of reporting. As it is determined on an unfiltered sample it includes dissolved nitrogen and nitrogen bound to particles suspended in the water sample. Total nitrogen values ranged between 0.04 and 13 mg/L in the bore samples, with the latter, recorded at T564, an outlier in the data. The average for all groundwater sampling sites was 2.64 mg/L; for shallow bores it was 3.15 mg/L; and for deep bores 2.22mg/L; all significantly above the guideline trigger value of 1.2 mg/L for freshwater ecosystems in near-pristine condition (ANZECC & ARMCANZ 2000). The wetland surface water samples recorded TN values between 2.8 and 5.5 mg/L, with an average of 4.4 mg/L. Values of between 1–7 mg/L are not unexpected in areas used for cattle grazing or areas with remnant native *Acacia* species (Davidson 1995). Figure 4-5 illustrates that higher nitrogen values tend to be more concentrated in the Nambeelup region, in the central portion of the plain. This may be a feature of high nitrogen inputs for cattle grazing from fertilisers and nitrogen fixing pasture crops. The several locations with high concentrations of the nitrate and nitrite forms of nitrogen in the TN figure may pose a risk of oxidising PASS in the long term (see below). There may also be samples that contain a high percentage of nitrogen bound to particulate matter. The sample from HS100B recorded very high TN (12 mg/L), TP (3.7 mg/L) and iron (31 mg/L). There is no obvious cause for these values based on surface observations and they are in stark contrast to the much lower values in the corresponding deep nested bore HS100A.

Nitrate reduction and the coupled oxidation of sulfides is of considerable concern in areas where PASS and high nitrogen inputs are coincident. Nitrate reduction in groundwater can occur through the oxidation of dissolved Fe(II), $H_2S$ and $CH_4$ (Appelo & Postma 2005). Nitrate reduction commonly occurs by reaction with organic matter, but may also be reduced by sulphides in oxygen limited environments, for example:

$$5FeS_2 + 14NO_3^- + 4H^+ \rightarrow 7N_2 + 5Fe^{+2} + 10SO_4^{-2} + 2H_2O$$
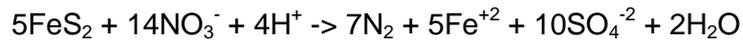
## 4.7  Phosphorus

In areas of remnant native vegetation on the Swan Coastal Plain, the concentration of phosphorus in groundwater is generally low (Yesertner 2009). In urban and agricultural areas phosphorus has been added through the use of fertilisers and animal waste (including human sewage). It usually occurs as phosphate ($PO_4^{3-}$), and is known to be an important nutrient stimulating algal growth in the rivers, wetlands and estuaries on the Swan Coastal Plain. Most phosphate species have poor solubility and bind to soil particles if suitable adsorption sites exit. Therefore an important factor affecting the concentration of phosphate is the phosphorus retention capacity of the soil. Typically Bassendean Sand has poor phosphorus retention capacity and therefore the phosphate is transported through the soil by groundwater with relative ease (Kelsey et al. 2010).

The average concentration of total phosphorus (TP) was 0.24 mg/L for all groundwater bores, significantly above guideline trigger values of 0.065 mg/L for freshwater ecosystems in near-pristine condition (ANZECC & ARMCANZ 2000). Similar to TN, TP represents the total of all phosphate including dissolved P and that absorbed to particles suspended in the sample. The highest concentration recorded was 3.7 mg/L at HS100B.  Figure 4-6 illustrates that the higher TP values tended to be more concentrated in the Nambeelup region, in the central portion of the plain. The average concentration of TP in shallow bores was 59 percent higher than the average concentration in deeper Superficial Aquifer bores (0.27 mg/L versus 0.17 mg/L). This is potentially caused by gradual sorption of phosphorus to soil as groundwater percolates deeper into the Superficial Aquifer, as well as the gradual uptake of phosphorus as it percolates deeper through the root zone. For wetland sampling sites the TP concentration ranged between 0.037 mg/L and 0.62 mg/L, with an average of 0.30 mg/L, similar to the average concentration in the shallow groundwater.

## 4.8  Other metals and metalloids

Analyses of groundwater samples included testing for a range of metals and metalloids. Here these are compared to guideline values for the investigation of groundwater outlined in DEC (2010), specifically assessment values for long-term irrigation water quality (IWQ), freshwater aquatic ecosystems (FAE) and domestic non-potable water supply (DNPS). Table 4-2 lists the metals and metalloids determined and the number of sites that exceeded guideline values for the relevant assessment criteria.

Soluble aluminium exceeded the guideline values of 5 mg/L at two sites for IWQ and DNPS but at nearly all sites compared to FAE values. Chromium exceeded the FAE guideline value of 0.01 mg/L at most sites, with a peak value of 0.14 mg/L, however in most circumstances the concentration did not exceed the assessment values for IWQ or DNPS. Copper concentrations exceed the FAE guideline values in many locations but many of the values were at the limit of reporting, the highest value of 0.095 mg/L being recorded at T564. It did not exceed the guideline values for IWQ and DNPS. Iron exceeded guideline values at most sites for all assessment levels, although it is not uncommon for iron values to be greater than

3 mg/L in the Superficial Aquifer (see Section 4.5). Similar to copper, lead exceeded the FAE guideline values at most sites but did not exceed the IWQ and DNPS limits. Mercury did not exceed guideline values while manganese was found to exceed the IWQ limits at only one site. Nickel exceeded the guideline values for FAE at five sites and three sites for IWQ, but it did not exceed guideline value for DNPS. Zinc exceeded the FAE values of 0.008 mg/L at 25 sites, but again it did not exceed guideline values for IWQ and DNPS.

Arsenic, boron, cadmium, cobalt and selenium were below the guideline values at all sites where guideline values were available. In some cases the limit of reporting (LOR) was at the guideline value.

In situations where sample values are in excess of the assessment values listed in DEC (2010), care should be taken when abstracting these waters. Other water quality variables such as pH, hardness, redox potential and other components may influence whether the groundwater is considered fit for purpose.

*Table 4-2  Number of sites exceeding recommended groundwater quality limits for metals and metalloids (Limits from DEC 2010)*

| Metal or Metalloid | Long-term Irrigation Limit[1] (mg/L) | Number of sites exceeding | Aquatic Ecosystem Limit[1] (µg/L) | Number of sites exceeding | Domestic non-potable groundwater[2] (mg/L) | Number of sites exceeding |
|---|---|---|---|---|---|---|
| Aluminium (Al) | 5 | 2 sites, max 11 mg/L | 55 | most sites | 2 | 9 sites |
| Arsenic (As) | 0.1 | none | 50 | none | 0.07 | none |
| Boron (B) | 0.5-6.0 | none | No values | NA | 40 | none |
| Cadmium (Cd) | 0.01 | none | 0.2 | none (LOR 0.002 mg/L) | 0.02 | none |
| Chromium (Cr) | 1.0 | 2 sites, max 0.14 mg/L | 1 | most sites (LOR is 0.005 mg/L) | 0.05 | 4 sites |
| Cobalt (Co) | 0.05 | none | No values | NA | No values | NA |
| Copper (Cu) | 0.2 | none | 1.4 | 40+ sites (LOR is 0.005 mg/L) | 0.2 | none |
| Iron (Fe) | 1.0 | most sites* | 300 | most sites* | 3 | 28 sites, max. 87 mg/L |
| Lead (Pb) | 2 | none | 3.4 | 40+ sites (LOR is 0.01 mg/L) | 0.1 | none |
| Manganese (Mn) | 0.2 | 1 site, max 3.1 mg/L | No values | NA | 5 | none |
| Mercury (Hg) | 0.002 | none | 0.06 | none | 0.01 | none |
| Molybdenum (Mo) | 0.01 | 2 sites, max 0.023 mg/L | No values | NA | 0.5 | none |
| Nickel (Ni) | 0.02 | 3 sites, max 0.15 mg/L | 15-150 | 5 sites | 0.2 | none |
| Selenium (Se) | 0.02 | none | 5 | none (LOR 0.005 mg/L) | 0.1 | none |
| Zinc (Zn) | 2 | none | 8 | 25 sites | 30 | none |

* Natural Superficial Aquifer groundwater commonly exceeds limit 1 mg/L, LOR = limit of reporting

1. ANZECC & ARMCANZ (2000) values reported in DEC (2010); 2. DoH (2006) values reported in DEC (2010)

## 4.9   Chloride ratios

Plotting major ions against chloride indicates the hydrochemical evolution of the groundwater, and relevant water – rock interaction. Figure 4-7a to 4-7e are plots of common major ions in groundwater plotted against chloride in units of milliequivialents per litre. The data is plotted against the conservative ion chloride to compensate for evapoconcentration of the water constituents. The blue line represents the seawater ratio of the respective ion/chloride combination.

The sodium to chloride (Na/Cl) ratio plots very close to the seawater ratio. This not only indicates that the groundwater recharge occurs from typical coastal rainfall, but also there is negligible dissolution of sodium rich minerals occurring in the aquifer that may be present.

Typical coastal rainfall recharge is also evidenced by the Br/Cl ratio which also deviates little from the seawater ratio.

The calcium to chloride ratio (Ca/Cl) deviates away from the seawater ratio indicating calcium enrichment. Previous studies have noted the sharp increase in the Ca/Cl ratio as groundwater flows from Bassendean Sand to Tamala Limestone (Yesertner 2009). Similarly as groundwater flows through the Ascot Formation it also dissolves carbonates mainly in the form of sea shells.

There are some samples that are enriched in potassium relative to chloride, most often in central parts of the study area. This may be the result of the weathering of K-feldspar in parts of the superficial and tertiary formations. It is known that microcline, a type of K-feldspar, is commonly found in the Rockingham Sand (Passmore 1970). Drilling undertaken for the *Murray hydrological studies* (Hall et al. 2010) also found traces of feldspar in varying amounts in the superficial formations and similarly in the Rockingham Sand, and therefore the enrichment of potassium relative to chloride may be a result of chemical weathering of K-feldspar.

The magnesium to chloride ratio (Mg/Cl) deviates little from the seawater ratio indicating there is little weathering of magnesium-rich minerals if present in the aquifer.

The mass ratio of chloride to sulfate (both in units of mg/L) was calculated and plotted in Figure 4-8. This illustrated elevated sulfate to chloride ratios in the Barragup Lake (PLI 3945) region, in wetland PLI 5724 and nearby groundwater bore HS99-1B. The source of the elevated sulfate could be fertilisers and other anthropogenic sources, or it may be the result of pyrite oxidation following disturbance of acid sulfate soil.

Multivariate analysis was used to explore trends in the major ion concentrations associated with screen depth in the Superficial Aquifer. With the exception of TDS values, principle component analysis (PCA) of major ion data showed that although variation between bores existed, there was no significant difference in bores screened less than 7 m bgl and bores screened greater than 7 m bgl (Figure 4-9). This indicates there is little change in the ratio of major ion in the vertical profile for a given location. Other multivariate analysis that included wetland chemistry also showed that the major ion composition of these waters was similar to the groundwater chemistry, which supports conclusions regarding their close interaction and the importance of groundwater levels to wetland levels (Hall et al. 2010c).

# 5    Discussion and conclusions

## 5.1    Acid sulfate soil risk assessment

The modelling identified that there were generally small increases or even decreases in risk of PASS exposure due to hydrological disturbance from drainage and development alone. However, it did identify increasing risk of PASS exposure with land development during drying climate combined with the use of garden bores in urban development. Note this study only assess the risk of watertable modification exposing potential acid sulfate soils, it does not assess the risks associated with short term activities such as de-watering during a developments construction phase, nor does it assess the volumes of acid that would be produced.

For scenarios S0, S11 and S15 the predictions from using AbMinGL and AAMinGL were compared. The results show that using the absolute minimum groundwater level for the modelling increased the number of extreme risk sites by 20% to 47% depending on the scenario. Risk management planning should assess whether maintaining AbMinGL above the level of potential acid sulfate soils during drought years is necessary.

An important finding of this study has been that fill and urban development may reduce the effect of a drier climate on PASS exposure risk. By raising the land surface the results indicate that the minimum watertable level is raised slightly. This is due to the root depth of vegetation being raised relative to the pre-development scenario with matching climate, as well as through a small amount of additional recharge that may occur in an urban setting. However most of these scenarios assumed that there was no groundwater drawdown due to garden bores which potentially reverses this effect. A further assumption is that as the climate becomes drier root depth remains constant. In reality the roots may 'chase' water and grow deeper. This will in turn lead to lower AAMinGLs than used here.

The risk resulting from garden bore extraction was incorporated into scenario S40. The results of the modelling agree with previous research that has shown that garden bores lower AbMinGL by between 0.6 and 1.0 m. The reduced groundwater levels are closely matched to the area of the urban development (Hall 2010c), and therefore increases the risk of exposing shallow PASS in developed urban areas, potentially freeing metals to be cycled into the urban environment via shallow bores.

The historical wet climate scenario illustrated that there had been little change in risk between the 1945–1974 period and the 1978–2007 period. This is mainly due to the aquifer continuing to fill until the phreatic surface reaches the ground surface in many areas, thus indicating that decreased rainfall has largely resulted in decreased runoff and evaporation rather than a lower watertable. The seasonally over-spilling Superficial Aquifer may have effectively buffered the risk of reduced water levels in the past. Continuing declines in rainfall or increased extraction may remove this buffer, resulting in the summer drying cycle starting from a lower level and ending with lower minimum groundwater levels.

A drying climate is demonstrated to be an important factor increasing the risk of PASS oxidation. Scenario S27 shows a markedly higher risk profile than S0 with eight more extreme risk sites in the study area and a similar number of high risk sites. These numbers

illustrate that a drying climate may eventually result in actual acid sulfate soils, which may affect water quality in certain areas if not managed. Consideration may have to be given to the management and suitable uses of groundwater if climate change predictions are fulfilled.

A major limitation with the study has been the diminished sensitivity of the results due to the mean sea level rule explained in Section 2.2. The impact that this has on the results varies for each scenario. For example S0 AAMinGL had 103 sites with a modelled watertable height increased to 0.0 mAHD, compared to 132 sites for S27 AAMinGL. Because 103 sites are already set to 0.0 mAHD, this same number shows no reduction in water level across the two scenarios.

Further improvement in the calibration of the modelled seasonal minimum water levels would be ideal. However data shortfalls such as a lack of water level observations and plant root depth information mean this is difficult. The large model grid size in the groundwater model also causes errors in undulated areas. Local area models such as the wetland models constructed in Hall et al. (2010b) would improve model accuracy and may also allow smaller 90th percentiles to be used for risk classification.

Within the scope of this project we are confident this study illustrates the broad risks of how climate and land-use change may affect PASS oxidation as a result of watertable height modification. Local studies for development are still required as the scale of this study is not appropriate for understanding risks at the individual development scale.

## 5.2  Hydrochemistry

As part of the *Murray hydrological studies* a hydrochemistry survey of the Superficial Aquifer was completed over the period 2008 to 2009. The hydrochemistry investigation was undertaken to further understand groundwater hydrodynamics, determine regional patterns in groundwater quality, discuss probable water-rock interactions and identify potential acid sulfate soil issues. Understanding the water quality is particularly important for understanding the suitability of the groundwater for different purposes, and identifying potential environmental risks that reside within the groundwater. A total of 64 bores and 9 wetland sites were sampled for this study.

The groundwater is generally suitable for irrigation although in some areas use will be limited due to poor water quality. Salinity was less than 1500 mg/L in all but four locations, The hydrochemistry investigation identified two distinct water types, one dominated by silica weathering north of the Murray River, the other dominated by carbonate dissolution south of the Murray River. These reflect the aquifers the water is flowing through and indicate the waters south of the River Murray are more strongly buffered against acidification. pH was usually slightly acidic to neutral; however pH values of less than 4 around Greyhound Rd wetland PLI5032 may indicate that the groundwater is becoming affected by acid sulfate soil oxidation. Further investigation will be required to establish the cause of this acidity.

High average concentrations of iron in the order of 4-6 mg/L may reduce the number of suitable uses for groundwater due to the likelihood of clogging of irrigation systems and staining. High iron concentrations may also contribute to acidity under certain conditions and therefore care should be taken when using these waters.

High nutrient concentrations were evident in many bores, with the highest values being observed in the Nambeelup region. For both TP and TN the nutrient concentration in the wetlands and the nearby shallow Superficial Aquifer was closely related. Managing the water quality of wetlands will therefore require a holistic approach including management of the interacting shallow groundwater system. Where there are high levels of nutrient in the groundwater the mobilisation of these nutrients may become issue as the lithology and aquifer dynamics are disturbed.

There are some groundwater samples which exceed guideline concentration values for metals and metalloids. Most of the groundwater is suitable for irrigation and domestic non-potable use; however, the groundwater must be used appropriately to avoid potential adverse consequences. The analysis of major ion to chloride ratios indicates there are regional differences in the hydrochemistry, however PCA indicates there is little difference in the major ion composition between shallow and deep screened bores in the Superficial Aquifer.

In conclusion, if the Superficial Aquifer is developed as a water resource it must be recognised that there are areas which will have water quality which is unsuitable for certain uses. The data indicates interaction between the shallow Superficial Aquifer and wetlands, and therefore the management of water levels in the aquifer is also important for both minimising risks associated with the oxidation of acid sulfate soils and managing protected wetlands.

# Figures
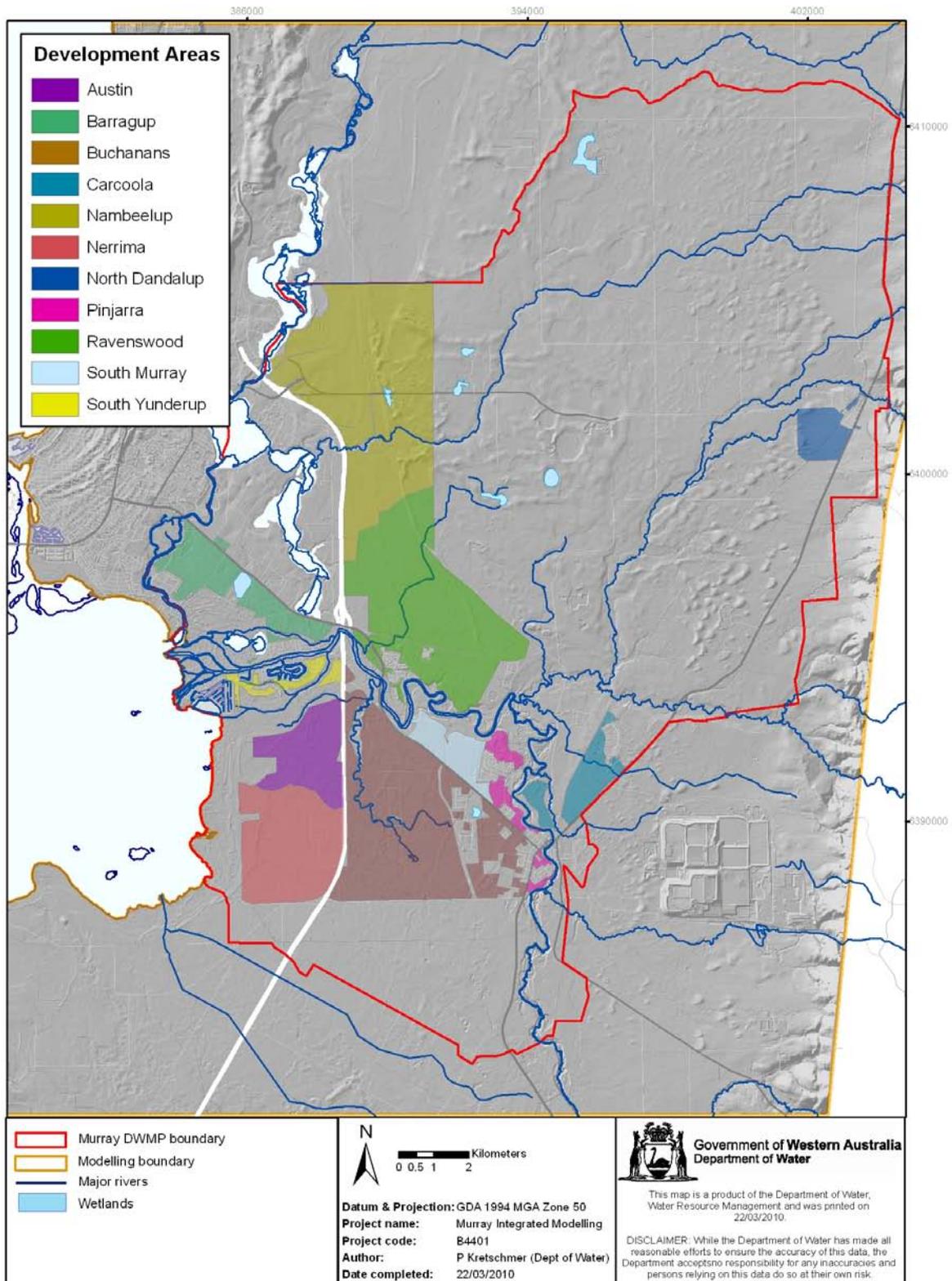
*Figure 1-2: Proposed urban development areas in the Murray DWMP region.*
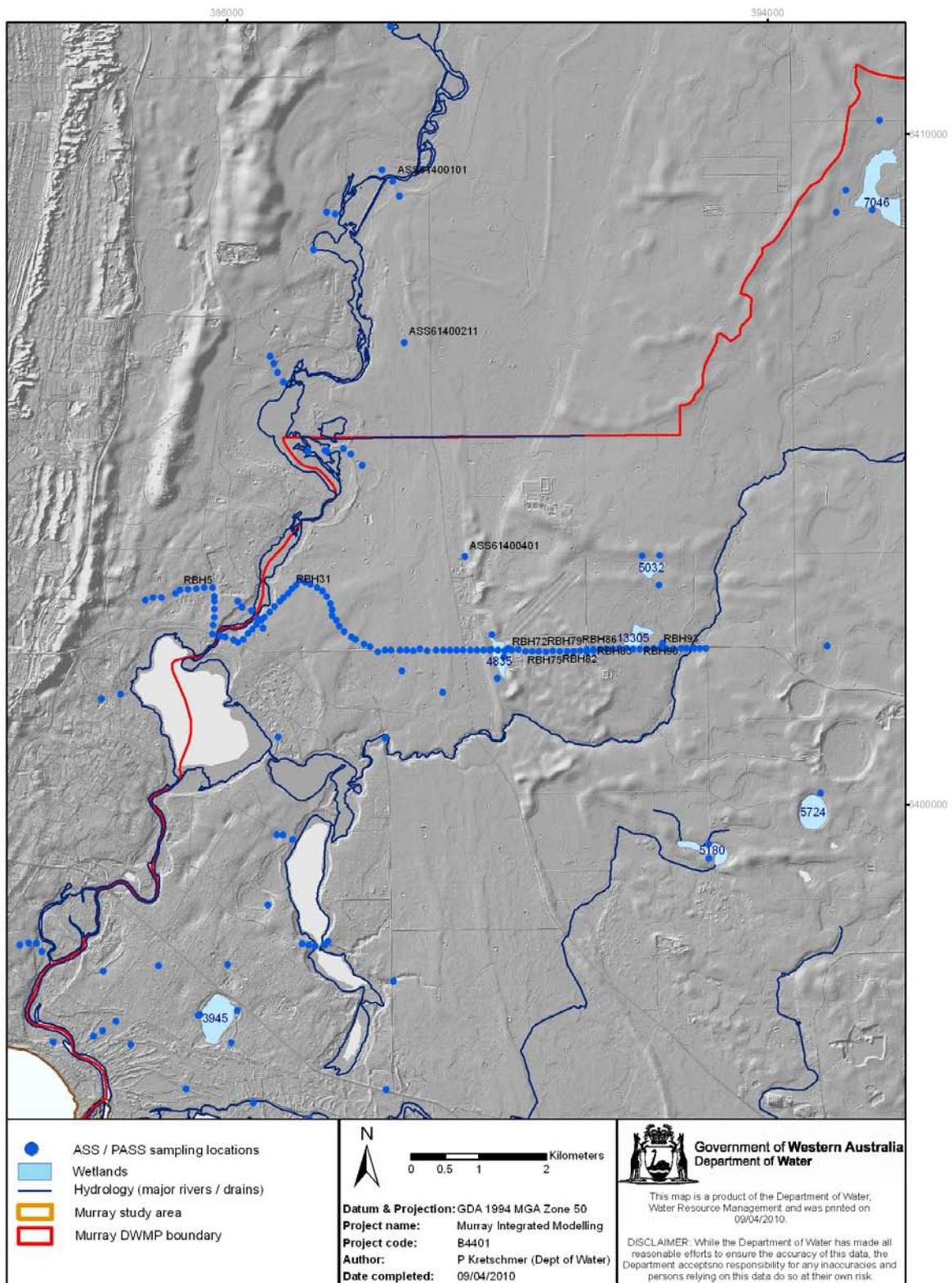
*Figure 2-1a: Wetlands and acid sulfate soil investigation sites located in the northern study area. Sites rated as extreme risk have been labelled.*
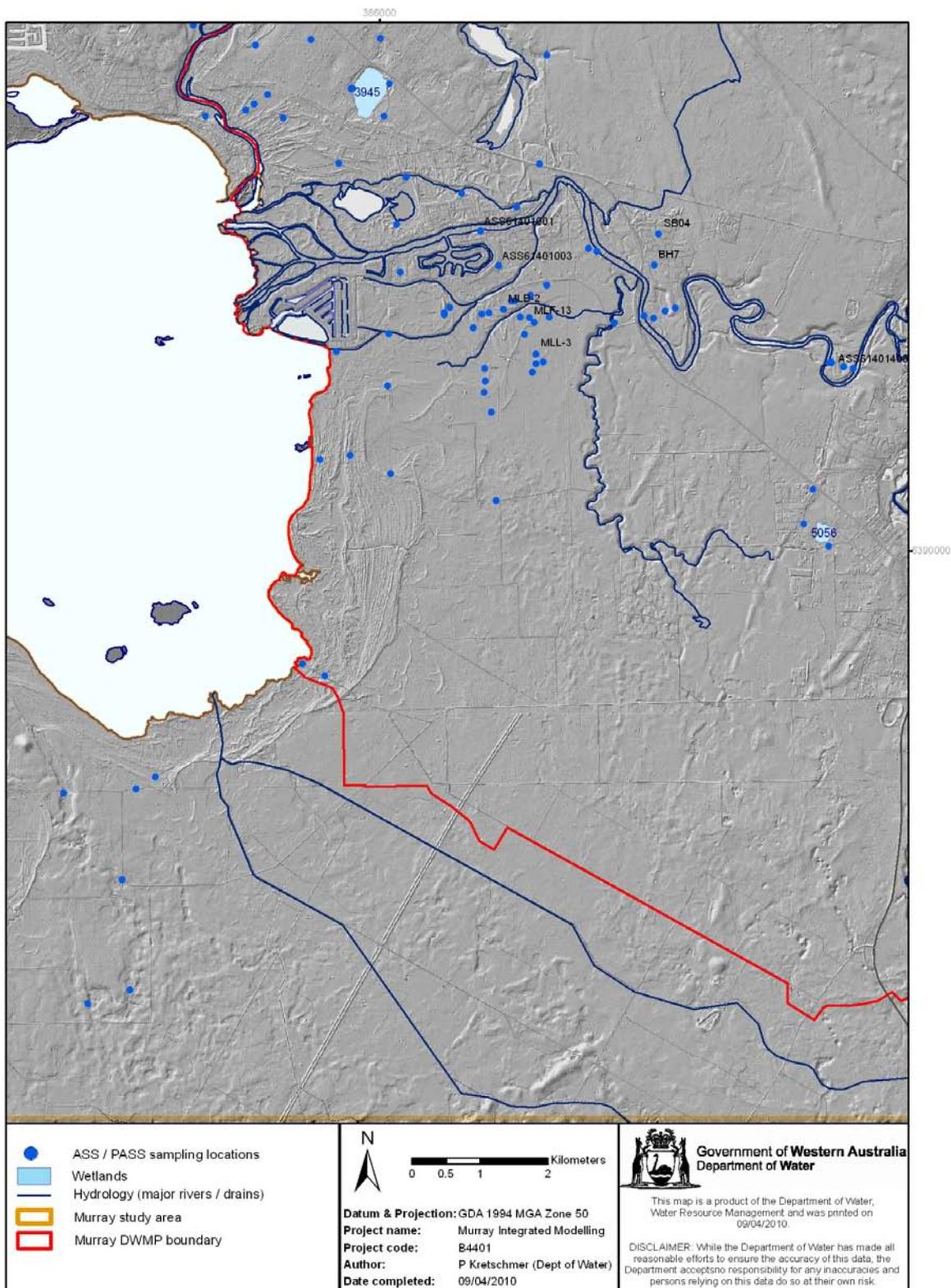
*Figure 2-1b: Wetlands and acid sulfate soil investigation sites located in the southern study area. Sites rated as extreme risk have been labelled.*

*Figure 2-2: Groundwater sampling locations.*
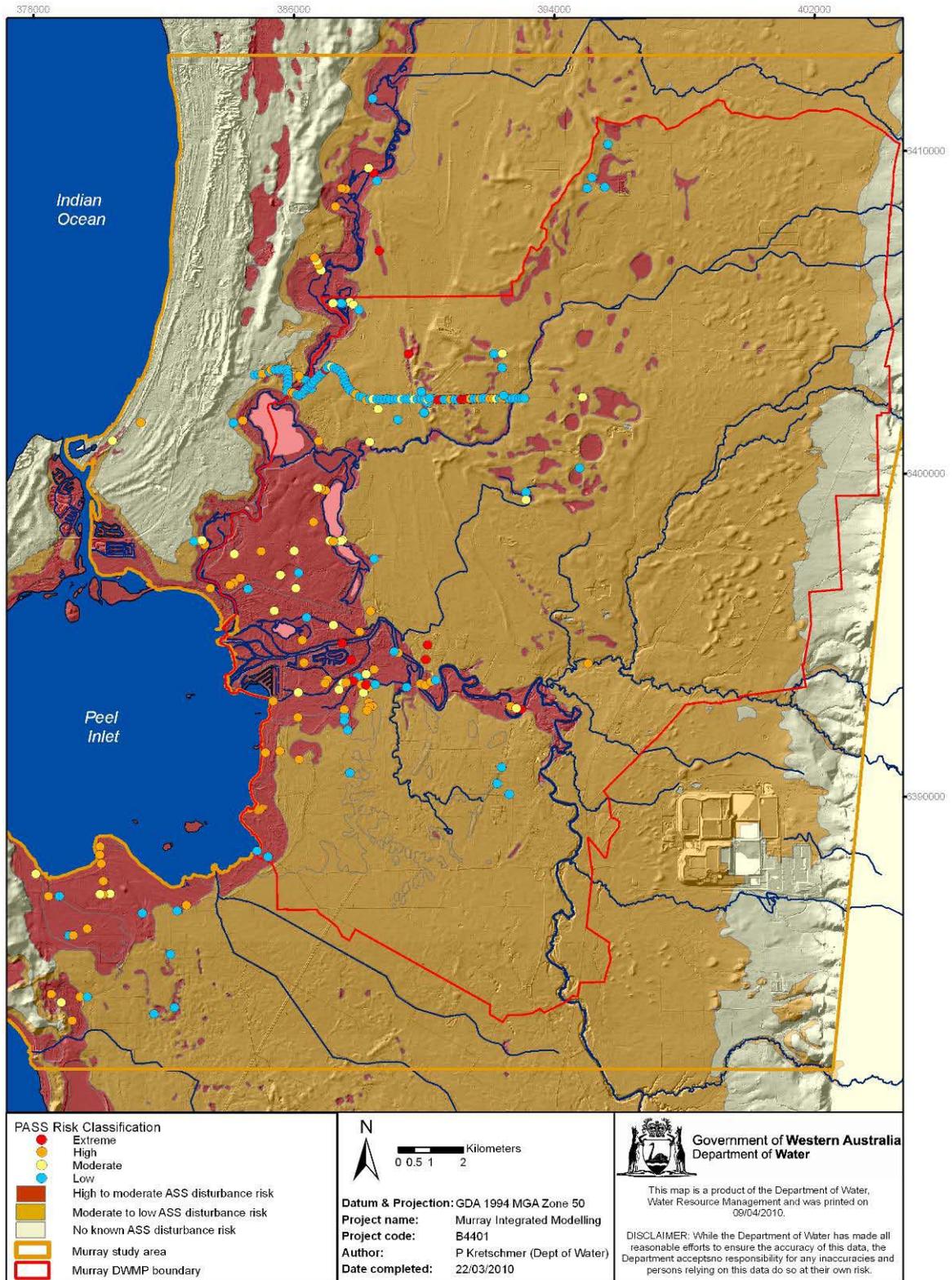
*Figure 3-1a: Scenario 0 AAMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
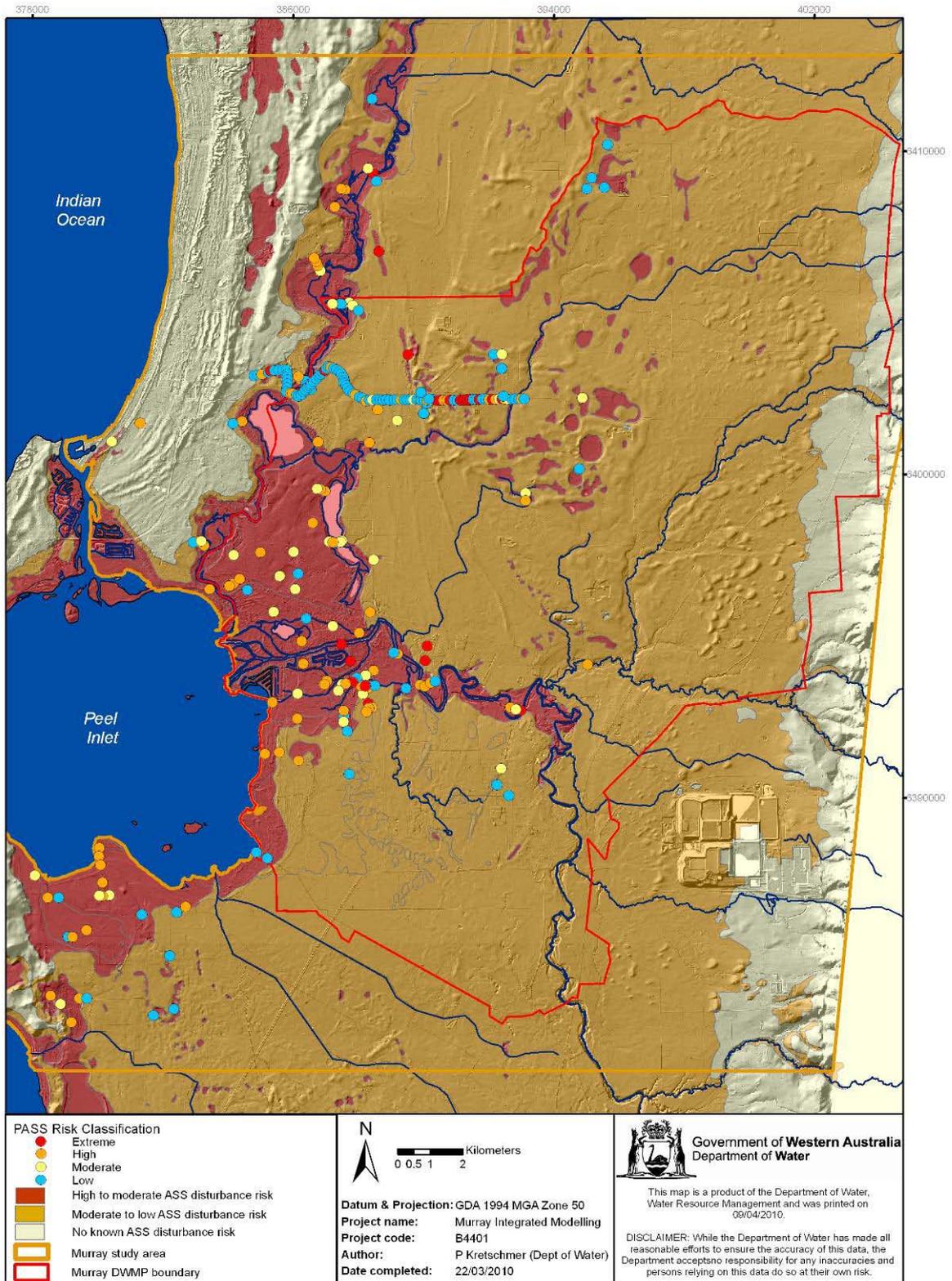
*Figure 3-1b: Scenario 0 AbMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
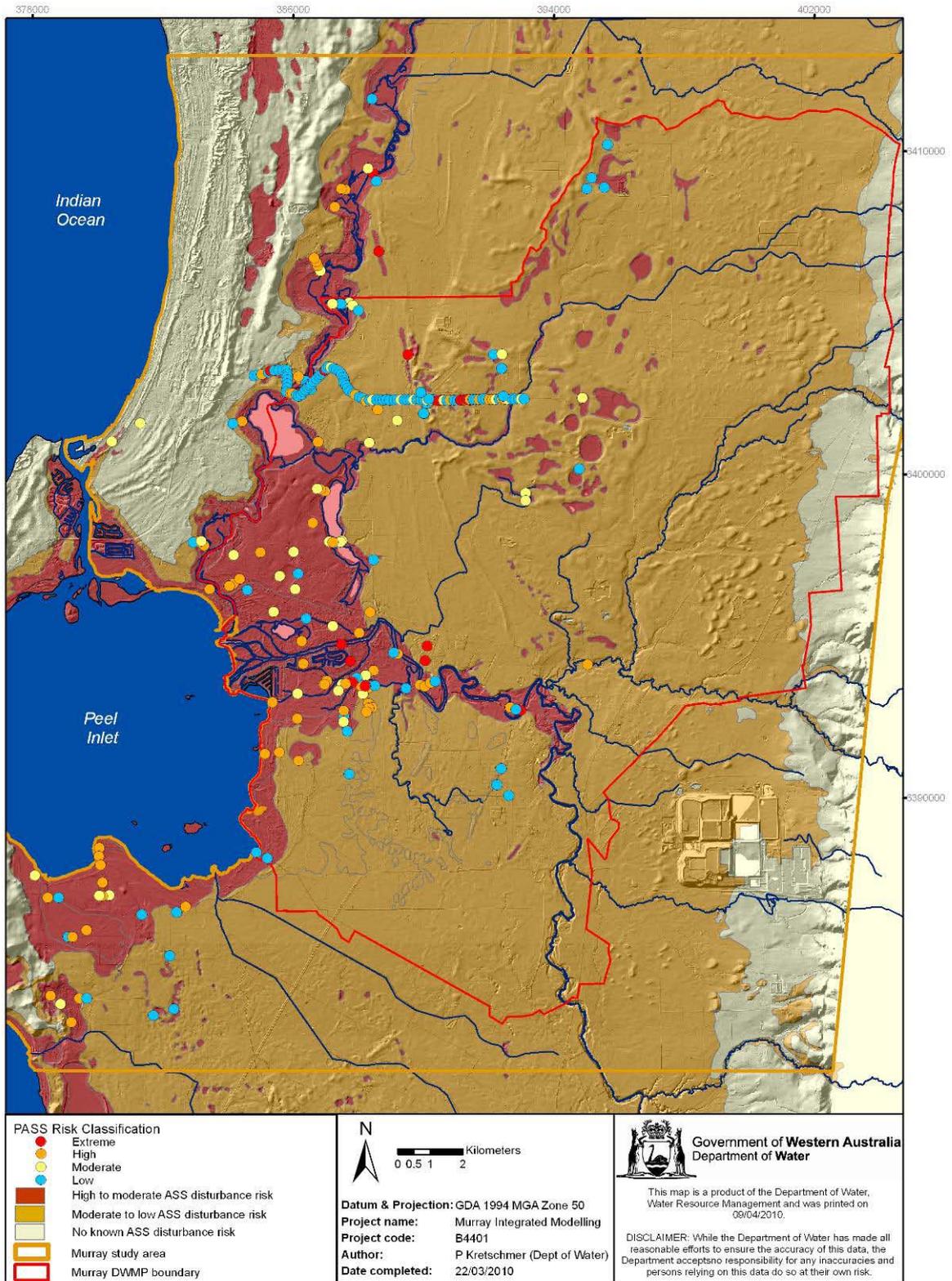
*Figure 3-2: Scenario 9 AAMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
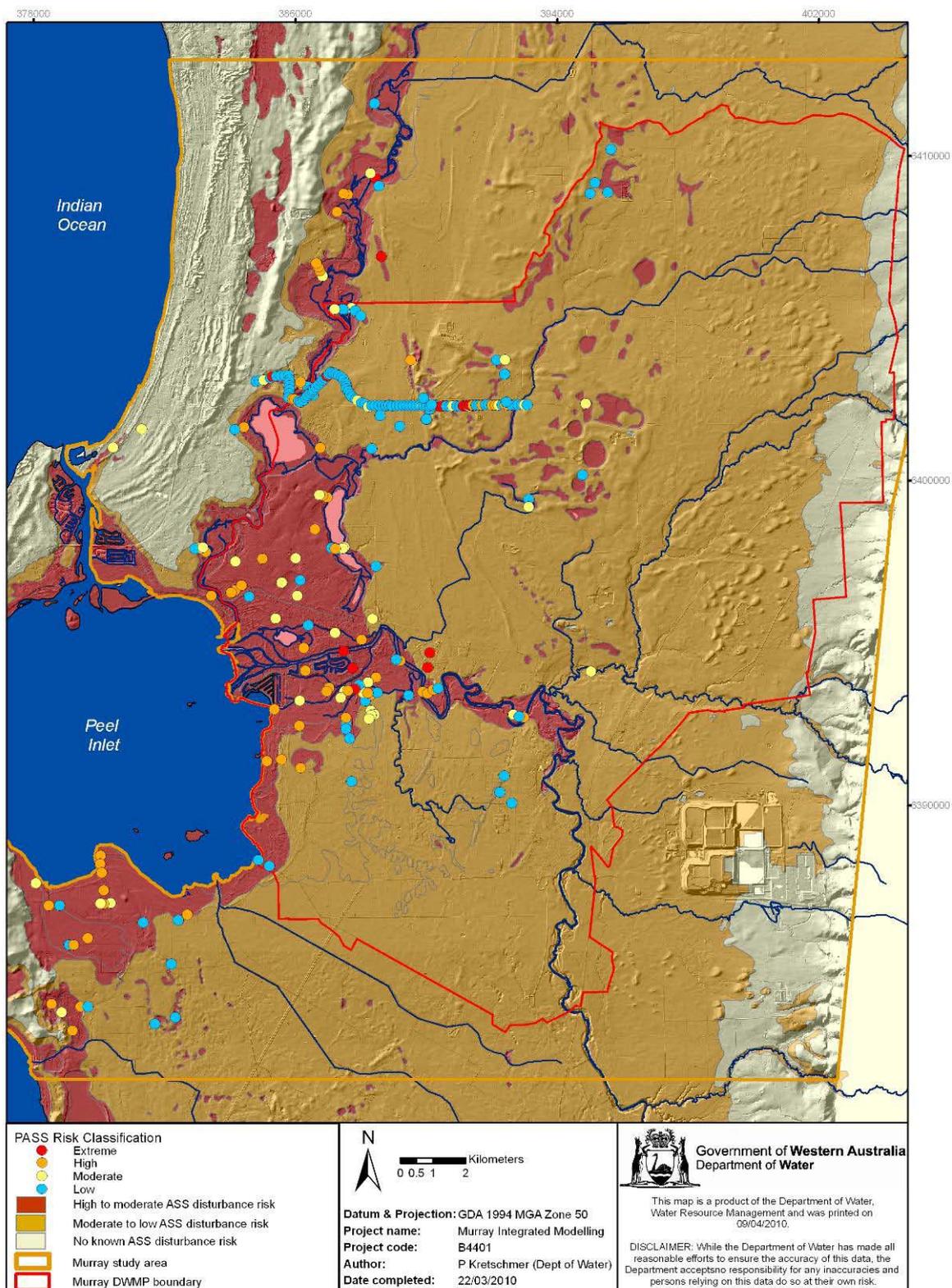
*Figure 3-3a: Scenario 11 AAMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
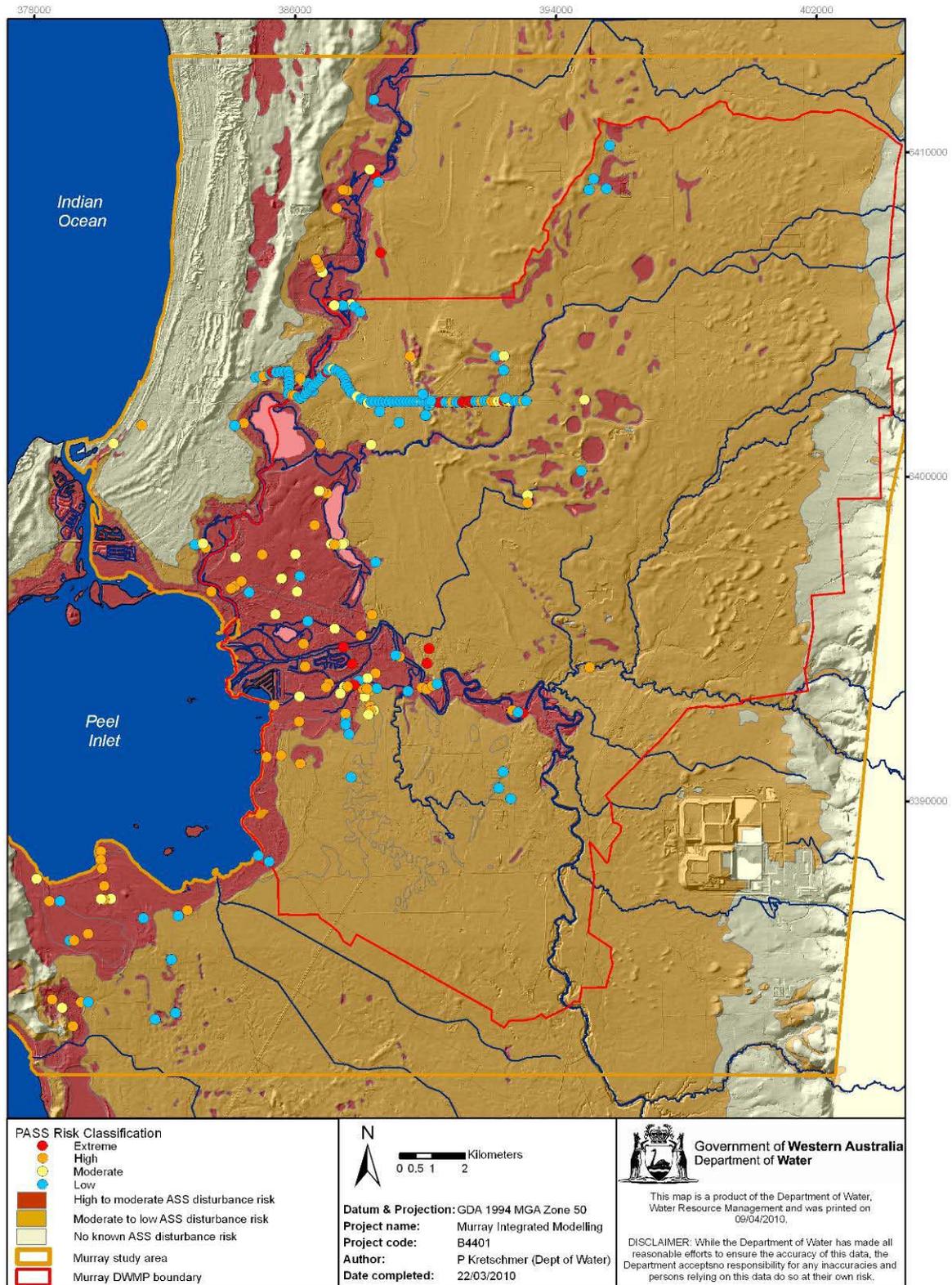
*Figure 3-3b: Scenario 11 AbMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
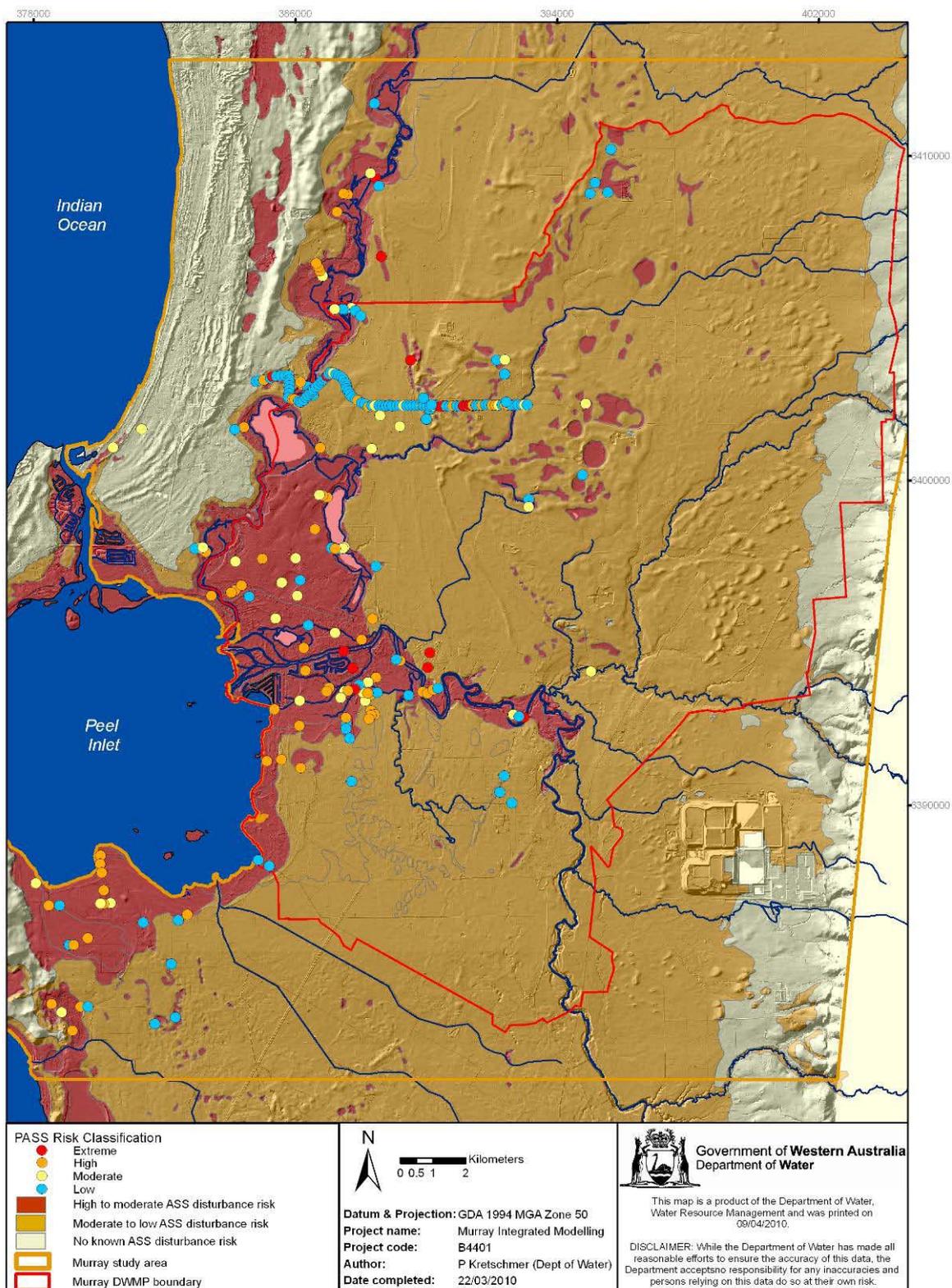
*Figure 3-4a: Scenario 15 AAMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
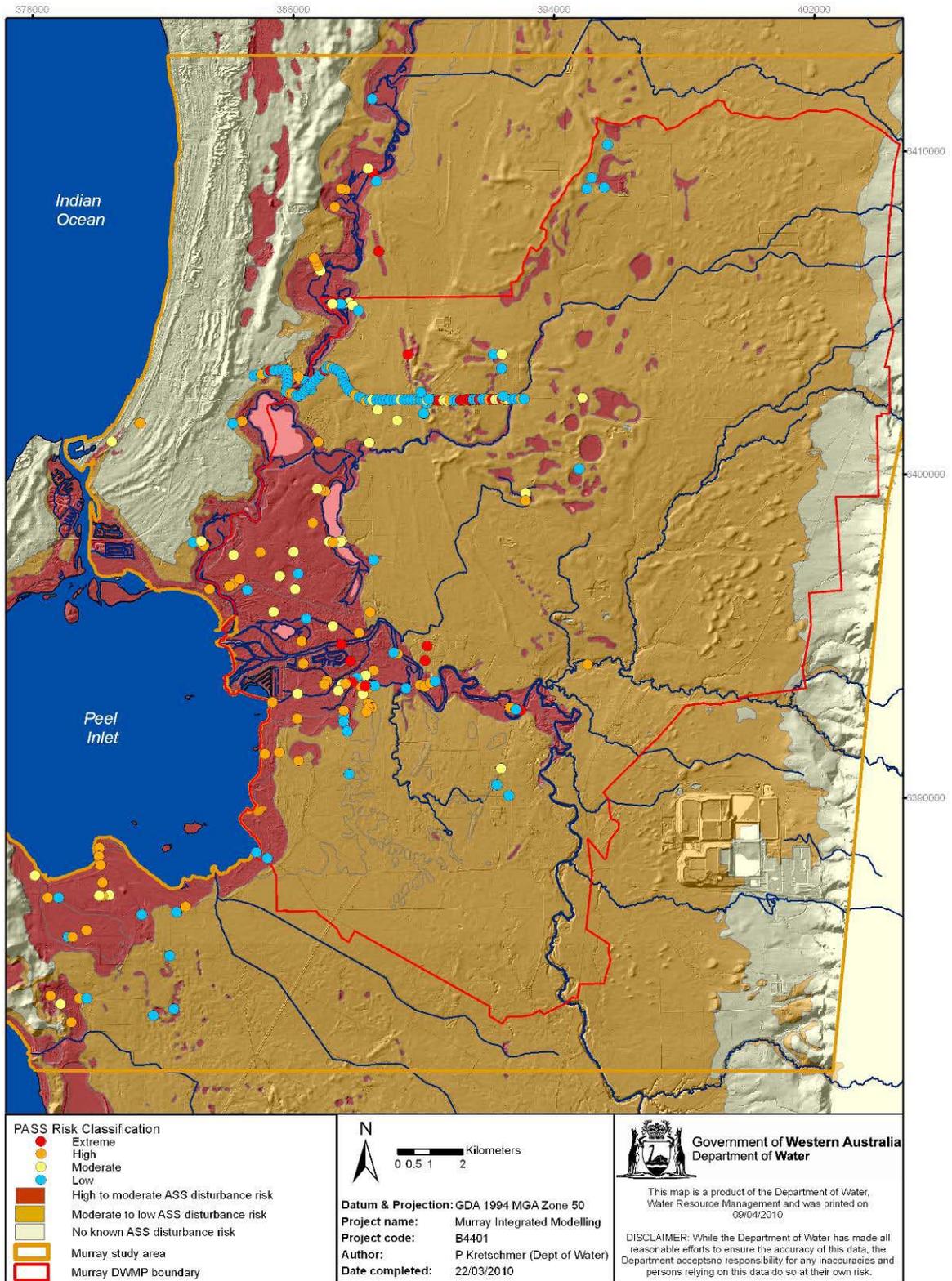
*Figure 3-4b: Scenario 15 AbMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
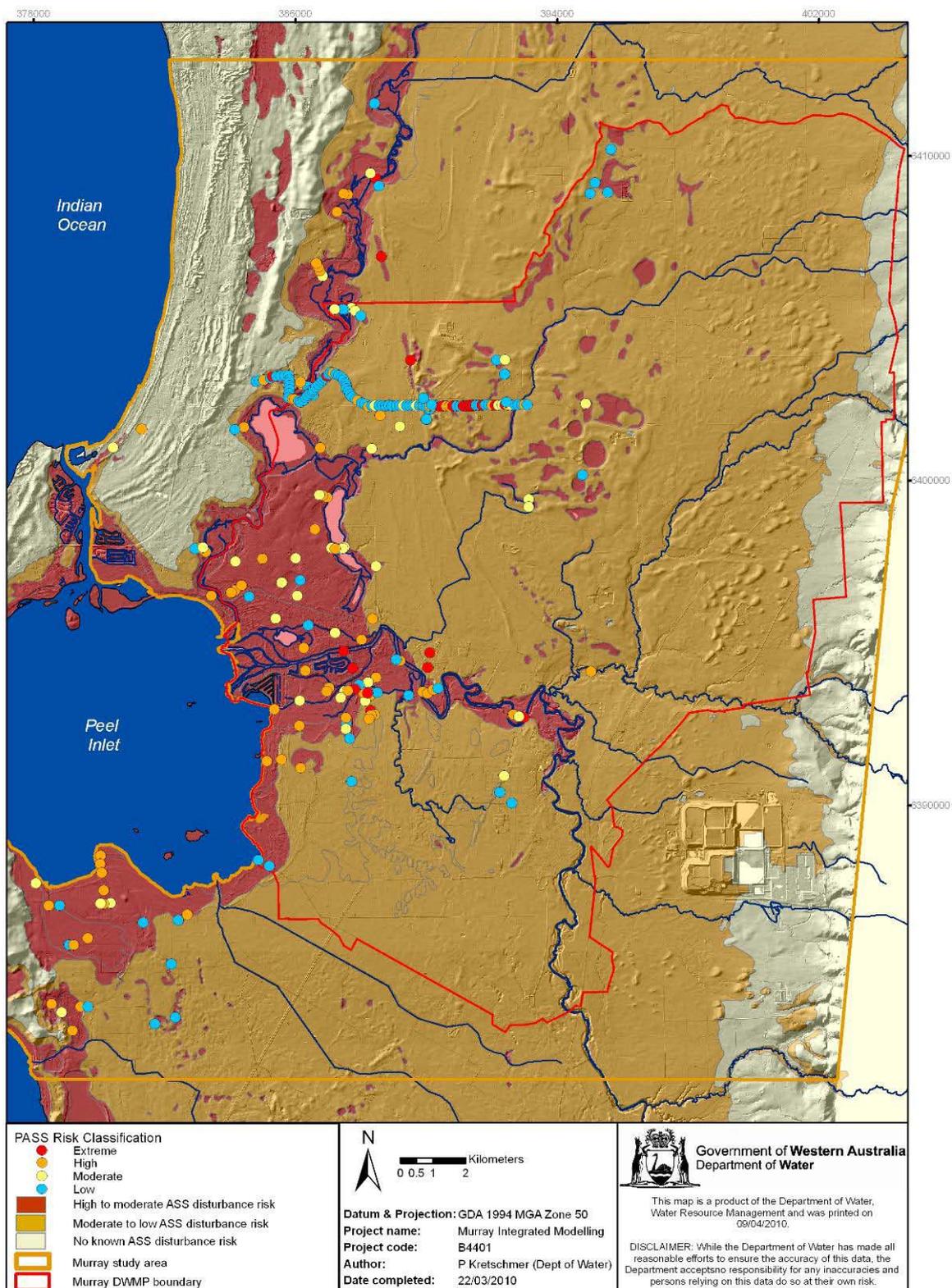
*Figure 3-5: Scenario 27 AAMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
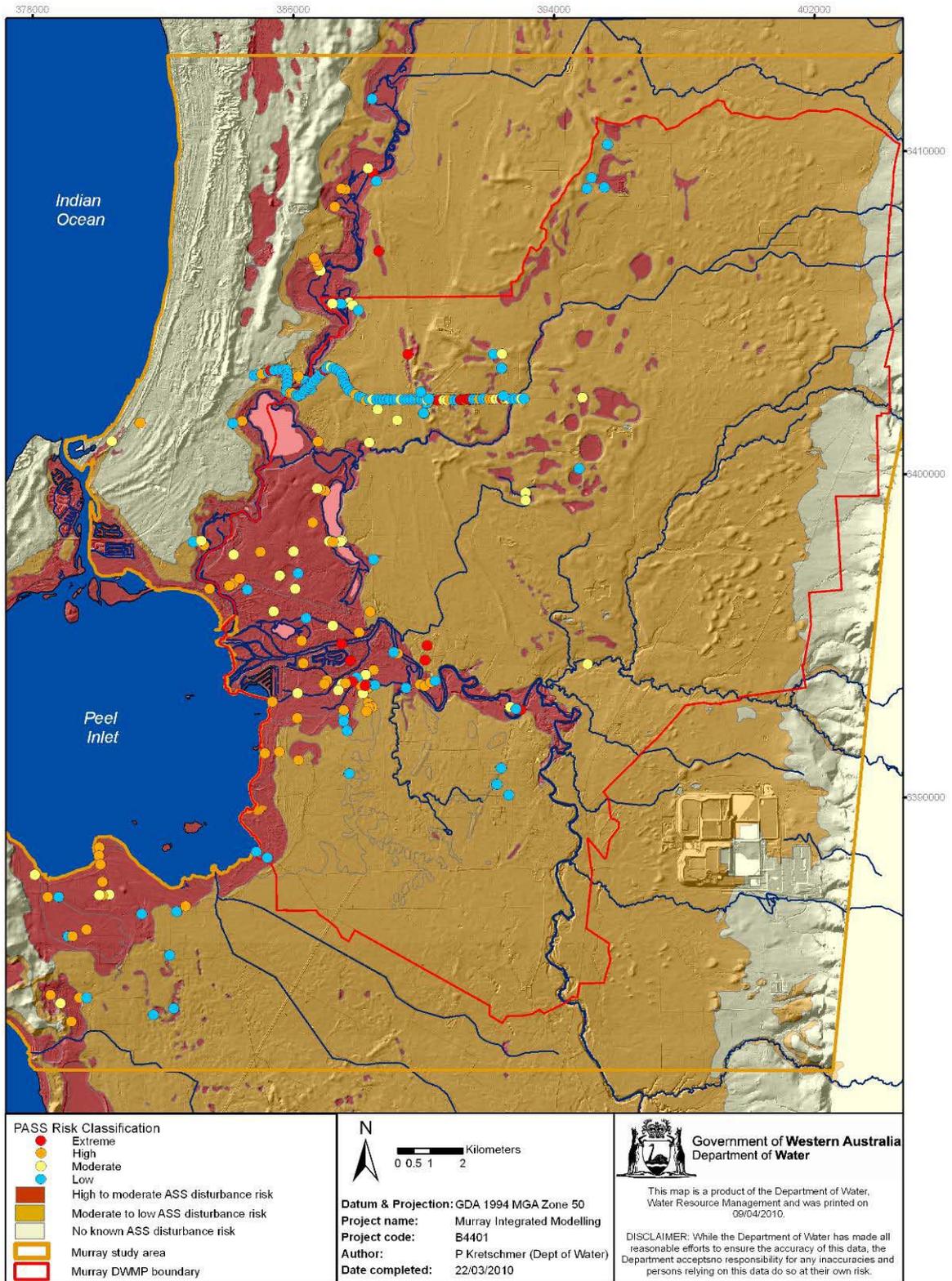
*Figure 3-6: Scenario 33 AAMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
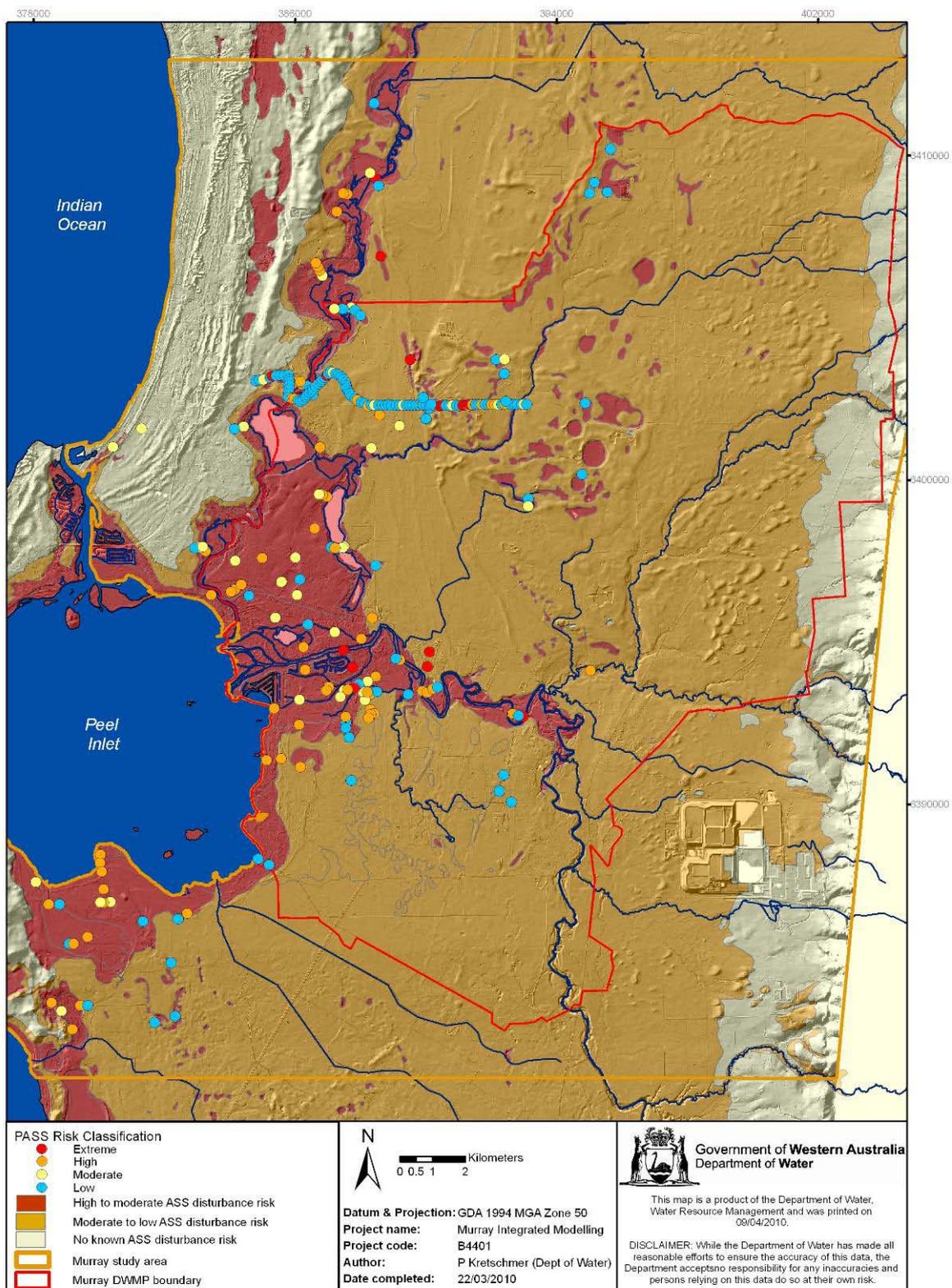
*Figure 3-7: Scenario 36 AAMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
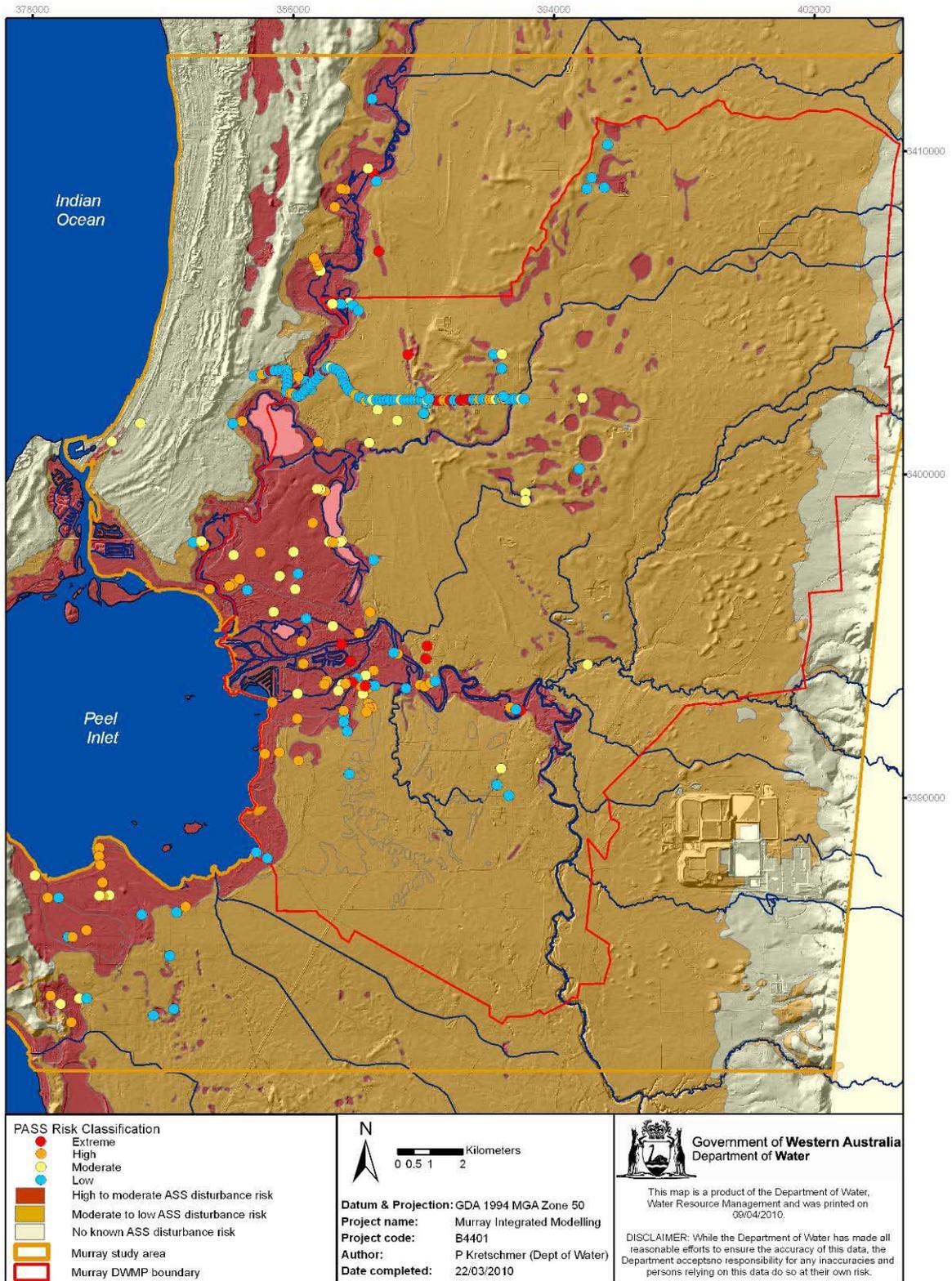
*Figure 3-8: Scenario 40 AAMinGL PASS oxidation risk assessment. Soil risk map from Degens (2009).*
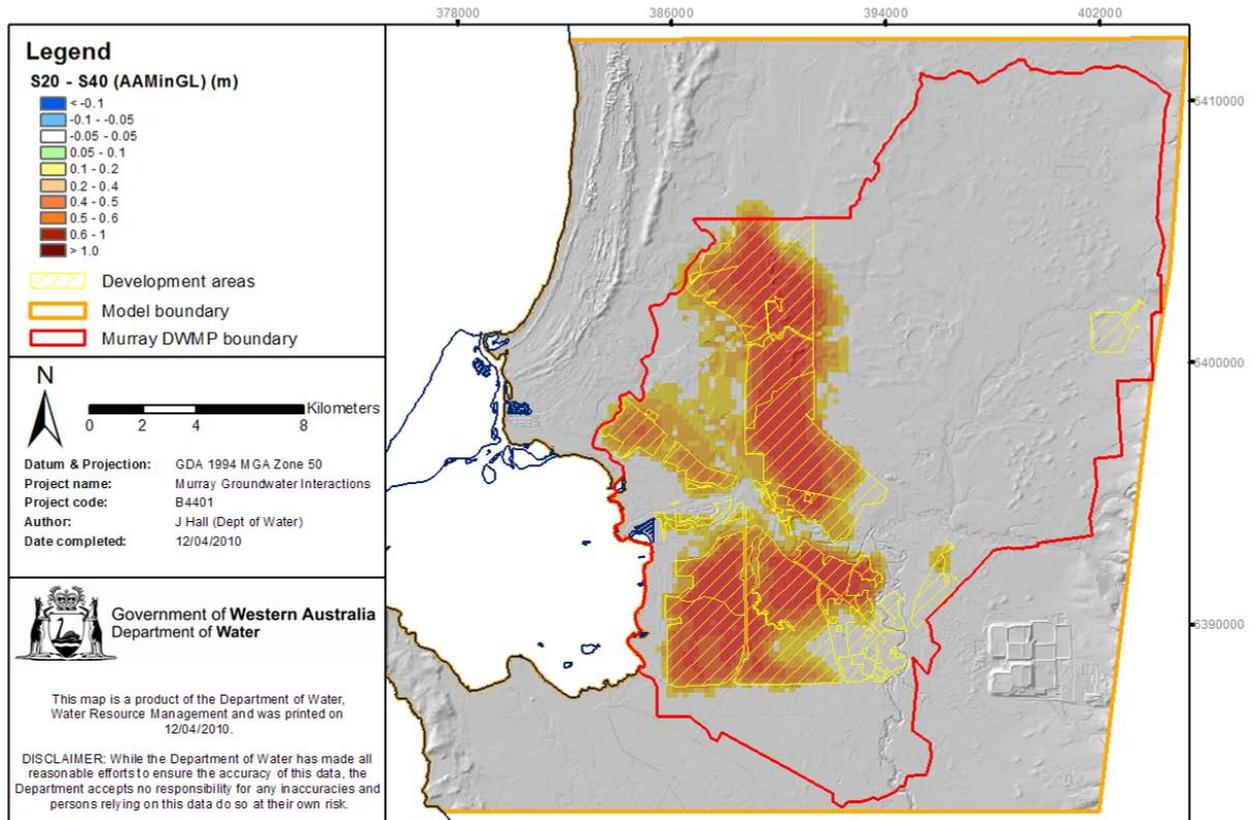
*Figure 3-9: The difference in AAMinGLs resulting when garden bore abstraction is added to the model. Source: Hall et al. 2010c.*
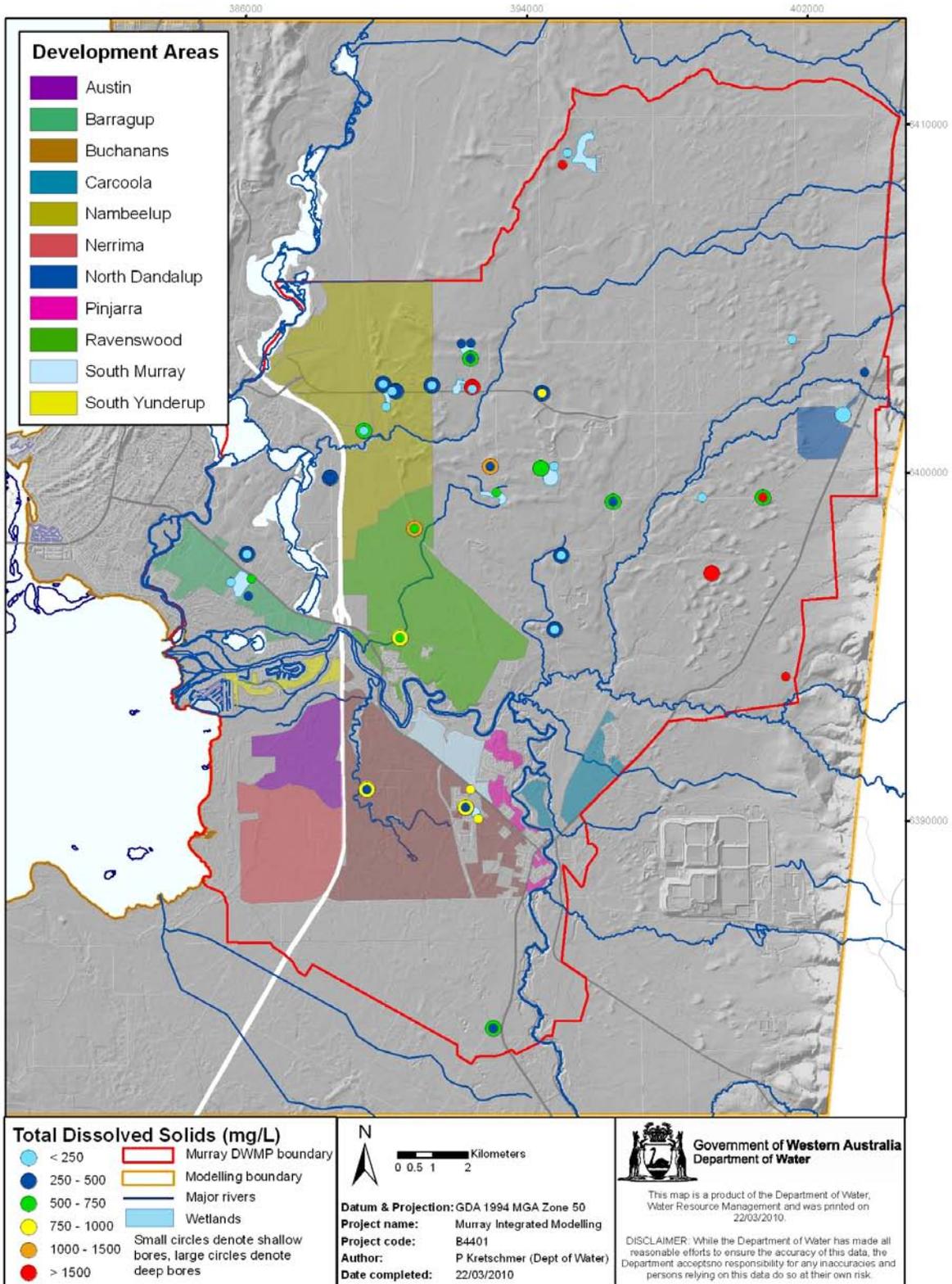
*Figure 4-1: Groundwater total dissolved solids. Note TDS tends to be higher in the deeper (large circle) bores.*
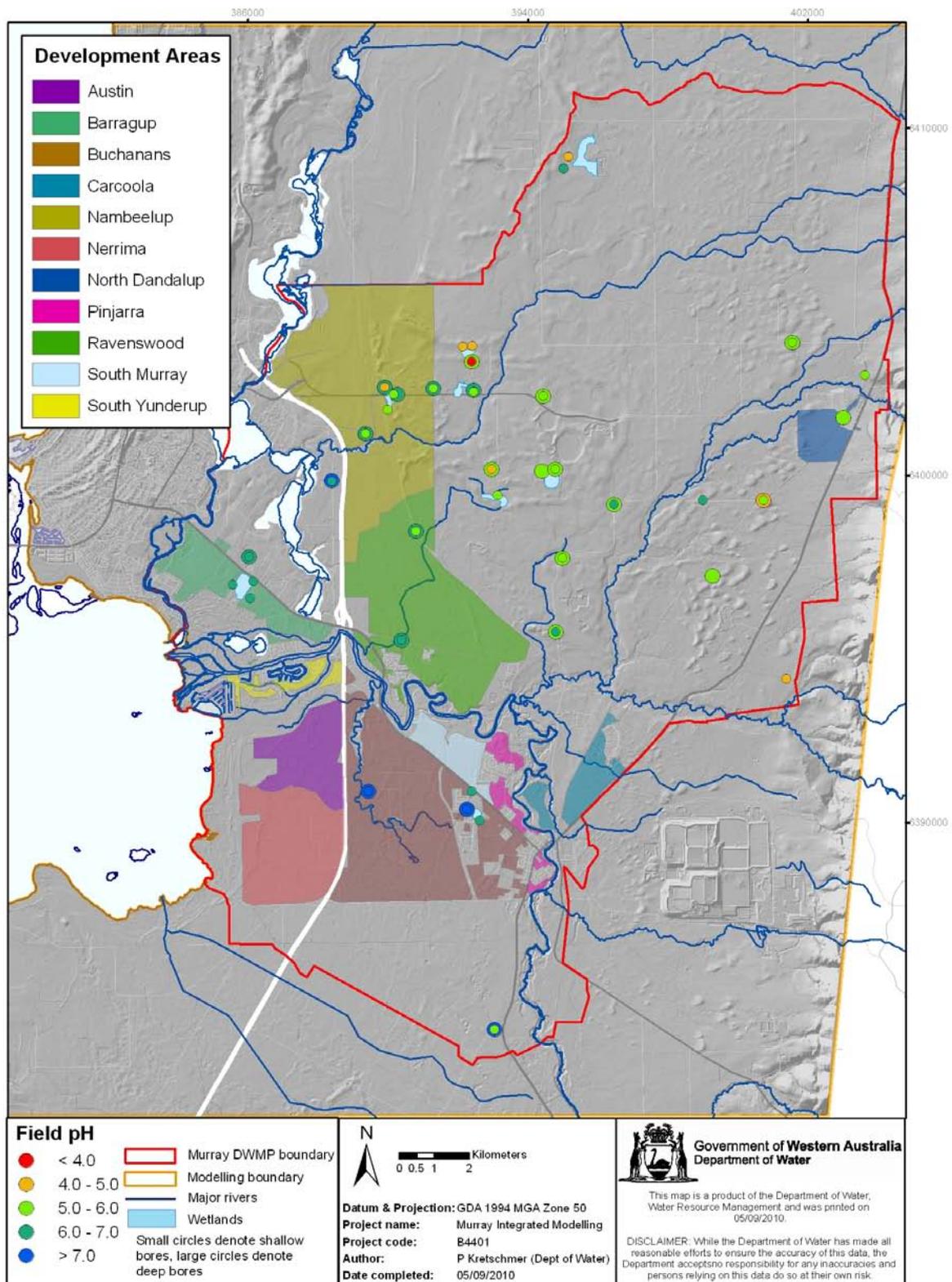
*Figure 4-2: Groundwater pH as measured in the field. Note there is a general increase in pH from the north-east to south-west.*
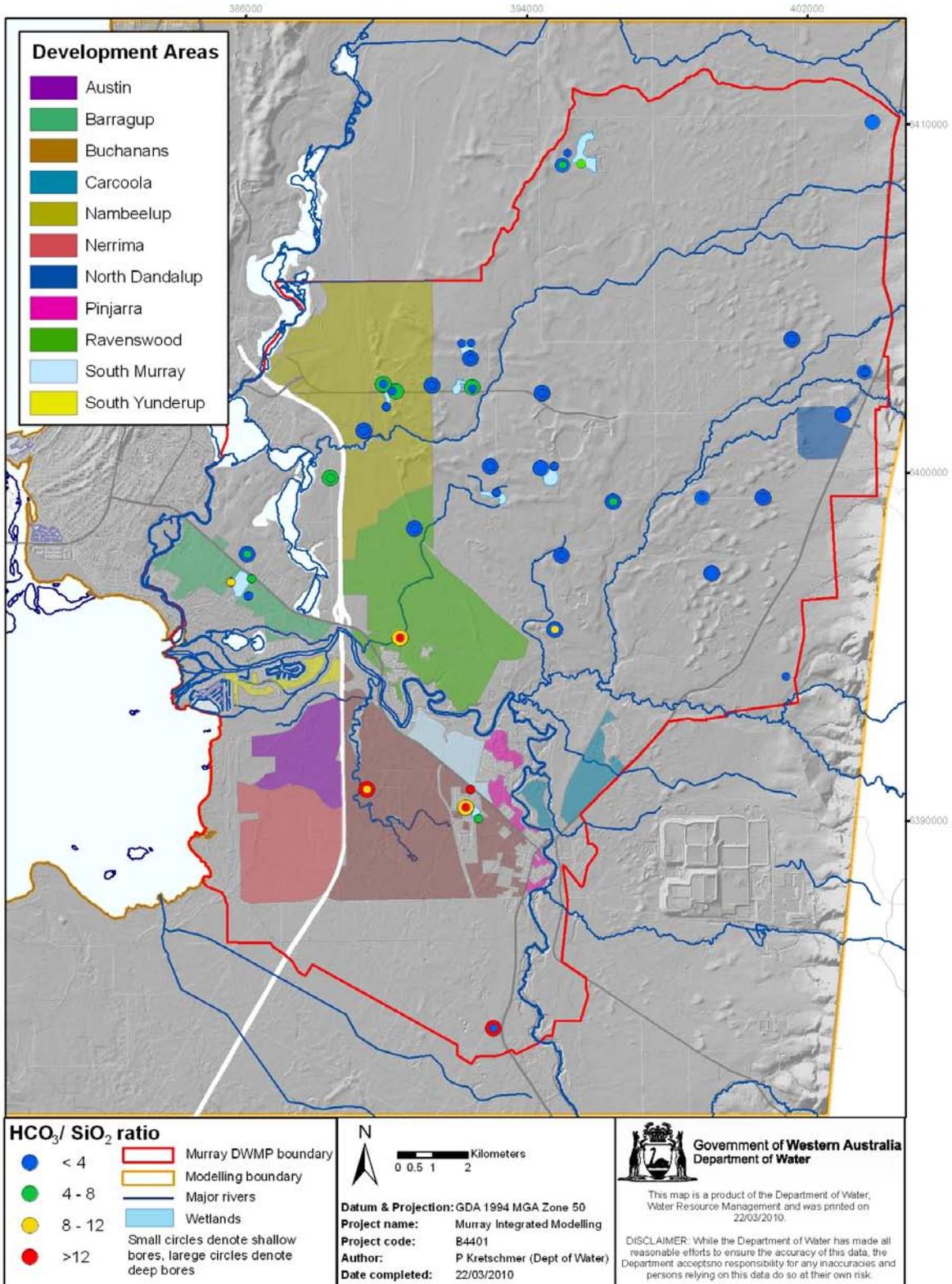
*Figure 4-3: Groundwater bicarbonate – silica ratio. Note the significant separation types between north and south of the River Murray.*
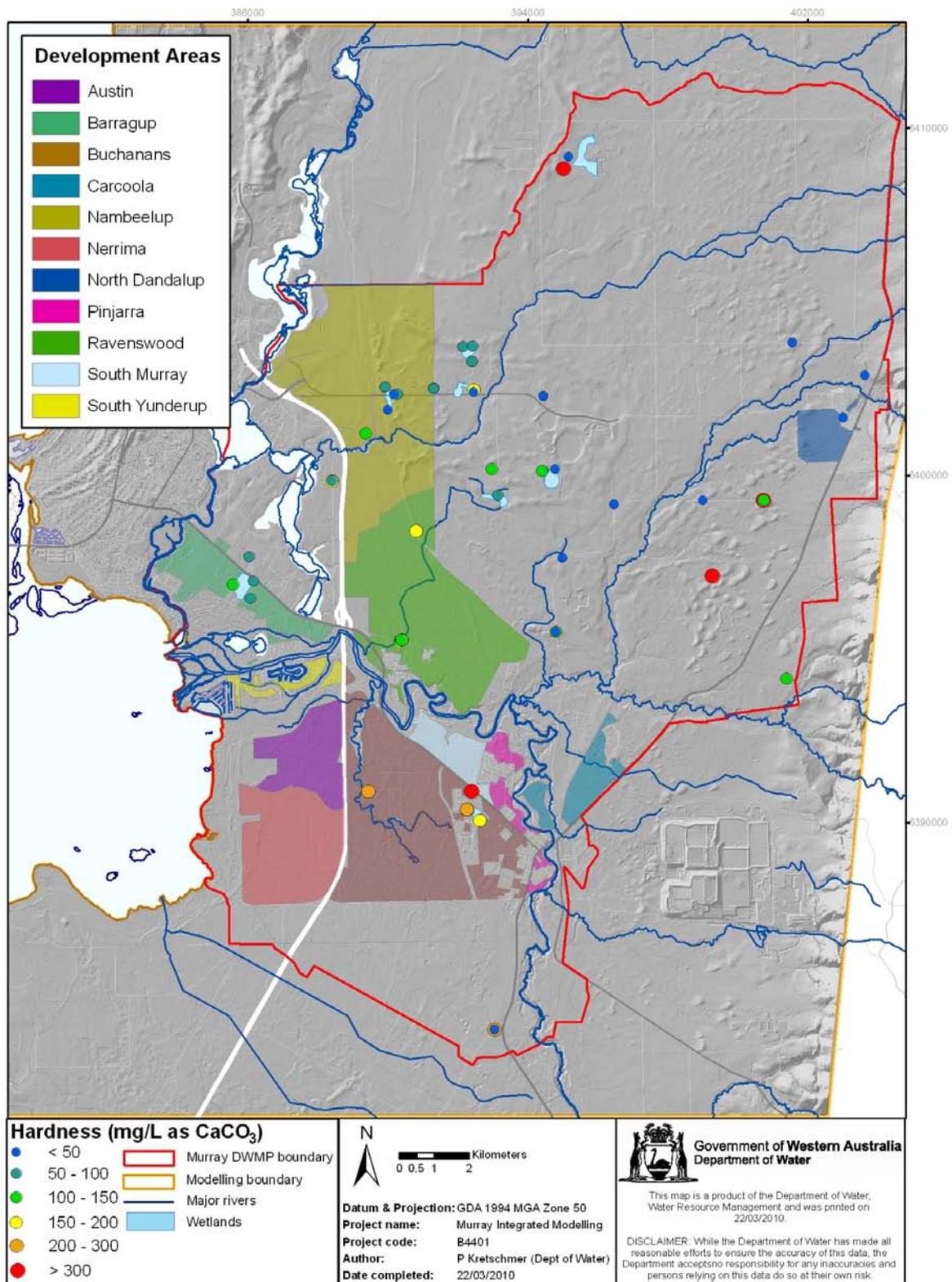
*Figure 4-4: Groundwater hardness.*
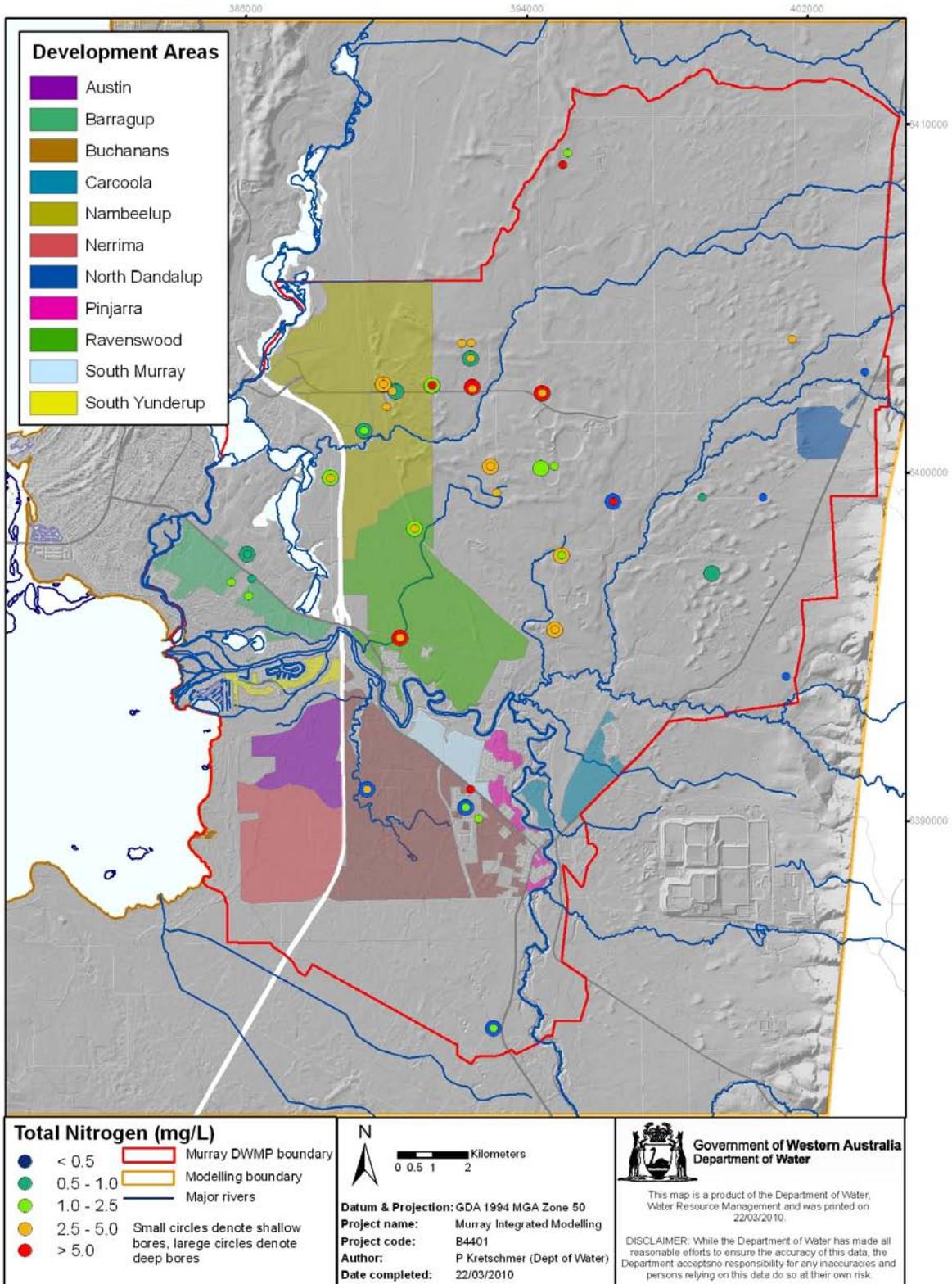
*Figure 4-5: Groundwater total nitrogen concentration.*
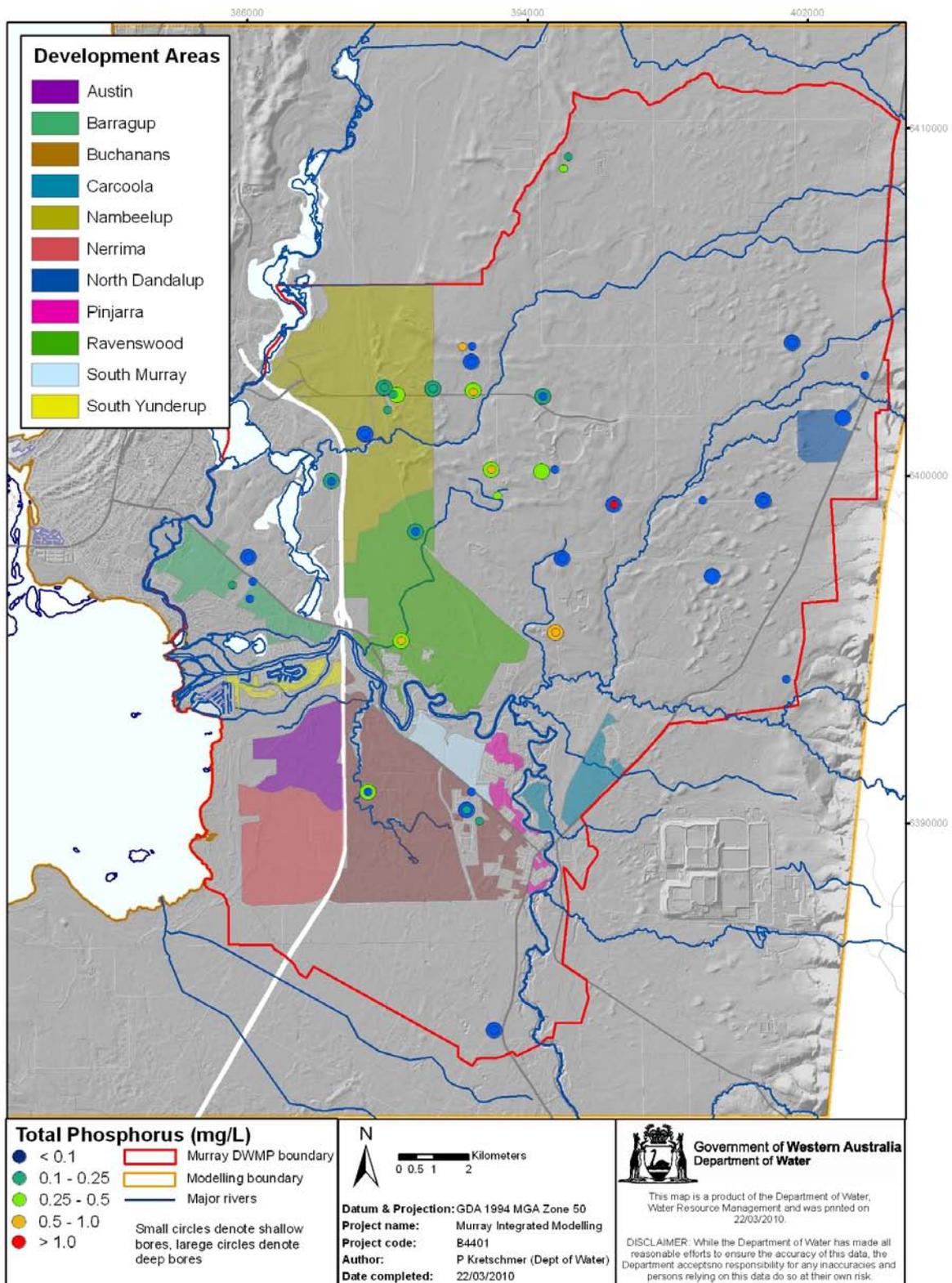
*Figure 4-6: Groundwater total phosphorus concentration.*

*Figure 4-7:     Major ions plotted against chloride (horizontal axis). Note the blue line denotes the seawater ratio for the respective major ion.*
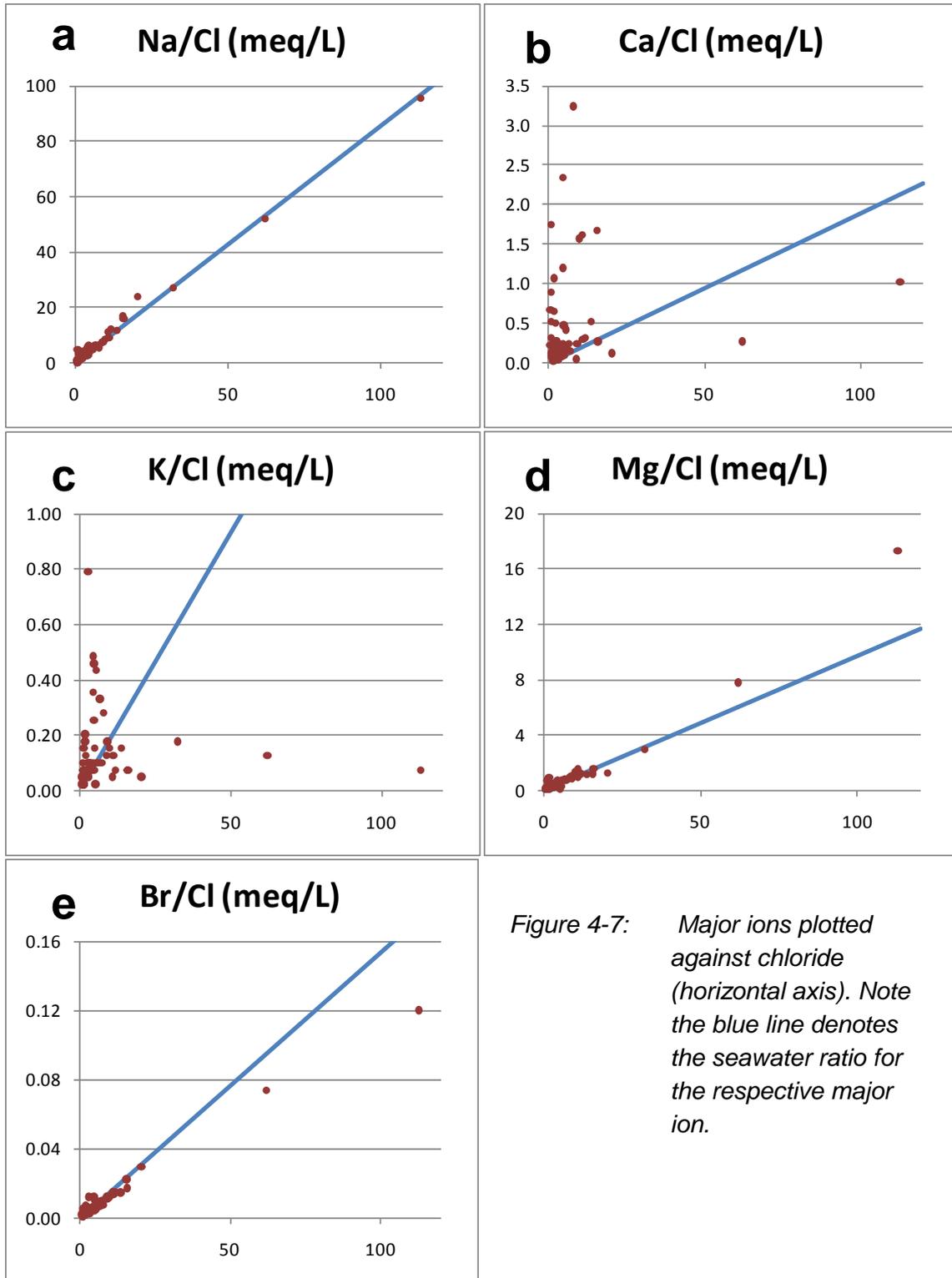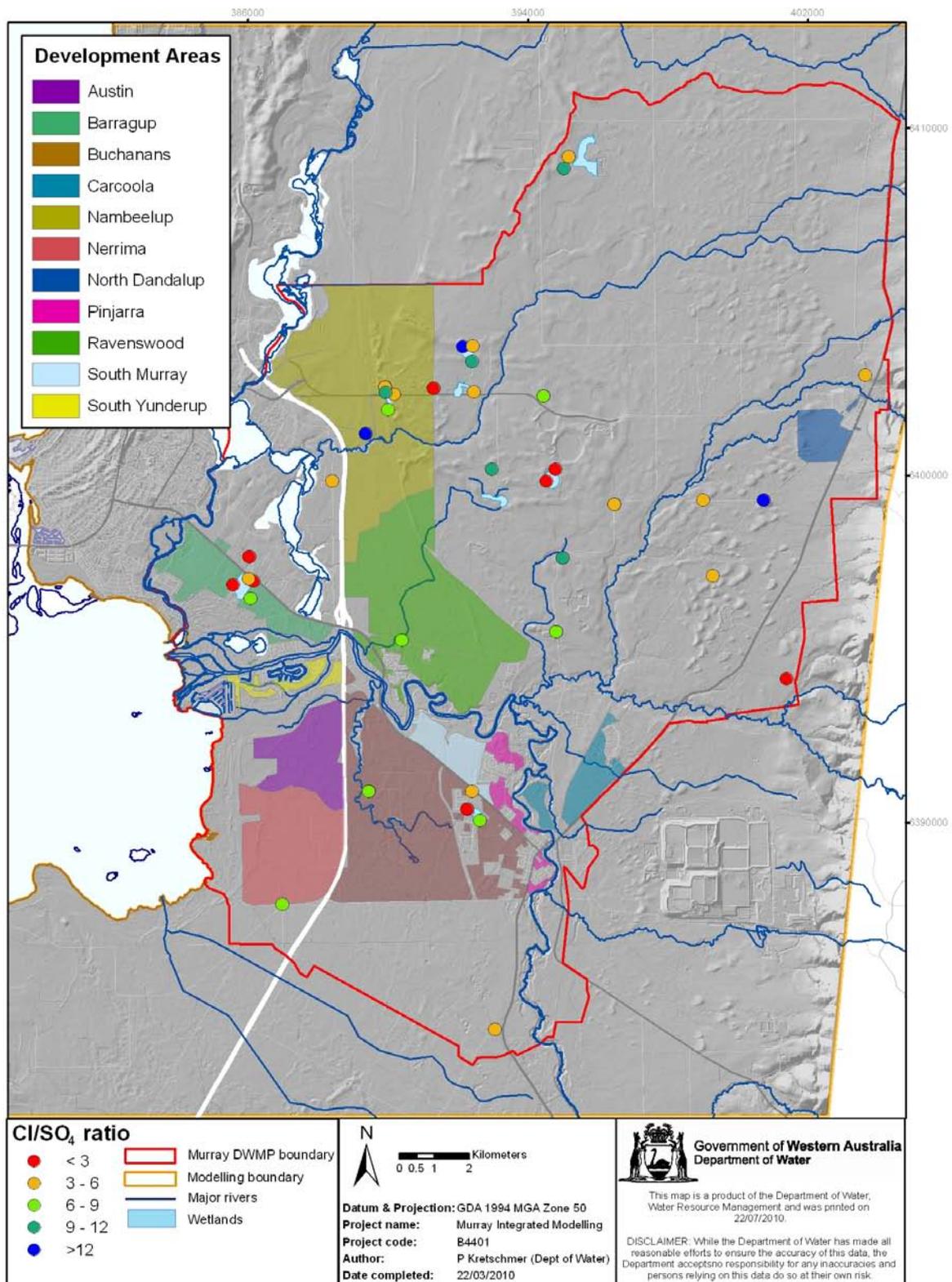
*Figure 4-8: The chloride to sulfate ratio indicated that sulfate levels were elevated near Barragup Lake (PLI 3945) and wetland PLI 5724 in the centre of the study area.*
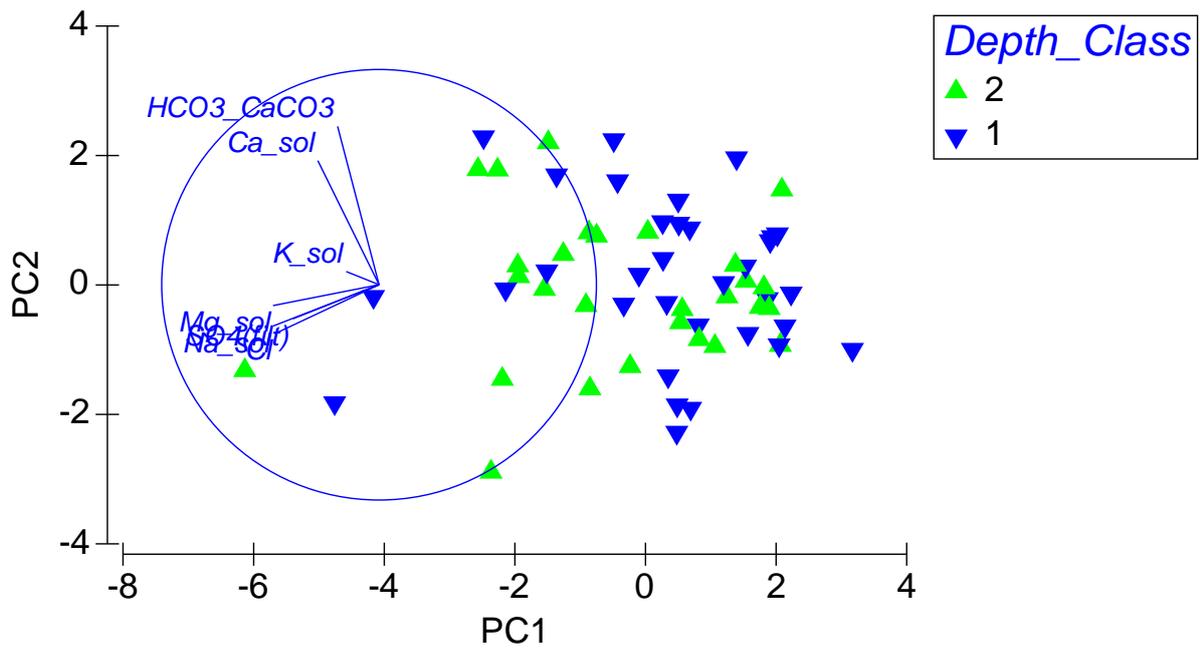
*Figure 4-9: Results of PCA when analysing major ions. '1' indicates bores screened less than 7 m bgl, '2' indicates bores screened greater than 7 m bgl.*

# Appendices

# Appendix 1    Acid sulfate soil sampling sites used in study

*Table A-1.1   Acid sulphate soil sampling sites (Pages 60 to 65).*

| Location | BORE ID | Easting | Northing | PASS (mbgl)* | ShaPass (mAHD) |
|---|---|---|---|---|---|
| Lakes Road Pipeline | RBH1 | 384792 | 6403049 | NSP | na |
| Lakes Road Pipeline | RBH2 | 384906 | 6403082 | NSP | na |
| Lakes Road Pipeline | RBH3 | 385030 | 6403085 | 2 | 0.6 |
| Lakes Road Pipeline | RBH4 | 385234 | 6403151 | NSP | na |
| Lakes Road Pipeline | RBH5 | 385303 | 6403199 | 1 | 1.2 |
| Lakes Road Pipeline | RBH6 | 385426 | 6403212 | NSP | na |
| Lakes Road Pipeline | RBH7 | 385544 | 6403222 | 3 | -0.8 |
| Lakes Road Pipeline | RBH8 | 385665 | 6403232 | NSP | na |
| Lakes Road Pipeline | RBH9 | 385790 | 6403237 | NSP | na |
| Lakes Road Pipeline | RBH10 | 385816 | 6403100 | NSP | na |
| Lakes Road Pipeline | RBH11 | 385811 | 6403028 | NSP | na |
| Lakes Road Pipeline | RBH12 | 385809 | 6402918 | NSP | na |
| Lakes Road Pipeline | RBH13 | 385809 | 6402793 | NSP | na |
| Lakes Road Pipeline | RBH14 | 385796 | 6402677 | NSP | na |
| Lakes Road Pipeline | RBH15 | 385790 | 6402546 | NSP | na |
| Lakes Road Pipeline | RBH16 | 385906 | 6402513 | 2 | 0.5 |
| Lakes Road Pipeline | RBH17 | 385977 | 6402500 | 2.5 | 0.5 |
| Lakes Road Pipeline | RBH18 | 386093 | 6402456 | 3.5 | -0.9 |
| Lakes Road Pipeline | RBH19 | 386162 | 6402417 | 4.5 | -1.0 |
| Lakes Road Pipeline | RBH20 | 386239 | 6402464 | NSP | na |
| Lakes Road Pipeline | RBH21 | 386315 | 6402553 | NSP | na |
| Lakes Road Pipeline | RBH22 | 386371 | 6402610 | NSP | na |
| Lakes Road Pipeline | RBH23 | 386437 | 6402681 | NSP | na |
| Lakes Road Pipeline | RBH24 | 386510 | 6402750 | NSP | na |
| Lakes Road Pipeline | RBH25 | 386548 | 6402792 | NSP | na |
| Lakes Road Pipeline | RBH26 | 386630 | 6402876 | NSP | na |
| Lakes Road Pipeline | RBH27 | 386704 | 6402950 | NSP | na |
| Lakes Road Pipeline | RBH28 | 386779 | 6403029 | NSP | na |
| Lakes Road Pipeline | RBH29 | 386835 | 6403087 | NSP | na |
| Lakes Road Pipeline | RBH30 | 386902 | 6403150 | NSP | na |
| Lakes Road Pipeline | RBH31 | 386964 | 6403215 | 1.5 | 3.0 |
| Lakes Road Pipeline | RBH32 | 387018 | 6403270 | NSP | na |
| Lakes Road Pipeline | RBH33 | 387079 | 6403339 | NSP | na |
| Lakes Road Pipeline | RBH34 | 387152 | 6403316 | 2.5 | 0.3 |
| Lakes Road Pipeline | RBH35 | 387232 | 6403278 | NSP | na |
| Lakes Road Pipeline | RBH36 | 387329 | 6403237 | NSP | na |
| Lakes Road Pipeline | RBH37 | 387409 | 6403179 | NSP | na |
| Lakes Road Pipeline | RBH38 | 387473 | 6403102 | 4.5 | 0.1 |
| Lakes Road Pipeline | RBH39 | 387527 | 6402996 | NSP | na |
| Lakes Road Pipeline | RBH40 | 387558 | 6402903 | NSP | na |
| Lakes Road Pipeline | RBH41 | 387558 | 6402816 | NSP | na |
| Lakes Road Pipeline | RBH42 | 387618 | 6402744 | NSP | na |
| Lakes Road Pipeline | RBH43 | 387665 | 6402658 | NSP | na |
| Lakes Road Pipeline | RBH44 | 387731 | 6402578 | 4 | -1.3 |

| Location | BORE ID | Easting | Northing | PASS (mbgl)* | ShaPass (mAHD) |
|---|---|---|---|---|---|
| Lakes Road Pipeline | RBH45 | 387843 | 6402500 | 3 | 0.7 |
| Lakes Road Pipeline | RBH46 | 387901 | 6402459 | 1.5 | 2.3 |
| Lakes Road Pipeline | RBH47 | 388029 | 6402391 | NSP | na |
| Lakes Road Pipeline | RBH48 | 388116 | 6402359 | NSP | na |
| Lakes Road Pipeline | RBH49 | 388234 | 6402273 | 1 | 3.0 |
| Lakes Road Pipeline | RBH50 | 388334 | 6402305 | 3 | 1.4 |
| Lakes Road Pipeline | RBH51 | 388425 | 6402300 | 2.5 | 2.7 |
| Lakes Road Pipeline | RBH52 | 388557 | 6402300 | NSP | na |
| Lakes Road Pipeline | RBH53 | 388657 | 6402300 | 5 | 0.5 |
| Lakes Road Pipeline | RBH54 | 388757 | 6402295 | 3 | 1.9 |
| Lakes Road Pipeline | RBH55 | 388857 | 6402319 | 3.5 | 1.7 |
| Lakes Road Pipeline | RBH56 | 388957 | 6402298 | 3 | 2.8 |
| Lakes Road Pipeline | RBH57 | 389096 | 6402302 | 4 | 2.5 |
| Lakes Road Pipeline | RBH58 | 389196 | 6402303 | NSP | na |
| Lakes Road Pipeline | RBH59 | 389296 | 6402303 | 2.5 | 4.8 |
| Lakes Road Pipeline | RBH60 | 389396 | 6402302 | NSP | na |
| Lakes Road Pipeline | RBH61 | 389496 | 6402303 | 3 | 4.3 |
| Lakes Road Pipeline | RBH62 | 389596 | 6402304 | NSP | na |
| Lakes Road Pipeline | RBH63 | 389696 | 6402302 | 2 | 5.4 |
| Lakes Road Pipeline | RBH64 | 389796 | 6402303 | NSP | na |
| Lakes Road Pipeline | RBH65 | 389896 | 6402305 | 2.5 | 7.4 |
| Lakes Road Pipeline | RBH66 | 389911 | 6402308 | NSP | na |
| Lakes Road Pipeline | RBH67 | 390011 | 6402307 | NSP | na |
| Lakes Road Pipeline | RBH68 | 390111 | 6402297 | 3.5 | 7.2 |
| Lakes Road Pipeline | RBH69 | 390211 | 6402306 | 3.5 | 8.4 |
| Lakes Road Pipeline | RBH70 | 390311 | 6402316 | NSP | na |
| Lakes Road Pipeline | RBH71 | 390417 | 6402284 | 1.5 | 11.2 |
| Lakes Road Pipeline | RBH72 | 390517 | 6402289 | 2 | 10.9 |
| Lakes Road Pipeline | RBH73 | 390617 | 6402289 | 5 | 8.7 |
| Lakes Road Pipeline | RBH74 | 390717 | 6402280 | 5 | 8.7 |
| Lakes Road Pipeline | RBH75 | 390817 | 6402291 | 5 | 10.2 |
| Lakes Road Pipeline | RBH76 | 390929 | 6402287 | NSP | na |
| Lakes Road Pipeline | RBH77 | 391029 | 6402286 | NSP | na |
| Lakes Road Pipeline | RBH78 | 391129 | 6402287 | 1.5 | 12.6 |
| Lakes Road Pipeline | RBH79 | 391229 | 6402293 | 2 | 12.3 |
| Lakes Road Pipeline | RBH80 | 391329 | 6402276 | 5 | 11.0 |
| Lakes Road Pipeline | RBH81 | 391424 | 6402292 | 1.5 | 15.3 |
| Lakes Road Pipeline | RBH82 | 391324 | 6402314 | 3 | 13.1 |
| Lakes Road Pipeline | RBH83 | 391425 | 6402314 | 5 | 11.9 |
| Lakes Road Pipeline | RBH84 | 391519 | 6402312 | NSP | na |
| Lakes Road Pipeline | RBH85 | 391605 | 6402317 | NSP | na |
| Lakes Road Pipeline | RBH86 | 391709 | 6402319 | 2.5 | 11.6 |
| Lakes Road Pipeline | RBH87 | 391802 | 6402328 | NSP | na |
| Lakes Road Pipeline | RBH88 | 391910 | 6402325 | NSP | na |

| Location | BORE ID | Easting | Northing | PASS (mbgl)* | ShaPass (mAHD) |
|---|---|---|---|---|---|
| Lakes Road Pipeline | RBH89 | 392013 | 6402319 | 1.5 | 11.8 |
| Lakes Road Pipeline | RBH90 | 392108 | 6402318 | 1.5 | 11.9 |
| Lakes Road Pipeline | RBH91 | 392206 | 6402323 | 2.5 | 11.0 |
| Lakes Road Pipeline | RBH92 | 392316 | 6402326 | 3 | 10.6 |
| Lakes Road Pipeline | RBH93 | 392407 | 6402326 | 1 | 12.3 |
| Lakes Road Pipeline | RBH94 | 392498 | 6402323 | 1.5 | 11.6 |
| Lakes Road Pipeline | RBH95 | 392605 | 6402322 | 2.5 | 10.5 |
| Lakes Road Pipeline | RBH96 | 392719 | 6402329 | 2.5 | 10.3 |
| Lakes Road Pipeline | RBH97 | 392805 | 6402330 | 4.5 | 7.9 |
| Lakes Road Pipeline | RBH98 | 392918 | 6402326 | NSP | na |
| Lakes Road Pipeline | RBH99 | 392995 | 6402326 | 1.5 | 10.8 |
| Lakes Road Pipeline | RBH100 | 393088 | 6402330 | 3.5 | 9.6 |
| Monitoring Bore HS80-01 | 61410656 | 392386 | 6390900 | 4 | 5.1 |
| Monitoring Bore HS80-2B | 61410658 | 392253 | 6390391 | 3.7 | 4.3 |
| Monitoring Bore HS80-3 | 61410659 | 392618 | 6390062 | 4.3 | 4.5 |
| Monitoring Bore HS87-1B | 61410661 | 386148 | 6396928 | 2.9 | -1.3 |
| Monitoring Bore HS87-2 | 61410662 | 385575 | 6396856 | 1.5 | -0.1 |
| Monitoring Bore HS87-3 | 61410663 | 386063 | 6396448 | 2.5 | -0.3 |
| Monitoring Bore HS96-1B | 61410665 | 393129 | 6399417 | 2.8 | 9.8 |
| Monitoring Bore HS96-2 | 61410666 | 393127 | 6399187 | 2.5 | 9.7 |
| Monitoring Bore HS99-1B | 61410668 | 394782 | 6400167 | 4.5 | 11.5 |
| Monitoring Bore HS104-1B | 61410670 | 390157 | 6402327 | NSP | na |
| Monitoring Bore HS104-2A | 61410671 | 389916 | 6402534 | NSP | na |
| Monitoring Bore HS104-2B | 61410672 | 389916 | 6402536 | NSP | na |
| Monitoring Bore HS104-3A | 61410673 | 390001 | 6401879 | NSP | na |
| Monitoring Bore HS104-3B | 61410674 | 390000 | 6401883 | NSP | na |
| Monitoring Bore HS108-1B | 61410676 | 392447 | 6402412 | NSP | na |
| Monitoring Bore HS108-2A | 61410677 | 392393 | 6403275 | 4 | 12.5 |
| Monitoring Bore HS108-2B | 61410678 | 392393 | 6403275 | 3.6 | 12.9 |
| Monitoring Bore HS109-1 | 61410679 | 392144 | 6403710 | 5 | 14.5 |
| Monitoring Bore HS109-2 | 61410680 | 392405 | 6403715 | 4.2 | 15.8 |
| Monitoring Bore T560S | 61410681 | 395653 | 6410202 | 3.4 | 18.2 |
| Monitoring Bore T561 | 61410682 | 395155 | 6409168 | 4.1 | 17.6 |
| Monitoring Bore T563 | 61410684 | 395010 | 6408838 | 4.4 | 17.3 |
| Monitoring Bore T564 | 61410685 | 395549 | 6408873 | 2.7 | 18.1 |
| CALM RESERVE AUSTIN BAY | ASS61300101 | 379090 | 6385686 | 4 | -3.2 |
| CALM RESERVE OFF CARRABUNGUP RD, AUSTIN BAY | ASS61300102 | 378456 | 6386906 | 0.4 | 0.3 |
| CALM RESERVE OFF CARRABUNGUP RD, AUSTIN BAY | ASS61300103 | 378790 | 6386913 | 2.75 | -1.1 |
| FARM ENTRY AT AUSTIN BAY CARRABUNGUP RD | ASS61300104 | 378067 | 6387590 | 0.6 | 0.0 |
| CALM CONSERVATION AREA, AUSTIN BAY | ASS61300201 | 380354 | 6386981 | 1 | -0.3 |
| CALM RESERVE BOGGY BAY | ASS61300202 | 380038 | 6388442 | 1.1 | 0.1 |
| CALM RESERVE BOGGY BAY | ASS61300203 | 380032 | 6388179 | 0.7 | 0.4 |
| CALM RESERVE BOGGY BAY | ASS61300204 | 380083 | 6387913 | 1.5 | 0.1 |
| CALM RESERVE TRACK OFF CARRABUNGUP RD | ASS61300205 | 380124 | 6386958 | 1.5 | 0.8 |

| Location | BORE ID | Easting | Northing | PASS (mbgl)* | ShaPass (mAHD) |
|---|---|---|---|---|---|
| CALM RESERVE TRACK OFF CARRABUNGUP RD | ASS61300206 | 380039 | 6386965 | 3.1 | -0.1 |
| BOGGY BAY CLOSED SWAMP DEPRESSION | ASS61300207 | 380138 | 6387373 | 0.7 | 0.5 |
| CARRABUNGUP RD NEAR MEELUP RD | ASS61300301 | 382209 | 6385101 | 3.1 | -0.9 |
| LAKE MEELUP ROAD | ASS61300401 | 382322 | 6383458 | NSP | na |
| LAKE MEELUP ROAD FARM | ASS61300402 | 381700 | 6383260 | 3.25 | -0.8 |
| LAKE MEELUP PS | ASS61300501 | 378543 | 6383878 | 1.5 | 0.5 |
| LAKE MEELUP WEST SHORE | ASS61300502 | 378856 | 6383611 | 1.5 | -0.6 |
| LAKE MEELUP | ASS61300503 | 379184 | 6383054 | 1.5 | 0.3 |
| EAST LAKE MEALUP | ASS61300504 | 379427 | 6383790 | 0.6 | 0.0 |
| EAST LAKE MEALUP EAST 2 | ASS61300505 | 379653 | 6383789 | NSP | na |
| CARRABUNGUP RD EAST BOGGY BAY | ASS61302201 | 382693 | 6386627 | 0.8 | 0.4 |
| CARRABUNGUP RD EAST BOGGY BAY | ASS61302202 | 382415 | 6386451 | NSP | na |
| SHANNON RD PEEL NORTH | ASS61402704 | 380420 | 6401018 | 2.6 | -0.4 |
| TINDALE ST PEEL NORTH | ASS61402705 | 381298 | 6401581 | 0.9 | 1.0 |
| OFF GULL RD, STH SERPENTINE RIVER | ASS61400101 | 388451 | 6409303 | 0.25 | 1.0 |
| OFF GULL RD, STH SERPENTINE RIVER | ASS61400102 | 388555 | 6409073 | 5 | -1.6 |
| SERPENTINE RIVER | ASS61400201 | 386831 | 6406301 | 0.6 | -0.4 |
| SERPENTINE RIVER RESERVE; ACCESS ROAD, STAKEHILL | ASS61400202 | 386750 | 6406450 | 1.2 | 0.2 |
| SERPENTINE RESERVE ACCESS TRACK, STAKEHILL | ASS61400203 | 386694 | 6406575 | 2 | 0.2 |
| SERPENTINE DRIVE , STAKEHILL | ASS61400204 | 386640 | 6406687 | 2.5 | 0.6 |
| OFF FOWLER ROAD | ASS61400205 | 387721 | 6405310 | 1.2 | -0.2 |
| FOWLER ROAD | ASS61400206 | 387829 | 6405226 | 2.5 | -0.5 |
| OFF FOWLER ROAD | ASS61400207 | 387999 | 6405063 | 2.5 | -0.7 |
| CALM RESERVE, OFF WOODLAND PDE STAKEHILL | ASS61400301 | 386224 | 6402945 | 2.4 | 0.1 |
| SERPENTINE RIVER RESERVE OFF SHEOAK RD STAKEHILL | ASS61400302 | 386364 | 6402891 | 2.4 | -0.9 |
| FOWLER RD, GOVT MRD LAND | ASS61400303 | 386535 | 6402630 | NSP | na |
| FOWLER RD BETWEEN SERPENTINE & FOWLER RDS | ASS61400304 | 386454 | 6402773 | 2.5 | -0.9 |
| CALM RESERVE, STAKEHILL | ASS61400305 | 386160 | 6403032 | 4 | 0.4 |
| TRACK NAMBELLUP OFF GULL RD, NTH KENNELS | ASS61400401 | 389518 | 6403699 | 1.5 | 7.7 |
| LAKES ROAD | ASS61400402 | 390097 | 6402193 | 77 | -67.2 |
| OFF DUNKERTON RD, BARRAGUP | ASS61400501 | 386966 | 6399477 | 1.3 | 0.1 |
| CNR DUNKERTON & BROYDON RD BARRAGUP | ASS61400502 | 386828 | 6399543 | 2 | 0.0 |
| COODANUP NEAR BIRCHLEY ROAD | ASS61400601 | 383257 | 6397805 | 0.75 | 0.2 |
| OFF WANJEEP DRIVE | ASS61400602 | 383068 | 6397926 | 3.2 | 0.4 |
| OFF RONLYN ROAD FURNISSDALE | ASS61400603 | 384990 | 6397590 | 2.8 | 0.7 |
| WOODVIEW WAY BARRAGUP | ASS61400604 | 386009 | 6397605 | 2.4 | -0.3 |
| SERPENTINE RIVER, RODGERS ROAD WEST | ASS61400605 | 387308 | 6397885 | 1 | -0.7 |
| RODGERS RD OFF FIEGERTS RD 300M FROM RIVER | ASS61400606 | 387492 | 6397952 | 3 | -0.1 |
| RODGERS ROAD | ASS61400607 | 387108 | 6397922 | 3.5 | -0.5 |
| BETWEEN RIVERSIDE DRIVE & RONLYN ROAD | ASS61400608 | 384170 | 6397510 | 2 | 0.0 |
| OFF WANJEEP ROAD COODANUP | ASS61400609 | 382928 | 6397901 | NSP | na |
| OFF RONLYN ROAD FURNISSDALE | ASS61400701 | 384156 | 6396626 | 1.3 | 0.0 |
| OFF RONLYN ROAD FURNISSDALE | ASS61400702 | 384353 | 6396767 | 0.9 | 0.4 |
| POWER TRACK OFF RONLYN ROAD | ASS61400703 | 384030 | 6396541 | 1.2 | 0.6 |

| Location | BORE ID | Easting | Northing | PASS (mbgl)* | ShaPass (mAHD) |
|---|---|---|---|---|---|
| OFF FURNISSDALE ROAD | ASS61400704 | 384581 | 6396421 | NSP | na |
| TONKIN DRIVE, NTH YUNDERUP | ASS61400801 | 385397 | 6395748 | 1.5 | -0.4 |
| JANNALI RD, WETLANDS | ASS61400802 | 385600 | 6396864 | 0.9 | 0.2 |
| WILGIE CREEK OFF NTH YUNDERUP | ASS61400901 | 387214 | 6395304 | 2.5 | -0.3 |
| NTH YUNDERUP, CORREAS STREET | ASS61400902 | 388022 | 6395102 | 0.8 | 0.5 |
| NTH YUNDERUP, WILGIE CREEK | ASS61400903 | 386393 | 6395544 | 2 | -0.9 |
| WETLANDS NTH YUNERUP ROAD | ASS61400904 | 386250 | 6394838 | 0.1 | 0.5 |
| BANKSIA TCE EAST, STH YUNDERUP | ASS61401001 | 387485 | 6394746 | 0.2 | 1.2 |
| YUNDERUP ROAD, YUNDERUP | ASS61401002 | 386309 | 6394134 | 1.2 | 0.2 |
| SOUTH YUNDERUP MAIN DRAIN | ASS61401101 | 385362 | 6392949 | 0.2 | 0.6 |
| SOUTH YUNDERUP NEAR MAIN DRAIN | ASS61401102 | 386138 | 6393216 | 1.1 | 0.0 |
| OFF STH YUNDERUP RD, YUNDERUP | ASS61401103 | 387999 | 6393701 | NSP | na |
| MURRAY WATER PROPERTY, STH YUNDERUP | ASS61401104 | 386953 | 6393530 | 1.8 | -0.1 |
| STH YUNDERUP RD, MURRAY WATERS | ASS61401105 | 387508 | 6393510 | 2 | 0.0 |
| LEANDER WAY, YUNDERUP | ASS61401201 | 389204 | 6394445 | 2 | 0.1 |
| LEANDER WAY, STH YUNDERUP | ASS61401202 | 389076 | 6394484 | 3 | -1.1 |
| CROWN LAND EAST OF RAVENSWOOD CARAVAN PARK | ASS61401301 | 389894 | 6393486 | 1.5 | 0.4 |
| CROWN LAND EAST OF RAVENSWOOD CARAVAN PARK | ASS61401302 | 390037 | 6393444 | 2 | 0.1 |
| CROWN LAND EAST OF RAVENSWOOD CARAVAN PARK | ASS61401303 | 390206 | 6393555 | 1 | 0.1 |
| OLD SARUN LODGE | ASS61401401 | 392637 | 6392787 | 1.7 | 0.9 |
| OLD SARUN LODGE | ASS61401402 | 392661 | 6392784 | 2.5 | 0.5 |
| OLD SARUN LODGE, MURRAY RIVER BANK | ASS61401403 | 392986 | 6392699 | 2.2 | 1.6 |
| OLD SARUN LODGE | ASS61401404 | 392837 | 6392725 | 3.3 | -0.3 |
| BENS ROAD, PINJARRA WEST | ASS61401501 | 387561 | 6392515 | 3 | -1.4 |
| OFF BENS ROAD, PINJARRA WEST | ASS61401502 | 387544 | 6392347 | 2.5 | -0.5 |
| OFF BENS ROAD, PINJARRA WEST | ASS61401503 | 387652 | 6392054 | NSP | na |
| AUSTIN BAY RESERVE; 200M OF ESTURY | ASS61401601 | 385126 | 6391352 | 0.5 | 0.4 |
| AUSTIN BAY RESERVE 700M E OF INLET | ASS61401602 | 385572 | 6391406 | 2 | 0.1 |
| AUSTIN BAY RESERVE, EAST BOUNDARY | ASS61401603 | 386161 | 6391138 | 0.6 | 0.9 |
| 60M WEST OF CNR BEECHAN & PARKHILLS LANE | ASS61401604 | 387716 | 6390732 | NSP | na |
| OFF GREENLANDS RD | ASS61401701 | 384866 | 6388307 | NSP | na |
| OFF GREENLANDS RD, FAUNTLEROY DRAIN TRACK | ASS61401702 | 385197 | 6388127 | NSP | na |
| ROGERS RD 100M FROM BLACK LAKE | ASS61400610 | 387448 | 6397905 | 1.7 | 0.0 |
| ROGERS RD EAST | ASS61400611 | 387213 | 6397900 | 0.95 | 0.3 |
| DUNKERTON RD SOUTH BARRAGUP | ASS61401901 | 386601 | 6398498 | 0.6 | 0.4 |
| COODANUP BASE OF DUNE EAST SERPENTINE BANK | ASS61400612 | 383177 | 6397933 | 1 | 0.0 |
| STAKEHILL NORTH EAST BANK | ASS61400208 | 387478 | 6405269 | NSP | na |
| AMARILLO SERPENTINE BRIDGE NORTH BANK BACKSWAMP | ASS61400103 | 388295 | 6409466 | 0.6 | -0.1 |
| LAKE ON AMARILLO UPPER SERPENTINE WEST BANK | ASS61402401 | 388414 | 6411608 | 0.8 | -0.8 |
| STAKEHILL NORTH EAST BANK SERPENTINE | ASS61400209 | 387445 | 6405278 | 1.1 | -1.2 |
| STAKEHILL NORTH EAST BANK SERPENTINE BACKSWAMP | ASS61400210 | 387196 | 6405274 | 0.8 | -0.5 |
| SW AMARILLO WEST BANK SERPENTINE | ASS61402501 | 387281 | 6408273 | 0.3 | 0.8 |
| WEST AMARILLO WEST BANK SERPENTINE | ASS61402601 | 387596 | 6408812 | 0.1 | 0.2 |
| LOWER NAMBEELUP BROOK CROSSING, FIEGERTS RD NORTH | ASS61402101 | 388335 | 6400983 | 1.2 | 0.4 |

| Location | BORE ID | Easting | Northing | PASS (mbgl)* | ShaPass (mAHD) |
|---|---|---|---|---|---|
| LAKES RD LAKE GOEGERUP WEST | ASS61402102 | 384424 | 6401647 | 1.2 | 0.5 |
| DUNKERTON RD NORTH LAKE GOEGERUP EAST | ASS61402103 | 386757 | 6401008 | 1.9 | 0.4 |
| HOUGHAM RD BARRAGUP | ASS61400503 | 386736 | 6399551 | 1.3 | -0.1 |
| SOUTH YUNDERUP - MURRAY R. DRIVE BACKSWAMP | ASS61401106 | 388465 | 6393934 | 0.3 | 0.0 |
| PEEL PARADE WEST BANK SERPENTINE MOUTH | ASS61400705 | 383432 | 6396449 | 0.6 | 0.4 |
| WEST AMARILLO WEST BANK SERPENTINE #2 | ASS61402602 | 387474 | 6408841 | 0.9 | 0.8 |
| WETLAND EAST OF SOUTH YANGEDI RD NAMBEELUP | ASS61402001 | 394881 | 6402369 | 1.6 | 13.5 |
| BLACK LAKE SOUTH END PINJARRA RD | ASS61402201 | 388359 | 6395738 | 2.3 | 0.2 |
| NORTH OF BEECHAM RD SOUTH OF MURRAY FLOOD DRAIN | ASS61402301 | 386118 | 6392442 | 0.25 | 0.7 |
| CROWN LAND EAST OF RAVENSWOOD CARAVAN PARK | ASS61401304 | 390361 | 6393597 | NSP | na |
| WEST LAKE GOEGERUP | ASS61402104 | 384141 | 6401570 | 2.8 | -2.3 |
| PINJARRAH RD AND SOUTH YUNDERUP RD INTERSECTION | ASS61401107 | 389466 | 6393379 | 1.6 | -1.1 |
| DELTA CRESCENT, SOUTH YUNDERUP | ASS61401003 | 387755 | 6394231 | 1 | 2.1 |
| BENS ROAD, PINJARRA WEST | ASS61401504 | 387549 | 6392697 | 0.5 | 0.8 |
| CALM RESERVE AUSTIN BAY | ASS61300105 | 379650 | 6385901 | 0.5 | 0.0 |
| CALM RESERVE AUSTIN BAY | ASS61300106 | 379221 | 6385687 | 0.25 | 0.4 |
| CARRABUNGUP RD VERGE WETLAND | ASS61300208 | 381345 | 6386383 | 1.9 | -1.6 |
| PATTERSON  RD, DANDALUP RIVER | None | 395038 | 6394118 | 1.5 | 1.7 |
| GULL RD TRACK | ASS61400211 | 388625 | 6406893 | 1.5 | 4.7 |
| FIEGERTS RD WETLAND | ASS61402202 | 388463 | 6397360 | 1 | 0.5 |
| Development site | SB04 | 390112 | 6394696 | 1.4 | 4.1 |
| Development site | BH7 | 390045 | 6394236 | 1.5 | 2.8 |
| Development site | MB5 | 388280 | 6393384 | 0.6 | 0.9 |
| Development site | MB8 | 388140 | 6393209 | 2 | -0.3 |
| Development site | MLL-3 | 388306 | 6392917 | 0.8 | 1.1 |
| Development site | MB13 | 388414 | 6392795 | 1.1 | 0.7 |
| Development site | MLL-4 | 388308 | 6392770 | 0.9 | 1.0 |
| Development site | MB16 | 388251 | 6392648 | 1 | 0.8 |
| Development site | MLB-7 | 388504 | 6393460 | 2.6 | -0.8 |
| Development site | MLB-9 | 388076 | 6393466 | 2 | 0.0 |
| Development site | MLF-13 | 388204 | 6393452 | 0.8 | 1.0 |
| Development site | MB2 | 388225 | 6393782 | 1.8 | -0.2 |
| Development site | MLF-6 | 387940 | 6393701 | 2.8 | -0.7 |
| Development site | MLB-2 | 387827 | 6393580 | 0.1 | 1.8 |
| Development site | MLB-3 | 387610 | 6393529 | 1.9 | 0.3 |
| Development site | MLF-10 | 387380 | 6393300 | 2 | -0.5 |
| Development site | MLF-15 | 387034 | 6393606 | 2 | 0.0 |
| Development site | MLF-16 | 386956 | 6393503 | 1 | 0.7 |
| Development site | NBB5 | 389191 | 6401671 | 3 | 4.0 |
| Development site | NBB6 | 388590 | 6401993 | 1 | 2.8 |

* NPS = no significant PASS material recorded

# Appendix 2    Sampling bore details and analysis

*Table A- 2: Hydrochemistry sampling locations and analysis results (Pages 63 to 77)*

| Site Name | AWRC | Sample Date | Sample ID | Easting | Northing | Ground Level (mAHD) | Top Screen (m bgl) | Bottom Screen (m bgl) | Field Cond Uncomp (µS/cm) | Field DO mg/L (mg/L) | Field pH | Lab pH | Lab Comp (µS/cm) | Acidity (CaCO3) (mg/L) | CO3-CaCO3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HS91B | 61410615 | 9/10/2008 | 24668043 | 386039 | 6397647 | 2.70 | 1.00 | 5.00 | 146 | | 6.17 | 6.7 | 170 | 32 | <1 |
| HS91A | 61410616 | 9/10/2008 | 24668044 | 386039 | 6397646 | 2.62 | 10.50 | 13.50 | 827 | | 6.61 | 7.1 | 890 | 10 | <1 |
| HS92B | 61410617 | 9/10/2008 | 24668041 | 388397 | 6399839 | 3.85 | 1.00 | 5.00 | 467 | 0.61 | 6.01 | 6.7 | 510 | 130 | <1 |
| HS92A | 61410618 | 9/10/2008 | 24668042 | 388397 | 6399841 | 3.86 | 11.50 | 14.50 | 540 | | 7.06 | 7.7 | 580 | 8 | <1 |
| HS97B | 61410619 | 9/10/2008 | 24668038 | 389356 | 6401197 | 7.01 | 1.00 | 5.00 | 176 | | 5.59 | 6.2 | 190 | 52 | <1 |
| HS97A | 61410620 | 28/11/2008 | 24688075 | 389356 | 6401196 | 6.99 | 8.50 | 11.50 | 294 | | 5.73 | 6.0 | 320 | 84 | <1 |
| HS79B | 61410621 | 7/10/2008 | 24631165 | 389452 | 6390892 | 3.94 | 1.00 | 5.00 | 361 | 2.95 | 7.35 | 7.6 | 410 | 3 | <1 |
| HS79A | 61410622 | 7/10/2008 | 24631166 | 389451 | 6390892 | 3.94 | 7.00 | 10.00 | 1653 | 2.27 | 7.33 | 7.7 | 1710 | 4 | <1 |
| HS88B | 61410623 | 28/11/2008 | 24688072 | 390380 | 6395259 | 6.62 | 2.50 | 5.50 | 661 | | 6.48 | 6.7 | 800 | 89 | <1 |
| HS88A | 61410624 | 28/11/2008 | 24688074 | 390380 | 6395257 | 6.64 | 7.00 | 10.00 | 783 | | 6.59 | 6.2 | 830 | 150 | <1 |
| HS93B | 61410625 | 9/10/2008 | 24668039 | 390794 | 6398388 | 9.37 | 1.00 | 5.00 | 577 | 2.82 | 5.41 | 5.5 | 680 | 58 | <1 |
| HS93A | 61410626 | 9/10/2008 | 24668040 | 390794 | 6398387 | 9.35 | 10.80 | 13.80 | 1680 | | 6.01 | 6.7 | 1680 | 53 | <1 |
| HS105B | 61410627 | 6/10/2008 | 24668411 | 391304 | 6402507 | 17.42 | 2.00 | 6.00 | 427 | 1.08 | 5.32 | 5.5 | 500 | 43 | <1 |
| HS105A | 61410628 | 6/10/2008 | 24668412 | 391305 | 6402509 | 17.31 | 11.50 | 14.50 | 181 | 1.47 | 6.43 | 6.5 | 200 | 10 | <1 |
| HS98B | 61410629 | 8/10/2008 | 24667465 | 392953 | 6400175 | 13.48 | 0.50 | 2.70 | 217 | 0.46 | 4.61 | 4.6 | 250 | 94 | <1 |
| HS98A | 61410630 | 8/10/2008 | 24667466 | 392954 | 6400175 | 13.47 | 8.00 | 11.00 | 1020 | 1.09 | 5.67 | 5.8 | 1140 | 110 | <1 |
| HS76A | 61410632 | 16/12/2008 | 24695983 | 393049 | 6384047 | 14.18 | 7.50 | 10.50 | 833 | 1.36 | 7.08 | 7.8 | 950 | 13 | <1 |
| HS99B | 61410633 | 8/10/2008 | 24667467 | 393049 | 6384047 | 17.12 | 2.00 | 8.00 | 181 | 1.45 | 5.28 | 5.6 | 210 | 47 | <1 |
| HS99A | 61410634 | 8/10/2008 | 24667469 | 394399 | 6400126 | 17.13 | 10.30 | 13.30 | 731 | 0.51 | 5.48 | 5.4 | 810 | 85 | <1 |
| HS106B | 61410635 | 6/10/2008 | 24668413 | 394438 | 6402289 | 17.55 | 0.80 | 5.00 | 200 | | 5.5 | 5.8 | 230 | 32 | <1 |
| HS106A | 61410636 | 2/12/2008 | 24689508 | 394439 | 6402288 | 17.50 | 12.00 | 16.00 | 581 | | 5.98 | 6.3 | 600 | 57 | <1 |
| HS89B | 61410637 | 8/10/2008 | 24667472 | 394797 | 6395491 | 11.88 | 1.00 | 5.00 | 248 | 2.25 | 6.47 | 7.0 | 280 | 28 | <1 |
| HS89A | 61410638 | 2/12/2008 | 24689511 | 394797 | 6395490 | 11.82 | 6.00 | 9.00 | 218 | | 5.45 | 5.8 | 210 | 37 | <1 |
| HS94B | 61410639 | 8/10/2008 | 24667471 | 394981 | 6397625 | 13.64 | 1.00 | 5.00 | 122 | | 5.24 | 5.5 | 140 | 58 | <1 |
| HS94A | 61410640 | 28/11/2008 | 24688076 | 394981 | 6397626 | 13.64 | 6.50 | 9.50 | 204 | | 5.05 | 5.3 | 220 | 110 | <1 |
| HS100B | 61410641 | 28/11/2008 | 24688077 | 396460 | 6399169 | 17.72 | 0.50 | 2.00 | 460 | | 6.13 | 6.3 | 450 | 76 | <1 |
| HS100A | 61410642 | 8/10/2008 | 24667470 | 396460 | 6399168 | 17.66 | 8.00 | 11.00 | 470 | 0.77 | 5.94 | 6.3 | 520 | 59 | <1 |
| HS101A | 61410645 | 7/10/2008 | 24631160 | 398995 | 6399275 | 24.64 | 7.50 | 10.50 | 171 | 2.52 | 6.06 | 6.4 | 210 | 11 | <1 |
| HS95 | 61410647 | 16/12/2008 | 24695984 | 399265 | 6397114 | 21.44 | 6.00 | 9.00 | 10000 | 3.83 | 5.82 | 5.8 | 12200 | 110 | <1 |
| HS102B | 61410648 | 2/12/2008 | 24689510 | 400723 | 6399284 | 27.14 | 1.10 | 5.10 | 6460 | | 5.91 | 5.5 | 6980 | 160 | <1 |
| HS102A | 61410649 | 7/10/2008 | 24631161 | 400724 | 6399285 | 27.14 | 6.50 | 9.50 | 1014 | 0.61 | 4.95 | 5.1 | 1120 | 69 | <1 |
| HS90 | 61410650 | 7/10/2008 | 24631164 | 401380 | 6394139 | 24.03 | 4.00 | 7.00 | 2750 | 4.04 | 4.47 | 4.5 | 2840 | 91 | <1 |
| T680B | 61410651 | 2/12/2008 | 24689509 | 401550 | 6403825 | 35.98 | 1.00 | 4.00 | 161 | | 6 | 6.3 | 170 | 9 | <1 |
| T680A | 61410652 | 6/10/2008 | 24668415 | 401551 | 6403825 | 35.93 | 7.50 | 10.50 | 149 | | 5.74 | 5.7 | 170 | 10 | <1 |
| HS103A | 61410654 | 6/10/2008 | 24668416 | 403003 | 6401666 | 42.84 | 11.30 | 14.30 | 364 | | 5.28 | 5.5 | 400 | 53 | <1 |

| Site Name | AWRC | Sample Date | Sample ID | Easting | Northing | Ground Level (mAHD) | Top Screen (m bgl) | Bottom Screen (m bgl) | Field Cond Uncomp (µS/cm) | Field DO mg/L (mg/L) | Field pH | Lab pH | Lab Comp (µS/cm) | Acidity (CaCO3) (mg/L) | CO3-CaCO3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HS110 | 61410655 | 16/12/2008 | 24695985 | 403631 | 6402891 | 41.37 | 1.10 | 5.10 | 2750 | 3.73 | 5.53 | 5.6 | 750 | 91 | <1 |
| HS080-1 | 61410656 | 17/12/2009 | 25214144 | 392387 | 6390900 | 8.99 | 1.11 | 5.61 | 1394 | 2.81 | 6.56 | 7.2 | 1470 | 33 | <1 |
| HS080-2B | 61410657 | 17/12/2009 | 25214245 | 392253 | 6390389 | 7.90 | 12.00 | 15.00 | 2170 | 1.76 | 7.76 | 7.7 | 2340 | 7 | <1 |
| HS080-2C | 61410658 | 17/12/2009 | 25214244 | 392253 | 6390391 | 7.88 | 0.63 | 5.63 | 727 | 2.61 | 7.01 | 7.3 | 790 | 38 | <1 |
| HS080-3 | 61410659 | 17/12/2009 | 25214248 | 392619 | 6390063 | 8.63 | 2.51 | 5.51 | 1592 | 1.99 | 6.61 | 6.9 | 1620 | 26 | <1 |
| HS080-2A | 61410660 | 17/12/2009 | 25214147 | 392253 | 6390387 | 7.88 | 25.50 | 28.50 | 1504 | 1.41 | 7.69 | 8.3 | 1520 | 3 | <1 |
| HS087-1 | 61410661 | 16/12/2009 | 25214240 | 386159 | 6396950 | 2.37 | 0.90 | 3.90 | 932 | 3.1 | 6.54 | 7.7 | 970 | 5 | <1 |
| HS087-2 | 61410662 | 16/12/2009 | 25214242 | 385576 | 6396856 | 1.39 | 0.51 | 3.51 | 340 | 2.18 | 6.4 | 7.5 | 370 | 6 | <1 |
| HS087-3 | 61410663 | 16/12/2009 | 25214241 | 386063 | 6396449 | 2.15 | 1.00 | 4.00 | 407 | 3.12 | 6.01 | 6.4 | 410 | 23 | <1 |
| HS096-1B | 61410665 | 21/12/2009 | 25181018 | 393130 | 6399417 | 12.56 | 0.76 | 2.76 | 845 | 1.77 | 5.72 | 5.9 | 790 | 38 | <1 |
| HS099-1A | 61410667 | 23/12/2009 | 25215693 | 394784 | 6400167 | 16.04 | 7.08 | 10.08 | 740 | 1.34 | 5.6 | 4.6 | | | |
| HS099-1B | 61410668 | 21/12/2009 | 25181016 | 394783 | 6400168 | 16.04 | 4.56 | 6.06 | 176.4 | 1.75 | 5.1 | 5.5 | 190 | 30 | <1 |
| HS104-1A | 61410669 | 14/12/2009 | 25178902 | 390276 | 6402328 | 12.53 | 55.80 | 58.80 | 851 | 2.87 | 6.89 | 6.8 | 880 | 24 | <1 |
| HS104-1B | 61410670 | 14/12/2009 | 25178901 | 390158 | 6402328 | 12.07 | 0.62 | 3.62 | 219 | 2.5 | 5.84 | 6.2 | 240 | 17 | <1 |
| HS104-2A | 61410671 | 14/12/2009 | 25178900 | 389916 | 6402535 | 11.44 | 6.09 | 8.59 | 218 | 1.49 | 5.54 | 5.9 | 240 | 73 | <1 |
| HS104-2B | 61410672 | 14/12/2009 | 25178899 | 389917 | 6402536 | 11.42 | 1.45 | 3.45 | 157.9 | 4.2 | 4.83 | 5.2 | 160 | 21 | <1 |
| HS104-3A | 61410673 | 21/12/2009 | 25181020 | 389917 | 6402536 | 10.67 | 5.92 | 6.92 | 435 | 4.7 | 6.07 | 6.07 | 100 | 45 | <1 |
| HS104-3B | 61410674 | 21/12/2009 | 25181019 | 390000 | 6401883 | 10.66 | 1.20 | 4.20 | 274 | 4.4 | 5.4 | 5.8 | 270 | 44 | <1 |
| HS108-1A | 61410675 | 16/12/2009 | 25214234 | 392447 | 6402449 | 13.72 | 8.20 | 11.20 | 1954 | 2.28 | 6.04 | 6.6 | 2160 | 74 | <1 |
| HS108-1B | 61410676 | 16/12/2009 | 25214233 | 392447 | 6402412 | 13.75 | 0.91 | 2.41 | 179.5 | 2.63 | 5.61 | 6.4 | 190 | 11 | <1 |
| HS108-2A | 61410677 | 16/12/2009 | 25214237 | 392394 | 6403275 | 16.71 | 6.25 | 8.25 | 869 | 2.83 | 5.51 | 5.3 | 970 | 58 | <1 |
| HS108-2B | 61410678 | 16/12/2009 | 25214235 | 392393 | 6403275 | 16.71 | 0.97 | 3.47 | 496 | 2.82 | 3.96 | 3.9 | 550 | 44 | <1 |
| HS109-1 | 61410679 | 16/12/2009 | 25214239 | 392144 | 6403711 | 19.79 | 2.49 | 5.49 | 521 | 1.73 | 4.74 | 4 | 610 | 51 | <1 |
| HS109-2 | 61410680 | 16/12/2009 | 25214139 | 392405 | 6403716 | 20.08 | 2.55 | 5.55 | 459 | 2.65 | 4.15 | 3.8 | 520 | 65 | <1 |
| T561 | 61410682 | 15/12/2009 | 25178906 | 395155 | 6409168 | 21.69 | 1.10 | 4.10 | 104.4 | 2.76 | 4.65 | 4.5 | 110 | 45 | <1 |
| HS097 | 61410683 | 14/12/2009 | 25178903 | 389357 | 6401202 | 7.26 | 62.00 | 68.00 | 971 | 2.76 | 6.47 | 6.6 | 1020 | 33 | <1 |
| T563 | 61410684 | 14/12/2009 | 25179014 | 395010 | 6408839 | 21.53 | 5.40 | 8.40 | 419 | 3.78 | 5.56 | 5.4 | 440 | 44 | <1 |
| T564 | 61410685 | 15/12/2009 | 25178907 | 395010 | 6408839 | 20.69 | 2.00 | 5.00 | 4450 | 2.34 | 6.32 | 6.4 | 4710 | 80 | <1 |

| Site Name | AWRC | Sample Date | Sample ID | Easting | Northing | Ground Level (mAHD) | Top Screen (m bgl) | Bottom Screen (m bgl) | Field Cond Uncomp (µS/cm) | Field DO mg/L (mg/L) | Field pH | Lab pH | Lab Comp (µS/cm) | Acidity (CaCO3) (mg/L) | CO3-CaCO3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wetlands | | | | | | | | | | | | | | | |
| PLI7046 | 6140970 | 10/11/2009 | 25115002 | 395418 | 6409264 | | | | 537 | 1.58 | 6.95 | 6.39 | 610 | | |
| PLI5032 | 6140972 | 10/11/2009 | 25114999 | 392184.8 | 6403517.1 | | | | 712 | 2.67 | 4.16 | 4.16 | 800 | | |
| PLI5033 | 6140973 | 10/11/2009 | 25115000 | 392044.8 | 6402342.4 | | | | 737 | 2.96 | 5.91 | 5.91 | 830 | | |
| PLI5033 | 6140973 | 10/11/2009 | 25115001 | 392044.8 | 6402342.4 | | | | 737 | 2.96 | 5.91 | 5.91 | 830 | | |
| PLI4835N | 6140974 | 10/11/2009 | 25114998 | 389930.0 | 6402387.1 | | | | 238 | 0.82 | 6.31 | 6.31 | 280 | | |
| PLI4835S | 6140975 | 10/11/2009 | 25115005 | 390012.6 | 6402214.1 | | | | 381 | 1.57 | 7.19 | 7.19 | 410 | | |
| PLI5180 | 6140976 | 10/11/2009 | 25115004 | 393135.0 | 6399362.9 | | | | 1014 | 1.34 | 5.54 | 5.54 | 1100 | | |
| PLI5724 | 6140977 | 10/11/2009 | 25115003 | 394528.4 | 6399839.4 | | | | 2260 | 3.09 | 5.54 | 6.09 | 2380 | | |
| PLI5056 | 6140978 | 10/11/2009 | 25115006 | 392625.5 | 6390281.6 | | | | 1482 | 3.09 | 6.09 | 6.91 | 1560 | | |
| PLI3945 | 6140979 | 10/11/2009 | 25115007 | 386016.6 | 6397022.2 | | | | 17070 | 10.2 | 9.47 | 9.47 | 15700 | | |

| Site Name | AWRC | HCO3-CaCO3 (mg/L) | Al sol (mg/L) | Al tot (mgL) | As (mg/L) | B (mg/L) | Br (mg/L) | Ca sol (mg/L) | Ca tot (mg/L) | Cd (mg/L) | Cl (mg/L) | Co (µg/L) | Cr (mg/L) | Cu (mg/L) | F sol (mgL) | Fe (mg/L) | Hg (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HS91B | 61410615 | 38 | 0.410 | 8.3 | 0.005 | 0.034 | 0.180 | 7.0 | 9.0 | <0.002 | 20.0 | 0.005 | 0.013 | 0.005 | 0.20 | 6.10 | <0.0001 |
| HS91A | 61410616 | 53 | 0.007 | 1.1 | 0.005 | 0.190 | 0.440 | 7.0 | 8.0 | <0.002 | 150.0 | 0.005 | 0.005 | 0.005 | 0.20 | 6.80 | <0.0001 |
| HS92B | 61410617 | 140 | 1.100 | 3.4 | 0.005 | 0.017 | 0.510 | 22.0 | 26.0 | <0.002 | 60.0 | 0.005 | 0.005 | 0.005 | 0.30 | 9.50 | <0.0001 |
| HS92A | 61410618 | 130 | 0.270 | 10.0 | 0.005 | 0.077 | 0.410 | 7.0 | 10.0 | <0.002 | 100.0 | 0.005 | 0.017 | 0.006 | 0.20 | 2.50 | <0.0001 |
| HS97B | 61410619 | 19 | 1.000 | 3.2 | 0.005 | 0.043 | 0.460 | 2.0 | 2.0 | <0.002 | 40.0 | 0.005 | 0.005 | 0.005 | 0.20 | 3.20 | <0.0001 |
| HS97A | 61410620 | 32 | 1.600 | 5.0 | 0.005 | 0.010 | 0.580 | 2.0 | 3.0 | <0.002 | 70.0 | 0.005 | 0.009 | 0.005 | 0.20 | 59.00 | <0.0001 |
| HS79B | 61410621 | 120 | 0.450 | 8.5 | 0.005 | 0.120 | 0.270 | 7.0 | 10.0 | <0.002 | 40.0 | 0.005 | 0.010 | 0.005 | 0.70 | 1.70 | <0.0001 |
| HS79A | 61410622 | 360 | 0.031 | 7.4 | 0.005 | 0.035 | 1.200 | 62.0 | 65.0 | <0.002 | 380.0 | 0.005 | 0.039 | 0.005 | 0.20 | 5.00 | <0.0001 |
| HS88B | 61410623 | 150 | 0.940 | 3.4 | 0.005 | 0.029 | 0.480 | 43.0 | 48.0 | <0.002 | 160.0 | 0.005 | 0.006 | 0.005 | 0.20 | 3.40 | <0.0001 |
| HS88A | 61410624 | 91 | 4.500 | 7.1 | 0.005 | 0.025 | 0.600 | 16.0 | 17.0 | <0.002 | 190.0 | 0.005 | 0.007 | 0.005 | 0.20 | 9.40 | <0.0001 |
| HS93B | 61410625 | 16 | 0.720 | 1.6 | 0.005 | 0.039 | 0.370 | 18.0 | 19.0 | <0.002 | 170.0 | 0.005 | 0.005 | 0.005 | 0.20 | 0.55 | <0.0001 |
| HS93A | 61410626 | 53 | 0.700 | 3.3 | 0.005 | 0.026 | 1.200 | 16.0 | 21.0 | <0.002 | 480.0 | 0.005 | 0.017 | 0.005 | 0.20 | 4.60 | <0.0001 |
| HS105B | 61410627 | 15 | 0.660 | 7.8 | 0.005 | 0.021 | 0.460 | 3.0 | 3.0 | <0.002 | 120.0 | 0.005 | 0.010 | 0.005 | 0.20 | 5.20 | <0.0001 |
| HS105A | 61410628 | 40 | 0.390 | 5.4 | 0.005 | 0.021 | 0.100 | 22.0 | 27.0 | <0.002 | 20.0 | 0.005 | 0.007 | 0.005 | 0.20 | 0.50 | <0.0001 |
| HS98B | 61410629 | 2 | 0.370 | 0.5 | 0.005 | 0.022 | 0.180 | 8.0 | 9.0 | <0.002 | 60.0 | 0.005 | 0.005 | 0.005 | 0.20 | 0.72 | <0.0001 |
| HS98A | 61410630 | 34 | 2.000 | 11.0 | 0.005 | 0.026 | 0.920 | 6.0 | 10.0 | <0.002 | 320.0 | 0.005 | 0.007 | 0.005 | 0.20 | 7.00 | <0.0001 |
| HS76A | 61410632 | 230 | 0.005 | 1.6 | 0.005 | 0.047 | 0.570 | 90.0 | 94.0 | <0.002 | 160.0 | 0.005 | 0.008 | 0.005 | 0.20 | 1.90 | <0.0001 |
| HS99B | 61410633 | 10 | 1.300 | 4.0 | 0.005 | 0.010 | 0.110 | 2.0 | 2.0 | <0.002 | | 0.005 | 0.005 | 0.005 | 0.20 | 0.68 | <0.0001 |
| HS99A | 61410634 | 14 | 1.400 | 20.0 | 0.005 | 0.012 | 0.710 | 6.0 | 7.0 | <0.002 | | 0.005 | 0.005 | 0.005 | 0.20 | 7.00 | <0.0001 |
| HS106B | 61410635 | 22 | 1.500 | 2.5 | 0.005 | 0.020 | 0.210 | 4.0 | 4.0 | <0.002 | 40.0 | 0.005 | 0.005 | 0.005 | 0.20 | 1.70 | <0.0001 |
| HS106A | 61410636 | 52 | 1.800 | 4.8 | 0.005 | 0.038 | 0.510 | 2.0 | 4.0 | <0.002 | 150.0 | 0.005 | 0.005 | 0.005 | 0.20 | 5.80 | <0.0001 |
| HS89B | 61410637 | 70 | 0.095 | 20.0 | 0.005 | 0.034 | 0.090 | 32.0 | 36.0 | <0.002 | 30.0 | 0.005 | 0.005 | 0.005 | 0.20 | 1.20 | <0.0001 |
| HS89A | 61410638 | 18 | 2.000 | 3.2 | 0.005 | 0.010 | 0.150 | 2.0 | 3.0 | <0.002 | 40.0 | 0.005 | 0.005 | 0.005 | 0.20 | 4.20 | <0.0001 |
| HS94B | 61410639 | 10 | 0.730 | 4.2 | 0.005 | 0.014 | 0.110 | 5.0 | 5.0 | <0.002 | 30.0 | 0.005 | 0.005 | 0.005 | 0.20 | 1.50 | <0.0001 |
| HS94A | 61410640 | 10 | 11.000 | 17.0 | 0.005 | 0.010 | 0.270 | 1.0 | 1.0 | <0.002 | 50.0 | 0.014 | 0.015 | 0.006 | 0.20 | 13.00 | <0.0001 |
| HS100B | 61410641 | 59 | 4.300 | 27.0 | 0.005 | 0.033 | 0.300 | 11.0 | 11.0 | <0.002 | 90.0 | 0.009 | 0.020 | 0.006 | 0.40 | 31.00 | <0.0001 |
| HS100A | 61410642 | 50 | 0.750 | 7.3 | 0.005 | 0.010 | 1.000 | 1.0 | 2.0 | <0.002 | 100.0 | 0.005 | 0.005 | 0.005 | 0.20 | 1.50 | <0.0001 |
| HS101A | 61410645 | 17 | 0.036 | 9.8 | 0.005 | 0.010 | 0.160 | 3.0 | 4.0 | <0.002 | 40.0 | 0.005 | 0.005 | 0.005 | 0.20 | 1.20 | <0.0001 |
| HS95 | 61410647 | 23 | 0.160 | 2.5 | 0.005 | 0.044 | 9.600 | 41.0 | 41.0 | <0.002 | 4000.0 | 0.040 | 0.006 | 0.008 | 0.20 | 11.00 | <0.0001 |
| HS102B | 61410648 | 16 | 0.068 | 0.5 | 0.005 | 0.010 | 5.900 | 11.0 | 11.0 | <0.002 | 2200.0 | 0.005 | 0.005 | 0.005 | 0.20 | 87.00 | <0.0001 |
| HS102A | 61410649 | 10 | 0.069 | 0.2 | 0.005 | 0.011 | 0.990 | 2.0 | 2.0 | <0.002 | 310.0 | 0.005 | 0.005 | 0.005 | 0.20 | 0.69 | <0.0001 |
| HS90 | 61410650 | 1 | 0.240 | 4.9 | 0.005 | 0.021 | 2.400 | 5.0 | 5.0 | <0.002 | 720.0 | 0.007 | 0.005 | 0.017 | 0.20 | 5.50 | <0.0001 |
| T680B | 61410651 | 12 | 0.024 | 0.4 | 0.005 | 0.010 | 0.100 | 4.0 | 5.0 | <0.002 | | 0.005 | 0.005 | 0.005 | 0.20 | 0.07 | <0.0001 |
| T680A | 61410652 | 6 | 0.240 | 6.1 | 0.005 | 0.010 | 0.110 | 1.0 | 1.0 | <0.002 | | 0.005 | 0.005 | 0.005 | 0.20 | 0.50 | <0.0001 |
| HS103A | 61410654 | 16 | 0.025 | 1.4 | 0.005 | 0.014 | 0.260 | 1.0 | 2.0 | <0.002 | 100.0 | 0.005 | 0.005 | 0.005 | 0.20 | 1.20 | <0.0000 |

| Site Name | AWRC | HCO3-CaCO3 (mg/L) | Al sol (mg/L) | Al tot (mgL) | As (mg/L) | B (mg/L) | Br (mg/L) | Ca sol (mg/L) | Ca tot (mg/L) | Cd (mg/L) | Cl (mg/L) | Co (µg/L) | Cr (mg/L) | Cu (mg/L) | F sol (mgL) | Fe (mg/L) | Hg (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HS110 | 61410655 | 11 | 0.028 | 1.4 | 0.005 | 0.026 | 0.810 | 2.0 | 4.0 | <0.002 | 180.0 | 0.005 | 0.005 | 0.005 | 0.20 | 4.10 | <0.0001 |
| HS080-1 | 61410656 | 240 | 0.18 | 0.26 | <0.005 | 0.057 | 0.61 | 130 | 130 | <0.002 | 280 | <0.005 | <0.005 | <0.005 | <0.2 | 11.00 | <0.0001 |
| HS080-2B | 61410657 | 1 | 0.59 | 3.2 | 0.016 | 0.036 | 1.8 | 41 | 67 | <0.002 | 550 | <0.005 | 0.035 | 0.009 | 0.23 | 0.14 | <0.0001 |
| HS080-2C | 61410658 | 340 | 0.95 | 3.3 | <0.005 | 0.03 | 0.07 | 38 | 70 | <0.002 | 30 | <0.005 | 0.01 | 0.058 | 0.22 | 0.22 | <0.0001 |
| HS080-3 | 61410659 | 74 | 3.8 | 7.3 | 0.01 | 0.035 | 1.2 | 11 | 13 | <0.002 | 410 | <0.005 | 0.011 | 0.014 | <0.2 | 0.81 | 0.0004 |
| HS080-2A | 61410660 | 220 | 0.02 | 0.096 | <0.005 | 0.046 | 1 | 63 | 63 | <0.002 | 350 |  | <0.005 | <0.005 | <0.2 | 0.75 | <0.0001 |
| HS087-1 | 61410661 | 76 | 5.1 | 8.1 | 0.007 | 0.26 | 1 | 8 | 10 | <0.002 | 160 | <0.005 | <0.005 | <0.005 | <0.2 | 18.00 | <0.0001 |
| HS087-2 | 61410662 | 53 | 0.39 | 0.59 | 0.024 | 0.034 | 0.18 | 32 | 43 | <0.002 | 60 | <0.005 | 0.005 | 0.005 | <0.2 | 0.87 | <0.0001 |
| HS087-3 | 61410663 | 35 | 1.7 | 1.7 | 0.016 | 0.14 | 0.38 | 11 | 11 | <0.002 | 80 | 0.19 | 0.006 | <0.005 | <0.2 | 8.10 | <0.0001 |
| HS096-1B | 61410665 | 23 | 0.64 | 0.95 | <0.005 | 0.035 | 0.72 | 7 | 7 | <0.002 | 210 | <0.005 | <0.005 | <0.005 | <0.2 | 0.94 | <0.0001 |
| HS099-1A | 61410667 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| HS099-1B | 61410668 | 7 | 0.89 | 1.3 | <0.005 | 0.014 | 0.11 | 2 | 3 | <0.002 | 30 |  | <0.005 | <0.005 | <0.2 | 0.31 | <0.0001 |
| HS104-1A | 61410669 | 110 | 0.12 | 2.3 | <0.005 | 0.016 | 0.41 | 9 | 9 | <0.002 | 190 |  | 0.007 | 0.011 | 0.25 | 8.60 | <0.0001 |
| HS104-1B | 61410670 | 21 | 0.21 | 0.61 | <0.005 | 0.033 | 0.15 | 9 | 9 | <0.002 | 40 |  | <0.005 | <0.005 | <0.2 | 0.29 | <0.0001 |
| HS104-2A | 61410671 | 39 | 1.7 | 5.8 | <0.005 | 0.027 | 0.29 | 4 | 4 | <0.002 | 40 |  | 0.01 | <0.005 | <0.2 | 2.00 | <0.0001 |
| HS104-2B | 61410672 | 5 | 0.35 | 0.52 | <0.005 | 0.02 | 0.13 | 4 | 4 | <0.002 | 30 |  | <0.005 | <0.005 | <0.2 | 0.33 | <0.0001 |
| HS104-3A | 61410673 | 67 | 2.8 | 8.8 | 0.007 | 0.032 | 0.55 | 12 | 20 | <0.002 | 80 |  | 0.022 | 0.005 | <0.2 | 1.10 | <0.0001 |
| HS104-3B | 61410674 | 16 | 0.25 | 0.43 | <0.005 | 0.03 | 0.27 | 8 | 9 | <0.002 | 60 |  | <0.005 | <0.005 | <0.2 | 0.37 | <0.0001 |
| HS108-1A | 61410675 | 160 | 3.4 | 5.1 | 0.019 | 0.04 | 1.4 | 8 | 11 | <0.002 | 560 |  | 0.032 | 0.013 | <0.2 | 5.10 | <0.0001 |
| HS108-1B | 61410676 | 19 | 0.35 | 0.5 | <0.005 | 0.033 | 0.14 | 13 | 13 | <0.002 | 30 |  | <0.005 | <0.005 | 0.84 | 0.22 | <0.0001 |
| HS108-2A | 61410677 | 13 | 4 | 6.8 | 0.008 | 0.033 | 0.79 | 2 | 6 | <0.002 | 250 |  | 0.012 | 0.02 | <0.2 | 0.32 | <0.0001 |
| HS108-2B | 61410678 | 1 | 0.86 | 0.93 | <0.005 | 0.031 | 0.36 | 3 | 4 | <0.002 | 120 |  | <0.005 | <0.005 | <0.2 | 0.76 | <0.0001 |
| HS109-1 | 61410679 | 1 | 0.6 | 0.65 | <0.005 | 0.024 | 0.54 | 1 | 3 | <0.002 | 150 |  | <0.005 | <0.005 | <0.2 | 6.50 | <0.0001 |
| HS109-2 | 61410680 | 1 | 1 | 1.4 | <0.005 | 0.023 | 0.24 | 4 | 6 | <0.002 | 110 |  | <0.005 | <0.005 | <0.2 | 2.60 | <0.0001 |
| T561 | 61410682 | 1 | 0.75 | 2.4 | <0.005 | <0.01 | 0.07 | 4 | 4 | <0.002 | 20 |  | <0.005 | <0.005 | <0.2 | 0.23 | <0.0001 |
| HS097 | 61410683 | 83 | 0.065 | 0.29 | <0.005 | 0.022 | 0.6 | 10 | 10 | <0.002 | 230 |  | 0.008 | <0.005 | <0.2 | 7.50 | <0.0001 |
| T563 | 61410684 | 8 | 0.46 | 25 | <0.005 | <0.01 | 0.36 | 4 | 4 | <0.002 | 120 |  | 0.025 | <0.005 | <0.2 | 2.90 | <0.0001 |
| T564 | 61410685 | 140 | 1.5 | 70 | 0.011 | 0.034 | 3 | 16 | 16 | <0.002 | 1400 |  | 0.13 | 0.095 | 0.32 | 7.80 | <0.0001 |

| Site Name | AWRC | HCO3-CaCO3 (mg/L) | Al sol (mg/L) | Al tot (mgL) | As (mg/L) | B (mg/L) | Br (mg/L) | Ca sol (mg/L) | Ca tot (mg/L) | Cd (mg/L) | Cl (mg/L) | Co (µg/L) | Cr (mg/L) | Cu (mg/L) | F sol (mgL) | Fe (mg/L) | Hg (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wetlands | | | | | | | | | | | | | | | | | |
| PLI7046 | 6140970 | 36 | | 0.16 | | | 0.58 | 9 | | | 150 | | | | 0.24 | 1.7 | |
| PLI5032 | 6140972 | <1 | | 1.9 | | | 0.59 | 4 | | | 200 | | | | <0.2 | 2.7 | |
| PLI5033 | 6140973 | 22 | | 1.4 | | | 0.74 | 19 | | | 220 | | | | <0.2 | 3.4 | |
| PLI5033 | 6140973 | 24 | | 1.5 | | | 0.76 | 19 | | | 220 | | | | <0.2 | 3.4 | |
| PLI4835N | 6140974 | 25 | | 0.39 | | | 0.3 | 11 | | | 60 | | | | <0.2 | 0.82 | |
| PLI4835S | 6140975 | 74 | | 0.26 | | | 0.29 | 27 | | | 80 | | | | <0.2 | 0.81 | |
| PLI5180 | 6140976 | 23 | | 1.2 | | | 1.1 | 12 | | | 290 | | | | <0.2 | 2.1 | |
| PLI5724 | 6140977 | 24 | | 1.3 | | | 1.4 | 37 | | | 530 | | | | <0.2 | 3 | |
| PLI5056 | 6140978 | 68 | | 0.55 | | | 1.1 | 18 | | | 430 | | | | <0.2 | 1.7 | |
| PLI3945 | 6140979 | 220 | | 0.023 | | | 16. | 110 | | | 5500 | | | | 0.75 | 0.022 | |

| Site Name | AWRC | K | Mg | Mn sol | Mn Tot | Mo | Na | Ni | Pb | Se | SiO2 | Zn | SO$_4$ | TDS (Evap) | TSS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/L) | (mg/L) | (mg/L) | (mgL) | (mg/L) | (mg/L) | (mg/L) | (µg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| HS91B | 61410615 | 2.0 | 4.0 | 0.420 | 0.470 | 0.005 | 20.0 | 0.005 | 0.017 | 0.005 | 8.6 | 0.005 | 5.0 | 130 | |
| HS91A | 61410616 | 19.0 | 18.0 | 0.430 | 0.440 | 0.005 | 130.0 | 0.005 | 0.010 | 0.005 | 15.0 | 0.005 | 130.0 | 480 | |
| HS92B | 61410617 | 8.0 | 24.0 | 0.110 | 0.110 | 0.005 | 50.0 | 0.005 | 0.010 | 0.005 | 19.0 | 0.005 | 10.0 | 470 | |
| HS92A | 61410618 | 3.0 | 11.0 | 0.180 | 0.230 | 0.005 | 100.0 | 0.005 | 0.011 | 0.005 | 21.0 | 0.005 | 6.0 | 380 | |
| HS97B | 61410619 | 6.0 | 5.0 | 0.079 | 0.082 | 0.005 | 20.0 | 0.005 | 0.010 | 0.005 | 7.7 | 0.005 | 5.0 | 130 | |
| HS97A | 61410620 | 5.0 | 6.0 | 0.023 | 0.028 | 0.005 | 40.0 | 0.005 | 0.028 | 0.005 | 11.0 | 0.006 | 5.0 | 240 | |
| HS79B | 61410621 | 1.0 | 5.0 | 0.008 | 0.030 | 0.005 | 80.0 | 0.005 | 0.010 | 0.005 | 13.0 | 0.005 | 17.0 | 360 | |
| HS79A | 61410622 | 2.0 | 25.0 | 0.062 | 0.120 | 0.005 | 260.0 | 0.005 | 0.010 | 0.005 | 20.0 | 0.006 | 55.0 | 910 | |
| HS88B | 61410623 | 10.0 | 19.0 | 0.140 | 0.160 | 0.005 | 80.0 | 0.005 | 0.010 | 0.005 | 12.0 | 0.022 | 22.0 | 600 | |
| HS88A | 61410624 | 4.0 | 17.0 | 0.028 | 0.035 | 0.005 | 140.0 | 0.005 | 0.036 | 0.005 | 11.0 | 0.005 | 9.0 | 800 | |
| HS93B | 61410625 | 6.0 | 9.0 | 0.018 | 0.018 | 0.005 | 100.0 | 0.005 | 0.010 | 0.005 | 9.2 | 0.005 | 5.0 | 570 | |
| HS93A | 61410626 | 6.0 | 29.0 | 0.360 | 0.390 | 0.005 | 270.0 | 0.005 | 0.010 | 0.005 | 22.0 | 0.015 | 18.0 | 1040 | |
| HS105B | 61410627 | 4.0 | 8.0 | 0.160 | 0.170 | 0.005 | 60.0 | 0.005 | 0.010 | 0.005 | 15.0 | 0.005 | 5.0 | 190 | |
| HS105A | 61410628 | 1.0 | 3.0 | 0.025 | 0.026 | 0.005 | 10.0 | 0.005 | 0.010 | 0.005 | 9.8 | 0.005 | 7.0 | 320 | |
| HS98B | 61410629 | 7.0 | 4.0 | 0.100 | 0.100 | 0.005 | 30.0 | 0.005 | 0.010 | 0.005 | 6.0 | 0.005 | 5.0 | 290 | |
| HS98A | 61410630 | 7.0 | 22.0 | 0.410 | 0.410 | 0.005 | 170.0 | 0.005 | 0.010 | 0.005 | 13.0 | 0.006 | 7.0 | 1130 | |
| HS76A | 61410632 | 3.0 | 13.0 | 0.084 | 0.120 | 0.005 | 90.0 | 0.005 | 0.012 | 0.005 | 18.0 | 0.055 | 41.0 | 530 | |
| HS99B | 61410633 | 2.0 | 5.0 | 0.054 | 0.054 | 0.005 | 30.0 | 0.005 | 0.010 | 0.005 | 6.2 | 0.005 | | 180 | |
| HS99A | 61410634 | 4.0 | 18.0 | 0.590 | 0.590 | 0.005 | 120.0 | 0.006 | 0.010 | 0.005 | 11.0 | 0.006 | | 670 | |
| HS106B | 61410635 | 1.0 | 3.0 | 0.130 | 0.130 | 0.005 | 40.0 | 0.005 | 0.010 | 0.005 | 12.0 | 0.005 | 6.0 | 230 | |
| HS106A | 61410636 | 4.0 | 9.0 | 0.270 | 0.310 | 0.005 | 110.0 | 0.005 | 0.022 | 0.005 | 20.0 | 0.010 | 5.0 | 950 | |
| HS89B | 61410637 | 4.0 | 6.0 | 0.140 | 0.140 | 0.005 | 10.0 | 0.005 | 0.010 | 0.005 | 8.3 | 0.005 | 5.0 | 190 | |
| HS89A | 61410638 | 3.0 | 3.0 | 0.027 | 0.029 | 0.005 | 40.0 | 0.005 | 0.020 | 0.005 | 12.0 | 0.010 | 5.0 | 440 | |
| HS94B | 61410639 | 2.0 | 3.0 | 0.120 | 0.120 | 0.005 | 20.0 | 0.005 | 0.010 | 0.005 | 4.5 | 0.005 | 5.0 | 160 | |
| HS94A | 61410640 | 2.0 | 4.0 | 0.210 | 0.290 | 0.005 | 30.0 | 0.013 | 0.130 | 0.005 | 12.0 | 0.016 | 5.0 | 390 | |
| HS100B | 61410641 | 31.0 | 5.0 | 0.150 | 0.210 | 0.005 | 40.0 | 0.012 | 0.030 | 0.005 | 8.4 | 0.018 | 9.0 | 470 | |
| HS100A | 61410642 | 2.0 | 7.0 | 0.120 | 0.120 | 0.005 | 60.0 | 0.005 | 0.010 | 0.005 | 16.0 | 0.005 | 32.0 | 610 | |
| HS101A | 61410645 | 1.0 | 4.0 | 0.030 | 0.046 | 0.005 | 30.0 | 0.007 | 0.010 | 0.005 | 15.0 | 0.008 | 11.0 | 140 | |
| HS95 | 61410647 | 3.0 | 420.0 | 3.100 | 3.100 | 0.005 | 2200.0 | 0.069 | 0.021 | 0.005 | 86.0 | 0.078 | 890.0 | 8080 | |
| HS102B | 61410648 | 5.0 | 190.0 | 0.014 | 3.000 | 0.005 | 1200.0 | 0.005 | 0.010 | 0.005 | 16.0 | 0.017 | 480.0 | 4420 | |
| HS102A | 61410649 | 5.0 | 25.0 | 0.077 | 0.077 | 0.005 | 170.0 | 0.005 | 0.010 | 0.005 | 31.0 | 0.005 | 24.0 | 590 | |
| HS90 | 61410650 | 2.0 | 31.0 | 0.190 | 0.190 | 0.005 | 550.0 | 0.006 | 0.010 | 0.005 | 100.0 | 0.007 | 310.0 | 1880 | |
| T680B | 61410651 | 2.0 | 4.0 | 0.009 | 0.009 | 0.005 | 20.0 | 0.005 | 0.010 | 0.005 | 4.0 | 0.005 | | 90 | |
| T680A | 61410652 | 1.0 | 2.0 | 0.003 | 0.003 | 0.005 | 30.0 | 0.005 | 0.010 | 0.005 | 18.0 | 0.005 | | 80 | |
| HS103A | 61410654 | 4.0 | 8.0 | 0.027 | 0.030 | 0.005 | 60.0 | 0.005 | 0.010 | 0.005 | 44.0 | 0.012 | 5.0 | 230 | |

| Site Name | AWRC | K (mg/L) | Mg (mg/L) | Mn sol (mg/L) | Mn Tot (mgL) | Mo (mg/L) | Na (mg/L) | Ni (mg/L) | Pb (µg/L) | Se (mg/L) | SiO2 (mg/L) | Zn (mg/L) | SO₄ (mg/L) | TDS (Evap) (mg/L) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HS110 | 61410655 | 1.0 | 3.0 | 0.030 | 0.340 | 0.005 | 140.0 | 0.009 | 0.010 | 0.005 | 110.0 | 0.018 | 46.0 | 480 | |
| HS080-1 | 61410656 | 11 | 22 | 0.37 | 0.37 | <0.005 | 130 | <0.005 | <0.01 | <0.005 | 12 | 0.07 | 49 | 920 | 22 |
| HS080-2B | 61410657 | 3 | 30 | 0.026 | 0.063 | 0.011 | 390 | <0.005 | 0.02 | <0.005 | 16 | 0.015 | 60 | 1250 | 535 |
| HS080-2C | 61410658 | 1 | 19 | 0.005 | 0.05 | <0.005 | 110 | 0.011 | 0.034 | <0.005 | 13 | 0.1 | 16 | 440 | 1930 |
| HS080-3 | 61410659 | 3 | 30 | 0.91 | 1.1 | <0.005 | 280 | 0.019 | 0.057 | <0.005 | 14 | 0.013 | 67 | 940 | 653 |
| HS080-2A | 61410660 | 6 | 33 | 0.04 | 0.046 | 0.005 | 200 | <0.005 | <0.01 | <0.005 | 20 | <0.005 | 15 | 850 | 6 |
| HS087-1 | 61410661 | 18 | 14 | 0.11 | 0.11 | <0.005 | 150 | <0.005 | 0.012 | <0.005 | 12 | 0.007 | 99 | 530 | 184 |
| HS087-2 | 61410662 | 2 | 4 | 0.092 | 0.09 | 0.023 | 30 | 0.009 | <0.01 | <0.005 | 6.1 | 0.009 | 28 | 210 | 56 |
| HS087-3 | 61410663 | 3 | 11 | 0.023 | 0.023 | <0.005 | 50 | <0.005 | <0.01 | <0.005 | 15 | 0.005 | 13 | 320 | 10 |
| HS096-1B | 61410665 | 4 | 19 | 0.011 | 0.011 | <0.005 | 120 | <0.005 | <0.01 | <0.005 | 7.4 | <0.005 | 5 | 630 | 6 |
| HS099-1A | 61410667 | | | | | | | | | | | | | | |
| HS099-1B | 61410668 | 1 | 3 | <0.001 | 0.006 | <0.005 | 30 | 0.038 | <0.01 | <0.005 | 5.9 | <0.005 | 17 | 160 | 10 |
| HS104-1A | 61410669 | 17 | 9 | 0.14 | 0.15 | <0.005 | 140 | <0.005 | <0.01 | <0.005 | 21 | 0.013 | 10 | 460 | 94 |
| HS104-1B | 61410670 | 1 | 3 | 0.013 | 0.014 | <0.005 | 30 | <0.005 | <0.01 | <0.005 | 9 | <0.005 | 13 | 180 | 15 |
| HS104-2A | 61410671 | 3 | 8 | 0.11 | 0.13 | <0.005 | 30 | <0.005 | 0.011 | <0.005 | 13 | 0.006 | 5 | 350 | 273 |
| HS104-2B | 61410672 | 2 | 4 | 0.013 | 0.016 | <0.005 | 20 | <0.005 | <0.01 | <0.005 | 6.4 | 0.006 | 8 | 170 | 16 |
| HS104-3A | 61410673 | 4 | 8 | 0.39 | 0.52 | <0.005 | 50 | <0.005 | 0.043 | <0.005 | 8.8 | 0.009 | 5 | 330 | 1520 |
| HS104-3B | 61410674 | 2 | 6 | 0.019 | 0.02 | <0.005 | 30 | <0.005 | <0.01 | <0.005 | 5.9 | 0.006 | 9 | 190 | 33 |
| HS108-1A | 61410675 | 3 | 40 | 0.058 | 0.06 | <0.005 | 370 | 0.011 | <0.01 | <0.005 | 21 | 0.01 | 9 | 1710 | 16 |
| HS108-1B | 61410676 | 2 | 3 | 0.002 | 0.002 | <0.005 | 20 | <0.005 | <0.01 | <0.005 | 11 | <0.005 | 5 | 180 | 32 |
| HS108-2A | 61410677 | 4 | 19 | 0.005 | 0.006 | <0.005 | 150 | 0.006 | 0.032 | <0.005 | 14 | 0.02 | 7 | 740 | 1010 |
| HS108-2B | 61410678 | 4 | 11 | 0.002 | 0.002 | <0.005 | 70 | <0.005 | <0.01 | <0.005 | 9.4 | <0.005 | 11 | 460 | 19 |
| HS109-1 | 61410679 | 14 | 13 | 0.052 | 0.052 | <0.005 | 70 | <0.005 | <0.01 | <0.005 | 10 | <0.005 | 12 | 400 | 24 |
| HS109-2 | 61410680 | 3 | 13 | 0.03 | 0.031 | <0.005 | 60 | <0.005 | <0.01 | <0.005 | 8.8 | <0.005 | 23 | 440 | 40 |
| T561 | 61410682 | 1 | 2 | 0.003 | 0.003 | <0.005 | 10 | <0.005 | <0.01 | <0.005 | 6.8 | 0.007 | 5 | 120 | 1670 |
| HS097 | 61410683 | 13 | 20 | 0.16 | 0.16 | <0.005 | 150 | <0.005 | <0.01 | <0.005 | 23 | <0.005 | 15 | 600 | 5 |
| T563 | 61410684 | 3 | 9 | 0.039 | 0.048 | <0.005 | 60 | <0.005 | 0.059 | <0.005 | 9.1 | 0.006 | 5 | 250 | 1870 |
| T564 | 61410685 | 2 | 150 | 0.093 | 0.14 | 0.009 | 770 | 0.15 | 0.32 | <0.005 | 30 | 0.77 | 140 | 3050 | 10700 |

| Site Name | AWRC | K (mg/L) | Mg (mg/L) | Mn sol (mg/L) | Mn Tot (mgL) | Mo (mg/L) | Na (mg/L) | Ni (mg/L) | Pb (µg/L) | Se (mg/L) | SiO2 (mg/L) | Zn (mg/L) | SO₄ (mg/L) | TDS (Evap) (mg/L) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wetlands | | | | | | | | | | | | | | | |
| PLI7046 | 6140970 | 6 | 10 | 0.13 | | | 90 | | | | 44 | | 5 | | 36 |
| PLI5032 | 6140972 | 9 | 14 | 0.009 | | | 120 | | | | 18 | | 8 | | 31 |
| PLI5033 | 6140973 | 7 | 17 | 0.027 | | | 130 | | | | 17 | | 5 | | 56 |
| PLI5033 | 6140973 | 7 | 16 | 0.027 | | | 120 | | | | 17 | | 5 | | 53 |
| PLI4835N | 6140974 | 3 | 6 | 0.017 | | | 40 | | | | 4.2 | | 5 | | 8 |
| PLI4835S | 6140975 | 4 | 8 | 0.016 | | | 40 | | | | 12 | | 5 | | 8 |
| PLI5180 | 6140976 | 7 | 25 | 0.037 | | | 170 | | | | 13 | | 8 | | 26 |
| PLI5724 | 6140977 | 14 | 84 | 0.045 | | | 340 | | | | 14 | | 350 | | <1 |
| PLI5056 | 6140978 | 14 | 23 | 0.009 | | | 260 | | | | 3.9 | | 16 | | 28 |
| PLI3945 | 6140979 | 150 | 290 | 0.03 | | | 3100 | | | | 2.6 | | 1000 | | 5 |

| Site Name | AWRC | N (sum sol ox) {NOx-N, TON} (mg/L) | N (tot kjel) {TKN} (mg/L) | NH3-N/NH4-N (sol) (mg/L) | NO2-N (sol) (mg/L) | NO3-N (sol) (mg/L) | N (tot) {TN, pTN} (mg/L) | P (tot) {TP, pTP} (mg/L) | PO4-P (sol react) {SRP, FRP} (mg/L) | Hardness Calculated |
|---|---|---|---|---|---|---|---|---|---|---|
| HS91B | 61410615 | 0.024 | 0.510 | 0.066 | 0.010 | | 0.53 | 0.027 | 0.014 | 38.9 |
| HS91A | 61410616 | 0.015 | 0.520 | 0.340 | 0.010 | | 0.54 | 0.013 | 0.005 | 94.1 |
| HS92B | 61410617 | 0.071 | 5.000 | 1.100 | 0.010 | | 5.00 | 0.062 | 0.019 | 163.7 |
| HS92A | 61410618 | 0.038 | 1.300 | 0.160 | 0.010 | | 1.30 | 0.130 | 0.067 | 70.3 |
| HS97B | 61410619 | 0.023 | 1.700 | 0.500 | 0.010 | | 1.80 | 0.052 | 0.013 | 25.6 |
| HS97A | 61410620 | 0.011 | 2.000 | 0.680 | 0.010 | | 2.00 | 0.062 | 0.038 | 32.2 |
| HS79B | 61410621 | 2.500 | 0.310 | 0.055 | 0.024 | | 2.80 | 0.087 | 0.005 | 45.6 |
| HS79A | 61410622 | 0.021 | 0.210 | 0.120 | 0.010 | | 0.23 | 0.380 | 0.005 | 265.2 |
| HS88B | 61410623 | 0.013 | 4.800 | 0.940 | 0.010 | | 4.80 | 0.630 | 0.340 | 198.1 |
| HS88A | 61410624 | 0.036 | 5.400 | 0.770 | 0.010 | | 5.40 | 0.270 | 0.250 | 112.4 |
| HS93B | 61410625 | 0.081 | 3.200 | 0.310 | 0.010 | | 3.30 | 0.033 | 0.015 | 84.5 |
| HS93A | 61410626 | 0.066 | 1.700 | 0.470 | 0.010 | | 1.80 | 0.140 | 0.075 | 171.8 |
| HS105B | 61410627 | 0.038 | 1.400 | 0.720 | 0.010 | | 1.40 | 0.063 | 0.014 | 40.4 |
| HS105A | 61410628 | 5.300 | 1.900 | 0.044 | 0.038 | | 7.20 | 0.058 | 0.018 | 79.8 |
| HS98B | 61410629 | 0.058 | 3.700 | 0.640 | 0.010 | | 3.80 | 0.560 | 0.430 | 38.9 |
| HS98A | 61410630 | 0.087 | 3.400 | 0.820 | 0.010 | | 3.40 | 0.390 | 0.330 | 115.5 |
| HS76A | 61410632 | 0.012 | 0.280 | 0.010 | 0.010 | | 0.29 | 0.035 | 0.005 | 288.2 |
| HS99B | 61410633 | 1.200 | 0.960 | 0.083 | 0.010 | | 2.20 | 0.044 | 0.005 | 25.6 |
| HS99A | 61410634 | 0.069 | 2.200 | 0.450 | 0.010 | | 2.30 | 0.320 | 0.005 | 91.6 |
| HS106B | 61410635 | 0.078 | 1.800 | 0.190 | 0.010 | | 1.90 | 0.024 | 0.008 | 22.3 |
| HS106A | 61410636 | 0.076 | 3.000 | 0.620 | 0.010 | | 3.10 | 0.074 | 0.058 | 47.0 |
| HS89B | 61410637 | 1.500 | 1.600 | 0.300 | 0.010 | | 3.10 | 0.680 | 0.600 | 114.6 |
| HS89A | 61410638 | 0.069 | 3.100 | 0.530 | 0.010 | | 3.20 | 0.730 | 0.620 | 19.8 |
| HS94B | 61410639 | 0.020 | 2.200 | 0.460 | 0.010 | | 2.20 | 0.036 | 0.005 | 24.8 |
| HS94A | 61410640 | 0.026 | 3.000 | 1.300 | 0.010 | | 3.00 | 0.052 | 0.026 | 19.0 |
| HS100B | 61410641 | 0.040 | 12.000 | 6.000 | 0.010 | | 12.00 | 3.700 | 1.900 | 48.1 |
| HS100A | 61410642 | 0.044 | 0.440 | 0.140 | 0.010 | | 0.48 | 0.024 | 0.005 | 33.8 |
| HS101A | 61410645 | 0.640 | 0.320 | 0.054 | 0.016 | | 0.96 | 0.100 | 0.006 | 26.5 |
| HS95 | 61410647 | 0.019 | 0.760 | 0.210 | 0.012 | | 0.78 | 0.030 | 0.005 | 1831.4 |
| HS102B | 61410648 | 0.013 | 0.460 | 0.300 | 0.011 | | 0.47 | 0.005 | 0.005 | 809.7 |
| HS102A | 61410649 | 0.010 | 0.041 | 0.020 | 0.010 | | 0.05 | 0.012 | 0.005 | 107.9 |
| HS90 | 61410650 | 0.032 | 0.081 | 0.077 | 0.010 | | 0.11 | 0.021 | 0.005 | 140.1 |
| T680B | 61410651 | 3.500 | 0.390 | 0.013 | 0.010 | | 3.90 | 0.016 | 0.012 | 29.0 |
| T680A | 61410652 | 0.058 | 0.036 | 0.019 | 0.010 | | 0.09 | 0.013 | 0.005 | 10.7 |
| HS103A | 61410654 | 0.023 | 0.049 | 0.037 | 0.010 | | 0.07 | 0.016 | 0.005 | 37.9 |

| Site Name | AWRC | N (sum sol ox) {NOx-N, TON} | N (tot kjel) {TKN} | NH3-N/NH4-N (sol) | NO2-N (sol) | NO3-N (sol) | N (tot) {TN, pTN} | P (tot) {TP, pTP} | PO4-P (sol react) {SRP, FRP} | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | Calculated |
| HS110 | 61410655 | 0.011 | 0.180 | 0.042 | 0.010 | | 0.19 | 0.029 | 0.005 | 22.3 |
| HS080-1 | 61410656 | 4.000 | | 0.540 | 0.160 | | 5.10 | 0.012 | <0.005 | 415.2 |
| HS080-2B | 61410657 | 0.055 | | 0.130 | <0.01 | | 1.50 | 0.320 | 0.021 | 290.8 |
| HS080-2C | 61410658 | 0.069 | | 0.061 | <0.01 | | 2.50 | 0.170 | <0.005 | 253.0 |
| HS080-3 | 61410659 | 0.042 | | 0.120 | <0.01 | | 1.60 | 0.150 | 0.017 | 156.0 |
| HS080-2A | 61410660 | 0.015 | | 0.130 | <0.01 | | 0.25 | 0.065 | 0.044 | 293.2 |
| HS087-1 | 61410661 | 0.081 | | 0.310 | <0.01 | | 0.65 | 0.020 | 0.008 | 82.6 |
| HS087-2 | 61410662 | 0.790 | | 0.140 | <0.01 | | 1.60 | 0.140 | 0.065 | 123.8 |
| HS087-3 | 61410663 | 0.012 | | 0.220 | <0.01 | | 1.70 | 0.023 | <0.005 | 72.8 |
| HS096-1B | 61410665 | 0.057 | | 0.470 | <0.01 | | 3.30 | 0.260 | 0.210 | 95.7 |
| HS099-1A | 61410667 | | | | | | 1.60 | 0.170 | | |
| HS099-1B | 61410668 | 0.840 | | 0.076 | <0.01 | | 1.70 | 0.017 | 0.005 | 19.8 |
| HS104-1A | 61410669 | 0.034 | | 0.460 | <0.01 | | 0.72 | 0.330 | 0.210 | 59.5 |
| HS104-1B | 61410670 | 2.200 | | 0.077 | <0.01 | | 3.00 | 0.150 | 0.130 | 34.8 |
| HS104-2A | 61410671 | 0.021 | | 2.300 | <0.01 | | 5.20 | 0.370 | 0.290 | 42.9 |
| HS104-2B | 61410672 | 1.300 | | 0.860 | <0.01 | | 3.80 | 0.210 | 0.160 | 26.5 |
| HS104-3A | 61410673 | 0.010 | | 0.600 | <0.01 | | 3.50 | 0.170 | 0.012 | 82.9 |
| HS104-3B | 61410674 | 1.600 | | 0.160 | <0.01 | | 3.00 | 0.120 | 0.089 | 47.2 |
| HS108-1A | 61410675 | 0.068 | | 0.930 | <0.01 | | 6.20 | 0.370 | 0.240 | 192.1 |
| HS108-1B | 61410676 | <0.01 | | 1.100 | <0.01 | | 2.90 | 0.780 | 0.660 | 44.8 |
| HS108-2A | 61410677 | 0.110 | | 0.570 | <0.01 | | 0.88 | 0.029 | 0.028 | 93.2 |
| HS108-2B | 61410678 | 0.180 | | 0.340 | <0.01 | | 2.90 | 0.023 | 0.009 | 55.3 |
| HS109-1 | 61410679 | 0.070 | | 0.850 | <0.01 | | 2.70 | 0.800 | 0.680 | 61.0 |
| HS109-2 | 61410680 | 0.096 | | 0.450 | <0.01 | | 3.60 | 0.044 | 0.016 | 68.5 |
| T561 | 61410682 | 0.200 | | 0.360 | <0.01 | | 2.30 | 0.220 | 0.160 | 18.2 |
| HS097 | 61410683 | 0.030 | | 0.460 | <0.01 | | 0.91 | 0.030 | 0.030 | 107.3 |
| T563 | 61410684 | <0.01 | | 0.290 | <0.01 | | 1.50 | 0.089 | 0.005 | 47.0 |
| T564 | 61410685 | 0.042 | | 0.530 | <0.01 | | 13.00 | 0.270 | 0.026 | 657.5 |

| Site Name | AWRC | K (mg/L) | Mg (mg/L) | Mn sol (mg/L) | Mn Tot (mgL) | Mo (mg/L) | Na (mg/L) | Ni (mg/L) | Pb (µg/L) | Se (mg/L) | SiO2 (mg/L) | Zn (mg/L) | SO$_4$ (mg/L) | TDS (Evap) (mg/L) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wetlands | | | | | | | | | | | | | | | |
| PLI7046 | 6140970 | 6 | 10 | 0.13 | | | 90 | | | | 44 | | 5 | | 36 |
| PLI5032 | 6140972 | 9 | 14 | 0.009 | | | 120 | | | | 18 | | 8 | | 31 |
| PLI5033 | 6140973 | 7 | 17 | 0.027 | | | 130 | | | | 17 | | 5 | | 56 |
| PLI5033 | 6140973 | 7 | 16 | 0.027 | | | 120 | | | | 17 | | 5 | | 53 |
| PLI4835N | 6140974 | 3 | 6 | 0.017 | | | 40 | | | | 4.2 | | 5 | | 8 |
| PLI4835S | 6140975 | 4 | 8 | 0.016 | | | 40 | | | | 12 | | 5 | | 8 |
| PLI5180 | 6140976 | 7 | 25 | 0.037 | | | 170 | | | | 13 | | 8 | | 26 |
| PLI5724 | 6140977 | 14 | 84 | 0.045 | | | 340 | | | | 14 | | 350 | | <1 |
| PLI5056 | 6140978 | 14 | 23 | 0.009 | | | 260 | | | | 3.9 | | 16 | | 28 |
| PLI3945 | 6140979 | 150 | 290 | 0.03 | | | 3100 | | | | 2.6 | | 1000 | | 5 |

| Site Name | AWRC | N (sum sol ox) {NOx-N, TON} | N (tot kjel) {TKN} | NH3-N/NH4-N (sol) | NO2-N (sol) | NO3-N (sol) | N (tot) {TN, pTN} | P (tot) {TP, pTP} | PO4-P (sol react) {SRP, FRP} | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | Calculated |
| HS91B | 61410615 | 0.024 | 0.510 | 0.066 | 0.010 | | 0.53 | 0.027 | 0.014 | 38.9 |
| HS91A | 61410616 | 0.015 | 0.520 | 0.340 | 0.010 | | 0.54 | 0.013 | 0.005 | 94.1 |
| HS92B | 61410617 | 0.071 | 5.000 | 1.100 | 0.010 | | 5.00 | 0.062 | 0.019 | 163.7 |
| HS92A | 61410618 | 0.038 | 1.300 | 0.160 | 0.010 | | 1.30 | 0.130 | 0.067 | 70.3 |
| HS97B | 61410619 | 0.023 | 1.700 | 0.500 | 0.010 | | 1.80 | 0.052 | 0.013 | 25.6 |
| HS97A | 61410620 | 0.011 | 2.000 | 0.680 | 0.010 | | 2.00 | 0.062 | 0.038 | 32.2 |
| HS79B | 61410621 | 2.500 | 0.310 | 0.055 | 0.024 | | 2.80 | 0.087 | 0.005 | 45.6 |
| HS79A | 61410622 | 0.021 | 0.210 | 0.120 | 0.010 | | 0.23 | 0.380 | 0.005 | 265.2 |
| HS88B | 61410623 | 0.013 | 4.800 | 0.940 | 0.010 | | 4.80 | 0.630 | 0.340 | 198.1 |
| HS88A | 61410624 | 0.036 | 5.400 | 0.770 | 0.010 | | 5.40 | 0.270 | 0.250 | 112.4 |
| HS93B | 61410625 | 0.081 | 3.200 | 0.310 | 0.010 | | 3.30 | 0.033 | 0.015 | 84.5 |
| HS93A | 61410626 | 0.066 | 1.700 | 0.470 | 0.010 | | 1.80 | 0.140 | 0.075 | 171.8 |
| HS105B | 61410627 | 0.038 | 1.400 | 0.720 | 0.010 | | 1.40 | 0.063 | 0.014 | 40.4 |
| HS105A | 61410628 | 5.300 | 1.900 | 0.044 | 0.038 | | 7.20 | 0.058 | 0.018 | 79.8 |
| HS98B | 61410629 | 0.058 | 3.700 | 0.640 | 0.010 | | 3.80 | 0.560 | 0.430 | 38.9 |
| HS98A | 61410630 | 0.087 | 3.400 | 0.820 | 0.010 | | 3.40 | 0.390 | 0.330 | 115.5 |
| HS76A | 61410632 | 0.012 | 0.280 | 0.010 | 0.010 | | 0.29 | 0.035 | 0.005 | 288.2 |
| HS99B | 61410633 | 1.200 | 0.960 | 0.083 | 0.010 | | 2.20 | 0.044 | 0.005 | 25.6 |
| HS99A | 61410634 | 0.069 | 2.200 | 0.450 | 0.010 | | 2.30 | 0.320 | 0.005 | 91.6 |
| HS106B | 61410635 | 0.078 | 1.800 | 0.190 | 0.010 | | 1.90 | 0.024 | 0.008 | 22.3 |
| HS106A | 61410636 | 0.076 | 3.000 | 0.620 | 0.010 | | 3.10 | 0.074 | 0.058 | 47.0 |
| HS89B | 61410637 | 1.500 | 1.600 | 0.300 | 0.010 | | 3.10 | 0.680 | 0.600 | 114.6 |
| HS89A | 61410638 | 0.069 | 3.100 | 0.530 | 0.010 | | 3.20 | 0.730 | 0.620 | 19.8 |
| HS94B | 61410639 | 0.020 | 2.200 | 0.460 | 0.010 | | 2.20 | 0.036 | 0.005 | 24.8 |
| HS94A | 61410640 | 0.026 | 3.000 | 1.300 | 0.010 | | 3.00 | 0.052 | 0.026 | 19.0 |
| HS100B | 61410641 | 0.040 | 12.000 | 6.000 | 0.010 | | 12.00 | 3.700 | 1.900 | 48.1 |
| HS100A | 61410642 | 0.044 | 0.440 | 0.140 | 0.010 | | 0.48 | 0.024 | 0.005 | 33.8 |
| HS101A | 61410645 | 0.640 | 0.320 | 0.054 | 0.016 | | 0.96 | 0.100 | 0.006 | 26.5 |
| HS95 | 61410647 | 0.019 | 0.760 | 0.210 | 0.012 | | 0.78 | 0.030 | 0.005 | 1831.4 |
| HS102B | 61410648 | 0.013 | 0.460 | 0.300 | 0.011 | | 0.47 | 0.005 | 0.005 | 809.7 |
| HS102A | 61410649 | 0.010 | 0.041 | 0.020 | 0.010 | | 0.05 | 0.012 | 0.005 | 107.9 |
| HS90 | 61410650 | 0.032 | 0.081 | 0.077 | 0.010 | | 0.11 | 0.021 | 0.005 | 140.1 |
| T680B | 61410651 | 3.500 | 0.390 | 0.013 | 0.010 | | 3.90 | 0.016 | 0.012 | 29.0 |
| T680A | 61410652 | 0.058 | 0.036 | 0.019 | 0.010 | | 0.09 | 0.013 | 0.005 | 10.7 |
| HS103A | 61410654 | 0.023 | 0.049 | 0.037 | 0.010 | | 0.07 | 0.016 | 0.005 | 37.9 |

| Site Name | AWRC | N (sum sol ox) {NOx-N, TON} (mg/L) | N (tot kjel) {TKN} (mg/L) | NH3-N/NH4-N (sol) (mg/L) | NO2-N (sol) (mg/L) | NO3-N (sol) (mg/L) | N (tot) {TN, pTN} (mg/L) | P (tot) {TP, pTP} (mg/L) | PO4-P (sol react) {SRP, FRP} (mg/L) | Hardness Calculated |
|---|---|---|---|---|---|---|---|---|---|---|
| HS110 | 61410655 | 0.011 | 0.180 | 0.042 | 0.010 | | 0.19 | 0.029 | 0.005 | 22.3 |
| HS080-1 | 61410656 | 4.000 | | 0.540 | 0.160 | | 5.10 | 0.012 | <0.005 | 415.2 |
| HS080-2B | 61410657 | 0.055 | | 0.130 | <0.01 | | 1.50 | 0.320 | 0.021 | 290.8 |
| HS080-2C | 61410658 | 0.069 | | 0.061 | <0.01 | | 2.50 | 0.170 | <0.005 | 253.0 |
| HS080-3 | 61410659 | 0.042 | | 0.120 | <0.01 | | 1.60 | 0.150 | 0.017 | 156.0 |
| HS080-2A | 61410660 | 0.015 | | 0.130 | <0.01 | | 0.25 | 0.065 | 0.044 | 293.2 |
| HS087-1 | 61410661 | 0.081 | | 0.310 | <0.01 | | 0.65 | 0.020 | 0.008 | 82.6 |
| HS087-2 | 61410662 | 0.790 | | 0.140 | <0.01 | | 1.60 | 0.140 | 0.065 | 123.8 |
| HS087-3 | 61410663 | 0.012 | | 0.220 | <0.01 | | 1.70 | 0.023 | <0.005 | 72.8 |
| HS096-1B | 61410665 | 0.057 | | 0.470 | <0.01 | | 3.30 | 0.260 | 0.210 | 95.7 |
| HS099-1A | 61410667 | | | | | | 1.60 | 0.170 | | |
| HS099-1B | 61410668 | 0.840 | | 0.076 | <0.01 | | 1.70 | 0.017 | 0.005 | 19.8 |
| HS104-1A | 61410669 | 0.034 | | 0.460 | <0.01 | | 0.72 | 0.330 | 0.210 | 59.5 |
| HS104-1B | 61410670 | 2.200 | | 0.077 | <0.01 | | 3.00 | 0.150 | 0.130 | 34.8 |
| HS104-2A | 61410671 | 0.021 | | 2.300 | <0.01 | | 5.20 | 0.370 | 0.290 | 42.9 |
| HS104-2B | 61410672 | 1.300 | | 0.860 | <0.01 | | 3.80 | 0.210 | 0.160 | 26.5 |
| HS104-3A | 61410673 | 0.010 | | 0.600 | <0.01 | | 3.50 | 0.170 | 0.012 | 82.9 |
| HS104-3B | 61410674 | 1.600 | | 0.160 | <0.01 | | 3.00 | 0.120 | 0.089 | 47.2 |
| HS108-1A | 61410675 | 0.068 | | 0.930 | <0.01 | | 6.20 | 0.370 | 0.240 | 192.1 |
| HS108-1B | 61410676 | <0.01 | | 1.100 | <0.01 | | 2.90 | 0.780 | 0.660 | 44.8 |
| HS108-2A | 61410677 | 0.110 | | 0.570 | <0.01 | | 0.88 | 0.029 | 0.028 | 93.2 |
| HS108-2B | 61410678 | 0.180 | | 0.340 | <0.01 | | 2.90 | 0.023 | 0.009 | 55.3 |
| HS109-1 | 61410679 | 0.070 | | 0.850 | <0.01 | | 2.70 | 0.800 | 0.680 | 61.0 |
| HS109-2 | 61410680 | 0.096 | | 0.450 | <0.01 | | 3.60 | 0.044 | 0.016 | 68.5 |
| T561 | 61410682 | 0.200 | | 0.360 | <0.01 | | 2.30 | 0.220 | 0.160 | 18.2 |
| HS097 | 61410683 | 0.030 | | 0.460 | <0.01 | | 0.91 | 0.030 | 0.030 | 107.3 |
| T563 | 61410684 | <0.01 | | 0.290 | <0.01 | | 1.50 | 0.089 | 0.005 | 47.0 |
| T564 | 61410685 | 0.042 | | 0.530 | <0.01 | | 13.00 | 0.270 | 0.026 | 657.5 |

| Site Name | AWRC | N (sum sol ox) {NOx-N, TON} | N (tot kjel) {TKN} | NH3-N/NH4-N (sol) | NO2-N (sol) | NO3-N (sol) | N (tot) {TN, pTN} | P (tot) {TP, pTP} | PO4-P (sol react) {SRP, FRP} | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | Calculated |
| Wetlands | | | | | | | | | | |
| PLI7046 | 6140970 | 0.097 | 4.5 | 0.094 | <0.01 | 0.096 | 4.6 | 0.620 | 0.35 | 63.6 |
| PLI5032 | 6140972 | 0.098 | 5 | 0.19 | <0.01 | 0.095 | 5.1 | 0.037 | 0.025 | 67.6 |
| PLI5033 | 6140973 | 0.12 | 5.4 | 0.19 | 0.01 | 0.11 | 5.5 | 0.300 | 0.2 | 117.4 |
| PLI5033 | 6140973 | 0.13 | 5.2 | 0.19 | <0.01 | 0.12 | 5.3 | 0.310 | 0.2 | 113.3 |
| PLI4835N | 6140974 | 0.11 | 3.2 | 0.071 | <0.01 | 0.11 | 3.3 | 0.200 | 0.11 | 52.2 |
| PLI4835S | 6140975 | 0.12 | 2.6 | 0.066 | <0.01 | 0.12 | 2.8 | 0.095 | 0.033 | 100.4 |
| PLI5180 | 6140976 | 0.12 | 5 | 0.2 | <0.01 | 0.12 | 5.2 | 0.520 | 0.36 | 132.9 |
| PLI5724 | 6140977 | 0.14 | 3.8 | 0.15 | <0.01 | 0.14 | 3.9 | 0.097 | 0.062 | 438.2 |
| PLI5056 | 6140978 | 0.15 | 3.6 | 0.047 | <0.01 | 0.14 | 3.7 | 0.610 | 0.35 | 139.6 |
| PLI3945 | 6140979 | 0.062 | 4.2 | 0.026 | <0.01 | 0.058 | 4.2 | 0.180 | 0.041 | 1468.5 |

# Appendix 3  Laboratory analytes

*Table A- 3: Laboratory analytes measured*

| Analyte Group | Analyte | Special Instructions |
|---|---|---|
| | Unfiltered, 1L plastic | |
| Total Parameters | Acidity as CaCO$_3$ | WL 197, LOR 1 mg/L |
| | Alkalinity | WL 122, LOR 1 mg/L |
| | Bicarbonate HCO$_3$ | WL 122, LOR 1 mg/L |
| | Carbonate CO$_3$ | WL 122, LOR 1 mg/L |
| | Total nitrogen (TN) | WL 239, LOR 0.025 mg/L |
| | Total phosphorus (TP) | WL 239, LOR 0.005 mg/L |
| | Total dissolved solids (TDS) | WL 123, LOR 10 mg/L |
| | Total suspended solids (TSS) | WL 126, LOR 1 mg/L |
| | pH | WL 120 |
| | Conductivity at 25$^{o}$C | WL 121 1 mS/m |
| | Filtered 250 ml | |
| Dissolved Parameters | Ammonia (NH$_3$-N) | WL 239, LOR 0.0010 mg/L |
| | Nitrite (NO$_2$-N) | WL 239, LOR 0.01 mg/L |
| | NO$_2$-N + NO$_3$-N (NOx-N) {TON} | WL 239, LOR 0.01 mg/L |
| | Soluble reactive phosphorus (SRP) | WL 239, LOR 0.01 mg/L |
| | Sulfate (SO$_4$) | WL 119, LOR 5 mg/L as SO$_4$ 2 mg/L as SO$_4$-S |
| | Fluoride (F) | WL 128, LOR 0.2 mg/L |
| | Chloride (Cl) | WL 119, LOR 10 mg/L |
| | Silica (SiO$_2$) | WL 239, LOR 0.002 mg/L as SiO2 |
| | Bromide (Br) | WL 119, LOR 0.01 mg/L |
| | Filtered 125 mL, acid preserve | |
| Dissolved Metals | Iron (Fe) | WL 272, LOR 0.005 mg/L |
| | Magnesium (Mg) | WL 125, LOR 1 mg/L |
| | Sodium (Na) | WL 125, LOR 10 mg/L |
| | Potassium (K) | WL 125, LOR 1 mg/L |
| | Aluminium (Al) | WL 272, LOR 0.005 mg/L |
| | Calcium (Ca) | WL 125, LOR 1 mg/L |
| | Manganese (Mn) | WL 272, LOR 0.001 mg/L |
| | Unfiltered, 125 mL, aicd preserve | |
| Total Parameters | Aluminium (Al) | WL 272, LOR 0.005 mg/L |
| | Arsenic (As) | WL 272, LOR 0.005 mg/L |
| | Boron  (B) | WL 272, LOR 0.02 mg/L |
| | Cadmium (Cd) | WL 272, LOR 0.002 mg/L |
| | Calcium (Ca) | WL 272, LOR 1 mg/L |
| | Chromium (Cr) | WL 272, LOR 0.005 mg/L |
| | Cobalt (Co) | WL 272, LOR 0.005 mg/L |
| | Copper (Cu) | WL 272, LOR 0.005 mg/L |
| | Iron (Fe) | WL 272, LOR 0.005 mg/L |
| | Lead (Pb) | WL 272, LOR 0.01 mg/L |
| | Manganese (Mn) | WL 272, LOR 0.001 mg/L |
| | Mercury (Hg) | WL 41, LOR 0.0001 mg/L |
| | Molybdenum (Mo) | WL 272, LOR 0.005 mg/L |
| | Nickel (Ni) | WL 272, LOR 0.005 mg/L |
| | Selenium (Se) | WL 272, LOR 0.005 mg/L |
| | Zinc (Zn) | WL 272, LOR 0.005 mg/L |

*LOR = Limit of reporting*

*Table A- 4: Laboratory measurement method*

| |
|---|
| WL 272 USEPA 200.7, 200.8 |
| WL 42 USEPA 200.7, 200.8 |
| WL 121 Conductivity meter (APHA 2510B) |
| WL 120 pH meter (APHA 4500) |
| WL 126 Gravimetry (APHA 2540C) |
| WL 128 Ion selective electrode (APHA 4500-F-C) |
| WL 239 Autoanalyser method based on APHA |
| WL 119 Ion chromatography |
| WL 197 Titration (APHA 2310B) |
| WL 122 Titration (APHA 2320B) |
| WL 240 (APHA 5310) |
| WL 125 AAS (APHA 311B,D) |

# Glossary

| | |
|---|---|
| **AAMinGL** | average annual minimum groundwater level |
| **mAHD** | metres Australian height datum, which is equivalent to: mean sea level (MSL) + 0.026 m, low water mark Fremantle (LWMF) + 0.756 m. |
| **DAFWA** | Department of Agriculture and Food Western Australia |
| **DWMP** | Murray drainage and water management plan |
| **LiDAR** | light distance and ranging |
| **m BGL** | metres below ground level |
| **AbMinGL** | absolute minimum water level |
| **MSL** | mean sea level |
| **PASS** | potential acid sulfate soil. Naturally occurring, these are soils containing significant quantities of reduced sulfur (pyrite and other sulfides). When these soils are disturbed the reduced sulfur is oxidised resulting in the release of acidity and often toxic metals |
| **pHf** | field pH |
| **pHfox** | pH after oxidation with a strong oxidising agent |
| $\mathbf{S_{CR}}$ | chromium reducible sulphur |
| **ShaPass** | shallow PASS – the minimum depth to PASS in a core measurement (used in Appendix 1). |
| **SPOCAS** | suspension peroxide oxidation combined acidity and sulfur |

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