



APPROVALS - SUSTAINABILITY - COMPLIANCE

JOHN LEONARD CONSULTING SERVICES

Groundwater and Environmental Consultants



**Response to the 'notice to conduct or
commission another Environmental Evaluation'**

**Incitec Pivot Limited, Phosphate Hill,
Queensland**

DISCLAIMER

EnviroRisk Management Pty Ltd provides comment within this Report relating to the status of environmental site contamination/ impact associated with the nominated property(s) as of the specified assessment date(s). The report is based on environmental risk issues identified during the period of the site assessment and the completeness of information provided by nominated site personnel and made available by others following enquiries.

Determinations made are, by necessity, based on a discussion of groundwater quality results obtained at specific locations.

No professional however, can definitively quantify the presence or confirm the absence of all contamination. There remains the possibility that contaminants are present in locations outside the sampling locations undertaken for this assessment.

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QUALITY CONTROL

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1.0 INTRODUCTION

Southern Cross Fertilisers Pty Ltd (a subsidiary of Incitec Pivot Limited) was issued with a notice (STAT1099) to conduct or commission another environmental evaluation and submit a report on the investigation to the Department of Environment and Heritage Protection (EHP) concerning potential groundwater impact at their Phosphate Hill mine site. The notice specified five (5) requirements that the investigation must address.

Provided below, and supported by an accompanying flash drive containing all raw form data, is a response that aims to, as best practicable, address each of the requirements outlined within the notice.

2.0 RESPONSE TO REQUIREMENTS

The Phosphate Hill mine is located in a very complex, geological setting. Evidence from bore logs, groundwater level data and trends, observed hydraulic response to pumping stresses, and hydro-chemical data indicates the presence of a number of graben and horst like structures caused by major general north-south aligned regional faults and many cross-cutting smaller faults. The faults have not only juxtapositioned rocks of different lithologies and hydrogeological characterisation but have caused aquifer compartmentalisation.

Hydrochemical characterisation identified a number of different water types suggesting areas of younger waters with more rapid (relative) recharge (e.g., bore SDMB02) and other areas of older waters. Mixing of the different groundwaters could contribute to changing water chemistries, particularly major cations and anions, rendering any absolute statements concerning salinity sources challenging.

Groundwater systems have been the subject to a number of investigations [C&R 2010, EnviroRisk 2015, EnviroRisk 2016; JLCS 2016] with a summary of groundwater background information and a conceptual hydrogeological model provided in Appendix 2.

The groundwater quality variability is particularly applicable to major cations and anions where spatial variations across the region have been documented [JLCS, 2016; C&R, 2010]. As an example of salinity variations, Table 1 below illustrates variations in the chloride concentrations between differing aquifer systems within the vicinity of the mine locality that are all unlikely to have any potential mining activity interference.

Salinity, as measured by EC, has also been recorded in regional bores up to 2,880 $\mu\text{S}/\text{cm}$ in the central DEA and up to 4,430 $\mu\text{S}/\text{cm}$ in the far southern aquifer (C&R, 2010). EC was measured at 1,415 $\mu\text{S}/\text{cm}$ and 1,026 $\mu\text{S}/\text{cm}$ for planned reference groundwater bores WAS-RB and EAS-RB respectively at the Phosphate Hill mine site (ref. field notes Sept. 2017).

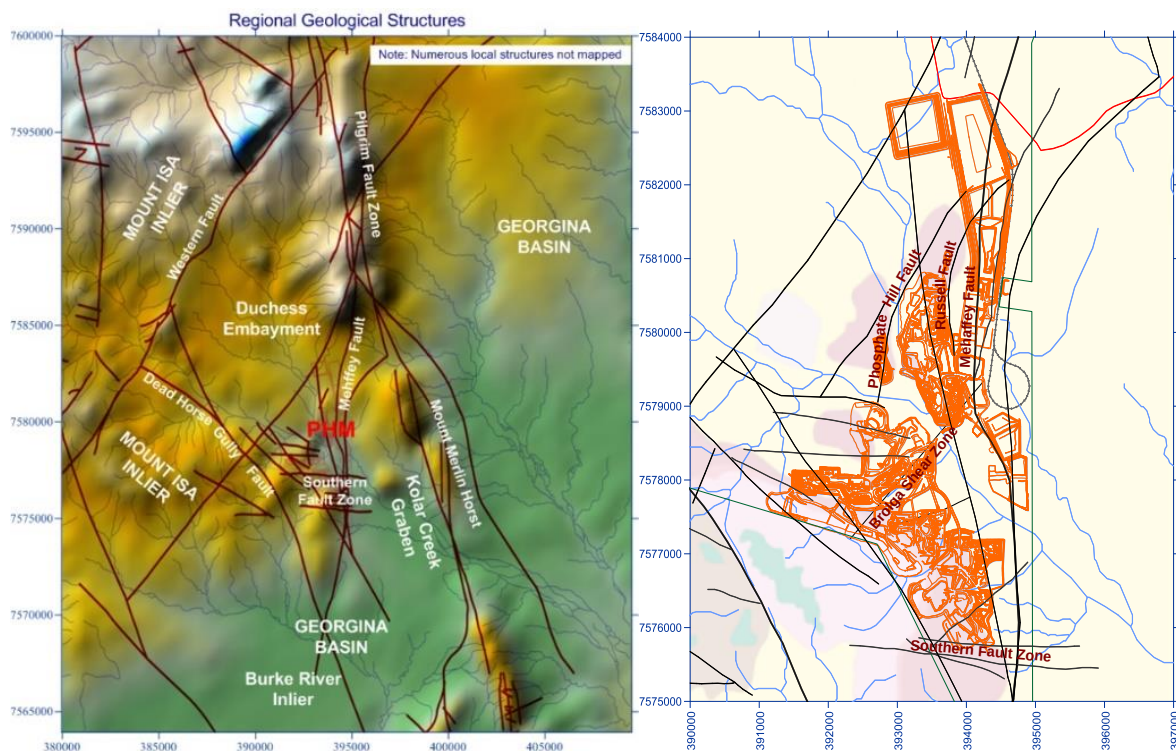
Table 1: Variances in groundwater ‘background’ concentrations of chloride

Aquifer System ¹	Concentration (mg/L)	Reference
Eastern (north on mine lease)	100	Bore EAS-RB
Western (north-west on mine lease)	300	Bore WAS-RB
Eastern (south on mine lease)	175	Bore SDMB02
South, south-west (35km off mine lease)	1,200	Bore MAKBAT
South margin Duchess Embayment Aquifer-DEA	743	Bore MB3002
Central north DEA	528	Bore 87A
South (approx. 16km)	957 & 1,310	District Bores 31 & 32

! Note: some off-site data is from the year 2009

For dissolved solids, there will therefore be technical limitations when gauging environmental impact via direct comparison against a single groundwater bore’s data.

Furthermore, our analysis of bores surrounding the mine site’s ‘Plant Area’, a consequence of the investigation triggered by the DEHP Notice, has identified an inaccuracy with the previously mapped location of the Mehaffy Fault that transects the mine lease. The revised fault location has been incorporated into all hydrogeological mapping undertaken as part of this project. This revision of the fault line, coupled with the identification of additional splinter faults, is an example of the complexity of the mine site geological setting.

**Figure 1. Illustration of regional and local mapped faults in proximity to the mine site.**

Consequently, comparison of the standard up- and down hydraulic groundwater monitoring data to gauge direct mine impact has questionable validity in all instances at the Phosphate Hill mine site.

Various approaches for data interpretation and relevance of background variability against up-gradient reference bores are specified in the Queensland Department of Science, Information Technology and Innovation guidelines document “Using monitoring data to assess groundwater quality and potential environmental impacts” (DSITI, 2017).

The response provided below to each Notice requirement takes into consideration the likelihood of natural geochemistry variabilities when interpreting the Queensland DSITI guidelines.

2.1 Requirement 1:

Continue to collate data to establish the background reference water quality of each aquifer. This should include, but not be limited to:

2.1.1 Requirement 1a

A data set which comprises a minimum of 12 sampling rounds from the background reference bore of each aquifer which has been analysed for the parameters listed in Table E4 of your EA.

Response:

Monitoring results have been collected from monthly sampling rounds commencing June 2016 through to September 2017 inclusive, for the two bores installed with the intention of providing reference groundwater quality data: Bore WAS-RB; and Bore EAS-RB. The locations of the bores illustrated in Figure 2.

Sampling over the period was undertaken by experienced environmental practitioners from C&R Consulting with analysis predominantly conducted by ALS’s environmental laboratories under NATA certification.

Analytes investigated have, as a minimum, included all parameters specified in the Environmental Authority (EA).

Results have been tabulated and subjected to statistical analysis (Appendix 5 and 6).

A spreadsheet with the raw data has been provided to the DEHP separately to this report as a *Master File* on flash drive.

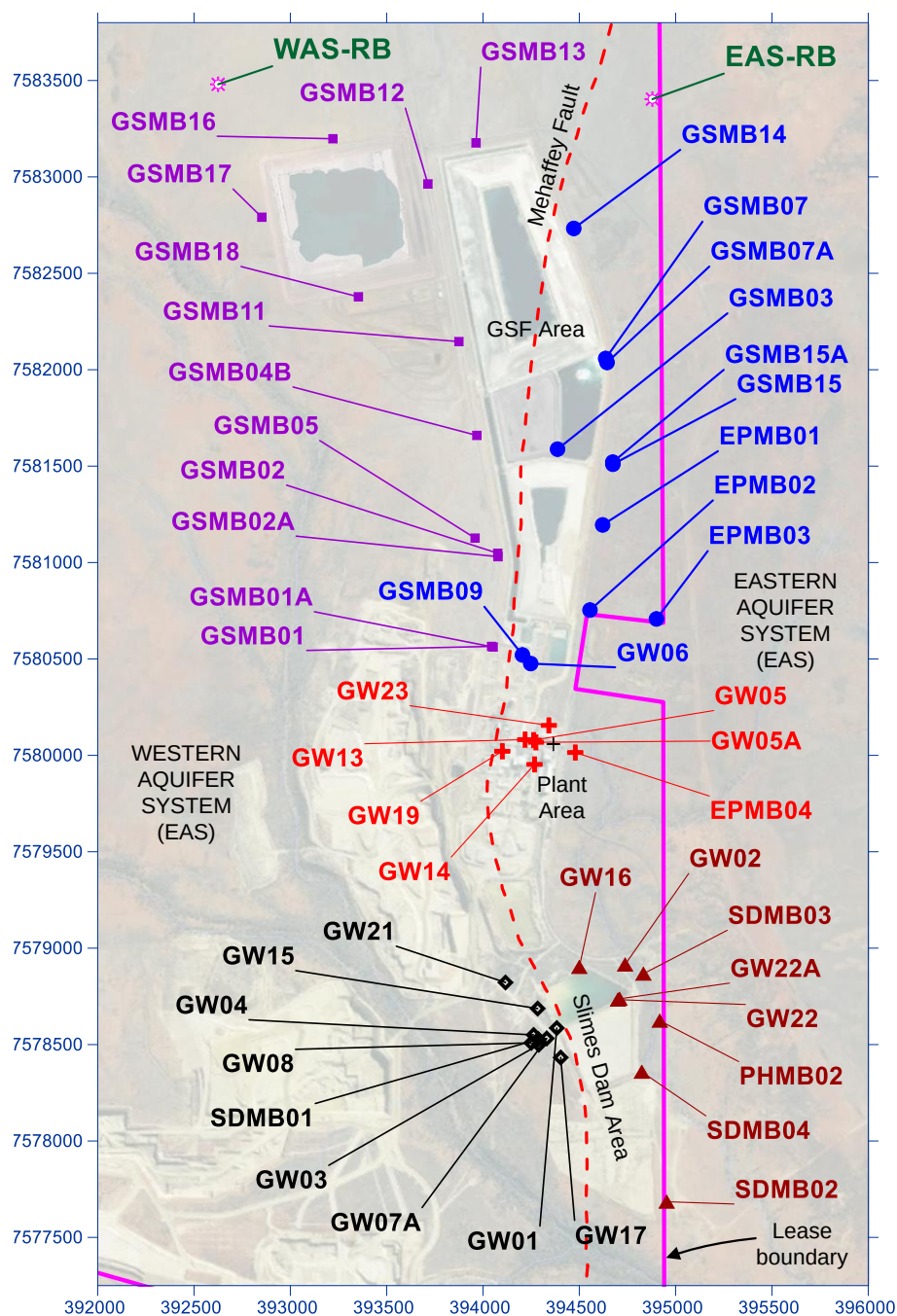


Figure 2: Bore locations

2.1.2 Requirement 1b

Descriptive statistics for each background reference bore (i.e. date range, count, median, mean, minimum, maximum, 80th and 95th percentiles).

Response:

Refer to full data set provided in Appendices 5 and 6.

A summary of statistical outcomes is provided below in Table 2a and 2b.

Table 2a: Water Quality in Reference Bore EAS-RB (selected statistics)

Indicator	Unit	EAS-RB				Dissolved Metals			
		min	Ave.	80th	95th	min	Ave.	80th	95th
pH	pH	7.62	7.99	8.14	8.32				
EC	µS/cm	799	952	983	1044				
TDS	mg/L	468	553	561	612				
Calcium	mg/L	59	87	92	103				
Chloride	mg/L	87	97	102	106				
Fluoride*	mg/L	0.40	0.55	0.60	0.70				
Nitrogen-total*	mg/L	0.30	0.48	0.60	0.69				
Sulphate	mg/L	31	33	34	34				
Total P*	mg/L	0.03	0.26	0.30	0.78				
Reactive P*	mg/L	0.01	0.02	0.02	0.09				
Al*	mg/L	0.26	1.50	2.32	3.94	0.01	0.01	0.01	0.04
As	µg/L	0.5	1.2	2.0	2.3	0.5	0.6	0.5	1.0
Cd	µg/L	0.1	0.1	0.2	0.3	0.1	0.1	0.1	0.1
Co	µg/L	0.5	1.9	3.0	4.9	0.5	0.6	0.5	0.9
Cr	µg/L	1.0	4.2	6.0	10.0	0.5	0.5	0.5	0.5
Cu	µg/L	7.0	20.1	23.6	48.0	0.5	7.6	10.2	11.3
Hg	µg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ni	µg/L	5.0	6.0	9.2	14.2	0.5	2.1	3.2	5.5
Pb	µg/L	2.0	6.9	8.4	19.8	0.5	0.7	0.5	2.0
Se	µg/L	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
U	µg/L	7.0	7.5	8.0	8.0	4.0	6.4	7.0	7.3
Zn	µg/L	12.0	41.6	54.0	96.7	2.5	12.7	14.4	31.4

<LOR results taken as 50% of detection limit. * - results rounded to 2 significant figures.

Table 2b: Water Quality in Reference Bore WAS-RB (selected statistics)

Indicator	Unit	WAS-RB				Dissolved metals			
		min	Ave.	80th	95th	min	Ave.	80th	95th
pH	pH	7.6	8.18	8.35	8.37				
EC	µS/cm	1360	1419	1452	1460				
TDS	mg/L	790	825	833	866				
Calcium	mg/L	70	81	85	95				
Chloride	mg/L	258	282	294	298				
Fluoride*	mg/L	0.80	1.03	1.12	1.20				
Nitrogen-total*	mg/L	0.05	0.23	0.34	0.50				
Sulphate	mg/L	32	64	73	76				
Total P*	mg/L	0.02	0.35	0.55	1.02				
Reactive P*	mg/L	0.01	0.01	0.02	0.03				
Al*	mg/L	0.02	0.22	0.32	0.54	0.01	0.02	0.01	0.06
As	µg/L	1.0	3.0	4.0	6.0	1.0	3.0	3.0	6.0
Cd	µg/L	0.1	0.1	0.1	0.1	0.05	0.05	0.05	0.05
Co	µg/L	0.5	0.9	1.2	2.3	0.5	0.7	0.5	2.0
Cr	µg/L	0.5	1.5	2.0	4.7	0.5	0.5	0.5	0.5
Cu	µg/L	4.0	8.3	12.0	13.6	0.5	1.4	1.2	4.8
Hg	µg/L	0.1	0.1	0.1	0.1	0.05	0.05	0.05	0.05
Ni	µg/L	0.5	7.4	10.4	23.7	0.5	3.5	4.8	14.0
Pb	µg/L	0.5	1.3	2.0	2.6	0.5	0.7	0.5	1.3
Se	µg/L	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
U	µg/L	2.0	4.3	5.2	6.0	2.0	3.6	5.0	5.0
Zn	µg/L	14.0	30.9	45.2	62.2	2.5	14.3	7.0	69.9

<LOR results taken as 50% of detection limit. * - results rounded to 2 significant figures.

2.1.3 Requirement 1c

Box plots for all background reference bores for each water quality parameter which shows the median, 20th and 80th percentiles and the environmental value of livestock drinking water, and EA limits.

Response:

Box plots for the EAS and WAS-reference bores are provided in Appendices 5 and 6, respectively.

Plots have been generated as per standard analytical practice and in accordance with the Queensland's assessment of groundwater quality guidelines (Reference 7). These box plots reveal the box range within the first and third quartiles (i.e. 25 & 75thile)¹. They also show the maximum, minimum and outliers (as small red squares).

Please note that a full breakdown of statistics including all 20th and 80th percentiles are included within the tabulated data summary along with selected plots illustrating the recommended EA triggers and limits.

For the bores installed for reference purposes:

- i. all analytical results were below current specified EA Limits (not 95thile, given GW05A should not be adopted as a reference bore) other than Total Aluminium in bore EAS-RB that returned a maximum singleton result of 6.95 mg/L² (c.f. a limit of 5mg/L);
- ii. all indicators are well within the livestock drinking water quality criteria.

2.1.4 Requirement 1d

The distribution of major anions and cations in each bore (i.e. piper diagram).

Response:

Piper diagrams representing major cation and anions are provided the Appendices 5 and 6. Durov diagrams are also provided as they tend to better illustrate outliers as the chart includes TDS and pH in addition to major cations and anions.

Bore WAS-RB's piper diagram has been reproduced below:

¹ Individual limits have not been included on all plots.

² This result is an outlier but is presented here for illustrative purposes to reveal potential Al fluctuations.

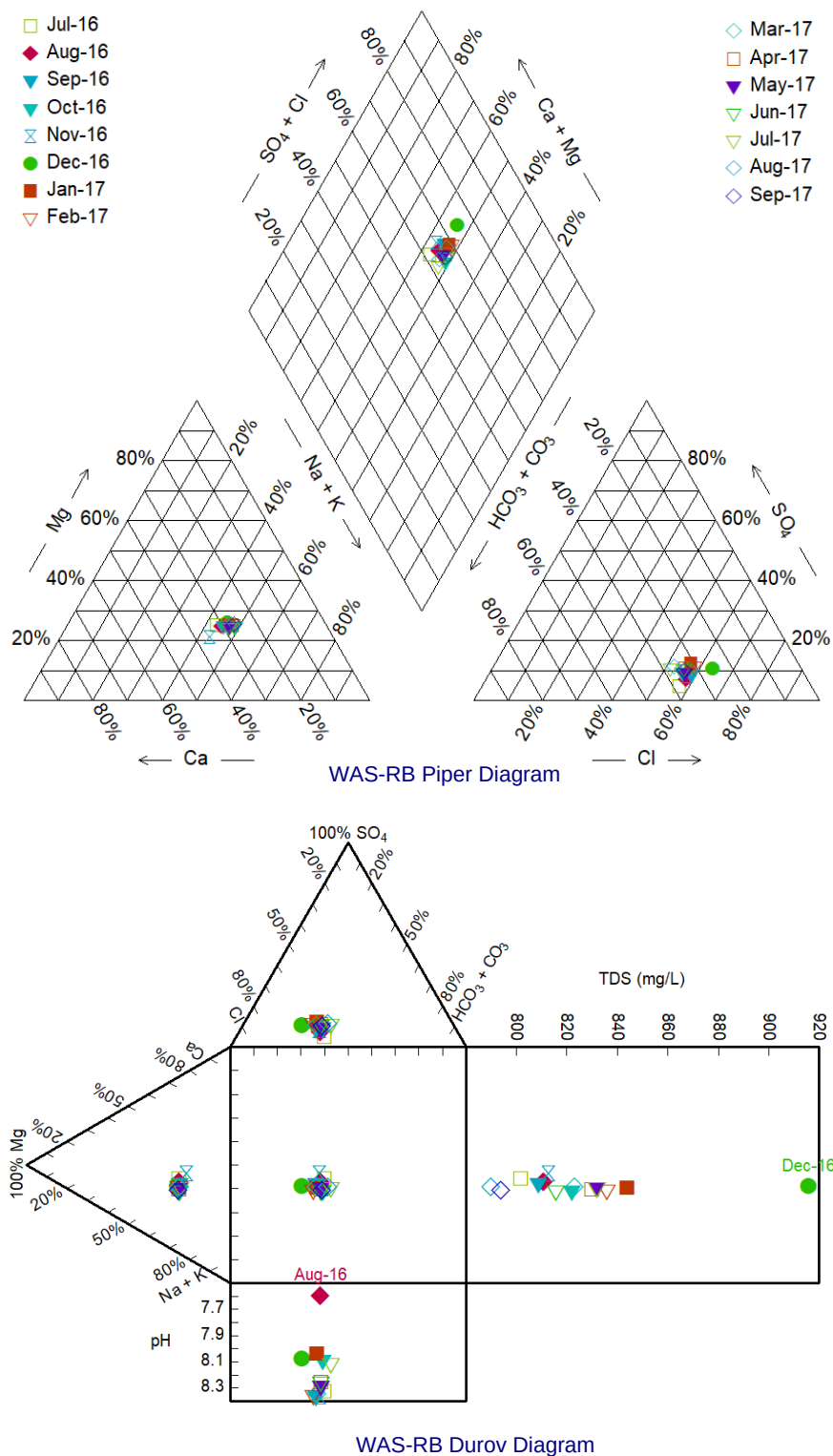


Figure 3: Piper Diagram & Durov Diagram WAS-RB

2.1.5 Requirement 1e

Time series plots and statistical analysis of the water quality for each data to assess trends in water quality parameter concentrations.

Response:

Time series plots for WAS-RB and EAS-RB are provided in Appendices 5 and 6, respectively.

Major cations and anions and other indicators within the reference bores revealed no discernible trends over the monitoring period.

Allowing for the initial few monitoring rounds post bore construction, water quality appears to have stabilised to reveal a consistent water quality within bores WAS-RB and EAS-RB.

Given the slow water movement to the south within the Eastern Aquifer System (i.e. cm to m/year) it would be preferential to have data attained over a longer period (e.g. 3-5 years) to ensure possible varying quality is captured. This is consistent with Queensland guidelines (QWQG, 2009).

Notwithstanding this, the data set appears a reasonable representation of the groundwater at locations monitored, with minimal chemical variations reported over the latter half of monitoring rounds.

2.1.6 Requirement 1f

Time series plots and statistical analysis for the data collected from each background reference bore for each monitoring parameter.

Response:

Time series plots and statistical analysis for major cations and anions and a selection of other indicators are provided Appendices 5 and 6.

Note: An indicator that is at, or below, analytical level of reporting limits has not been included as a time series plot.

2.2 Requirement 2:

Using the information collected in Requirement 1a) determine appropriate trigger values and limits.

Note: The method of assessing groundwater quality and deriving trigger values and contaminant limits must be consistent with the document titled 'Using monitoring data to assess groundwater quality and potential environmental impacts' (March 2017, Department of Science, Information Technology and Innovation).

Response:

The guidelines have been applied to generate trigger values and environmental limits. In particular, the recommended four (4) steps to derive triggers have been followed, namely:

Step 1 – *Are there sufficient good quality monitoring data and bores to calculate statistically robust trigger values?*

A reasonable data set is available with 15 monitoring events capturing reference bore water quality. Trigger values have been calculated on the range available. Given the aquifer properties, particularly to the east, monitoring over a longer period (e.g., 36 months) would be required to definitively capture changes due to a slow groundwater flow to the south. The monitoring frequency should also be increased to bi-annual.

Step 2 – Compare 20th (for pH) and 80th percentiles of monitoring data to relevant water quality guidelines.

Statistical analysis has been conducted on all results and 80th percentile values derived for all indicators including heavy metal concentrations.

Step 3 – Determine locally derived water guidelines where appropriate.

The values derived are based on the Environmental Values (EV) of the groundwaters wherever practicable.

- Within the Eastern Aquifer System (EAS) the EV is for livestock drinking.
- Within the Western Aquifer System (WAS), given the lifespan of the mine (i.e. approx. 20 years), the EV is for potable purposes and thereafter for livestock drinking purposes.

Due to spatial variations in groundwater conditions (as identified during the analysis undertaken as part of Step 2 above), the blanket application of percentile limits against a number of indicators is not deemed appropriate including: pH, TDS/ EC, fluoride, nitrogen, phosphorus, uranium and zinc.

Heavy metals other than Uranium and Zinc have been observed not to be subject to spatial variations and are present in low concentrations within the groundwaters of both major aquifer systems. Background reference bore water quality conditions have therefore, been used to derive investigation trigger values for all heavy metals/ metalloids other than Uranium and Zinc.

Step 4 - Test the locally derived trigger values.

Locally derived trigger values were tested against likely background variations and the ability to provide an early warning for an emerging impact well prior to the environmental limit being reached.

With consideration to the limitations explained at the beginning of this section, the following trigger levels for investigation³ have been derived based on the suggested approach within the guidelines for the 'reference' bores.

³ According to the guidelines 'trigger values should be fit for purpose and conservative enough such that, when applied, they provide an early warning of emerging potential impacts to the quality of the groundwater' recognising that 'ideally, groundwater quality should be maintained within its natural range of variability'. (DSITI, 2017)

Table 3: Derived Trigger Values and Environmental Limits

Indicator	Unit	Bore WAS-RB		Bore EAS-RB	
		EV = Drinking Water		EV = Livestock Watering	
		Trigger ^Q Dissolved/ Total	Limit ^{%Q}	Trigger ^Q Dissolved/ Total	Limit ^Q
pH	pH	6.5 – 8.5 ^{SS}	5.0 – 9.0 ^{EA}	6.5 – 8.5 ^{SS}	5.0 – 9.0 ^{EA}
EC ^A	µS/cm	1,791 ^{SS}	5,970 ^{SS}	2,985 ^{SS}	5,970
TDS	mg/L	1,200 ^{SS}	4,000 ^{*SS}	2,000 ^{SS}	4,000
Calcium	mg/L	250 ^{SS}	1,000	250 ^{SS}	1,000
Chloride	mg/L	Interpretation Only ^{EA}		Interpretation Only ^{EA}	
Fluoride	mg/L	1.12 ^{BG}	1.5	1.0 ^{SS}	2.0
Nitrogen-total	mg/L	0.34 ^{BG}	1.83 ^{SS}	0.6 ^{BG}	9.13 ^{SS}
Nitrite as NO ₂ ⁻	mg/L	1.5 ^{SS}	6 [@]	7.5 ^{SS}	30
Nitrate as NO ₃ ⁻	mg/L	25 ^{SS}	100 [@]	100 ^{SS}	400
Sulphate	mg/L	154 ^{BG}	500	250 ^{SS}	1,000
Total P	mg/L	0.55 ^{BG}	3.12 ^{EA}	0.30 ^{BG}	3.12 ^{EA}
Reactive P	mg/L	0.04 ^{EA}	0.09 ^{SS}	0.04 ^{EA}	0.09 ^{BG}
Al	mg/L	0.01 / 0.32	5.0 ^{EA}	0.01 / 2.32	5.0
As	mg/L	0.003 / 0.004	0.01	0.001 / 0.002	0.5
Cd	mg/L	0.0001 / 0.0001	0.002	0.0001 / 0.0002	0.01
Co	mg/L	0.001 / 0.0012	0.005 ^C	0.001 / 0.003	1.0
Cr	mg/L	0.001 / 0.002	0.05 [#]	0.001 / 0.006	1.0
Cu	mg/L	0.0014 / 0.012	2.0	0.010 / 0.0236	0.5
Hg	mg/L	0.0001 / 0.0001	0.001	0.0001 / 0.0001	0.002
Ni	mg/L	0.005 / 0.0104	0.02	0.003 / 0.0092	1.0
Pb	mg/L	0.001 / 0.002	0.01	0.001 / 0.0084	0.1
Se	mg/L	0.01 / 0.01	0.01	0.01 / 0.01	0.02
U	mg/L	0.013 ^{SS} / 0.015 ^{SS}	0.017	0.013 ^{SS} / 0.015 ^{SS}	0.2
Zn	mg/L	0.072 ^{EA} / 0.072 ^{EA}	3.0	0.072 ^{EA} / 0.072 ^{EA}	20.0

LEGEND:

Shaded indicators are not presently part of the EA but are recommended as they are indicators of health impact and are captured in the environmental value criteria.

Q - Triggers for both dissolved and total metals and metalloids have been specified, but the Limit relates to the 'total concentration of the constituent, irrespective of whether it is dissolved, complexed with an organic compound, or bound to suspended solids' [ANZECC, 2000, Vol1: Section 4.3.4 Heavy Metals page 4.3-4].

% - Limit is based on Drinking Water Criteria – as potable water will be sourced from WAS for an estimated 20 years and thereafter the EV will need to meet an equivalent, or less stringent, criteria of Livestock Watering.

BG – Trigger is from respective Reference Bores (i.e. WAS-RB; EAS-RB) 80th percentile; Limit at 95th percentile

SS – Site specific locally derived trigger or limit

EA – Environmental Authority specified limit or trigger (2017) has been retained

***** - Given variations across the mine within the WAS, and that the potable supply can (and is) managed by the mine, the long- term Livestock Watering criteria is specified as the Limit.

^ EC trigger derived from TDS value of a typical NaCl dominated water i.e. divide by 0.67.

- As hexavalent chromium

@ - Adult standard specified as no bottle feeding of children occurs on the mine site, including the Village.

C - Cobalt (WAS) – 0.005 mg/L has been specified which is the upper acceptable range reported by World Health Organisation (WHO)

2.2.1 Rationale For Limits And Triggers

LIMITS:

The Limit was taken directly from the Environmental Value investigation criteria as specified by relevant Australian guidelines i.e.

- WAS = Australian Drinking Water Guidelines 6: 2011 (updated October 2017) NHMRC/NRMMC;
- EAS – Australian and New Zealand Guidelines for Fresh and Marine Water Quality, 2000 ANZECC/ARMCANZ).

Note: Limits for heavy metals/ metalloids are specified as ‘total’ concentrations.

Where no health based limit is specified in the EV criteria, the following has been applied:

pH-

The range as specified in the current EA has been adopted. This provides for coverage of pH levels that are unlikely to represent health issues. Given the varied water systems the range is appropriate to protect the environmental values.

TDS (& EC) –

Varied waters systems are observed across the mine site with a range of salinities. The limit within both the WAS & EAS has adopted the Livestock Watering value. The approach aims to avert natural variation being above the limit at times across the WAS aquifer. TDS is a palatability issue and may be controlled by mine site management where necessary. This palatability threshold is catered for in the investigation trigger concentration. The limit aims to protect the long- term values of the groundwater.

Phosphorus –

The limit as specified in the current EA has been adopted. Given the varied water systems and occurrence of Phosphate ore across the mine site, total phosphate has been observed to be variable. Retention of the existing EA concentration limit is considered protective of health values and makes allowances for site specific natural fluctuations in quality (arising as a result of groundwater table changes observed naturally and from draw down).

Reactive Phosphorus –

The 95th percentile value taken from the EAS -RB reference bore has been applied to both aquifer systems. The site- specific limit for the WAS bores was adopted due to water quality variabilities observed within the WAS. The WAS-RB does not appear to reflect possible natural variations in the water systems encountered. The approach taken aims to avert limit excursions due to natural variabilities across the mine site.

Nitrogen –

A site- specific limit for nitrogen (total) has been derived from the Nitrite drinking water criteria. This is a reasonably conservative approach associated with the likely health implications of nitrogen compounds to both humans and livestock.

The approach taken, as opposed to using reference bore calculations, aims to avert natural variation in total nitrogen being above the limit.

Aluminium –

The limit as specified in the current EA has been adopted. As Aluminium is found within bore sediments, the approach taken, as opposed to using reference bore calculations, aims to avert natural variation in total metal content being above the limit.

TRIGGERS:**For non-metal indicators:**

To avert triggering an investigation based on natural variations in water quality, a site-specific trigger value (identified by 'SS') has been specified at 25% of the 'Limit' value unless:

- i. the background is elevated (identified by the superscript 'BG'), whereas the 80th percentile from the reference bore quality data has been specified; or
- ii. other site- specific conditions, considered likely to be as a result of natural variations, required the use of a derived value based on broader mine site bore data (as outlined below).

TDS (& EC) –

The WAS trigger replicates the Limit given the potable supply is managed by IPL for the mine under site specific area constraints. The groundwater quality is observed to vary around this 'palatability' trigger. This is recognised by the mine and control measures over drinking water palatability are already in place at the mine and village.

TDS (& EC) –

The trigger for the EAS represents 50% of the Limit (given the variability in salinity). The approach taken aims to avert natural variations being above the trigger value.

pH –

site specific trigger is protective of all drinking water use and facilitates the effectiveness of chlorination.

For metals/ metalloids (triggers have been set for both filtered (dissolved) and total metal concentrations):

Trigger values have been derived from 80th percentile values from the respective WAS and EAS Reference Bore data for both dissolved and total concentration, capped at 1ppb (0.001mg/L) for metals other than Cd and Hg being set at 0.01ppb (0.00001mg/L) and Selenium at 10ppb (i.e. typical analytical 'limit of reporting' (LOR)) other than for:

- **Uranium:** The statistically derived dissolved reference bore value of 0.010mg/L was observed to be exceeded, albeit marginally, in a number of bores. These bores were observed to have no upward trend in concentrations. Therefore, to avert likely natural fluctuations being unnecessarily triggered, a value of 0.013mg/L has been derived. A similar process was undertaken for total Uranium and a value of 0.015mg/L derived.

- **Zinc:** The 0.072mg/L trigger specified in the current EA has been adopted. As Zinc is found within bore sediments, the adoption of the current trigger to cater for natural variation in total metal content being above the triggers will prevent unnecessary investigations.

- **Fluoride:** Whilst the WAS trigger is based on statistical analysis of the WAS-RB (i.e. 80thile), a site-specific derived trigger is specified for the EAS equivalent to 50% of the Limit. Variability in data from a number of bores including in pre-2010 data (e.g. GSMB07, GSMB14, EPMB03 and others) suggest fluctuations in quality may occur that could reasonably represent natural variations. To avert likely natural fluctuations being unnecessarily triggered, a value of 1mg/L has been derived.

The rationale followed to derive trigger values was for the value to be sufficiently below the Limit to provide a reasonable response time should the need arise, but also reasonable against the natural expected fluctuations so as to not unnecessarily trigger an investigation.

In the case of nitrite and nitrate, being nitrogen based compounds, further conservatism exists as they are also captured within the total nitrogen trigger concentration.

Conformance Appraisal

Conformance with the trigger and limit values is recommended to be assessed as per the Queensland guidelines, that includes a:

- Tier 1 (rolling mean using 50thile of 8-12 samples across wet and dry seasons); and
- Tier 2 (95th percentile) for 3 consecutive exceedances approach. Exceedance of a trigger value should be assessed against both filtered and total concentrations.

2.3 Requirement 3:

Compare the results from Requirement 1a) to all current and historical groundwater monitoring results and determine:

- a. if groundwater has been impacted by mining activities.*
- b. the source, cause and extent of any environmental harm caused by mining activities.*

Note: The sample analysis requirements of sections 1(a)(i)-(f) must also be utilised when reviewing current and historical groundwater monitoring results.

Response:

The requirement states '*compare results... to all current and historical groundwater monitoring results*'. Since the mines establishment in the 1970's, there have been many bores drilled that have intersected to groundwater and many results reported. Some bores were however, monitored only once, with limited detail recorded to verify the reliability and integrity of data.

To ensure data stands up to an acceptable level of scientific scrutiny, the following interpretation has been made as to bore results that need reporting against this requirement:

- i) All current bores used to monitor groundwater quality as per the Environmental Authority;
- ii) Any additional bores installed as part of investigations into the Plant Area and the GSF where sufficient data is available to permit statistical analysis and interpretation, i.e. at least 4 separate monitoring events underpinned by relatively sound analytical techniques; and
- iii) Historic monitoring results from other bores to be included where there is a data set that is likely to be verifiable and substantial enough to permit investigation and interpretation i.e. at least 4 separate monitoring events underpinned by relatively sound analytical techniques.

Under this interpretation, all groundwater monitoring results from the bores listed in Table 4 below have been assessed for groundwater impact.

The table lists the period bores have been monitored, monitoring frequency and whether the bore continues to be included in the monitoring program.

Although there are other bores across the mine site, including mines site bores, extraction bores for production and other GW series bores, those selected for statistical analysis have met the selection criteria as specified above.

The number and breadth of bores selected is considered representative of a reasonable coverage of the mine site within both major aquifer systems.

Table 4: Monitoring Programs and Bore Status

Aquifer System	Area	Bore	Monitored Periods	Program	Currently Monitored	Monitoring Frequency	No of Analyses
EAS		EAS-RB	Jun-16 to Sep-17	EMP	✓	Monthly	14
WAS		WAS-RB	Jun-16 to Sep-17	EMP	✓	Monthly	14
EAS	GSF	GSMB14	Oct-02 to Jul-17	EMP	✓	6-Monthly	31
		GSMB07	Jul-02 to Jul-08	EMP	×		14
		GSMB07A	Aug-09 to Jul-17	EMP	✓	6-Monthly	14
		GSMB03	Jul-02 to Jul-06	EMP	Destroyed		10
		GSMB15A	Jul-06 to Jul-17	EMP	✓	Quarterly	33
		GSMB15	May-06 to Jan-09	EMP	×		7
		EPMB01	Oct-02 to Jul-17	EMP	✓	Quarterly	41
		EPMB02	Jul-02 to Jul-17	EMP	✓	Quarterly	44
		EPMB03	Jul-02 to Oct-05	EMP	Destroyed		9
		GSMB09	Jul-02 to Jul-17	EMP	✓	Quarterly	39
		GW06	Nov-11 to Aug-09	DD	×		9
WAS	GSF	GSMB16	Sep-14 to Jul-17	EMP	✓	6-Monthly	7
		GSMB13	Jul-02 to Jul-17	EMP	✓	6-Monthly	29
		GSMB12	Jul-02 to Jul-17	EMP	✓	6-Monthly	32
		GSMB17	Jul-15 to Jul-17	EMP	✓	6-Monthly	4
		GSMB18	Sep-14 to Jan-17	EMP	Destroyed	6-Monthly	4
		GSMB11	Sep-04 to Jul-17	EMP	✓	6-Monthly	30
		GSMB04B	Aug-09 to Jul-17	EMP	✓	Quarterly	27
		GSMB05	Jul-02 to Aug-09	EMP	×		17
		GSMB02	Aug-99 to Dec-06	EMP	×		12
		GSMB02A	Oct-15 to Jul-17	EMP	✓	Quarterly	27
		GSMB01	Jul-02 to May-07	EMP	×		14
		GSMB01A	Aug-09 to Jul-17	EMP	✓	Quarterly	27
EAS	Plant	GW23	Jun-07 to Aug-10; Sep-17	DD	×		12
		GW13	Nov-06 to Aug-09; Sep-17	DD	×		10
		GW05	Nov-06 to Apr-09	DD	×		9
		GW05A	Aug-09 to Jul-17	EMP	✓	Quarterly	26
		GW19	Jun-07 to Aug-08	DD	×		13
		EPMB04	Oct-06 to Jul-17	EMP	✓	Quarterly	40
		GW14	Nov-06 to Oct-07; Sep-17	DD	✓		5
EAS	Slimes Dams	GW02	Nov-06 to Jan-10	EMP	×		12
		GW16	Jun-07 to Aug-09	DD	×		8
		SDMB03	Jul-02 to Jul-17	EMP	✓	6-Monthly	37
		GW22A	Aug-09 to Aug-10	DD	×		5
		GW22	Jun-07 to Apr-09	DD	×		7
		PHMB02	Jun-09 to Aug-10	TEP	×		6
		SDMB04	Jul-02 to Jul-17	EMP	✓	6-Monthly	40
		SDMB02	Jul-02 to Jul-17	EMP	✓	6-Monthly	39
WAS	Slimes Dams	GW21	Jun-07 to Aug-10	DD	×		12
		GW15	Jun-06 to May-10	DD	×		10
		GW01	Nov-06 to Aug-10	DD	×		15
		GW04	Nov-06 to Aug-10	DD	×		14
		GW07A	Nov-06 to Aug-10	DD	×		14
		SDMB01	Jul-02 to Jul-17	EMP	✓	6-Monthly	43
		GW08	Nov-06 to Jan-10	DD	×		9
		GW03	Nov-06 to Aug-10	DD	×		13
		GW17	Jun-07 to Aug-09	DD	×		8

Notes:

EMP= Environment Monitoring Program; DD = Due Diligence monitoring,

Bore GW05A is the current reference bore.

Bores WAS-RB and EAS-RB were sited up-hydraulic gradient from the Phosphate Hill mine as potential reference bores.

The other assessed bores were sited to monitor potential contamination sources including the Gypsum Storage Facility (GSF), the plant area or the Slimes Dams area.

2.3.1 Groundwater Impact Determination

Groundwater impact has initially been assessed by comparing the 20th (in the case of pH) and the 80th percentile results against the derived criteria: trigger values and limits. Box and whisker plots similar to that provided below have been generated to illustrate groundwater quality conditions and are included in Appendix 5 (EAS-RB) and 6 (WAS-RB). Bores are listed as best possible from the north to the south of the mine site along the X- axis. The three(3) main potential contamination source areas, the Gypsum Storage Facility (GSF), the Plant Area and the Slimes Dams Area, are indicated on the Box and Whisker plots with an example provided in Figure 4.

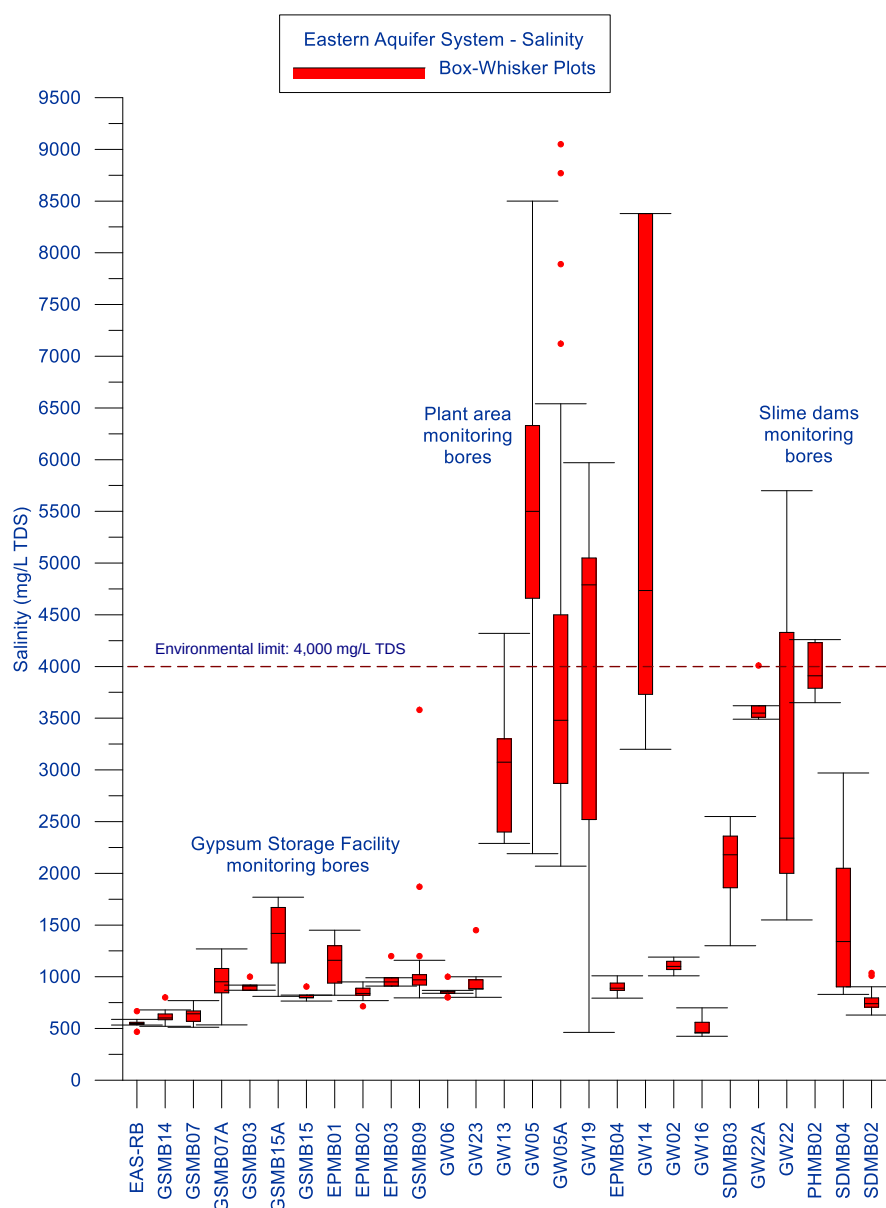


Figure 4: Box-Whisker plot - TDS (Eastern Aquifer System)

From the data set, and with consideration to likely variations in expected regional and local water quality, Tables 5 and 6 outline the bores with potential to exhibit at least contributory impact from mining activities and includes a comment on the likely significance of results.

Table 5: Bores with an indicator that has exceeded the nominated environmental Limit[#]

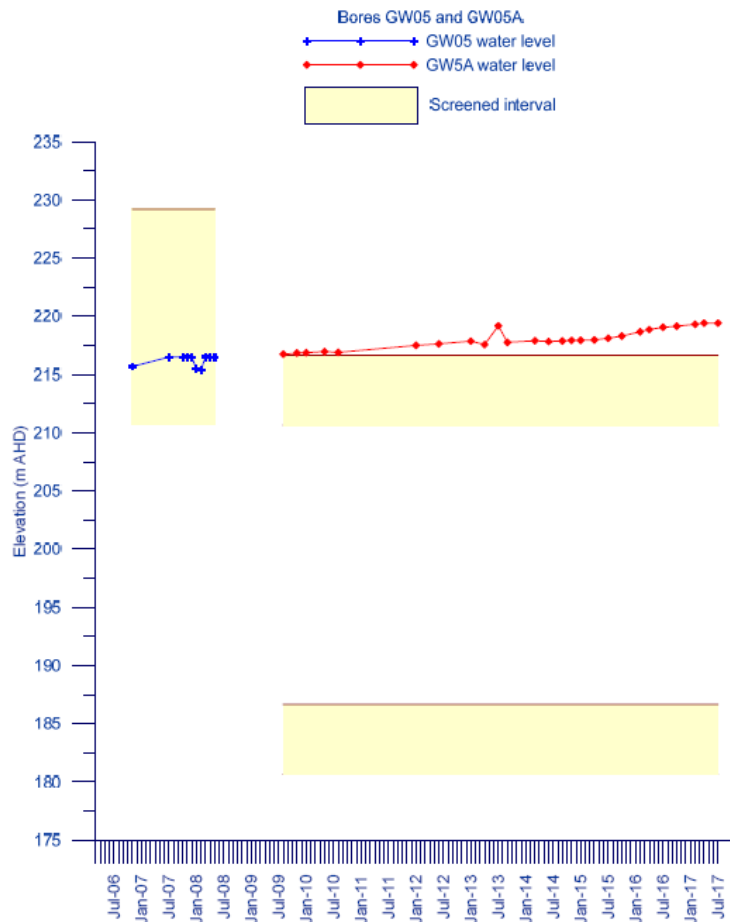
Bore(s)	Indicator(s) ⁺	Aquifer/ Location	Comment
GSMB15	Fluoride	EAS/ East of GSF	Latest Result 2009. Highest = 2.3 mg/L c.f. limit of 2.0mg/L (Bore no longer exists). Refer to comments on replacement bore GSMB15A
GSMB15A	Reactive Phosphorus	EAS/ East of GSF	Latest result = 2017 A number of Total P results are less than Reactive P placing questions on data veracity. Highest = 0.19 mg/L c.f. limit of 0.09mg/L
GW5/ GW05A	TDS	EAS/ Plant: Central north	Chloride is the dominant anions in the TDS. Whilst the source of Chloride has not definitively been confirmed, it is at a level that cannot readily be explained by natural variations. TDS Highest=9,050mg/L c.f. limit of 4,000mg/L
GW14	TDS	EAS/ Plant: Central area	The TDS increased from 3,730 mg/L in Nov 2006 to 8,380 in September 2018 with Cl the dominant ion. Whilst the source of Chloride has not been definitively confirmed, it is at a level that cannot readily be explained by natural variations. Latest result = 2017 (single round); previously monitored over 2006-09. Highest=8,380mg/L c.f. limit of 4,000mg/L
GW19	TDS	EAS/ Plant: Central area	Latest result = 2010 (Bore no longer exists)
GW22A	TDS	EAS/Slimes dams	Latest result = 2010. Historic result needs re-confirmation.
		Nil excursions within WAS	

Notes:

[#]- Conformance assessed by using Tier 1 rolling average (generally requires 8-12 consecutive readings) and Tier 2, 3x consecutive readings above limit. Where data points are sparse, a common sense likely to conform appraisal has been taken.

⁺ - TDS has been used in preference to EC.

Bores that have been routinely monitored over past years were subjected to charting to determine whether increasing trends were evident, as illustrated in Figures 5 and 6. Full details of time response charts and associated data is provided in the Appendices 5 - 8.



Note: July 2013 spike does not coincide with rain – 2013 was a very low rainfall year. The spike coincides with a dip in ionic content suggesting a water leak that entered groundwater.

Figure 5: Bore GW5/GW05A Time Series Hydrograph

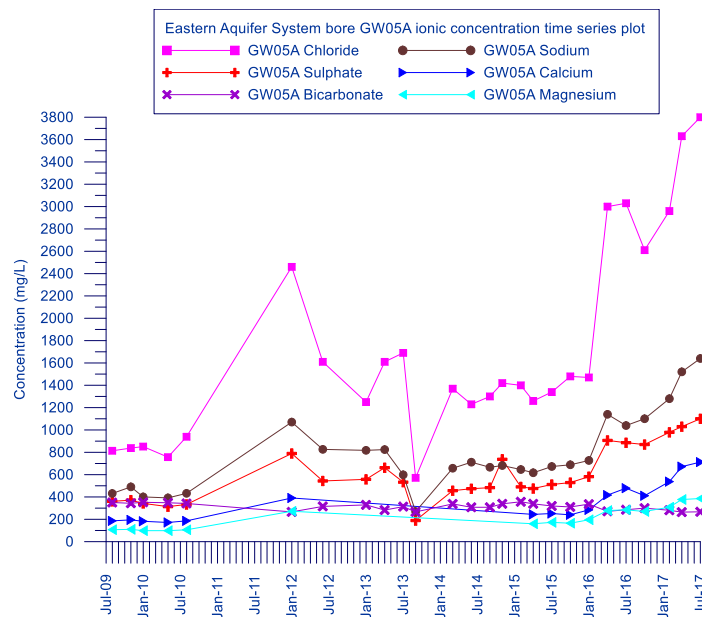


Figure 6: Bore GW05A cation and anion timeline trends

Other bores exhibit indicators that exceed the trigger thresholds warranting further investigation and continued monitoring of any trends. Some of the prominent results where triggers were exceeded are outlined in Table 6:

Table 6: Bores revealing impact against the nominated investigation Trigger Value

Bore(s)	Indicator(s) ⁺	EAS Location	Result Overview
GSMB15A	Sulphate, nitrogen	East of GSF	Highest = 383 mg/L c.f. trigger of 250mg/L Highest = 2.3 mg/L c.f. trigger of 0.6mg/L
EPMB01	Fluoride	South east of GSF	Highest = 3.2 mg/L c.f. trigger of 1.0mg/L Potential historic analytical anomaly from 2006-2007 dataset. All F ⁻ results post 2009 conform and are <1mg/L.
GW05A	Sulphate, mercury, uranium	Plant: Central north	Highest = 1,100 mg/L c.f. trigger of 250mg/L Highest = 3µg/L c.f. trigger of 1µg/L Highest = 57µg/L c.f. trigger of 13µg/L
GW13	TDS, nitrogen (total) sulphate, uranium	Plant: Central	Highest = 3690 mg/L c.f. trigger of 2000mg/L Highest = 2.3 mg/L c.f. trigger of 0.6mg/L Highest = 416 mg/L c.f. trigger of 250mg/L Highest = 28µg/L c.f. trigger of 13µg/L
GW14	Sulphate, nitrogen (total) arsenic, selenium, uranium	Plant: Central	Highest = 988 mg/L c.f. trigger of 250mg/L Highest = 12.8 mg/L c.f. trigger of 0.6mg/L Highest = 21µg/L c.f. trigger of 1µg/L Highest = 20µg/L c.f. trigger of 1µg/L Highest = 49µg/L c.f. trigger of 13µg/L Latest result 2017; previously monitored over 2006-2007. Sparsity of metal data.
GW19	Sulphate nitrogen (total)	Plant: Central	Highest = 502 mg/L c.f. trigger of 250mg/L Highest = 3.2 mg/L c.f. trigger of 0.6mg/L Latest result = 2010 (Bore no longer exists)
GW22A	Sulphate, nitrogen (based on nitrate), uranium	Slimes dam	Highest = 776 mg/L c.f. trigger of 250mg/L Highest = 1.48 mg/L c.f. trigger of 0.6mg/L Highest = 26µg/L c.f. trigger of 13µg/L Last monitored 2010

Bore(s)	Indicator(s) ⁺	EAS Location	Result Overview
PHMB02	TDS nitrogen (based on nitrate), sulphate, uranium	Slimes dam	Highest=4260 mg/L c.f. trigger of 2000mg/L Highest = 2.36 mg/L c.f. trigger of 0.6mg/L Highest = 808 mg/L c.f. trigger of 250mg/L Highest = 20µg/L c.f. trigger of 13µg/L Last monitored 2010
SDMB03	TDS, nitrogen sulphate uranium	Slimes dam	Highest=4150 mg/L c.f. trigger of 2000mg/L Highest = 7.7 mg/L c.f. trigger of 0.6mg/L Highest = 431 mg/L c.f. trigger of 250mg/L Highest = 20µg/L c.f. trigger of 13µg/L
SDMB04	TDS nitrogen sulphate uranium	Slimes dam	Highest=2970 mg/L c.f. trigger of 2000mg/L Highest = 2.1 mg/L c.f. trigger of 0.6mg/L Highest = 587 mg/L c.f. trigger of 250mg/L Highest = 22µg/L c.f. trigger of 13µg/L
Bore(s)	Indicator(s) ⁺	WAS Location	Comment
GSMB01 GW01A,04, 07A, & 21. SDMB01	TDS [!]	GSF Slimes Dam	Spatial variations in TDS exist & range 330mg/L – 2,600 mg/L across bores. (Exceedances are likely to reflect natural spatial variations within water systems)
GSMB16	Fluoride	GSF	Highest = 1.5mg/L c.f. limit of 1.12mg/L Monitored 2014-2017
GW21	Phosphorus	Slimes dam	Highest = 4.55mg/L c.f. limit of 0.55mg/L Last monitored 2010
GW17	Nitrogen(total), nickel	Slimes dam	Highest = 3.3mg/L c.f. limit of 0.34mg/L Last monitored 2009 All TKN suggests organic content – possible sample integrity issue.
GW04	Sulphate	Slimes Dams	Highest = 332mg/L c.f. limit of 250mg/L Last monitored 2010
GW08	Arsenic	Slimes Dams	Highest = 8µg/L c.f. limit of 3µg/L Last monitored 2010
GW07A	Sulphate, nitrogen (total), cadmium	Slimes Dams	Highest = 4190mg/L c.f. limit of 250mg/L Highest = 0.6mg/L c.f. limit of 0.34mg/L Highest = 8µg/L c.f. limit of 1µg/L Last monitored 2010
SDMB01	Sulphate cadmium	Slimes Dams	Highest = 2780mg/L c.f. limit of 250mg/L Highest = 4µg/L c.f. limit of 1µg/L Last monitored 2017. Field pH <7 may influence metal solubility

! Note: TDS in many of the WAS bores is above the potable water palatability trigger. This is however, likely to relate to background variability within the WAS.

Of note is that:

- Chloride, and sulphate concentrations in a number of bores around the Plant Area and within some Slimes Dam monitoring bores, are trending upwards.
- No excursions of note were identified against either field nor laboratory provided pH levels. Field levels were, at times between 0.5-1 pH unit lower than laboratory reported results.
- Outside the anomaly around the central Plant Area, there is no evidence of heavy metal impact of any significance. Elevated dissolved metals generally coincide with a slightly acidic field pH reading within the same bore.
- Elevated dissolved Uranium is noted to be linearly aligned with elevated chloride concentration.

Bores that exceed trigger values and limits are recommended for action as per Tables 7a and 7b below.

Table 7a: EAS Bores exceeding Limits/ Trigger and Recommended Action

Bore(s)	Location	Recommendation Action
GSMB15A	GSF	Maintain monitoring and chart results to assess trends
EPMB01	GSF	Maintain monitoring and chart results to assess trends
GW05A	Plant Area	Refer Section 2.4, Recommendations 17-1 to 7
GW13, 14	Plant Area	Refer Section 2.4, Recommendations 17-1 to 7
GW19	Plant Area	Refer Section 2.4, Recommendations 17-1b
GW22A	Slimes Dams	Locate and re-sample bore to evaluate need for action based on a more recent data set.
SDMB03	Slimes Dams	Refer Section 2.4, Recommendations 17-1 to 7
SDMB04	Slimes Dams	Refer Section 2.4, Recommendations 17-1 to 7
PHMB02	Slimes Dams	Re-sample bore to evaluate need for action based on a more recent data set. Refer Recommendations 17-1b

Table 7b: WAS Bores exceeding Limits/ Trigger and Recommended Action

Bore(s)	Location	Recommendation Action
GSMB01 GW01A, 04, 07A, & 21. SDMB01	Across WAS	Continue with mine controls over palatability issues associated with elevated TDS (e.g. notification and supply of bottled water).
GSMB16	GSF	Maintain monitoring and chart results to assess trends
GW04, 07A, 08, 17, 21	Slimes Dams	Re-sample bores to evaluate need for action based on more recent data set.
GW07A	Slimes Dams	Re-sample bores to evaluate need for action based on more recent data set. (Refer Rec. 17 – 5)
SDMB01	Slimes Dams	Chart field pH with metals and factor into updated risk assessment. (Refer Rec. 17 – 5)

2.3.2 Source Identification

A map containing potential site sources and their location across the site is provided in Appendix 11.

Some Plant Area bores, including GW05A, GW13, GW14, are revealing water quality changes within an increasing water table that appears inconsistent with that typical of a stable geological setting. The observed increases in ionic components are likely to be influenced by surface activities. Other bores revealing less pronounced salinity and indicator change however, cannot definitively be stated to result from anthropological impact against possible natural variations within the various and interconnected groundwater systems.

An example of a bore evidencing an apparent trending of indicators is presented in Figure 7 for Bore GSMB15A that has shown an increasing salinity (i.e. TDS) trend. Of interest is that all anions and cations, including those not particularly associated with mining activities (i.e. bicarbonate and magnesium), are also trending upwards. The increase in all anions and cations renders it difficult to establish a definitive source-pathway-effect. The rising eastern aquifer water table has been apparent since routine monitoring commenced in early 2000 in all bores (refer hydrograph series in Appendix 4) may be producing a soil dissolution effect that is at least contributing to an altered cation/ anion groundwater chemistry.

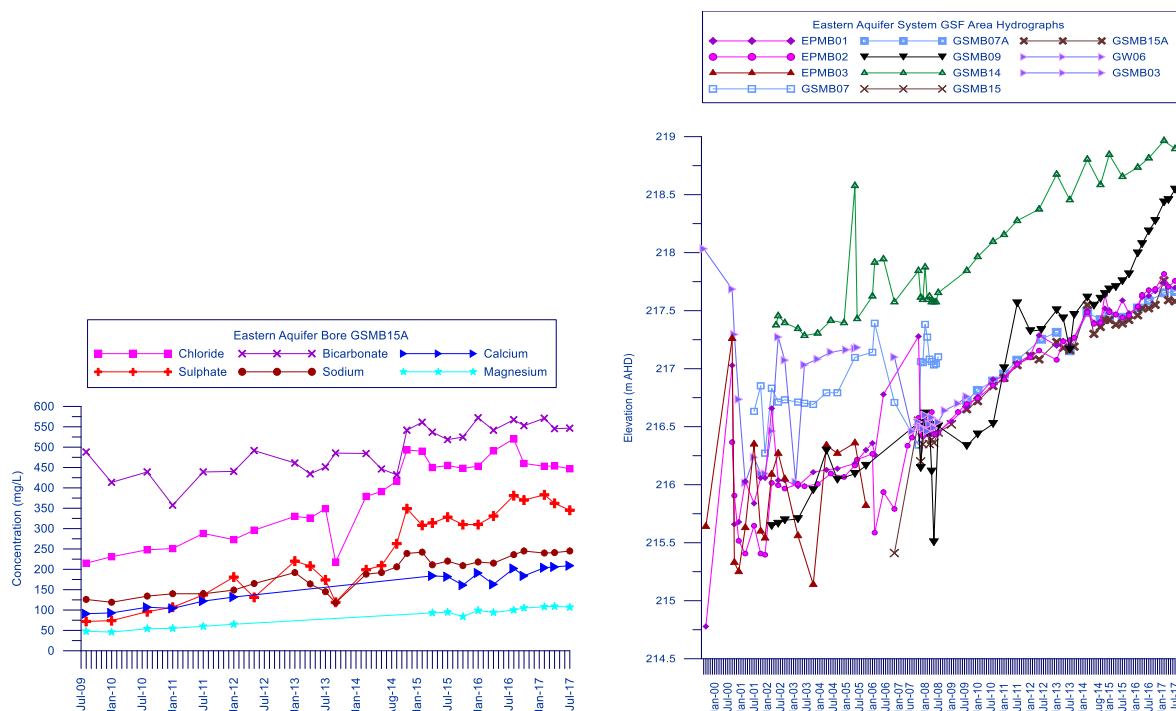


Figure 7: Bore GSMB15A (GSF) cation and anion timeline trends

The source of elevated salinity, and in particular chloride and sodium, was investigated from 2006 through to 2010 around the plant and slime dams (C&R,2010). Based on information derived at the time it was concluded:

‘the anomalous saline elevated ground waters beneath the Phosphate Hill mining and processing facility were naturally derived from low flowing waters through fault and possible minor karst systems equilibrating with limestone rocks’; and

‘artificial year round recharge of the fault and karst systems beneath the plant are considered to be responsible at least in part for the sudden variations observed in both groundwater chemistry and static water levels of the central fault zone’.

This determination had technical merit at the time given the arguments made within the C&R report. The report referenced the likely presence of Halite and potentially F-Apatite in association with changing water tables impacting Karst aquifer systems as the most likely source of chloride.⁴

In addition to the potential for a Halite source, there may be groundwater systems of different ages (Dr. P. Macumber pers. comm., 2017) that interact with varying water

⁴ Apatite (P_2O_5) may contain up to 0.2% (2,000 mg/kg) chloride. Chloride concentrations during 2010 were up to around 2,000 mg/L in Bore GW19 and 900 mg/L in Bore GW5.

tables. The most recent recharge producing a 'fresher' layer sitting atop older more saline waters.

It is feasible that these units may be beginning to mix, possibly by water table changes as a result of preferential recharge producing a mound or depression; either via extraction (such as the production bore influence), large rain events (e.g. 2016) or continued water seepage into the aquifer (e.g. plant steam releases to ground).

A major consideration for a geological rock sequence as being the source of increasing chloride (and salinity) trends was that a contributory source of chloride was not sufficiently present within the mine's process waters to produce the concentrations being observed.

The conclusions reached in the 2010 report have been re-visited during this assessment. The investigative approach has included a review of all previously derived (and available) monitoring data, re-evaluation of scientific reports and references made within these reports, a site inspection of plant processes and drainage lines, interviews with production and operational mine site personnel and communications with a leading saline groundwater geochemist.

Our analysis of the mine site geology at the area exhibiting the most significant anion changes within the groundwater (i.e. immediately below the processing Plant Area derived from more than 15 bore logs) identified no definitive presence of Halite in the rock, nor did it confirm the presence of any mappable perched aquifer that may contribute to an upward trend of chloride due to dissolution.

The only suggestion Halite may be present was in a passing reference to a pseudo Halite structure within the Chatsworth Limestone that occurs to east of the Mehaffey Fault stratigraphically below the Ninmaroo Formation.

If Halite is present within the geological sequence we would expect a relatively stable sodium to chloride (i.e. Na:Cl) dissolution ratio of approximately 0.56 (typical sea water ratio).

A regression can however, occur at elevated concentrations due to cation exchange mechanisms removing sodium ions from the water phase, but normally only when a new sodium chloride source enters an aquifer with exchange sites available.

Impact by a brine solution to a relatively 'fresh' groundwater can be predicted by ratios of sodium to chloride < 0.4 , and chloride plus sodium over TDS > 0.64 (Ref. US Geological Society, 1986). From analysis of bore data, bores GW05A, SDMB01 and SDMB04 exceed these thresholds.

Impact by a Chloride source, potentially NaCl, source appears to be occurring as indicated within Table 8 and Figure 8 below.

However, the precise source of where the NaCl is originating from remains elusive.

Piper diagram analysis of bores across the eastern flank of the Mehafeff Fault (Eastern Aquifer) reveal chloride increasing with time in the GSF bore (GSMB15A) and the Plant bore (GW05A), and a decrease in the most southern bore – possibly resulting from the breaking of the drought between the 2009 and 2017 (refer Figure 9). Of note is that the piper diagram plots reveal all four bores to have differing water ionic compositions further illustrating the complexity of the hydrogeological setting.

Table 8: Sodium to chloride ratio analysis (July 2017)

Bore	Groundwater Na ⁺ :Cl ⁻ ratio	Bore	Groundwater Na ⁺ :Cl ⁻ ratio
EAS-RB	0.65	WAS-RB	0.60 approx.
GSMB07A	0.66	GSMB2A	0.60
GSMB15A	0.55	GSMB1A	0.65
GW05A	0.43 (Note: a 0.42 trend line is derived for Cl ⁻ conc. > 800mg/L)	SDMB01	0.41
PHMB2	0.42	GW17	1.23 (most southern bore – freshest water)
SDMB04	0.43		
SDMB02	0.74 (most southern bore)		

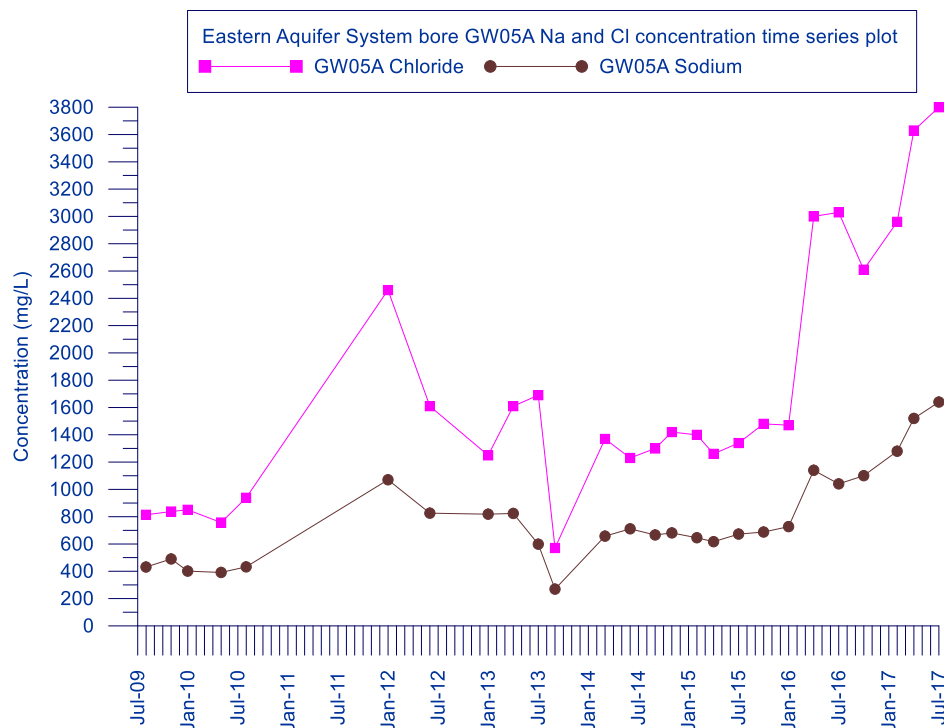


Figure 8: Time series plot of GW05A Chloride and Sodium concentrations.

Furthermore, the concentration of chloride during the period 2010 – 2017 has trended upwards particularly in recent years in Bore GW05A. Whilst natural variability is a factor and cannot be definitively ruled out at this location, this rapid increase in concentration encountered beneath the plant area cannot be explained by geological conditions alone. Trends in the water table and anion concentrations are not consistent with the natural variability of a geologically stable groundwater system that would reasonably be expected to exist beneath the Plant Area.

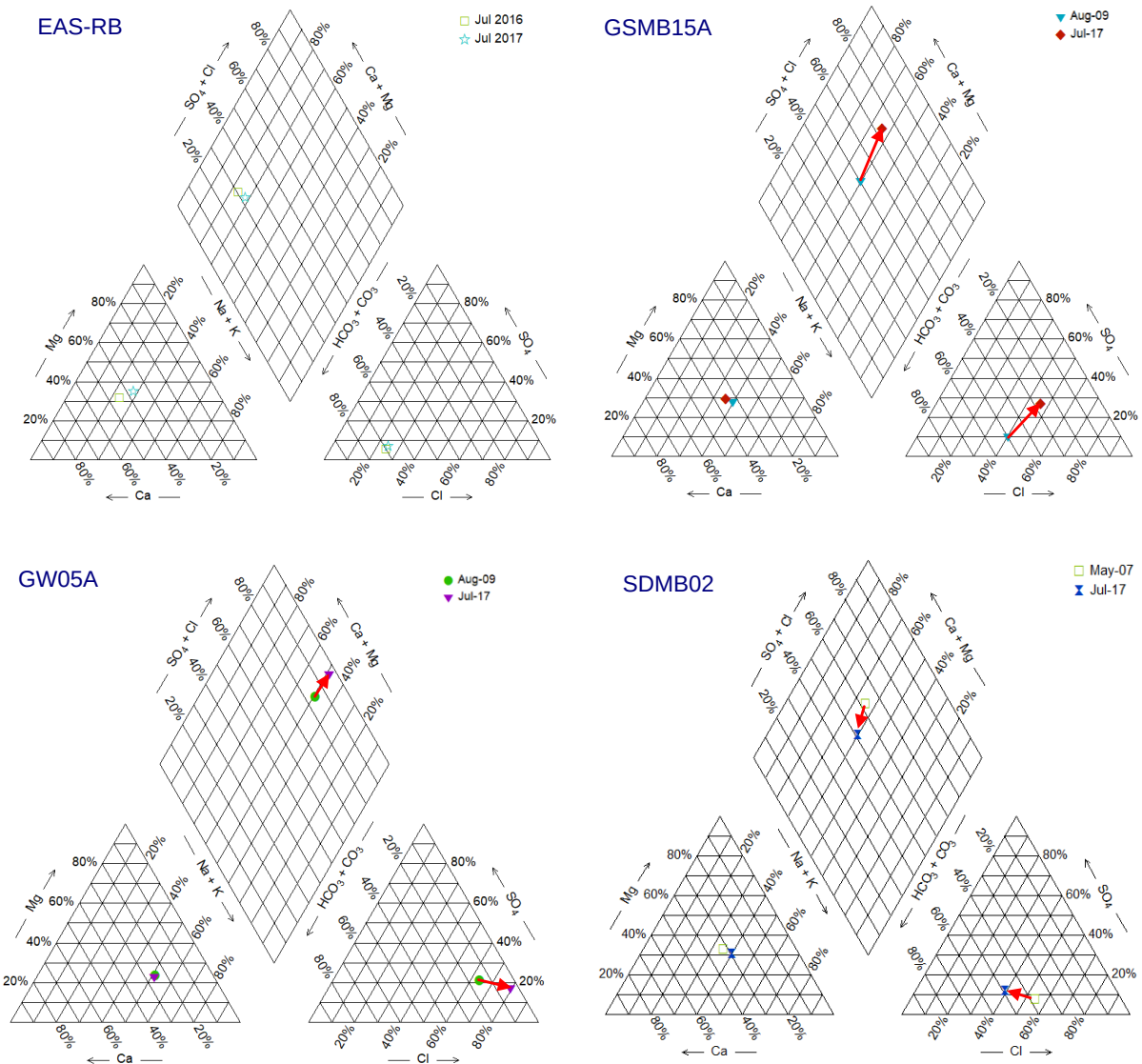


Figure 9: Piper diagrams for Chloride across the EAS 2007 c.f. 2017.

A rising water table is occurring across the EAS in all bores on the mine lease. However, the processing Plant Area appears to be rising at a greater rate indicating a probable mound (difficult to delineate due to many apparent anomalies in water table maps as shown in Figure 2.10, Appendix 2) under this area as illustrated by Bores GW05A, GW13 and GW14 in Figure 10).

Confounding water table height analysis even further is that Bore EAS-RB has a water table approximately 3m higher in elevation than other bores immediately south (i.e. GSMB14) (Figure 10).

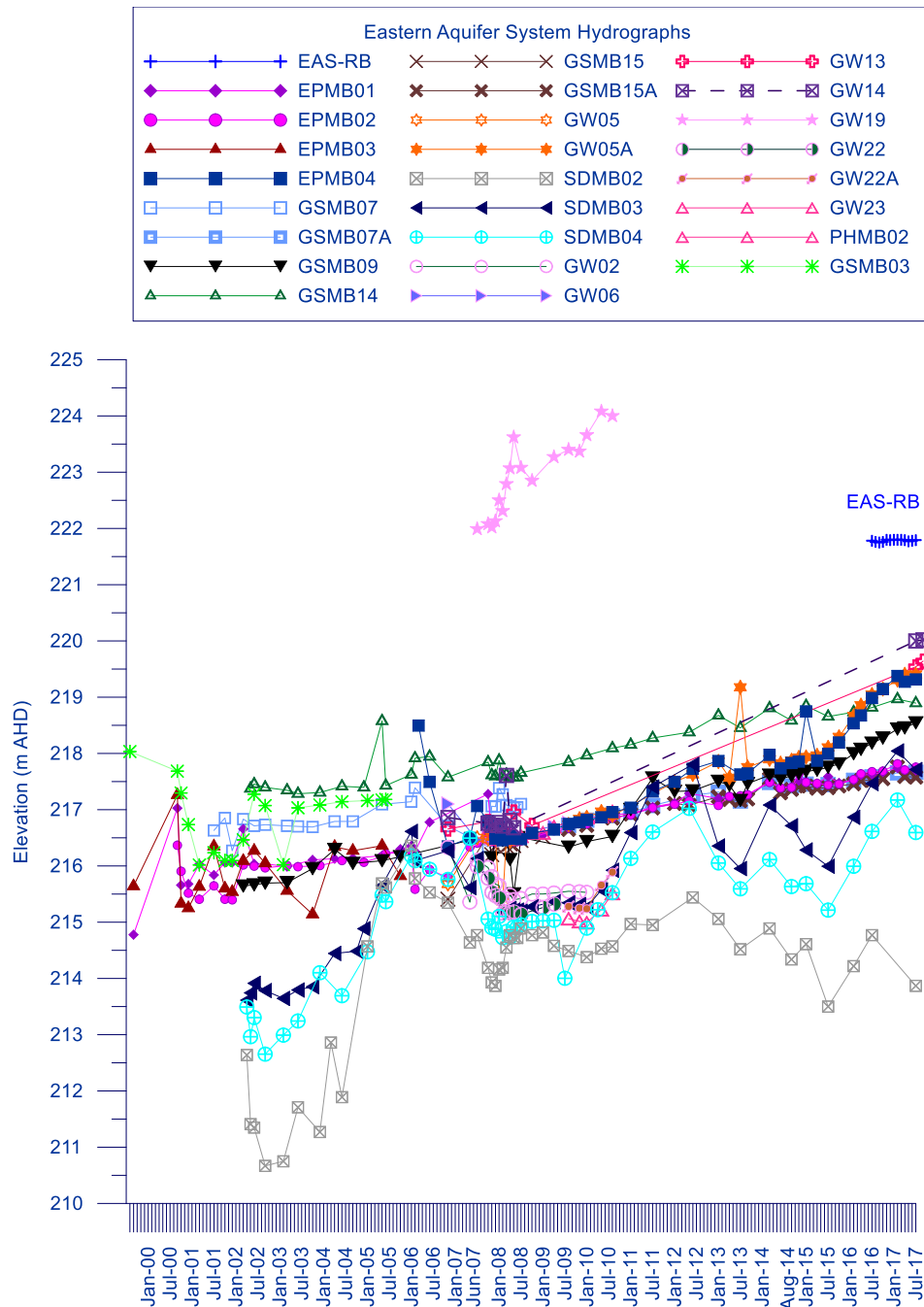


Figure 10. Water Tables – Eastern Aquifer System

Given water table depths have been shown to vary due to faults, it cannot conclusively be stated this 'mounding' is from process related activities. However, during the site visit component of the investigation, process water was observed to drain from steam release lines and process drains near the cooling towers of both the ammonia and phosphoric acid plants; presenting a source of water with potential to transport to groundwater over time.

Additionally, whilst it has been verified that wastewaters throughout the fertiliser production process continue to contain a relatively low chloride content (i.e. maximum of 825mg/L and generally <400mg/L), hypochlorite use has been identified as a possible source of chloride, not previously accounted for in earlier investigations. Hypochlorite has reportedly been used for microorganism control in the ammonia plant's cooling towers, potable water treatment and boiler water treatment since commissioning of the plant in 1999.

Usage rates occurring during 2017 amount to approximately 75KL/ annum of reportedly 12.5% hypochlorite (NaOCl) solution. Via extrapolation, conservatively this amounts to over 50 tonne of chloride composition requiring discharge over the years. The ammonia plant cooling tower wastewater stream is reportedly captured within a sump pit and transferred with other plant waters to the GSF or recycled within the plant.

Chloride has a low susceptibility to adsorption or ion exchange within the vadose zone or aquifer materials. It is highly mobile and not subject to biodegradation, biological transformation or oxidation- reduction reactions [Kochary et al, 2017]. Hence if there is a pathway for chloride to enter the soil, it potentially represents a lead indicator that surface chemicals are entering the groundwater.

If the wastewater containing hypochlorite was lost to the ground, and a pathway to the groundwater table was realised, the load of chloride used over the years could reasonably present itself at concentrations being evidenced within the groundwater beneath the plant area.

A saline discharge also arises from the reverse osmosis concentrate. This is reportedly directed to the raw process water pond for recycling.

Investigations into the two historic acid spill events (i.e. 2000 and 2002), did not identify any direct connection regarding chloride release, either within the spilled material or within emergency response and clean-up chemicals. The spillage involved concentrated sulphuric acid and was neutralised with Soda Ash. Neither chemical contains an appreciable amount of chloride, even as an impurity.

A source to the south other than the slimes dams, includes a former landfill, situated towards the east boundary south of the rail ring line. This reportedly has not been used for over 10 years with limited detail being available as to waste types and quantities that were disposed during WMC's occupancy of the site.

2.3.3 Cause (including discussions on potential pathways)

Trend increases in the water table of the Eastern Aquifer System are illustrated in the hydrographs within Figure 10 above and contained within Appendix 2. Amongst the mix of data covering water table heights are a few anomalies including:

- Bores around the Slimes Dams have shown a more stable groundwater table depth or, in the case of Bore SDMB02, a decreasing trend since 2006.
- Bores GW05A, GW13, GW14 and EPMB04 evidence an increasing trend out of kilter with the regional aquifer movement. The same holds true to a lesser extent for Bore GSMB09.
- Bore GW19 (not monitored since 2010⁵) historically revealed groundwater at a depth of six (6) meters above other nearby bores (i.e. GW05) that, at the time, were reported as being likely representative of the regional groundwater table. Previous investigations reported a potential perch water system existed within a splinter fault at this location. However, plots of the bore screen interval on the bore GW19 hydrograph showed the screens extend across the intervals screened in other nearby bores which indicates that the groundwater in GW19 is not perched.
- An inspection of the Plant Area made during September 2017 identified a variety of steam blow down points, process water channel runs, water pooling, sump pump pits and transfer lines with potential to seep into soil and ultimately result in a change to the water table.
- Recent monitoring results have shown a presence of nitrate in Bore GW05A (i.e. 17.2mg/L as nitrate + nitrite) located within the north central Plant Area. Increases in nitrate to concentrations >10mg/L are typically anthropogenically sourced. As there has now been repeated detection of elevated nitrogen compounds, it suggests a potential pathway to the groundwater table within this Plant Area vicinity exists.

Potential pathways for process waters to enter the groundwater that are reasonably foreseeable are considered to include:

1. Seepage over time on open ground with continually saturated soil providing a head that permits gravity feed to the groundwater table;
2. Migration down a conduit 'straw' resulting from historic investigation bores that may not have been decommissioned;
3. Caverns, conduits (refer Figure 11) and even karsts not previously mapped providing a preferential flow channel for saturated soil conditions;
4. Leaking from drains, transfer pump pits or the stormwater and process drainage capture collection pond that ultimately enter groundwater via a pathway identified in 1 or 2 above;
5. Damage to groundwater monitoring bores created by ground movements or surface activity (e.g. bore covers and caps). Bore GW05A was noted to be below ground surface and soil could directly enter the bore, influencing groundwater quality results including potentially nitrate; or

⁵ An intensive search for this bore, including use of a metal detector, failed to identify any presence of this bore to permit re-sampling.

6. Sub-surface fault movements, and near surface as a result of high rainfall events following by drying expanding and contracting highly reactive clays.



Figure 11: Evidence of in-filled cavity in Galah Pit. Potential pathway to groundwater

An evaluation of potential preferential flow pathways to the water table was supported by a mapping exercise to determine whether any potential hot spots represented by mounding were present.

Mapping the water table at the mine site however, proved difficult with many “bulls-eyes” evident in planar water table model (Figure 12) reflecting the complex local faulted geology. The main fault, the Mehaffey Fault, forms an effective hydrogeological barrier that isolates groundwater on the western side of the fault from that on the eastern side. In addition, lesser cross-cutting faults appear to form smaller groundwater flow compartments (refer Appendix 2) that appear to be hydraulically isolated from each other.

It is therefore, difficult to definitively identify potential mining contributions to groundwater mounding from naturally occurring fluctuations.

2.3.3.1 Anomalies

Being able to definitively determine the cause of impact is complicated by a number of observations that do not align with the source being process generated:

- Information sources state the presence of ‘Halite pseudomorphs’ within the Chatsworth limestone. Bore construction logging may have missed a sequence just above the water table that has become saturated as the water table rises.
- TDS concentrations vary widely within relatively short distances within the Western Aquifer System.

- Cation and anion ratios remain similar for many of the bores with magnesium tracking chloride increases, suggesting a mixing of shallow and deeper aquifers.

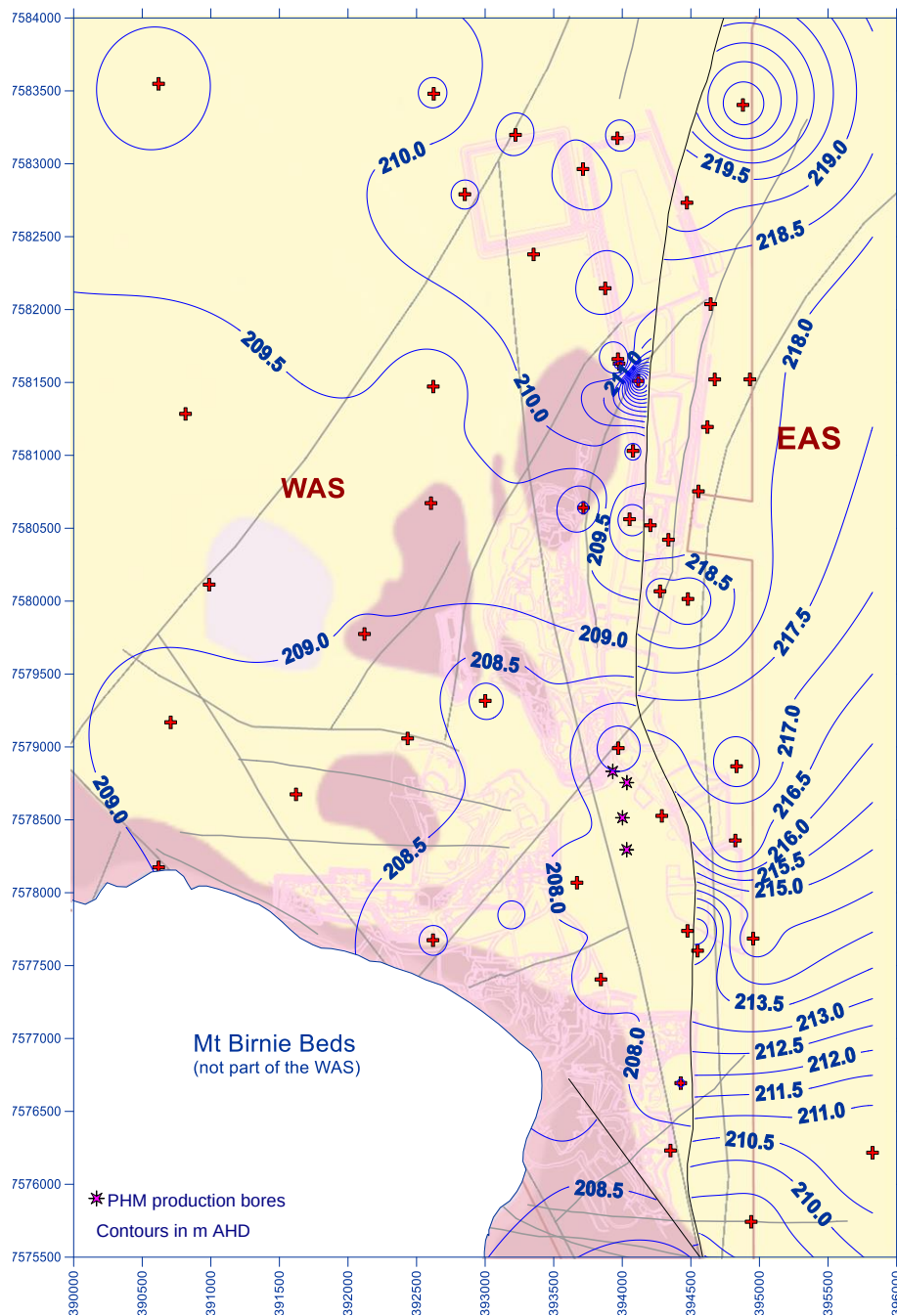


Figure 12. Mapped Water Table Heights – Broader Mine Site

2.3.4 Extent

Eastern Aquifer System

Groundwater flow system analysis within the Eastern Aquifer System around the GSF [EnviroRisk, 2016, JLCS, 2016] reveals flow is generally to the south at a rate of

centimetres to a meter per year. Localised mounding (Figure 12) can result in localised variations on the broader southern migratory regime.

Mapping of chloride concentrations (as an indicator of TDS) from 2010 in comparison to recent data from 2017 (where data is available) illustrates the potential extent of impact. Additional data from the historic monitoring bore network will assist in better defining migratory patterns of the waters revealing elevated chloride and sulphate dominated salinity profiles.

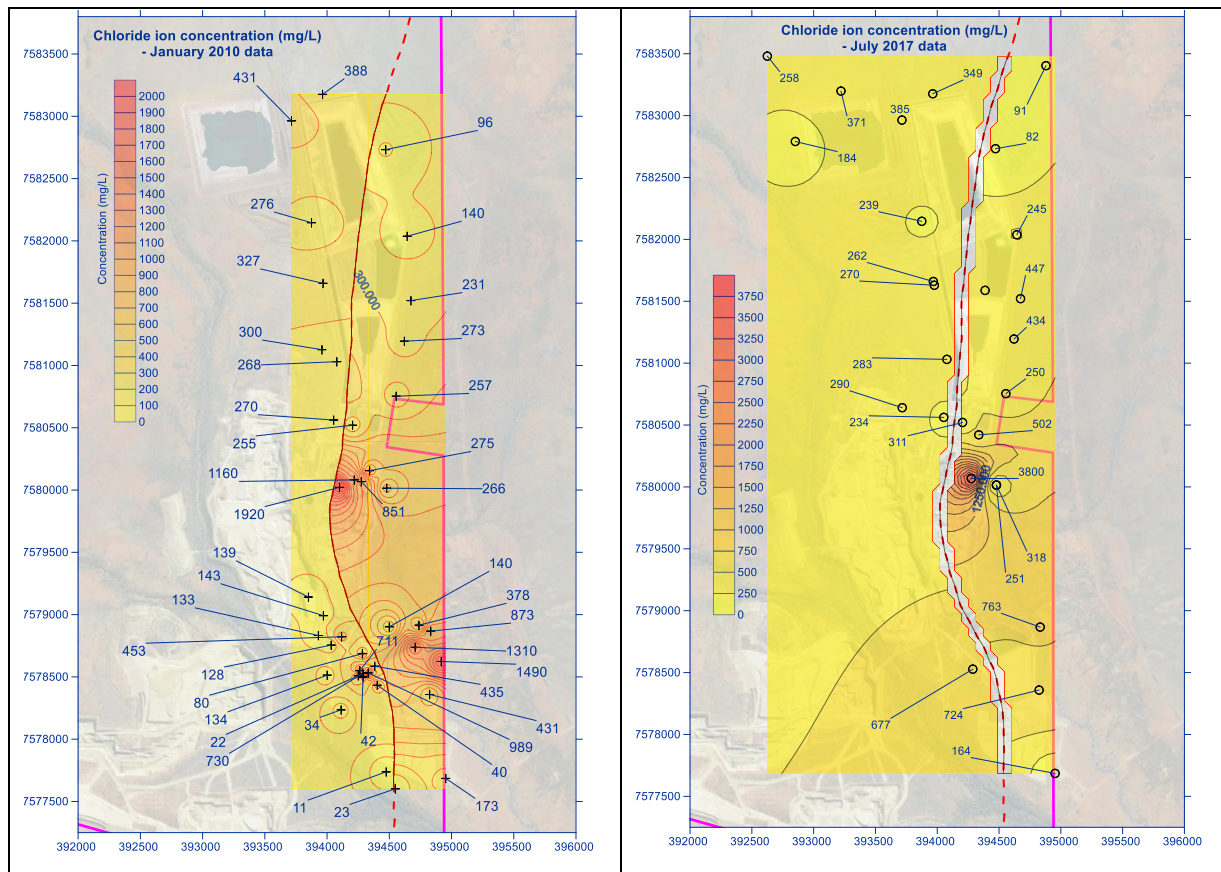


Figure 13. Mapped Chloride Concentrations Comparison 2010 vs 2017

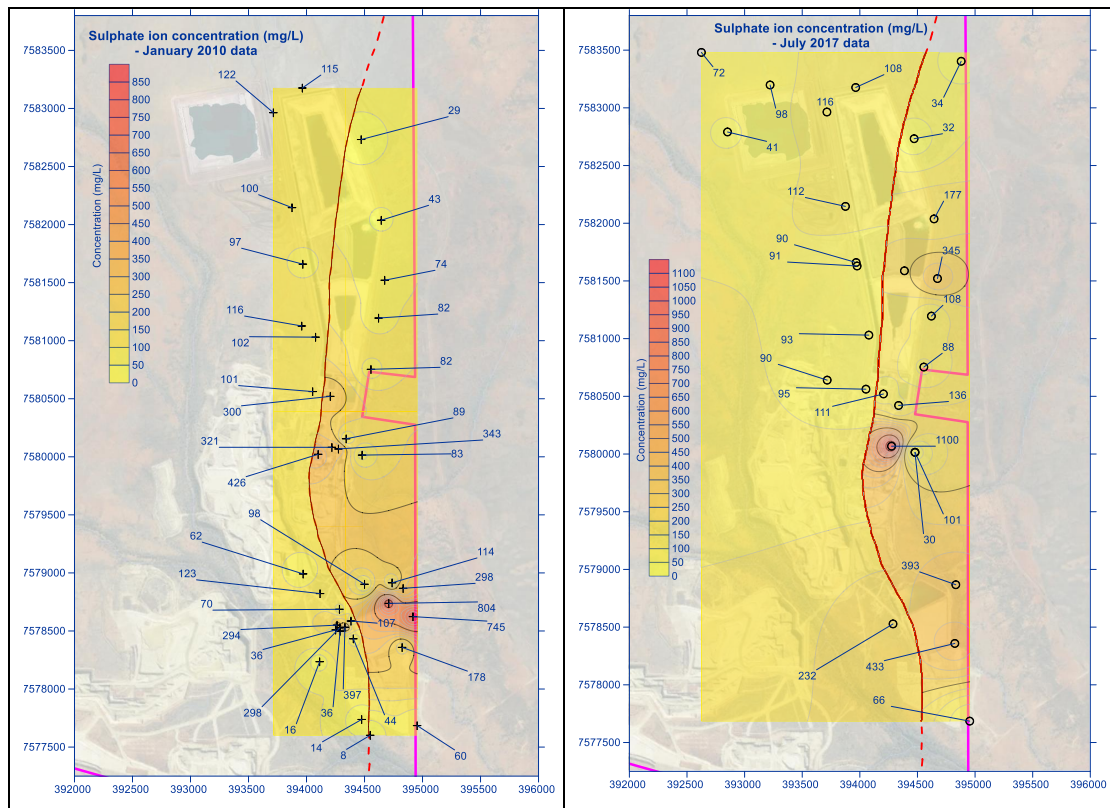


Figure 14. Mapped Sulphate 2010 vs 2017

Metal impact is predominantly limited to elevated dissolved Uranium. Bores that exhibit elevated chloride also contain elevated dissolved Uranium. This link has not been able to be fully categorised but may relate to pH levels, as field pH returned slightly acidic readings in these bores. Further investigation is warranted to establish any definitive relationship.

There were other bores where metals were elevated, but outside the Plant Area these were mainly bores last monitored pre-2011 and may be pH related. Additional data from these bores is required to comment further on whether metal impact remains.

Elevated nitrogen has been identified in a number of bores, predominantly confined to the Plant Area and as nitrate. As a number of bores that exhibited nitrogen have not been monitored regularly for many years, the extent of impact cannot be quantified. Additional monitoring will be required to better confirm the extent and significance of nitrogen impact and its potential source. Given that down-borehole impact was observed likely in bore GW05A, sealing of bore covers and caps is recommended to mitigate surface water entry.

Western Aquifer System (WAS)

Flow within the Western Aquifer System is captured within the depression created by the production bores groundwater extraction system that supplies the mine with its process water needs and the mine village with its potable water supply.

Salinity concentrations have been identified at concentrations that exceed the investigation trigger across the WAS in many bores. Historic bores, last monitored in 2010, also identified elevated salinity levels. Investigations on the near western side of the fault have not been able to categorically verify that whether the cause of the salinity is from natural variations within the groundwater regime or from mine related activities. This is mainly due to an absence of elevated chloride within the process waters that have been found to persist within bores around the slimes dams. Why elevated chloride is being found around this area is challenging and still warrants further investigation. It may be mixing of deeper waters with shallow. The spatial variability suggests however, that salinity within WAS groundwaters are likely to be influenced by natural background variations.

The urgency to define the extent of potential impact within the WAS is not as significant as the EAS given the WAS groundwater is within a controlled zone created by the production bores extraction. There is a limited chance that groundwater within the WAS is presently, or will in the foreseeable future, traverse beyond site boundaries (JLCS, 2016). This could be confirmed by updating the risk assessment.

Groundwater Impact Risk Assessment

A groundwater contamination risk assessment (GCRA) for the Gypsum Storage Facility was undertaken to identify the risk of harm to groundwater users and/or the environment (JLCS, 2016). The GSF GCRA included the risks to the important water resources in the Great Artesian Basin and the high conservation value groundwater dependent ecosystems (GDEs) in the Mount Merlin Area as well as receptor closer to the GSF.

Although the GCRA was focused on the risk to receptors from potential contamination in the GSF area, much of the assessment is relevant to the broader Phosphate Hill mine site. Consequently, the GCRA is reproduced in Appendix 10 as background for assessing the entire PHM site. However, it needs to be stressed that the GCRA would need to be revised to include the other areas exhibiting elevated indicators beneath the plant and slimes dam areas; particularly those on the EAS close to the mine lease boundary.

2.4 Requirement 4:

Based on the outcomes of investigations carried out in accordance with Requirements 1-3, describe all relevant remediation options including the works, costs and timeframes before recommending a preferred option.

Response:

It is considered premature to define remediation options when a definitive source of impact is yet to be quantified and definitive proof of impact against natural variations in geochemistry has not been established.

The following is recommended in the first instance to progress investigations; particularly around the Plant Area where mining activities are likely contributing to the altered water chemistry observed.

SOURCE IDENTIFICATION & MANAGEMENT

Recommendation 17-1.

- Undertake a comprehensive industrial process audit of activities that generate waste waters with the aim of quantifying discharge volumes, waste water quality and documenting the adequacy of beneficial re-use systems or waste transfer routes to a controlled area i.e. the GSF.

Recommendation 17-2.

- Following from the recommendation 17-1 and on a risk-based prioritisation, undertake an integrity review of drainage lines and capture pit sumps to ensure they are water tight and not able to overflow and enter the soil.

Recommendation 17-3.

- Following from Recommendation 17-2 and on a risk-based prioritisation, capture existing saline waste waters (e.g. TDS >500mg/L or equivalent EC) and slurries that currently drain onto the ground and either beneficially re-use or transfer in a controlled manner to the GSF stockpile for evaporation.

Recommendation 17-4.

- Following source removal and/or pathway isolation of saline waters within potential to impact groundwater around the Plant Area, implement a groundwater management plan whereby a team reviews feasible remediation and management options to protect Environmental Values.

Recommendation 17-5.

- Further investigate the potential for naturally present salts within the geology that could be contributing to the increase in ions being observed. This

includes further intrusive investigations into whether soil (and rock) saturation may be causing a dissolution and transportation of salts.

GROUNDWATER INVESTIGATION

Recommendation 17-6.

- Devise a groundwater investigation strategy that integrates available monitoring bores into a revised monitoring network that:
 - a) rationalises the monitoring frequency to an annual sampling event with an enhanced number and breadth of bores; particularly within the EAS where low flows exist;
 - b) includes accessible GW series bores that previously evidenced impact;
 - c) gives consideration to including eastern boundary and southern bores into the program (e.g. Bore J, PHMB02, etc.);
 - d) initiates replacement of down hydraulic gradient bores that cannot be located for monitoring or installation of boundary monitoring bores to the east and south where gaps are evident;
 - e) ensures that field stabilisation data is captured during groundwater sampling: pH, conductivity (EC), redox potential (eh), temperature (°C) & dissolved oxygen (DO);
 - f) repairs all bore casings and covers where surface water infiltration can occur;
 - g) adds Bromide and Lithium to analyte list where chloride is elevated to permit further geochemical or anthropological source tracing;
 - h) analyse for ammonia wherever nitrogen compounds are found to be approaching trigger values; and
 - i) analyse groundwater from selected bores for a range of isotopes to assist in determining groundwater age and source.

Recommendation 17-7.

- Update the groundwater risk assessment such that it caters for all mine site activities with consideration to the latest (2017) monitoring results.

This should also include undertaking 3-D geological mapping to better define mine site structural geology and enable development of a more robust groundwater flow model.

Examples of possible remediation options are nonetheless provided in Tables 8a – c. These are provided to facilitate preliminary discussions between stakeholders on the likely feasibility and scale of works required.

Table 9a: Remediation Options Analysis Matrix – GSF

Remedial Option	Works Description	Residual Risk	Timeframe	Costs ¹	Operational considerations
1. Do nothing: Eastern Aquifer System.	Leave as is until works complete. Couple this with 3D geological mapping, revised groundwater flow modelling and fate, transport studies, and extent risk assessment.	Impact remains and, if trends continue, could migrate off the mine lease at a concentration above stock water environmental value.	N/A	Nil	Do nothing likely to breach EA and IPL Company Policy. Risk Assessment complemented by predictive flow modelling required to define range of impact prior to dispersion and dilution to acceptable levels against highest future Environmental Value.
2. Do nothing: Western Aquifer System.	Leave as is until works complete. Couple this with 3D geological mapping, revised groundwater flow modelling and fate, transport studies, and extent risk assessment.	Groundwater controlled by extraction (current) and future sink due to pit voids	N/A	Nil additional	Predictive model could be refined to define final mine pit salinity levels.
3. Assisted dilution with monitoring natural attenuation	Pump in 'fresh' water to dilute chloride and salinity such that concentrations remain below Enviro. Value of stock drinking water.	Injection system using upgradient water to control flow and dilute impact.	1-2 years	>\$3-5m	Ongoing monitoring for non-cation anion risk. Low substrate permeability may negate zone of influence. Risk Assessment to verify acceptability of approach.
4. Pump and treat	Extract groundwater from series of bores and pump atop GSF for evaporation	Transfers saline waters onto 'land'. Chloride may mobilise with rain/ process waters.	>30 years	>\$10m	Feasibility questionable due to low permeability aquifer and potential size of impact zone.
5. Reline ponds to mitigate leakage	Reline stormwater, evaporation and drainage ditches	Pond liners are never leak proof. Seepage may recur.	3-5 years	>\$30m	Likely to interrupt production during works. Feasibility questionable.
6. Cap stockpiles and contain all liquids on EAS stacks	Soil cap stockpiles on EAS. Relocate water systems to WAS in new facilities.	Residues remain and impact may continue to trend up for several years.	1-3 years	>\$30m	Needs acceptance that impact may arise on WAS but be controlled in final pit lakes.

Table 9b: Remediation Options Analysis Matrix – Plant Area

Remedial Option	Works Description	Residual Risk	Timeframe	Costs ¹	Operational considerations
1. Do nothing. Eastern Aquifer.	Continue as per status quo	Impact could migrate laterally off the mine lease	N/A	Nil	Do nothing likely to breach EA and IPL Company Policy.
2. Do nothing. Western Aquifer.	Continue as per status quo	Groundwater controlled by extraction (current) and future sink due to pit voids	N/A	Nil additional	
3. Pump and treat (via evaporation on Gypsum Stacks)	Extract impacted water from impacted zone, pump into stormwater pond before sending to GSF for evaporation.	May not be able to contain plume.	10-20 years	>\$5m	Low substrate permeability may negate zone of influence. Source to first be identified and removed from ongoing contribution.
4. Assisted dilution with monitoring natural attenuation	Pump in 'fresh' water to dilute chloride and salinity such that concentrations remain below Enviro. Value of stock drinking water.	Injection system using upgradient water to control flow and dilute impact.	1-2 years	>\$10m	Ongoing monitoring for non- cation anion risk. Low substrate permeability may negate zone of influence. Needs confirmation by modelling and risk assessment.
5. Pump and treat (via RO or resin membrane)	Extract impacted water from impacted zone, pump into treatment plant for RO or similar treatment. Return permeate to aquifer or process use. Concentrate transferred to GSF.	Concentrate needs to be managed. May not be able to contain plume.	10-20 years	>\$10m	Low substrate permeability may negate zone of influence. Source to first be identified and removed from ongoing contribution

Table 9c: Remediation Options Analysis Matrix – Slimes Dams

Remedial Option	Works Description	Residual Risk	Timeframe	Costs ¹	Operational considerations
1. Do nothing. Eastern Aquifer.	Leave as is until works complete	Impact remains and could migrate off the mine lease	N/A	Nil	Do nothing likely to breach EA and IPL Company Policy.
2. Do nothing. Western Aquifer.	Continue as per status quo	Groundwater controlled by extraction (current) and future sink due to pit voids	N/A	Nil additional	Continue as per status quo
3. Reline dams to mitigate seepage.	Reline dams; relocate slimes during upgrade.		3-5 years	>\$50m	Feasibility questionable.
4. Pump and treat (via evaporation on stacks) EAS	Extract groundwater from new series of bores and pump atop GSF for evaporation	Transfers saline waters onto 'land'. Chloride may mobilise with rain/ process waters. May not be able to contain plume.	>30 years	>\$10m	Feasibility questionable due to low permeability aquifer and potential size of impact zone.
5. Pump and treat (via RO or resin membrane	Extract impacted water from impacted zone, pump into treatment plant for RO or similar treatment. Return permeate to aquifer or process use. Concentrate transferred to GSF.	Concentrate needs to be managed. May not be able to contain plume.	10-20 years	>\$10m	Low substrate permeability may negate zone of influence. Source to first be identified and removed from ongoing contribution

Notes:

1. Costs are provided for indicative budgetary purposes. A complete engineering design assessment followed by a competitive tendering process is required if accurate is to be improved.

2.5 Requirement 5:

The environmental report must include:

- a. the methodology applied in conducting this investigation, including any assumptions relied upon and their justification;*
- b. the outcomes and findings of the investigation, including justification for any conclusions;*
- c. the raw data for any graphical summaries with a clear indication of which data has been applied to each graph.*

Response:

These have been provided under each of the requirements above and supported, where necessary, with information provided in the nominated Appendices.

Appendix 1 contains a full description of data assessment and statistical analysis methodology.

In addition, a complete data set will accompany this report as a spreadsheet for EHP's internal review.

3.0 REFERENCES

1. IPL 2017. Master analytical data spreadsheet files dated Sept 2017
2. C&R 2010. Phosphate Hill Wider Aquifer Study. Comparison of Saline Waters beneath the mine site with groundwaters of the district – Scientific Report of Results, 5 November 2010.
3. Phosphate Hill Gypsum Storage Facility Groundwater Contamination Risk Assessment, JLCS, 28 October 2016
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5. EnviroRisk, 2016. Response to notice requiring additional information (#101/0008740 dated 14 April 2016), 31 October 2016.
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7. Department of Environment and Heritage Protection (2009) Queensland Water Quality Guidelines, Version 3, ISBN 978-0- 9806986-0-2. Re-printed July 2013
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11. Australian and New Zealand Environment and Conservation Council/ Agriculture and Resource Management Council of Australia and New Zealand. Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 3 Primary Industries –

- Rationale and Background Information (Irrigation and general water uses, stock drinking water, aquaculture and human consumers of aquatic foods) (Chapter9), October 2000.
12. National Health and Medical Research Council/ Natural Resource Management Ministerial Council National Water Quality Management Strategy Australian Drinking Water Guidelines 6, 2011 (Version 3.4 Updated October 2017)
 13. World Health Organisation, Cobalt and Inorganic Cobalt Compounds, Concise International Chemical Assessment Document 69, Kim, Dr James H. et al, undated.

ABBREVIATIONS

EA	Environmental Authority
EAS	Eastern Aquifer System
EC	Electrical Conductivity
EE	Environmental Evaluation
EV	Environmental Value
DEA	Duchess Embayment Aquifer
GSF	Gypsum Storage Facility
IPL	Incitec Pivot Limited
SD	Slimes Dams
WAS	Western Aquifer System

APPENDICES



APPROVALS - SUSTAINABILITY - COMPLIANCE

JOHN LEONARD CONSULTING SERVICES

Groundwater and Environmental Consultants



Response to the 'notice to conduct or commission
another Environmental Evaluation'

APPENDICES

Incitec Pivot Limited, Phosphate Hill, Queensland

LIST of APPENDICES

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- 3. Bore Details & Bore Locations**
- 4. Bore Hydrographs**
- 5. EAS-RB Chemical Data, Statistical Analysis, and Hydrochemical Plots**
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 - 7B) Individual Bore Piper Diagrams**
 - 7C) Analyte Concentration Time Series Plots**
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- 11. PHM Site Areas and Potential Contamination Sources**

APPENDIX 1

PROJECT DESCRIPTION and METHODOLOGY

PROJECT DESCRIPTION AND METHODOLOGY

GENERAL

All currently monitored environmental monitoring bores were resurveyed by IPL to verify bore coordinates (MGA94 Z54 coordinates used for this project) and elevations (m AHD) of the reference measuring point.

Data cleansing was undertaken in conjunction with IPL prior to data analysis.

Non-detects were assigned values of half the detection limit for plotting and data analysis.

The data analysis and reporting was based on the Queensland Department of Science, Information Technology and Innovation guidelines “Using monitoring data to assess groundwater quality and potential environmental impacts” (DSITI, 2017).

SETTING AND CONCEPTUAL MODEL

The physical setting of the Phosphate Hill Mine (PHM) and a Conceptual Hydrogeological Model are described in Appendix 2 as background for interpreting the water level and chemical data, and assessing impact(s) on groundwater. The descriptions were based on the comprehensive review undertaken by JLCS (2016) which was updated to include the findings of the current project.

ASSESSED BORES

A large number of bores at the PHM have been monitored dating back to the late 1990s. Unfortunately, the early monitoring tended to be on an *ad hoc* basis with varying (generally small) suite of analytes and infrequent monitoring. More routine monitoring commenced in the early 2000s with the environmental monitoring program formalised in 2010.

The IPL “Master” Chemical Data Spreadsheet was interrogated to identify (environmental and “GW” series) bores that have more than four rounds of chemical analyses. Forty-nine bores satisfied the search criteria. Although reality checking was conducted on the data, the veracity of value transfer from the analytical report into the spreadsheet was taken to be accurate without sample auditing or QC checking. Details of these bore are summarised in Table 3.1 and bore location plotted on a satellite image base map in Figure 3.1. The analytical program and monitoring bore status is presented in Table 3.2.

HYDROGRAPHS

Two sets of hydrographs were plotted; one set with screened interval elevations on the plots (not included in Appendices) and a second set with only water elevations plotted. Hydrographs for all assessed bores grouped by aquifer system (i.e., EAS or WAS) are included in Appendix 2 (Figure 2.6). Other hydrographs group by aquifer system and potential contamination source areas (e.g., Gypsum Storage Facility, Plant Area and Slimes Dams Area) are included in Appendix 4.

REFERENCE BORES

Two new bores were installed as part of the EnviroRisk/JLCS project work during May/June 2016. One bore (EAS-RB) was sited to the northeast of Cell 4B, and one to the northwest of Cell 5A (WAS-RB). Bore EAS-RB is about 700 m ENE from Cell 4B and WAS-RB is about 450 m NW from Cell 5A. The sites were selected in up-hydraulic gradient directions from the GSF. The downhole geology in WAS-RB was as expected based on other bores in the general area (i.e., Inca Formation). However, the EAS-RB bore intersected clays not limestone as expected; the drill cuttings did not effervesce when acid was applied indicating that the samples were non-calcareous, possibly fault zone material (L Bongers, mine site geologist, email dated 23 July 2017) but the actual unit is uncertain. The water table in this bore is also significantly higher (more than 2 m) than expected based on the level in bores closer to the GSF. This finding illustrates the complex local geological setting and the validity of using standard up- and down-hydraulic gradient as reference bores in complex hydrogeological settings.

Analytical results and data statistical analysis for reference bores EAS-RB and WAS-RB are presented in Appendix 6 and 7, respectively. Piper and Durov diagrams, and Box-Whisker plots for key contamination indicator parameters are also included in these appendices.

The Box-Whisker plots are arranged by bore in general north to south direction and the potential contamination source areas (i.e., Gypsum Storage Facility, Plant Area and Slimes Dams Area) are indicated on the plots.

The Box-Whisker plots show the 25th (lower quartile, Q1) 50th (median, Q2) and the 75th (upper quartile, Q3) percentiles. The interquartile range, $IQR = Q3 - Q1$, covers 50% of the data. The whiskers extend to data points $1.5 \times IQR$ from the edge of the box. Outliers are points that are less than or more than $1.5 \times IQR$.

AQUIFER SYSTEM HYDROCHEMICAL ANALYSIS

Appendices 7 and 8 present various hydrochemical plots of the data from the assessed EAS and WAS monitoring bores, respectively. The analysis includes Box-Whisker plots, time series plots, and Piper diagrams.

The nominated environment limits for key indicator parameters are plotted or indicated on respective Box-Whisker Plots and times series plots.

CONCENTRATION DISTRIBUTION MAPPING

Maps of the January 2010 chloride ion and sulphate ion concentrations, and July 2017 chloride, sulphate, fluoride, acidity, total nitrogen and total phosphorous are presented in Appendix 9. The contours maps indicate concentration highs in Plant Area bores GW19 and GW05A, and Slimes Dams Area bores PHMB02 (EAS) and SDMB01 (WAS). The maps are indicative only and cannot readily be compared because the data control points (bores) in 2017 were not the same as in 2010.

GSF GROUNDWATER CONTAMINATION RISK ASSESSMENT

A groundwater contamination risk assessment (GCRA) for the Gypsum Storage Facility was undertaken to identify the risk of harm to groundwater users and/or the environment (JLCS,

2016). The GSF GCRA (JLCS, 2016) included the risks to the important water resources in the Great Artesian Basin and the high conservation value groundwater dependent ecosystems (GDEs) in the Mount Merlin Area as well as receptor closer to the GSF. Although the GCRA was focused on the risk to receptors from potential contamination in the GSF area, much of the assessment is relevant to the PHM site. Consequently, the GCRA is reproduced in the following sections as background for assessing the entire PHM site. However, it needs to be stressed that the GCRA would need to be revised to include the other identified potential contamination sources in the plant and slimes dams areas.

POTENTIAL CONTAMINATION SOURCE

Potential sources of groundwater contamination at the PHM are indicated on a site aerial image in Appendix 11. The sources area (from north to south): 1) Gypsum Storage Facility, 2) Plant area, and 3) Slimes Dams and nearby old landfill.

APPENDIX 2

PHYSICAL CHARACTERISTICS AND CONCEPTUAL HYDROGEOLOGICAL MODEL

PHYSICAL CHARACTERISTICS AND CONCEPTUAL HYDROGEOLOGICAL MODEL

TOPOGRAPHY AND DRAINAGE

The PHM is situated on the northern portion of the Burke River Plain; a large inland alluvial plain that abuts against the rugged terrain of the Standish (west) and Selwyn ranges (north) with hill peaks attaining elevations in excess of 500 m AHD. The general level of the Burke River Plain falls from about 350 m AHD where the Burke River emerges from the Selwyn Ranges foothills to less than 200 m AHD in the Blair Athol Area about 75 km south of the PHM. The terrain across the Burke River Plain in the intervening area is mostly flat-lying. The main exception is the northwest-southeast aligned ridge line extending from Mount Murray (~5.2 km north of the GSF) through Mount Merlin (~3.8 km ESE of the GSF), Signal Hill (~14.6 km SE of the GSF) and Digby Peaks. The Burke River and its tributaries are part of the Lake Eyre drainage system. Flow in all streams including the Burke River is intermittent. Stream channels are typically incised approximately one to two metres into the alluvial plain.

The Phosphate Hill Mine, processing plant and waste storage facilities were developed in an area of low relief surrounding Phosphate Hill (Figure 2.1). The mine site is drained by a number of ephemeral drainage systems with flow generally within ill-defined channels. The main local systems are Dead Horse Gully which enters the PHM from the west and Galah Creek from the north with their confluence between the Galah and Brolga pits. Downstream of the confluence the system becomes the Kolar Creek. Flow events along these drainage lines are typically short lived (hours to days). Small pools may remain in the deeper sections of the channel for several weeks following flow events (Hill, et al., 2000, 2004).

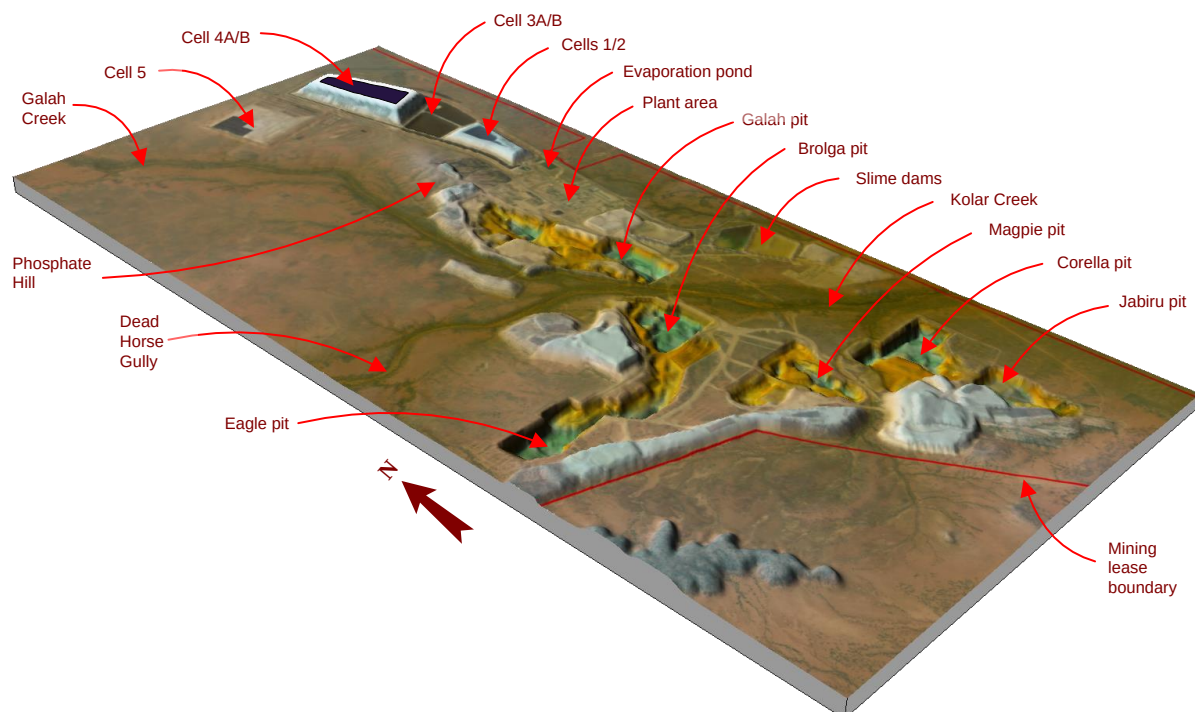


Figure 2.1: Phosphate Hill Mine Site Digital Elevation Model

The pre-mining topography across the mine site sloped gently to the south from elevation of 275-280 m AHD in the area north of cells 4 and 5 to less than 260 m AHD around Kolar Creek.

The topography has been extensively modified by mining operations (pits and spoil dumps) and the on-site gypsum storage cells.

GEOLOGICAL SETTING AND STRUCTURAL FRAMEWORK

Phosphate Hill is located within the Burke River Outlier (BRO), an outlying portion of the Burke River Structural Belt (BRSB) which is a fault-bounded sunken block (graben) about 180 km long and up to 60 km wide in the southeastern part of Georgina Basin.

Regional faults in the Phosphate Hill area mostly trend in general north-northwest to south-southeast directions. The main regional fault or more precisely “fault zone” is the Pilgrim Fault (Figure 2.2) which has been traced southward from the Mount Isa Inlier for at least 180 km as a zone of disturbance and west-up bedding offsets in Cambro-Ordovician rocks (Reynolds, 1965; Casey, 1968; Senior, 1973; Blake et al., 1984; Anderson et al., 2004). Other more localised general north-south aligned faults in the Phosphate Hill area include the Western, Mehaffey, Phosphate Hill and Russell faults, and number of west-east aligned faults to the south of the PHM site referred to by JLCS (2016) as the “Southern Fault Zone”. Many smaller, mostly unnamed general west-east faults have been mapped in the BRO including at Mt Murray and Phosphate Hill and in the Swift Hills area.

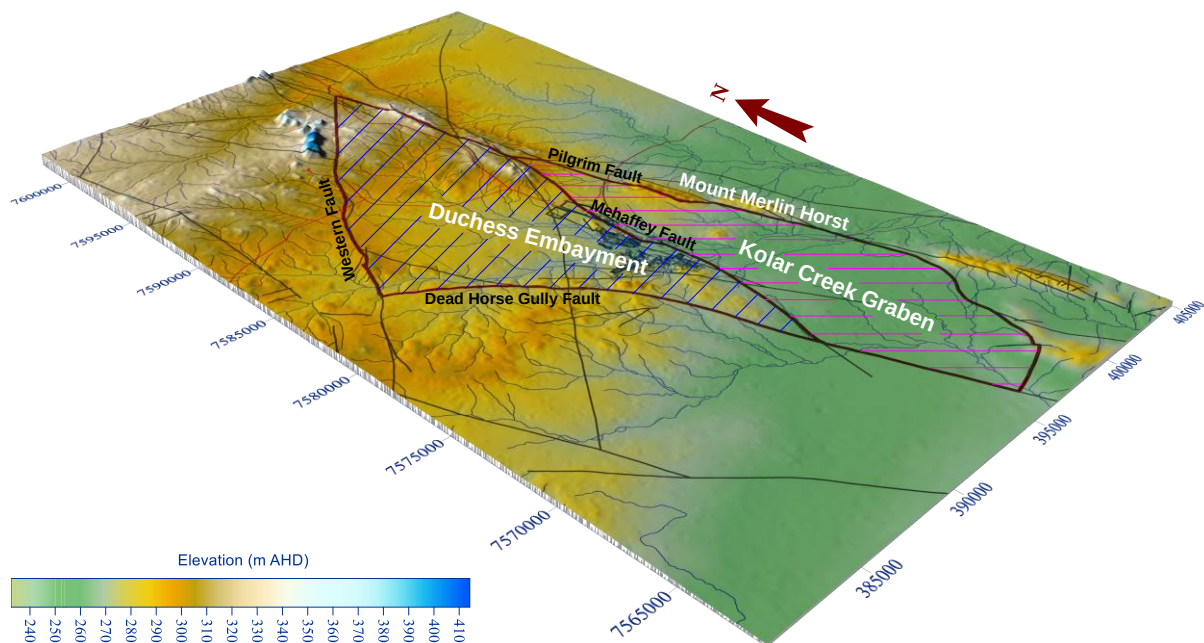


Figure 2.2: Major Structural Elements in the PHM Area (After JLCS, 2016)

The PHM pits, GSF Cell 5, the western parts of Cell 3A and Cell 4A and the processing plant are located in an embayment along the western margin of the Burke River Outlier referred to as the “Duchess Embayment”. The area of the Duchess Embayment (DE) has here been redefined based on detailed basin analysis to include the area of Cambrian rock to the south of the PHM site. The DE which is approximately triangular shaped is a fault-bounded sub-basin developed on the shelf of the basin of the BRO and is separated from the main area of the outlier by the Mehaffey Fault (Mehaffey Creek Fault in some early reports). It is bounded along its western and southwestern contacts with the Mount Isa Inlier by the Western Fault and by the Dead Horse Gully Fault system (named in this report).

The Mehaffey Fault joins the Pilgrim Fault Zone in the Mount Murray area about four km north of the GSF. The extension of the Pilgrim Fault Zone has been mapped about three km to the east of the GSF. Younger Ordovician aged rocks are exposed along a ridge immediately east of the Pilgrim Fault – this ridge is evident in Figure 2.3 showing the outcrop geology draped over a DEM – with a previously unidentified graben with upthrown rocks to the west and downthrown rocks to the east in the area between the Mehaffey and Pilgrim faults. The graben was informally named the Kolar Creek Graben (JLCS, 2016).

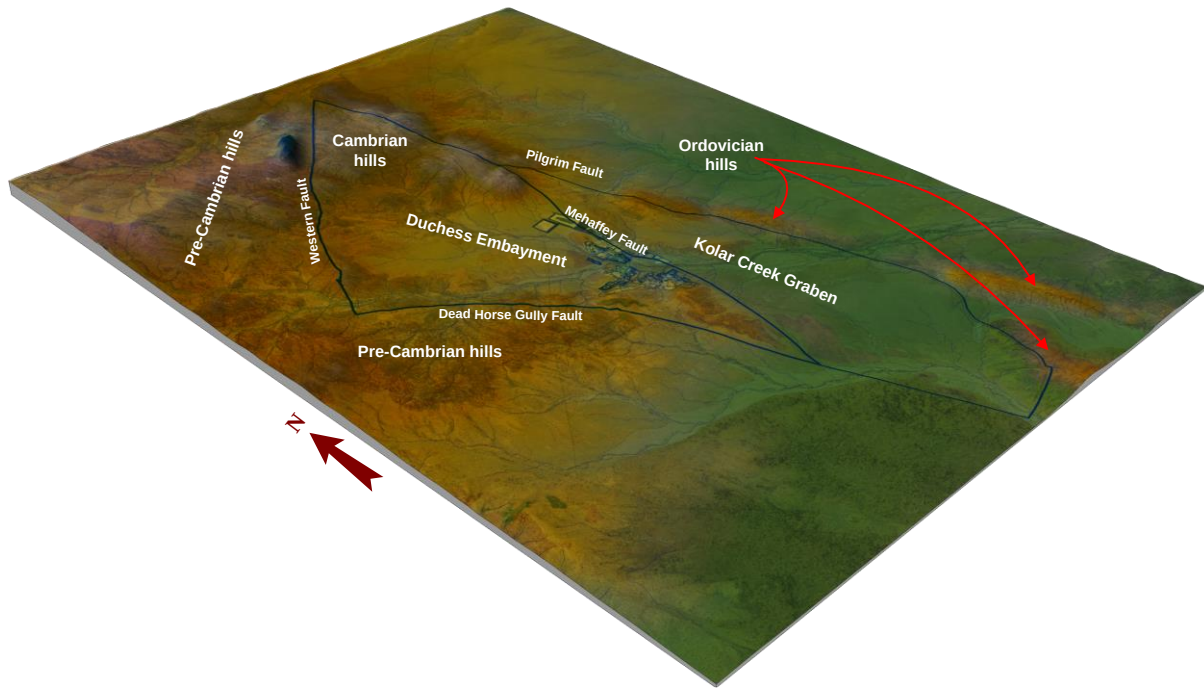


Figure 2.3: Local Geological Structures and Outcrop Geology Draped Over DEM

STRATIGRAPHY

The stratigraphic sequence in the Duchess Embayment consists of Cambrian age rocks whereas the rocks to the east of the Mehaffey Fault including in the Kolar Creek Graben, are younger upper Cambrian and Ordovician rocks. The Cambro-Ordovician rocks are generally overlain by a relatively thin veneer of Cainozoic rocks obscuring most of the Cambro-Ordovician rocks and geological structures in the area. Away from drainage channels, the Cainozoic sediments are typically comprised of highly ferruginous, hard clay matrix with rock fragments, however, along drainage channels the near-surface deposits are predominantly silty sandy gravelly alluvium.

The stratigraphic units identified at the PHM and dominant lithologies are summarised in Table 2.1. The outcrop geology and local geological structure are mapped in Figure 2.4. The geology was downloaded from the Queensland MinesOnlineMaps web site. The geology was simplified by grouping the different Proterozoic rocks and all the Cainozoic (Tertiary and Quaternary) cover rocks into two units. The locations of the faults shown were sourced from the MinesOnlineMaps and the various maps prepared by Western Mining Corporation exploration geologists. The geological structures within the PHM are shown at a larger scale in Figure 2.5.

The major fault elements are the Mehaffey, Phosphate Hill and Russell faults, the Brolga Shear Zone, and the (newly named) Southern Fault Zone. [It should be noted that the positions of the

faults with the possible exception of the Mehaffey Fault, are not well constrained. Consequently, they have been mapped in (slightly) different locations by previous researchers.] Russell and Truman (1971) considered that these faults are dominantly high-angle, block faulting, with no appreciable lateral movement. They estimated that the throw (vertical displacement) along the Mehaffey Fault is probably in excess of 300 m with smaller displacements of about 30 m and 60 m along the Phosphate Hill and Russell's faults, respectively.

Table 2.1: Identified Stratigraphic Units, PHM

Age	Stratigraphic Unit	Lithology	DE	KCG
Cainozoic	Quaternary sediment & soil	Alluvial clay, silt, sand, gravel, conglomerate.	✓	✓
	Tertiary laterite	Ferricrete.	✓	✓
Early Ordovician	Swift Formation	Sandstone, siltstone with limestone and chert.		✓
	Ninmaroo Formation	Sandy calcarenite, calcilutite, limestone, dolomitic limestone, marl.		✓
Middle Cambrian	Inca Formation			
	• Limestone Member	Fetid, cherty dolomitic limestone with minor calcareous shale.	✓	
	• Shale Member	Shale, cherty shale and siltstone, minor chert.	✓	
	Beetle Creek Formation		✓	
	• Monastery Creek Phosphorite Member	Phosphorite, phosphatic cherty siltstone, chert and fetid phosphatic limestone.		
	• Lower Siltstone Member	Calcareous and cherty phosphatic siltstone, chert, fetid dolomitic phosphatic limestone and minor phosphorite.		
	Thorntonia Limestone			
	• Chert Member	Silicified carbonate rock and coquina.	✓	
	• Carbonate Member	Dolomitic limestone and dolomite, minor chert.	✓	
Early Cambrian	Mt. Birnie Beds (MBB)	Ferruginous silty mudstone & sandstone, orthoquartzite and conglomerate, dolomite, marly dolomite, siltstone & chert, unsorted boulder clay of silty mudstone and polymictic fragments, pebbles and boulders.	✓	
Proterozoic	Kalkadoon Gneissic Granite	Coarse-grained porphyritic granite and granodiorite, amphibolite.	✓	✓

Notes: 1) Modified after Russell and Trueman 1971; 2) DE, Duchess Embayment; 3) KCG, Kolar Creek Graben;

Phosphate Hill, immediately east-southeast of Cell3A is an uplifted fault-bound (Phosphate Hill Fault to the west and Russel Fault to the east) lenticular block of the Monastery Creek Phosphorite Member (upper member of the Beetle Creek Formation).

There is a major zone of structural dislocation referred to as the Broglia Shear and Fold Zone, exposed in the Broлга pit where the phosphate ore body plunges downwards and dips steeply to the southeast. The footwall and hanging wall sediments are steeply dipping and highly contorted and the ore zone is near-vertical. The Broлга Shear and Fold zone is part of a northeast southwest-trending graben which passes through the deposit (PSM, 2015). The faults have caused a range of structural dislocations in the PHM area including convoluted folding, drag folding and consequential steepening of bedding. Bedding reversals associated with folding have been reported (PMS, 2015). Typically dips within the area are about 5° but steeper dips to 15° associated with faulting have been observed during mining (Rogers and Crase, 1979; PMS, 2015). Folding has been recognised on two scales with northerly-trending folds refolded about east trending axes to produce gentle domes and basins. The refolding regime has produced roughly circular structural “domes” characterised by gentle dips with bedding dipping in all directions away from the dome top.

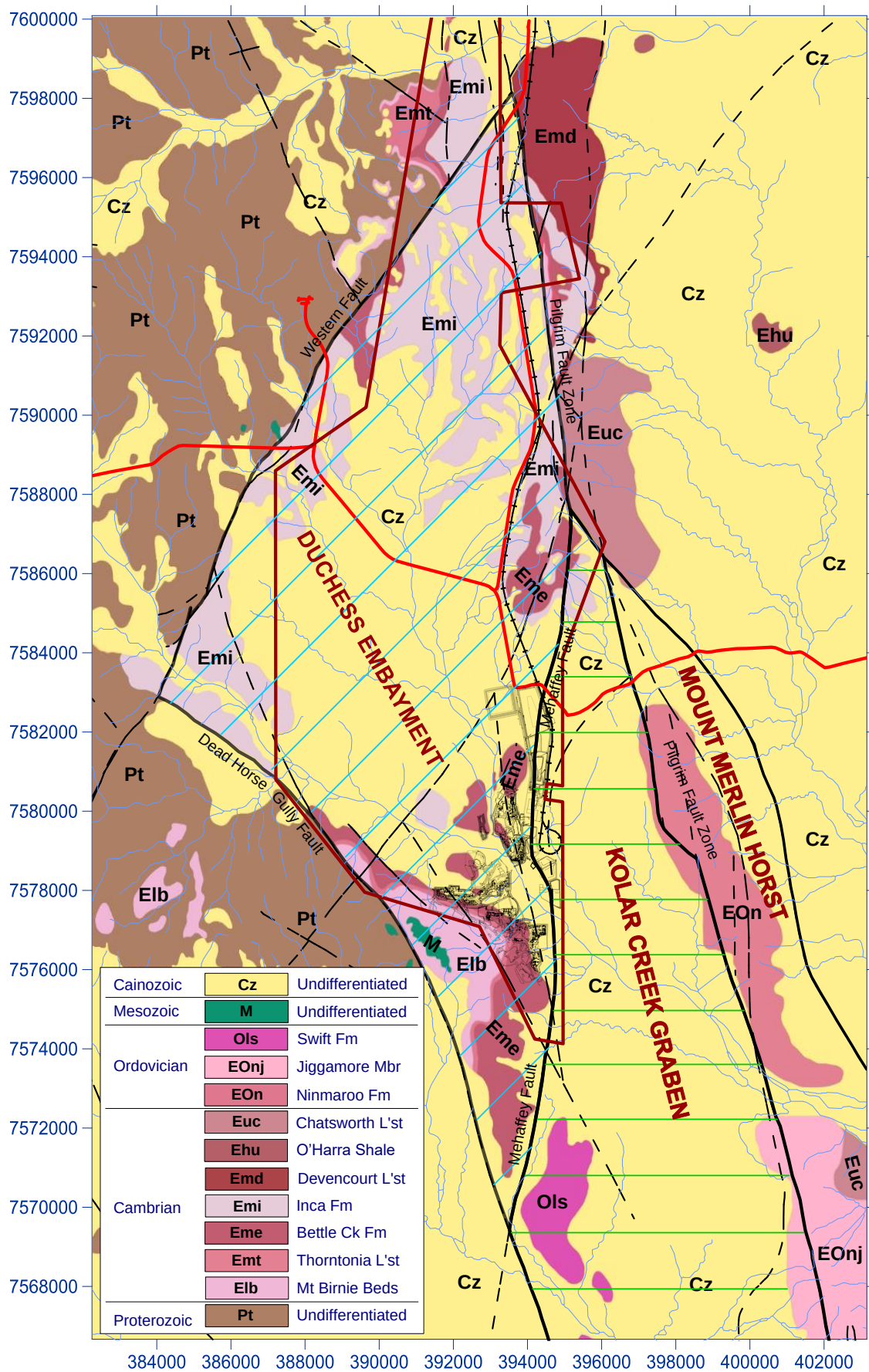


Figure 2.4: Simplified Geological Outcrop Map

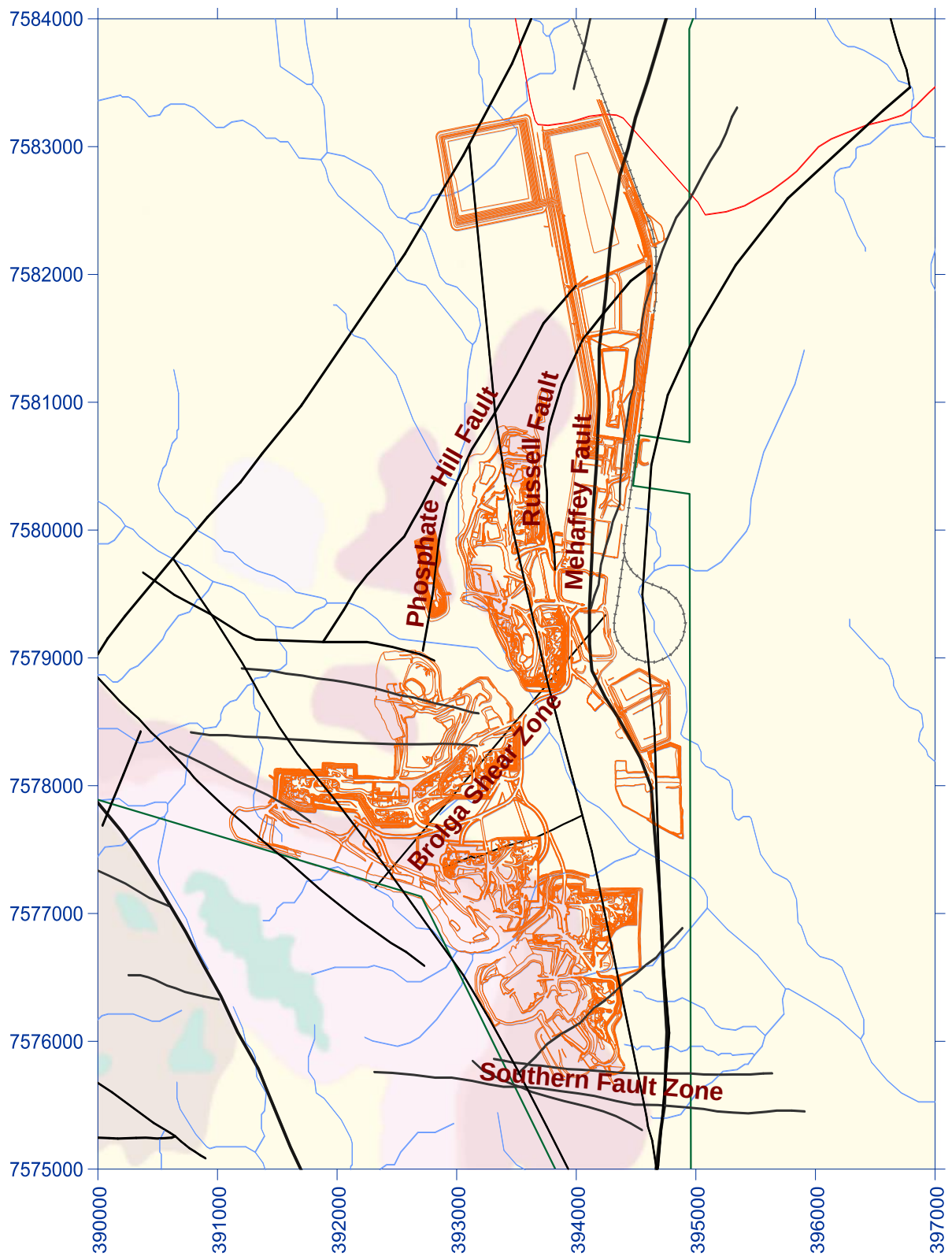


Figure 2.5: PHM Fault Traces

HYDROGEOLOGY

Compartmentalised Aquifer Systems

The faults in the Phosphate Hill area frequently act as hydrogeological barrier boundaries causing compartmentalised aquifer systems. Hydrogeological analysis undertaken by JLCS identified three separate “compartments”. Two of the compartments are within the Duchess Embayment and one in the Kolar Creek Graben. The analysis also suggested that there could be another compartment in the Kolar Creek Graben south of the PHM but the evidence is less conclusive.

The various stratigraphic units within the three identified compartments in PHM area are considered to form multilayered leaky aquifer systems. The aquifer systems are designated as Western Aquifer System (WAS) and Southern Aquifer System (SAS) within the Duchess Embayment, and the Eastern Aquifer System (EAS) in the Kolar Creek Graben. The geological (structural) setting and stratigraphic units in the various aquifer systems are summarised in Table 2.2 (see Figure 2.3 for locations of the different aquifer systems).

Table 2.2: Geological Blocks and Aquifer Systems

Duchess Embayment		Kolar Creek Graben
Western Aquifer System (WAS)	Southern Aquifer System (SAS)	Eastern Aquifer System (EAS)
Inca Formation Beetle Creek Formation Thorntonia Limestone	Inca Formation Beetle Creek Formation Thorntonia Limestone?	Swift Formation Ninmaroo Formation Chatsworth Limestone?

The hydrogeological barrier boundary between the WAS and the EAS is the Mehaffey Fault. The location of the fault is relatively well constrained to within 10s of metres. The location of the boundary between the SAS and the aquifer systems to the north is not as well constrained but is most likely associated with the general west-east faults in the area south of the PHM Jabiru Pit and may be influenced by a buried tongue of Mount Birnie Beds as postulated by WMC (2002), or a ridge of Proterozoic basement rocks. The inferred position of the boundary based on the down-hole stratigraphy and water level data from bores in the area to the north (bore I) and bores further south (bores 1502, 1503) is at about 7,575,500 m N (MGA Z54) which is about five km south of Cell 1 and well beyond the likely area of influence of any groundwater contamination originating from the GSF. A number of west-east faults have been mapped in this area (Rogers 1975, 1999; PPK, 2001).

It is highly likely that the barrier between the WAS and the SA extends further east into the Kolar Creek Graben forming a fourth local aquifer compartment.

Evidences for the compartmentalised aquifer conceptual hydrogeological model includes:

- Hydrography Analysis

The most compelling evidence for fault controlled groundwater flow systems is the observed water levels and trends in bores on opposite sides of the Mehaffey Faults and the hydraulic response of the groundwater levels to groundwater extraction from bores in the WAS located close to the fault. Hydrographs for all assessed bores plotted in Figure 2.6 show rising trends in all bores in the EAS and pronounced falling water levels in WAS bores.

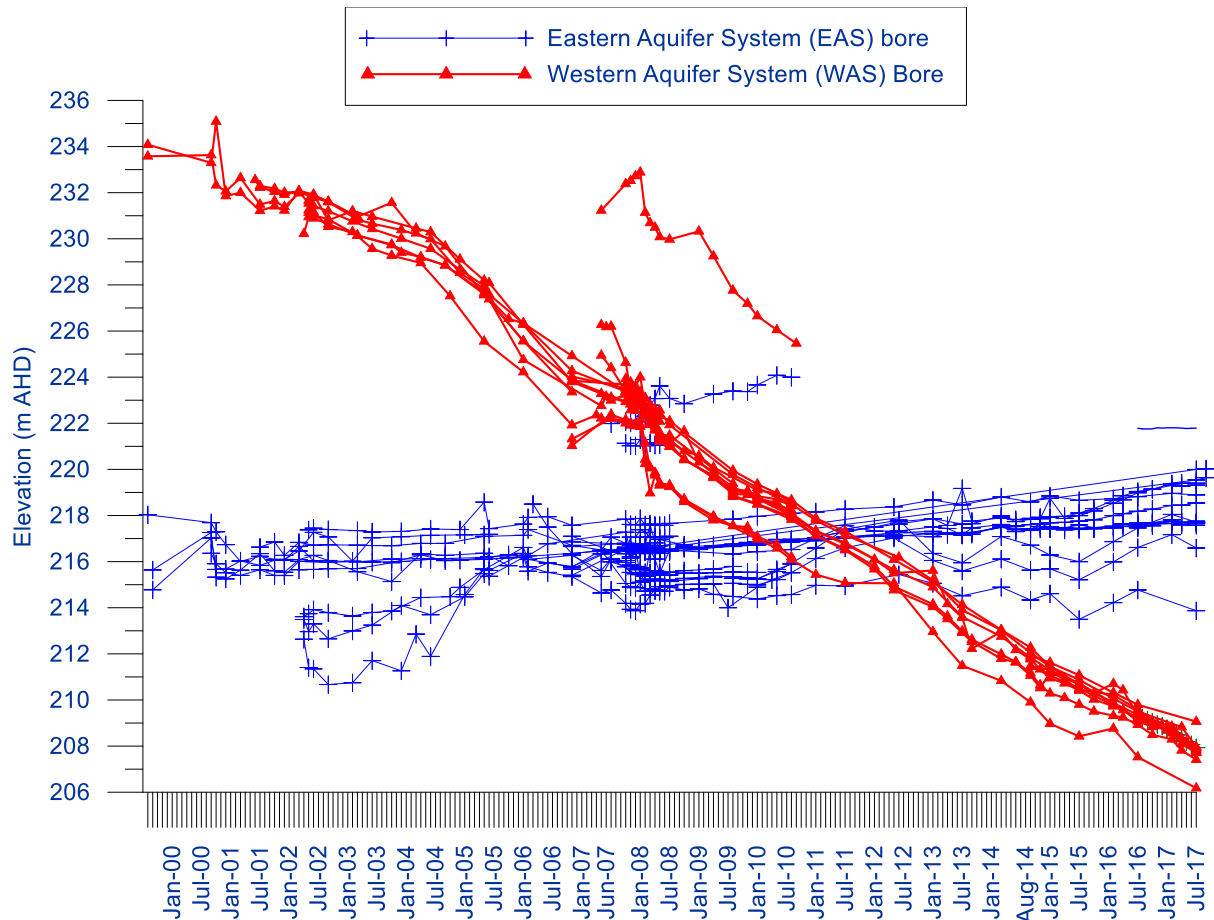


Figure 2.6: PHM Bore Hydrographs

- Structural and stratigraphic analysis

Rocks of different lithologies and hydraulic characteristics are juxtapositioned against each other on opposite sides of faults, e.g., Cambrian rock against younger Ordovician rocks by the Mehaffey Fault.

- Large hydraulic head differentials across faults:

Groundwater levels on opposites of faults are significantly different (Figure 2.7). For example, pre-mining the waters levels to the west of the Mehaffey Fault (WAS) were about 27 m higher than the levels to the east (EAS) of the fault (EAS); water levels in the WAS were at elevation of about 234 m AHD and in the EAS at elevations of about 207 m AHD.

The pre-mining water levels in bores 1502, 1503, and H in the SAS were at more than 30 m lower than the level in the adjoining WAS bores E, G, C-P and F-P (202-203 m AHD in the SAS bores compared to about 234 m AHD in the WAS bores). The water levels in these bores have remained relatively static since the groundwater pumping commenced at the PHM (Figure 2.8).

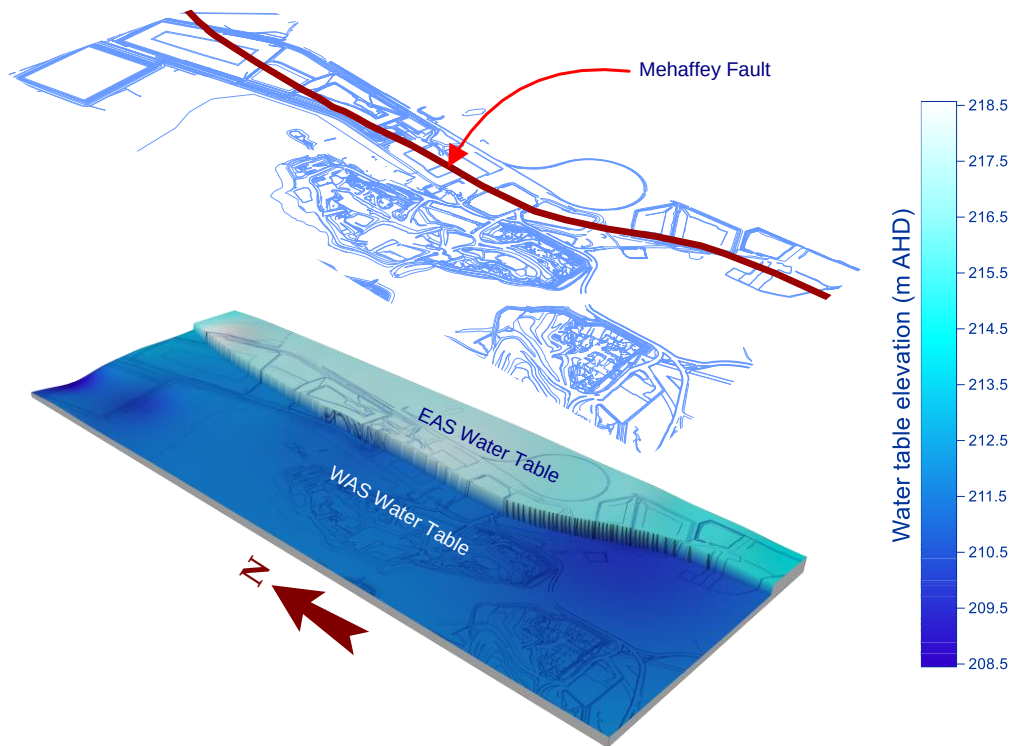


Figure 2.7: GSF Area Water Table Differentials 3D Visualisation

The pre-mining water levels in bores 1502, 1503, and H in the SAS were at more than 30 m lower than the level in the adjoining WAS bores E, G, C-P and F-P (202-203 m AHD in the SAS bores compared to about 234 m AHD in the WAS bores). The water levels in these bores have remained relatively static since the groundwater pumping commenced at the PHM (Figure 8).

Discharge of groundwater into Kolar Creek caused an increase of about 5-6 m in nearby bores (I and J) but no related response is evident in the hydrographs for bores 1502, 1503 and H. These observations suggest the possible presence of another aquifer compartment within the Kolar Creek Graben opposite the SAS. Further investigation is required to verify the existence of a fourth local aquifer system.

- Hydraulic head differential decreases

The head differences across the Mehaffey Fault have decreased substantially as the water level in the WAS has been lowered as a result of groundwater extraction for water supply and pit dewatering but the level in the EAS has not significantly changed; The head differential decreased from about 27 m pre-mining, to around 27 m in 2002 (WMC, 2002), and is now about four to five m higher than that in the WAS immediately opposite the fault after more than 15 years extracting groundwater from the WAS.

- Pumping test stress response

The water table in the Kolar Creek Graben to the east of the Mehaffey Fault was not affected by groundwater extraction during a series of controlled pumping tests on a number of bores to

the west of the fault in the Duchess Embayment as would have occurred if the aquifers in the EAS were in direct hydraulic connection with those in the WAS.

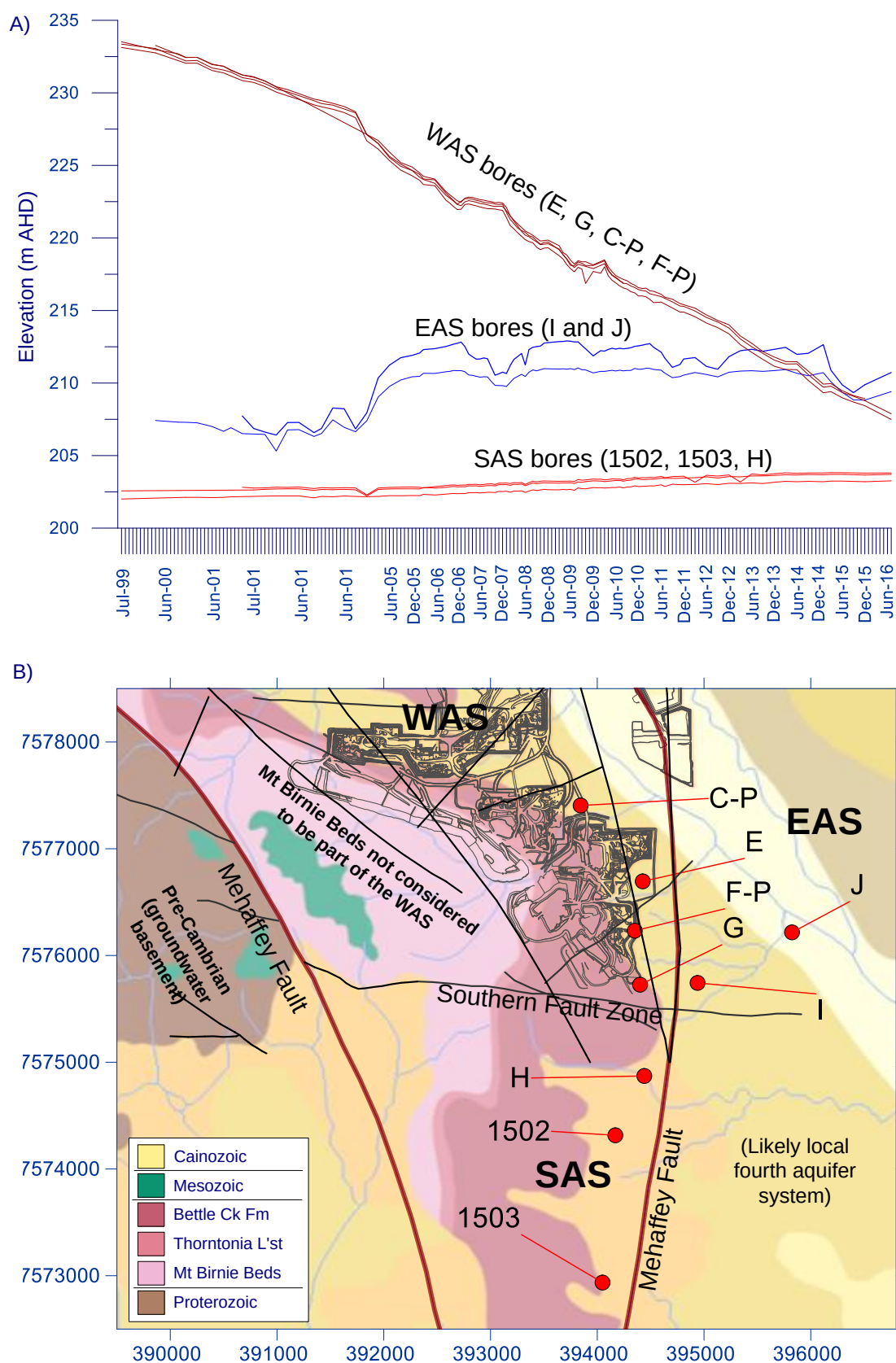


Figure 2.8: Phosphate Hill South Area Bore Hydrographs and Locations

- WAS Drawdown linearly related to cumulative abstraction

WMC identified a linear relationship between cumulative groundwater abstraction and water level (Figure 2.9) and considered that the relationship is evidence that the WAS is hydraulically isolated from surrounding rocks and that aquifer system responds as a “bath-tub” with a very flat water table.

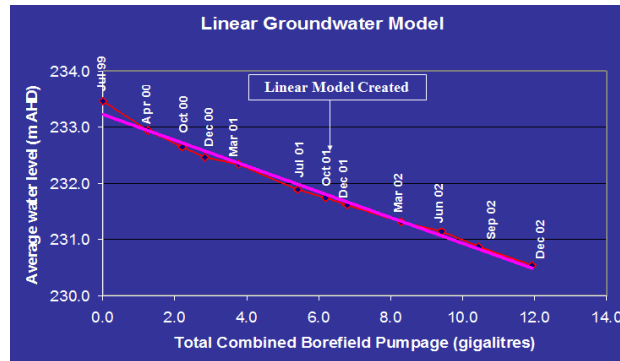


Figure 2.9: WAS Linear Groundwater Model (WMC, 2003)

Aquifers and hydraulic characteristics

The Cambro-Ordovician stratigraphic sequence in the Phosphate Hill area behaves as a leaky confined, horizontally stratified aquifer system overlain in large part by unsaturated Cainozoic sediments. The consolidated rocks in the WAS, EAS and SAS form fractured to dual porosity type aquifers but where deeply weathered or in fault gouge zones the rocks can form low permeability porous medium type aquitards. The storage and transmitting capacity of the fresh rock is dependent on the frequency and degree of interconnection of joints and fractures. Groundwater varies from unconfined to semi-unconfined depending on the hydraulic characteristics of the material above the water table.

The different Cambro-Ordovician rocks in the Phosphate Hill area are aquifers to varying degrees. The various stratigraphic units exhibit both siliceous and calcareous facies. The siliceous facies form fractured rock types aquifers whereas the calcareous facies act as dual porosity type aquifers. The Monastery Creek Phosphorite Member and the underlying Lower Siltstone Member in the Duchess Embayment (part of the WAS) are the most productive aquifers at the PHM site. The siliceous facies of these two members of the Beetle Creek Formation are highly transmissive; values of transmissivity determined from pumping tests of bores are mainly in the range 400 to 5,000 m²/day, and average of about 2,000 m²/day (Rockwater, 2002).

Airlift tests in bores constructed in the Ninmaroo Formation near the GSF produced yields of about two L/sec (180 m³/day) which is indicative of a low productivity aquifer. The tested intervals consisted of weakly fractured and cavernous limestone at depths around 100 m which is more than 50 m below the water table. The shallower monitoring bores installed during May 2016 and constructed across the water table did not intersect noticeable cavities and only yielded small amount of groundwater (recovery after sampling was very slow).

Aquifer hydraulic characteristics have not been evaluated except for transmissivities determined from pumping tests mainly carried out in the 1990s on bores west of the Mehaffey

Fault near the PHM pits in the Duchess Embayment. Transmissivity values derived from these tests are very likely not representative of the regional aquifer mass as the test bores were constructed in higher permeability zones (in order to maximise drawdown). No aquifer tests have been reported for the aquifers elsewhere within the Duchess Embayment or in the Kolar Creek Graben east of the Mehaffey Fault.

Perched Aquifers

A number of researches have mooted the presence of perched aquifers (C&R, 2007, 2015) above the main water table based on reported cavity intersections during drilling. However, review of drilling logs for the environmental bores and ore resource exploration drilling indicates that cavities above the water table are not extensive and not mappable. Many of the cavities including those exposed during mining are clay infilled. Any water filled cavities above the water table would therefore be very localised (and would represent incomplete pathways for groundwater contamination).

Aquifer type and groundwater confinement

The aquifer systems in the Phosphate Hill area are considered to be unconfined to semi-unconfined. This “model” differs from a number of researchers (e.g., Passmore, 2000) who considered that Inca Formation and calcareous facies of the Beetle Creek Formation are not aquifers and that where present, they confined the groundwater in the siliceous facies of the Beetle Creek Formation. However, the overlying units are considered to be (low permeability) aquifers based on available hydrogeological data. Consequently, all units below the water table are considered to be part of the respective aquifer systems.

The natural undisturbed hydraulic gradients in the different aquifer system are very flat except in the areas towards the groundwater extraction bores.

Recharge

Recharge is considered to mainly occur in areas where the siliceous phase of the Beetle Creek Formation outcrops or sub-crops beneath thin cover of alluvium, such as the western margin of the Duchess Embayment, the Mount Murray area and at Phosphate Hill.

Direct recharge would also occur in the areas of the open pits that are above the water table. Runoff into the drainage lines concentrates surface water forming linear recharge mounds after flood events. The recharge mounds are “short-lived”, with groundwater dissipating into the surrounding aquifer. Consequently, recharge events are difficult to identify in bore hydrograph records except for in a few bores that were installed close to stream beds.

High local recharge of low salinity water would control the locations of the reported low chloride groundwater zones.

Regional groundwater salinity

The salinity of the groundwater in the region is low to moderate with typical total dissolved solids (TDS) ranging from about 500 to 1,000 mg/L. The average salinity of groundwater from 39 bores screened in the Ninmaroo Formation in the Burke River Outlier was 980 mg/L (Randal, 1978).

Field analysis of groundwater from numerous regional bores on Chatsworth Station were undertaken in June 2004 by C&R. C&R (2007) reported that several of the station bores had EC readings over 1,000 $\mu\text{S}/\text{cm}$ and that two of the bores (Bore No. 31 and Makbat Bore) had EC readings of 2,960 and 3,940 $\mu\text{S}/\text{cm}$, respectively.

PHM WATER TABLE MAPPING

Mapping the water table at the PHM is difficult reflecting the complex local faulted geology and probable irregularly distributed groundwater recharge. The main fault, the Mehaffey Fault, forms an effective hydrogeological barrier that completely isolates groundwater on the western side of the fault from that on the eastern side. Water table contours generated using the Kriging algorithm assuming a planar water table are presented in Figures 2.10. A number of “bullseyes” centred on monitored bores are evident in the Figure 2.10 contours. The bullseyes indicate that the water table is not a simple planar surface. Three-dimensional visualizations of the water table surface generated using the Kriging and Nearest Neighbour gridding algorithms are shown in Figure 2.11A and 2.11B, respectively. The bulls-eyes are less obvious in Figure 2.11A because of the relative vertical to horizontal scale. The water table surface in Figure 2.11B is “blocky” and suggests the probable presence of a number of small aquifer sub-compartments within both the WAS and EAS formed by cross-cutting. The resulting smaller groundwater flow compartments are varyingly hydraulically isolated from each other.

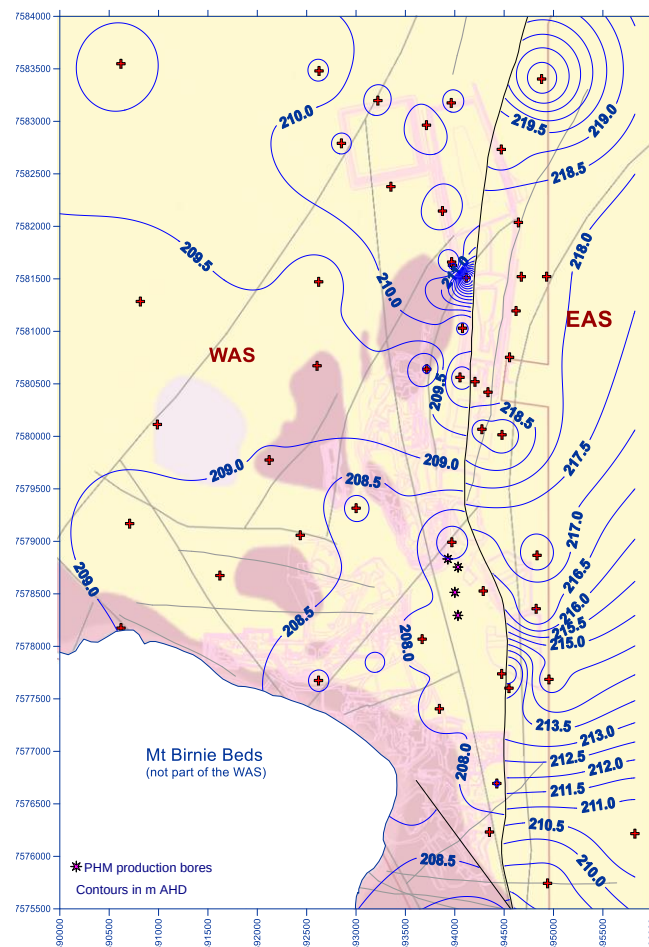


Figure 2.10: PHM July 2016 Water Table Contours – Planar Water Table Model (From JLCS, 2016).

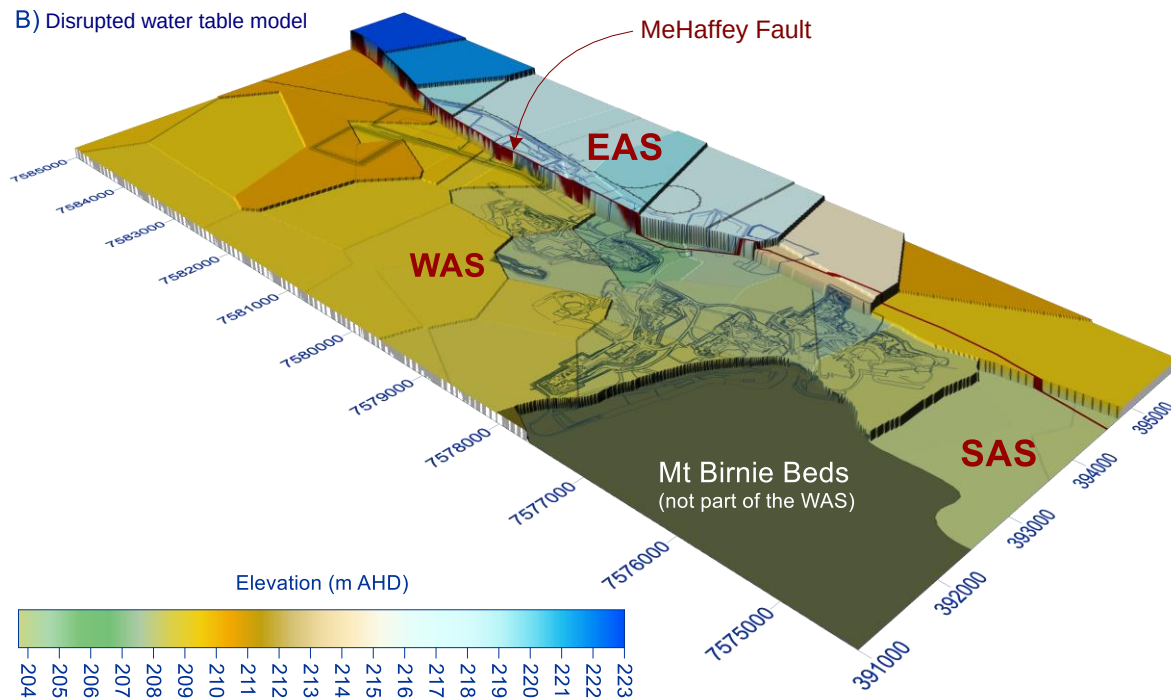
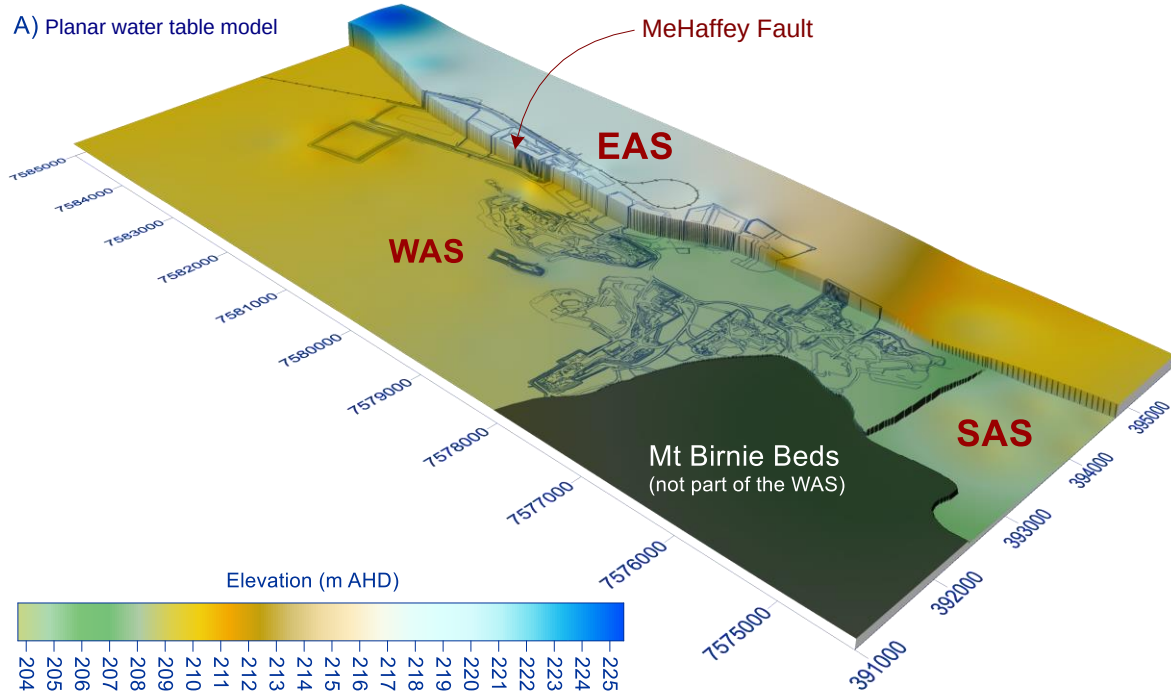


Figure 2.11: PHM Three-Dimensional Water Table Models, A) Planar Water Table, and B) Fault Disrupted Water Table – July 2016 Monitoring Data. (From JLCS, 2016)

GROUNDWATER USE AND ENVIRONMENTAL VALUE

WATER SUPPLY

Groundwater in the Phosphate Hill and surrounding area is an important source of water that is mainly used for stock watering. Groundwater is the source of drinking water at the PHM and is possibly used for domestic purpose including drinking water where the quality is suitable at station homesteads in the region.

Drinking water at the PHM mine and the mine camp at The Monument (reported in McRae-Williams, 2016) is obtained from two of the mine supply bores, PB08 and PB09 located immediately west of the Mehaffey Fault within the DE with the water extracted from the WAS. PB08 is located about 1,985 m and 2,795 m south of Cell 1 and Cell 3A, respectively, whilst PB09 is about 2,225 and 3,040 m south of Cell 1 and Cell 3A, respectively (Figure 2.12). Recent test results indicated that the pH, EC and chloride ion concentration of the water extracted from PB08 and PB09 were 7.43 pH units, 1,163 $\mu\text{S}/\text{cm}$ and 161 mg/L, and 7.33 pH units, 1,165 $\mu\text{S}/\text{cm}$ and 156 mg/L, respectively. The water is chlorinated prior to use.

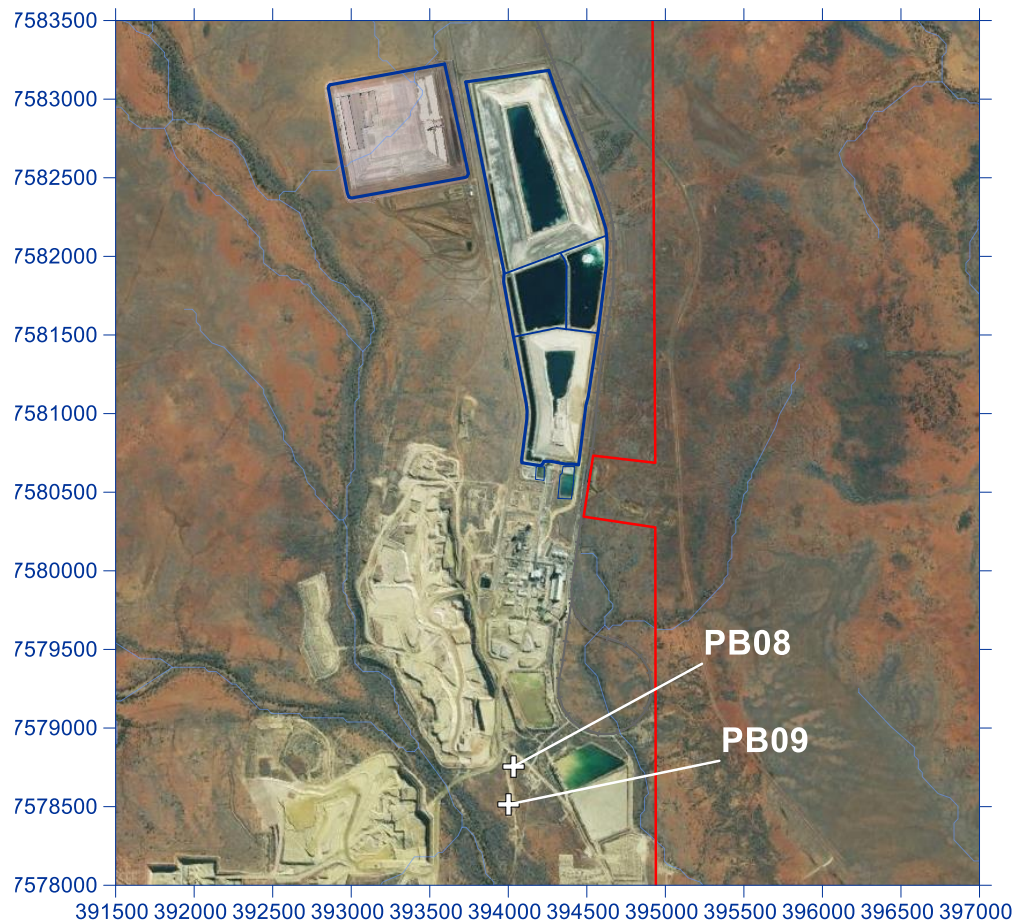


Figure 2.12: PHM Drinking Water Supply Bore Locations

Stations use groundwater primarily for stock water but possibly also for domestic purposes. Records of registered bores in Queensland were downloaded from the Department of Natural Resources and Mines groundwater database. The dataset was culled to obtain a data sub-set of water supply bores (designated as “station bores”) within a 40 km radius of the PHM GSF. There are 41 bores identified as “Supply Bore” within the stipulated search radius (Table 2.3). Station bore locations are mapped in Figure .2.13.

Table 2.3: Local Bore Details

DNRE Bore No.	MGA Z54 Coordinates		Plot No.	Depth (m)	Radial Dist. (km)	Bearing	Geological Entity
	Eastings	Northing					
14369	401351.3	7583512	1	34.1	7.365	EbN	BRO, East of Pilgrim Fault
14360	399706.4	7589528	2		9.565	NEbN	BRO, East of Pilgrim Fault
14370	403824.3	7578207	3	57.9	10.251	ESE	BRO, East of Pilgrim Fault
14361	401544.2	7589447	4		10.668	NE	BRO, East of Pilgrim Fault
14359	399618.2	7594386	5	67.1	13.809	NNE	BRO, East of Pilgrim Fault
14371	406009.4	7572533	6	42.7	14.992	SEbE	BRO, East of Pilgrim Fault
14401	399178.3	7595859	7	995.5	15.030	NNE	BRO, East of Pilgrim Fault
14367	409127.3	7579131	8		15.142	EbS	BRO, East of Pilgrim Fault
13746	395064.8	7566221	9	49.3	15.613	S	Kolar Ck Graben?
14366	410410.2	7580675	10		16.229	E	BRO, East of Pilgrim Fault
14362	406660.3	7593568	11	38.7	17.208	NE	BRO, East of Pilgrim Fault
13847	379881.4	7571802	12	45.1	17.434	SWbW	MII, Southwest of DE
13832	383548.2	7596031	13	0.0	17.864	NWbN & NNW	MII, West of DE
14364	411322	7586984	14	45.7	17.897	ENE & EbN	BRO, East of Pilgrim Fault
14363	409577.2	7590910	15	39.6	17.912	NE	BRO, East of Pilgrim Fault
14368	412065.3	7577148	16		18.434	EbS	BRO, East of Pilgrim Fault
14288	401444.6	7563956	17	61.6	19.276	SSE	South of Kolar Ck Graben
13844	375131.2	7588525	18	0.0	20.222	WNW	MII, West of DE
14398	407577.4	7599047	19	38.1	21.928	NE & NEbN	BRO, East of Pilgrim Fault
13748	392130.5	7559220	20	64.9	22.714	S & SbW	BRO, South of DE
13744	376967.5	7566582	21		22.973	SWbW	MII, Southwest of DE
14399	412412.5	7597567	22	45.7	24.161	NE	BRO, East of Pilgrim Fault
14365	418626.3	7584778	23	45.7	24.590	EbN & E	BRO, East of Pilgrim Fault
14373	418089.3	7588619	24	48.8	24.843	NEbE	BRO, East of Pilgrim Fault
13745	376238.3	7564485	25	40.8	24.938	SWbW	MII, Southwest of DE
14400	415439.3	7595585	26		25.368	NEbE	BRO, East of Pilgrim Fault
14397	409484.4	7602255	27	39.6	25.648	NE & NEbN	BRO, East of Pilgrim Fault
14372	418439.2	7570879	28	39.6	26.558	ESE	BRO, East of Pilgrim Fault
13749	390758.5	7554537	29	45.7	27.539	SbW & S	BRO, South of DE
13747	377140.6	7559110	30	54.9	28.402	SWbS & SW	BRO, Southwest of DE
14290	401620.3	7554178	31	50.0	28.662	SbE & SSE	South of Kolar Ck Graben
14292	411765.5	7558913	32	33.5	28.875	SE & SEbS	BRO, East of Pilgrim Fault
14395	401448.3	7609834	33	31.1	29.135	NbE	BRO, East of Pilgrim Fault
13831	380784.1	7608372	34	0.0	29.917	NNW & NWbN	MII, Northwest of DE
14394	404294.3	7609912	35	47.9	30.042	NNE	BRO, East of Pilgrim Fault
13810	370194.9	7563668	36	61.0	30.064	SWbW	BRO, South of DE
13820	374428.5	7557705	37	25.6	31.183	SW & SWbS	BRO, Southwest of DE
13751	388093.5	7550613	38	39.6	31.854	SbW & S	BRO, South of DE
14293	416072.4	7557552	39	30.8	32.677	SE	BRO, East of Pilgrim Fault
13812	370932.4	7557646	40	34.1	33.545	SW	GAB?, Southwest of DE
14294	419096.4	7554616	41		36.890	SE	BRO, East of Pilgrim Fault

Notes: 1) BRO, Burke River Outlier; 2) MII, Mt Isa Inlier; 3) GAB, Great Artesian Basin; and 4) “&” indicates bearing midway the two stated bearings.

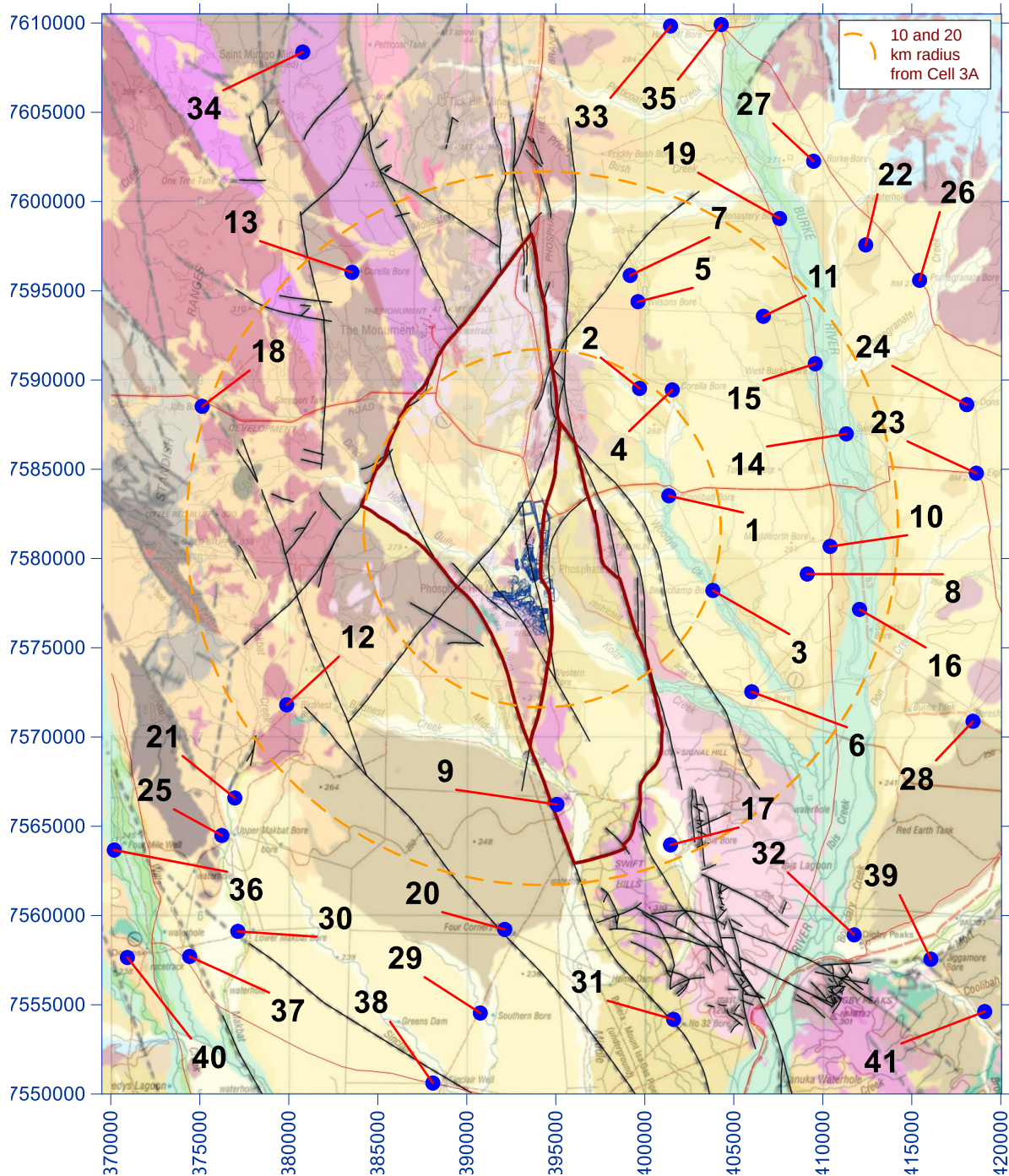


Figure 2.13: Phosphate Hill Area Station Bore Locations

The majority of the station bores are in areas that are separated from aquifers at the PHM by major faults and are not in direct hydraulically connection with the groundwater at the PHM. The possible exception is bore 13746 which is located about 15.6 km south of the GSF within the Kolar Creek Graben nears its western bounding fault. Bore 13746 is 49.3 m deep and is, based on the local outcrop geology, most likely constructed in the Swift Formation.

RECEIVING WATERS

The water table at the PHM is deep and does not intersect the ground surface. Consequently, groundwater does not discharge into local surface water features which are consistent with the observed intermittent flow following rainfall events in “creeks” in the area.

GROUNDWATER DEPENDENT ECOSYSTEM

Mapping by EHP identified Groundwater Dependent Ecosystems (GDEs) of high ecological significance (HES) about three km east of the GSF in the Mount Merlin area (Figure 2.14). The GDE is associated with sinkhole karst features in outcropping Ninmaroo Formation. Details on whether the sinkholes contain water and their connection to regional groundwater were not included in the reports provided by EHP (Glanville and Ryan, 2015). A large sink hole has been mapped at Mount Merlin (Rockwater, 1995) who referred to the sinkhole as a “vadose cave” implying that it is in the unsaturated (vadose) zone and therefore “dry”.

The Pilgrim Fault Zone bounds the Ninmaroo Formation outcrop at Mount Merlin and has produced significant steepening of bedding towards the west. Local mapping shows numerous fault planes with bedding dipping as much as 75 degrees to the west (Rockwater, 1995). The Pilgrim Fault is the eastern boundary of the Kolar Creek Graben and most likely forms a barrier between the EAS and aquifers in the Burke River Outlier on the eastern side of the Pilgrim Fault.

The Mount Merlin GDEs are across EAS groundwater hydraulic gradient and located within a different aquifer compartment than the GSF. Consequently, flow paths between the GSF and the Mount Merlin GDE would be incomplete.

GREAT ARTESIAN BASIN

The PHM does not overlie the Great Artesian Basin (GAB) but the margin of the GAB occurs about 30 km from the PHM at its closest points (Figure 2.14). The GAB is one of the largest underground water reservoirs in the world. It underlies about one fifth of the Australian continent, to the west of the Great Dividing Range. GAB groundwater is predominantly fresh. The water resources of the GAB supply many rural communities and associated pastoral/agricultural, mining, cultural and tourism activities. In addition, natural surface outflow support a diverse array of wildlife and ecosystems.

The GAB is a ‘confined’ groundwater basin containing a complex multi-layered system of aquifers separated by largely impervious rock units. The aquifers the extent across of the basin and occur up to 3,000 m below the surface in the central part. Habermehl (1983) considered that the aquifers are laterally continuous but more recent research by CSIRO and Geoscience Australia recognised that faulting has compartmentalised the groundwater flow systems. Recharge occurs mainly along the eastern edge of the basin, with a smaller recharge area along the western edge. Groundwater is confined and under sufficient pressure throughout most of the basin that bores free-flow at the surface (artesian bores).

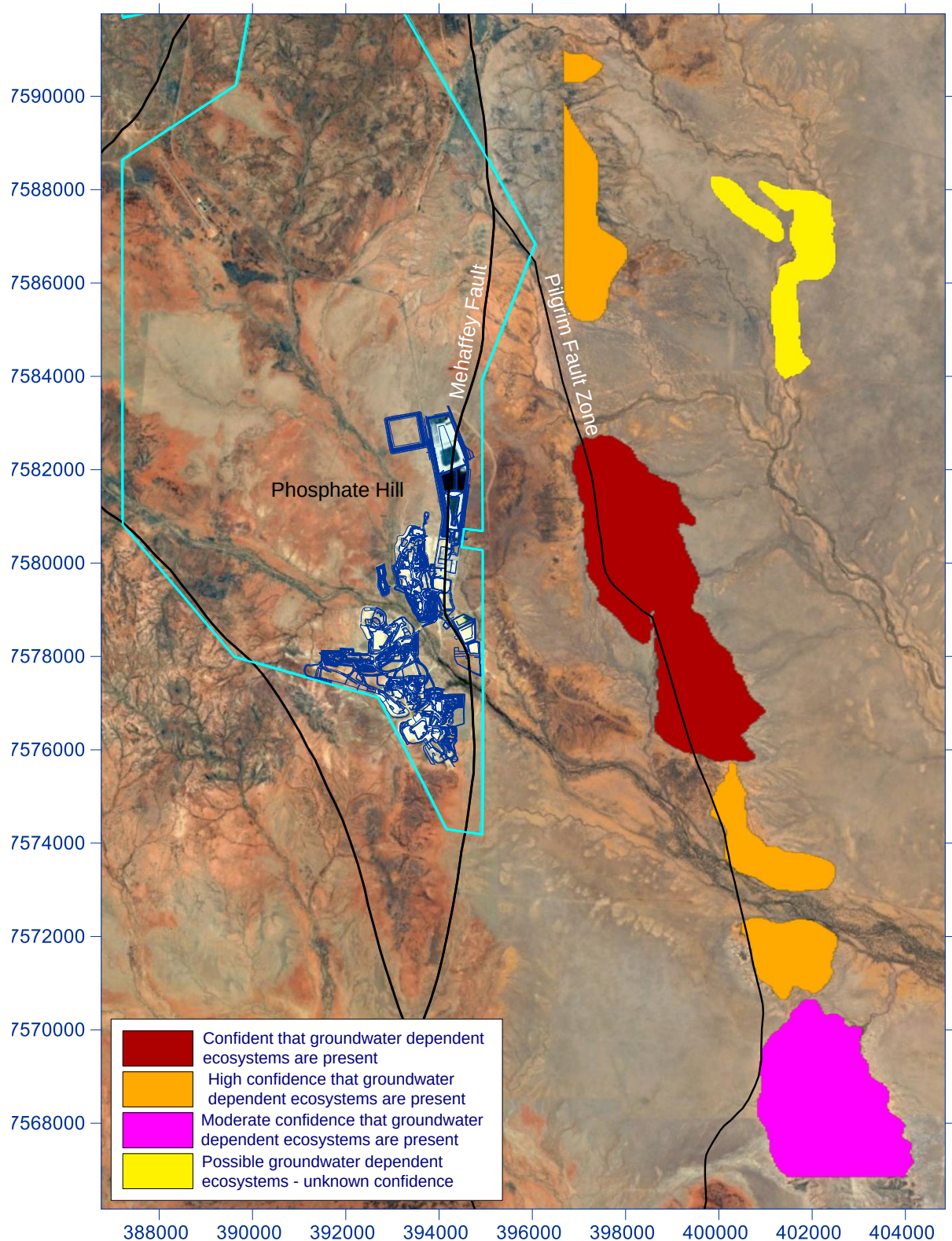


FIGURE 2.14 Phosphate Hill Area Mapped Groundwater Dependent Ecosystems

Maps in a number of recent GAB resource assessment reports (e.g., Ransley et al., 2012, 2015) indicate that the water table in the rocks above the main confined GAB aquifers is at an elevation of about 220 m AHD where the GAB is closest to the PHM at Buckingham Downs

(southwest) and Chatsworth (east), which is higher than the water table elevation in monitoring bores 1502 and 1503 (203-204 m AHD) located south of the mine site (Figure 4.4)

The water table in the Boulia area about 60 km south of the GSF in the direction of regional groundwater flow (based on hydraulic theory wherein the water table is a subdued reflection of surface topography) is at an elevation of about 200 m. A head loss of $(220 - 203 =) 17$ m over 60 km gives a hydraulic gradient of $(17/60,000 =) 0.00028$ which is extremely “flat” and very unlikely for regional groundwater flow further supporting the groundwater compartmentalisation conceptual model developed in this report.

APPENDIX 3

Assessed Bore Details & Bore Locations

Table 3.1: Bore Locations and Construction Details

Aquifer System	Area	Bore	MGA Z54		RLMP (mAHD)	RLGL (mAHD)	Depth (m)	Screened interval	Rock Unit(s)
			Easting	Northing					
EAS		EAS-RB	394879.4	7583403.4	279.82	279.18	67.00	48.5 - 69.8	S/N? (fault?)
WAS		WAS-RB	392625.1	7583480.2	277.62	277.06	85.00	40.0 - 82.0	MCPM/LSM
EAS	GSF Area	GSMB14	394471.3	7582732.6	274.68	274.28	88.00	55.0 - 86.0	S/N F
		GSMB07	394636.9	7582058.2	273.64	273.13	64.00	51.0 - 62.0	N
		GSMB07A	394644.1	7582037.4	273.25	272.67	84.00	72.0 - 84.0	N
		GSMB03	394387.0	7581587.8	272.06	271.72	61.90	58.0 - 61.0	N
		GSMB15A	394673.9	7581520.6	273.47	272.87	102.00	72.0 - 90.0	N
		GSMB15	394673.9	7581520.6	273.37	273.02	66.00	56.0 - 66.0	N
		EPMB01	394621.1	7581195.0	272.78	272.08	69.80	48.5 - 69.8	N
		EPMB02	394555.5	7580753.3	269.94	269.27	64.10	47.2 - 64.1	N
		EPMB03	394900.6	7580707.3	271.94	271.39	65.00	46.2 to 65.0	N
		GSMB09	394205.0	7580520.4	266.43	266.71	64.00	55.0 - 87.9	N
		GW06	394247.7	7580476.0	266.10	265.56	61.00	40.0 - 61.0	N
	Plant	GW23	394341.9	7580155.4	268.82	268.55	61.00	46.0 - 61.0	N
		GW13	394218.7	7580081.8	268.12	268.12	57.00	39.0 - 57.0	N
		GW05	394262.7	7580079.1	267.68	267.70	57.50	38.5 - 57.5	N
		GW05A	394275.1	7580067.7	267.58	267.66	88.00	51.0 - 87.0	N
		GW19	394100.5	7580021.4	269.02	269.02	67.00	49.0 - 67.0	N
		EPMB04	394479.3	7580014.7	265.50	265.07	64.00	47.2 - 59.2	N
		GW14	394267.7	7579953.1	267.86	267.86	65.00	37.0 - 65.0	N
	Slimes Dams	GW02	394737.7	7578915.1	263.36	262.76	57.30	39.5 - 57.3	N
		GW16	394500.1	7578902.3	263.40	263.05	64.00	49.0 - 64.0	N
		SDMB03	394832.8	7578867.4	261.61	261.26	94.00	44.2 - 80.2	N
		GW22A	394708.8	7578737.4	266.69	266.48	87.00	69.0 - 87.0	N
		GW22	394700.5	7578733.1	266.90	266.38	64.00	40.3 - 55.3	N
		PHMB02	394917.6	7578623.7	261.81	261.40	80.00	50.0 - 80.0	N
		SDMB04	394824.3	7578358.6	261.49	261.02	94.00	57.6 - 90.6	N
		SDMB02	394953.6	7577685.1	260.64	260.27	82.00	26.0 - 56.0	N
WAS	GSF Area	GSMB16	393221.1	7583197.9	276.53	276.04	95.00	65.0 - 95.0	LSM
		GSMB13	393963.9	7583176.3	275.56	274.64	100.00	49.5 - 97.5	I
		GSMB12	393714.3	7582963.6	274.74	274.42	106.00	45.9 - 102.9	I/MCPM
		GSMB17	392851.8	7582790.9	273.45	272.94	95.00	65.0 - 95.0	LSM
		GSMB18	393353.3	7582378.2	275.27	274.10	95.00	65.0 - 95.0	LSM
		GSMB11	393875.0	7582145.9	272.94	272.52	94.00	34.5 - 82.5	I
		GSMB04B	393968.1	7581659.4	270.87	270.25	84.00	68.0 - 84.0	LSM/T L'st
		GSMB05	393959.0	7581126.7	276.245	275.755	65.00	48.0 - 59.0	I /MCPM
		GSMB02	394076.5	7581048.4	270.58	269.64	47.00	40.0 - 46.0	LSM
		GSMB02A	394078.2	7581030.3	269.96	269.46	90.00	69.0 - 81.0	LSM/T L'st.
		GSMB01	394044.7	7580565.1	269.28	268.30	47.10	39.0 - 45.0	I
		GSMB01A	394053.0	7580561.8	268.52	268.10	89.00	68.0 - 89.0	I
	Slimes Dams	GW21	394116.8	7578822.2	264.23	263.71	75.00	40.3 - 55.3	N
		GW15	394283.8	7578686.8	264.07	263.58	64.00	49.0 - 64.0	MCPM
		GW01	394383.3	7578585.8	268.33	267.70	63.50	45.5 - 63.5	I
		GW04	394263.0	7578550.1	262.17	261.55	58.50	40.8 - 58.5	I/MCPM
		GW07A	394331.1	7578532.1	262.27	261.68	65.00	47.0 - 65.0	MCPM
		SDMB01	394287.9	7578527.6	262.22	261.76	72.00	48.0 - 70.0	I/MCPM/LSM
		GW08	394251.0	7578508.9	262.03	262.10	57.50	40.0 - 57.5	MCPM
		GW03	394289.7	7578499.3	262.03	262.03	57.50	40.0 - 57.0	I
		GW17	394403.5	7578432.9	262.94	262.46	61.00	34.7 - 49.7	I

Notes: GSF = Gypsum Storage Facility; S = Swift Formation; N = Ninmaroo Formation; I = Inca Formation; MCPM = Monastery Creek Phosphorite Member; LSM = Lower Siltstone Member; T L'st; Thorntonia Limestone

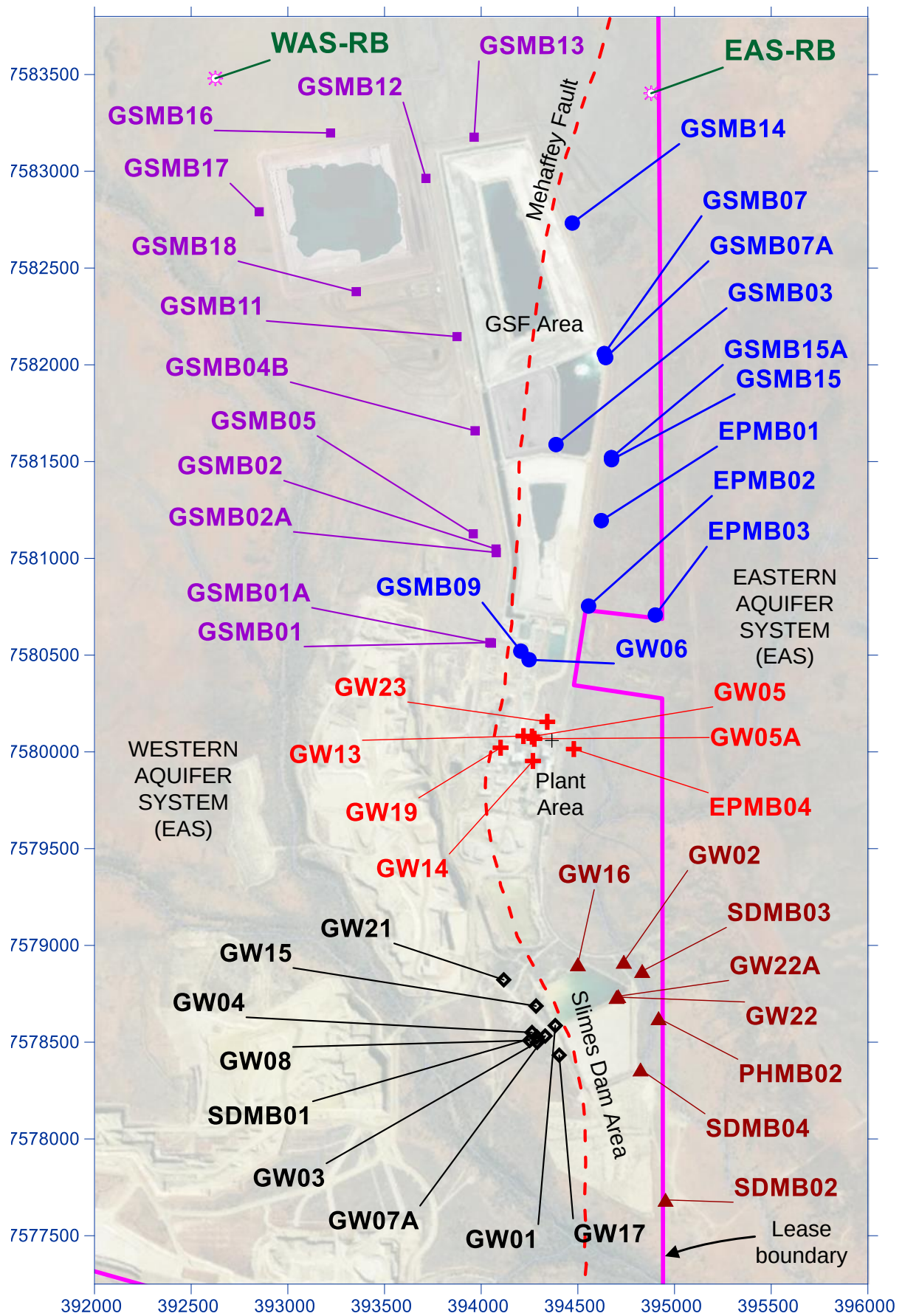


Figure 3.1: Assessed Bores Locations

Table 3.2: Monitoring Programs and Bore Status

Aquifer System	Area	Bore	Monitored Periods	Program	Currently Monitored	Monitoring Frequency	No of Analyses
EAS		EAS-RB	Jun-16 to Sep-17	EMP	✓	Monthly	14
WAS		WAS-RB	Jun-16 to Sep-17	EMP	✓	Monthly	14
EAS	GSF	GSMB14	Oct-02 to Jul-17	EMP	✓	6-Monthly	31
		GSMB07	Jul-02 to Jul-08	EMP	×		14
		GSMB07A	Aug-09 to Jul-17	EMP	✓	6-Monthly	14
		GSMB03	Jul-02 to Jul-06	EMP	Destroyed		10
		GSMB15A	Jul-06 to Jul-17	EMP	✓	Quarterly	33
		GSMB15	May-06 to Jan-09	EMP	×		7
		EPMB01	Oct-02 to Jul-17	EMP	✓	Quarterly	41
		EPMB02	Jul-02 to Jul-17	EMP	✓	Quarterly	44
		EPMB03	Jul-02 to Oct-05	EMP	Destroyed		9
		GSMB09	Jul-02 to Jul-17	EMP	✓	Quarterly	39
		GW06	Nov-11 to Aug-09	DD	×		9
WAS	GSF	GSMB16	Sep-14 to Jul-17	EMP	✓	6-Monthly	7
		GSMB13	Jul-02 to Jul-17	EMP	✓	6-Monthly	29
		GSMB12	Jul-02 to Jul-17	EMP	✓	6-Monthly	32
		GSMB17	Jul-15 to Jul-17	EMP	✓	6-Monthly	4
		GSMB18	Sep-14 to Jan-17	EMP	Destroyed	6-Monthly	4
		GSMB11	Sep-04 to Jul-17	EMP	✓	6-Monthly	30
		GSMB04B	Aug-09 to Jul-17	EMP	✓	Quarterly	27
		GSMB05	Jul-02 to Aug-09	EMP	×		17
		GSMB02	Aug-99 to Dec-06	EMP	×		12
		GSMB02A	Oct-15 to Jul-17	EMP	✓	Quarterly	27
		GSMB01	Jul-02 to May-07	EMP	×		14
		GSMB01A	Aug-09 to Jul-17	EMP	✓	Quarterly	27
EAS	Plant	GW23	Jun-07 to Aug-10; Sep-17	DD	×		12
		GW13	Nov-06 to Aug-09; Sep-17	DD	×		10
		GW05	Nov-06 to Apr-09	DD	×		9
		GW05A	Aug-09 to Jul-17	EMP	✓	Quarterly	26
		GW19	Jun-07 to Aug-08	DD	×		13
		EPMB04	Oct-06 to Jul-17	EMP	✓	Quarterly	40
		GW14	Nov-06 to Oct-07; Sep-17	DD	✓		5
EAS	Slimes Dams	GW02	Nov-06 to Jan-10	EMP	×		12
		GW16	Jun-07 to Aug-09	DD	×		8
		SDMB03	Jul-02 to Jul-17	EMP	✓	6-Monthly	37
		GW22A	Aug-09 to Aug-10	DD	×		5
		GW22	Jun-07 to Apr-09	DD	×		7
		PHMB02	Jun-09 to Aug-10	TEP	×		6
		SDMB04	Jul-02 to Jul-17	EMP	✓	6-Monthly	40
		SDMB02	Jul-02 to Jul-17	EMP	✓	6-Monthly	39
WAS	Slimes Dams	GW21	Jun-07 to Aug-10	DD	×		12
		GW15	Jun-06 to May-10	DD	×		10
		GW01	Nov-06 to Aug-10	DD	×		15
		GW04	Nov-06 to Aug-10	DD	×		14
		GW07A	Nov-06 to Aug-10	DD	×		14
		SDMB01	Jul-02 to Jul-17	EMP	✓	6-Monthly	43
		GW08	Nov-06 to Jan-10	DD	×		9
		GW03	Nov-06 to Aug-10	DD	×		13
		GW17	Jun-07 to Aug-09	DD	×		8

Notes: 1) EMP= Environment Monitoring Program; DD = Due Diligence monitoring, 2) Bore GW05A is the current reference bore. Bores WAS-RB and EAS-RB were sited up-hydraulic gradient from the PHM as potential reference bores. The other assessed bores were sited to monitor potential contamination sources including the Gypsum Storage Facility (GSF), the plant area, or the Slimes Dams area.

Five water table monitoring bores, GSMB19 to GSMB23 inclusive were not included in the statistical analysis because they have only been monitored twice, once in July 2016 and again in July 2017. However, the July 2017 water quality data was used in the analyte distribution mapping. Details of these five bores are summarised in Table 3.3 and their locations are shown in Figure 3.2.

Table 3.2 Additional GSF Deep Monitoring Bore Summary Details

Aquifer System	Area	Bore	MGA Z54		RLMP (mAHD)	RLGL (mAHD)	Depth (m)	Screened interval	Rock Unit(s)
			Easting	Northing					
EAS	GSF	GSMB21	394930.4	7581521.2	280.268	279.74	71.0	46.0 - 58.0	S/N? (fault?)
		GSMB23	394336.2	7580420.9	266.294	265.55	61.0	52.0 - 64.0	N
WAS	GSF	GSMB19	394116.1	7581510.3	276.643	276.612	74.00	35.0 - 71.0	Inca
		GSMB20	393976.4	7581629.3	270.555	269.922	73.00	34.0 - 70.0	LSM
		GSMB22	394116.1	7581510.3	276.643	276.612	74.00	35.0 - 71.0	Inca

Notes: GSF = Gypsum Storage Facility; S = Swift Formation; N = Ninmaroo Formation; I = Inca Formation.

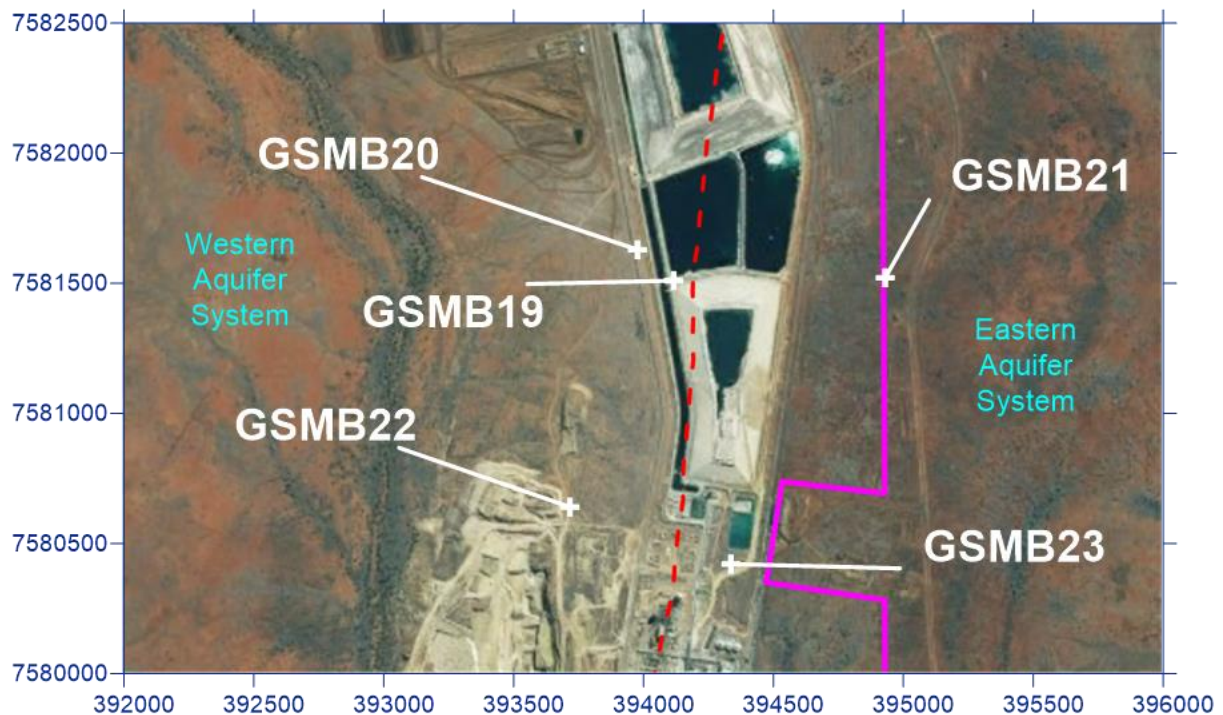
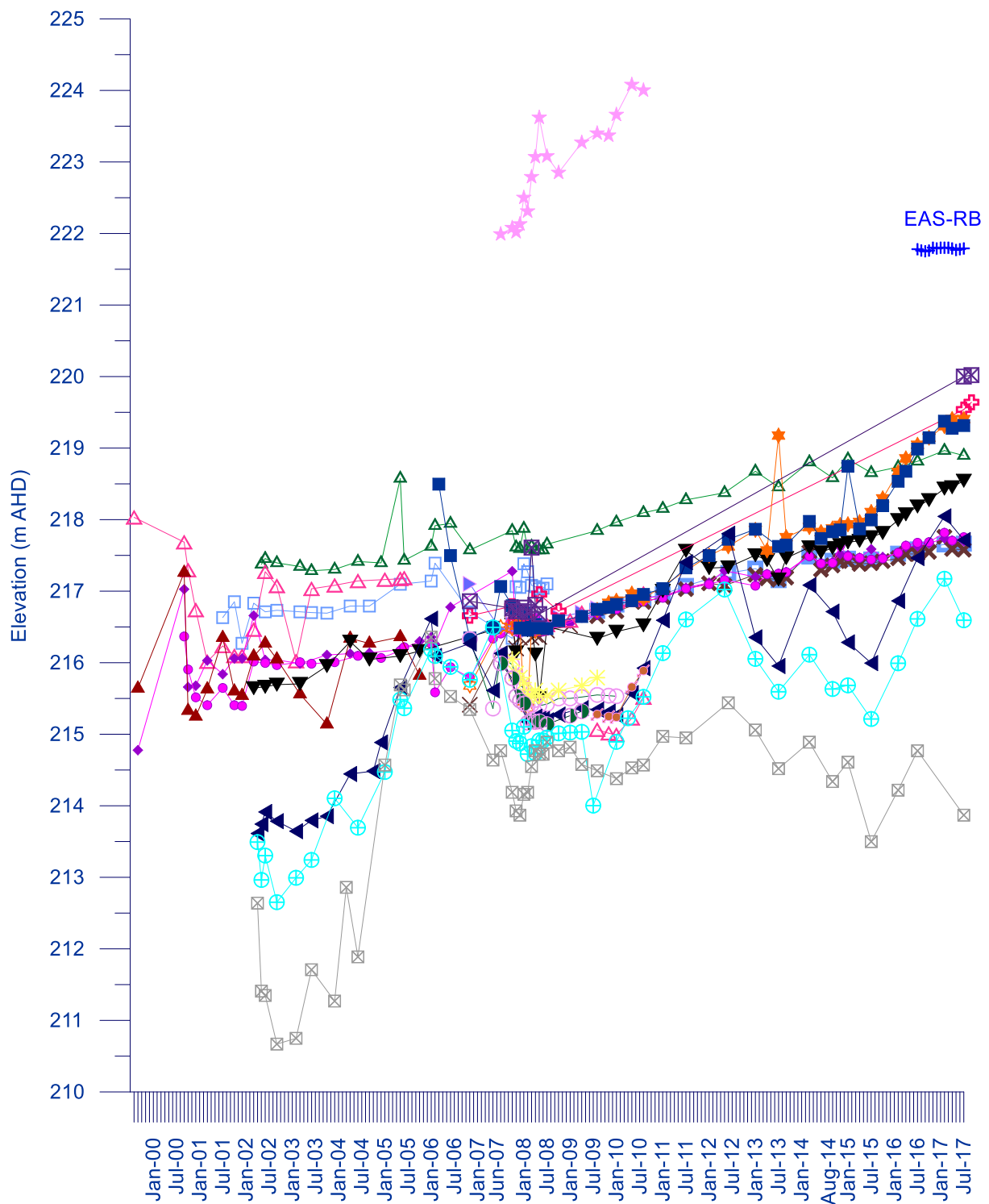
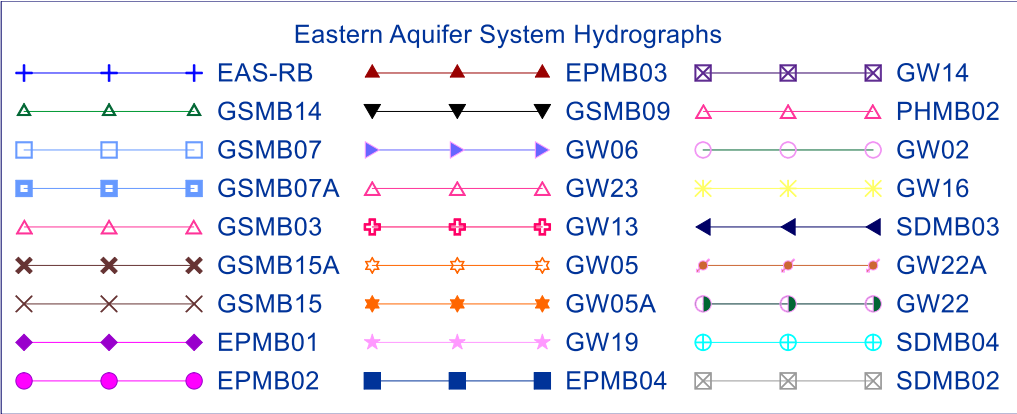
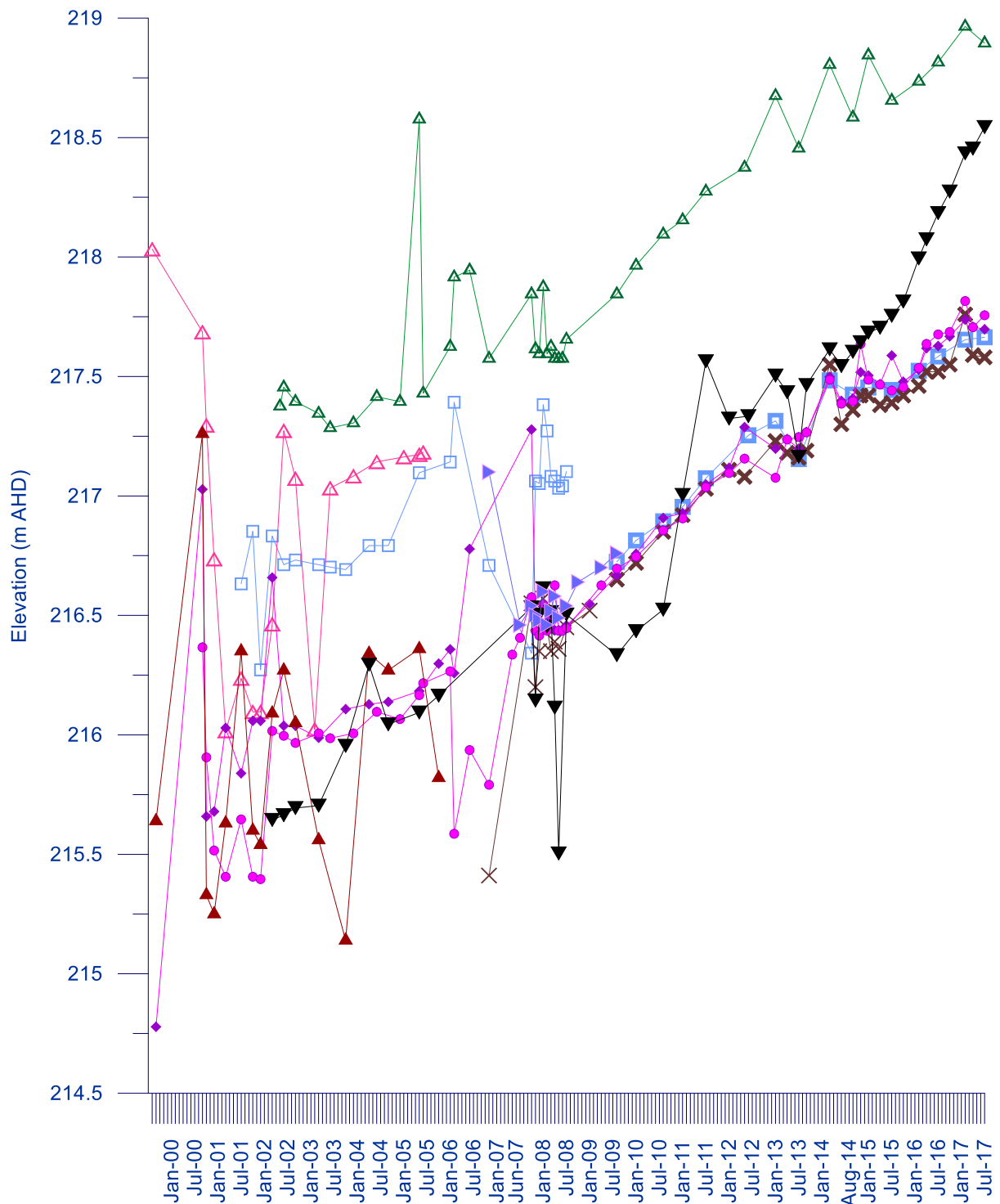
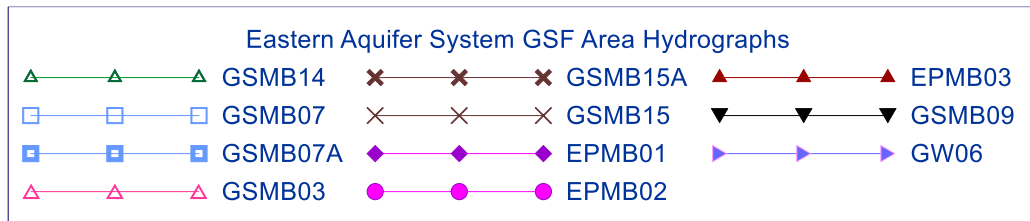


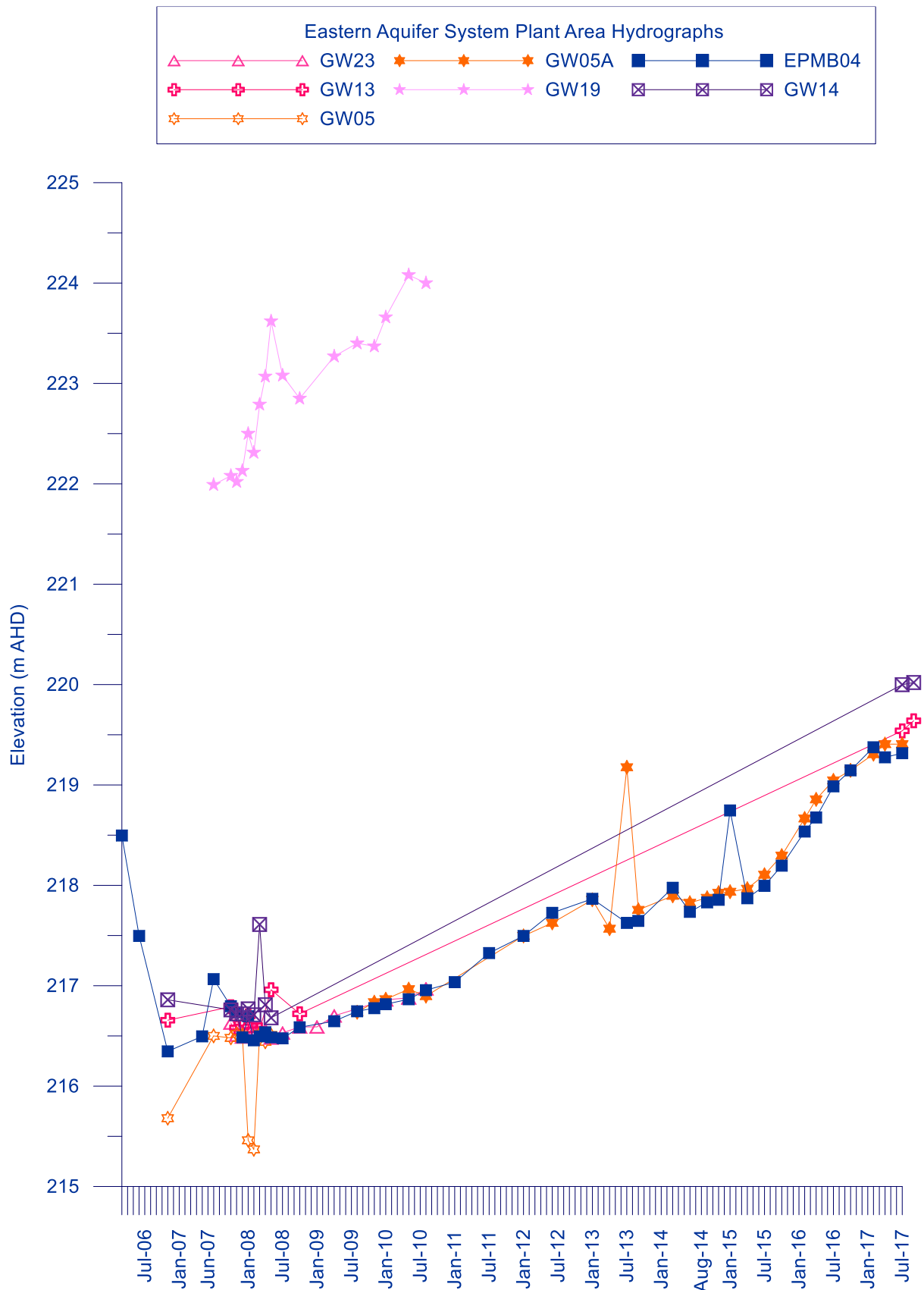
Figure 3.2: Locations of Water Table Monitoring Bores installed in Mid-2016

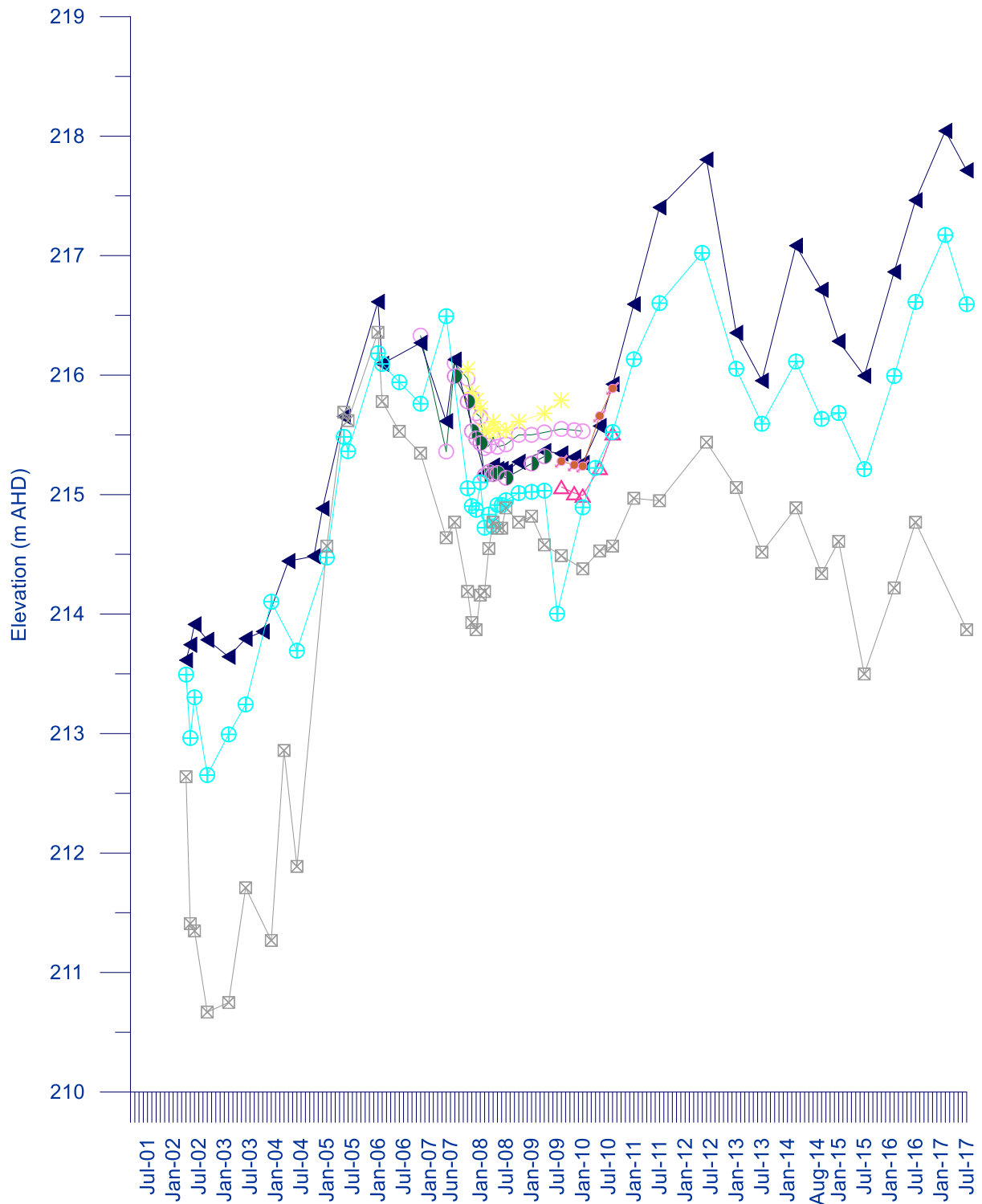
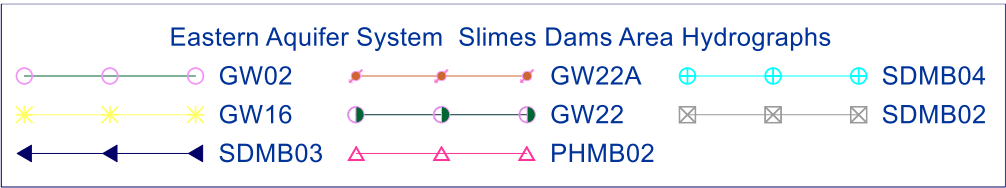
APPENDIX 4

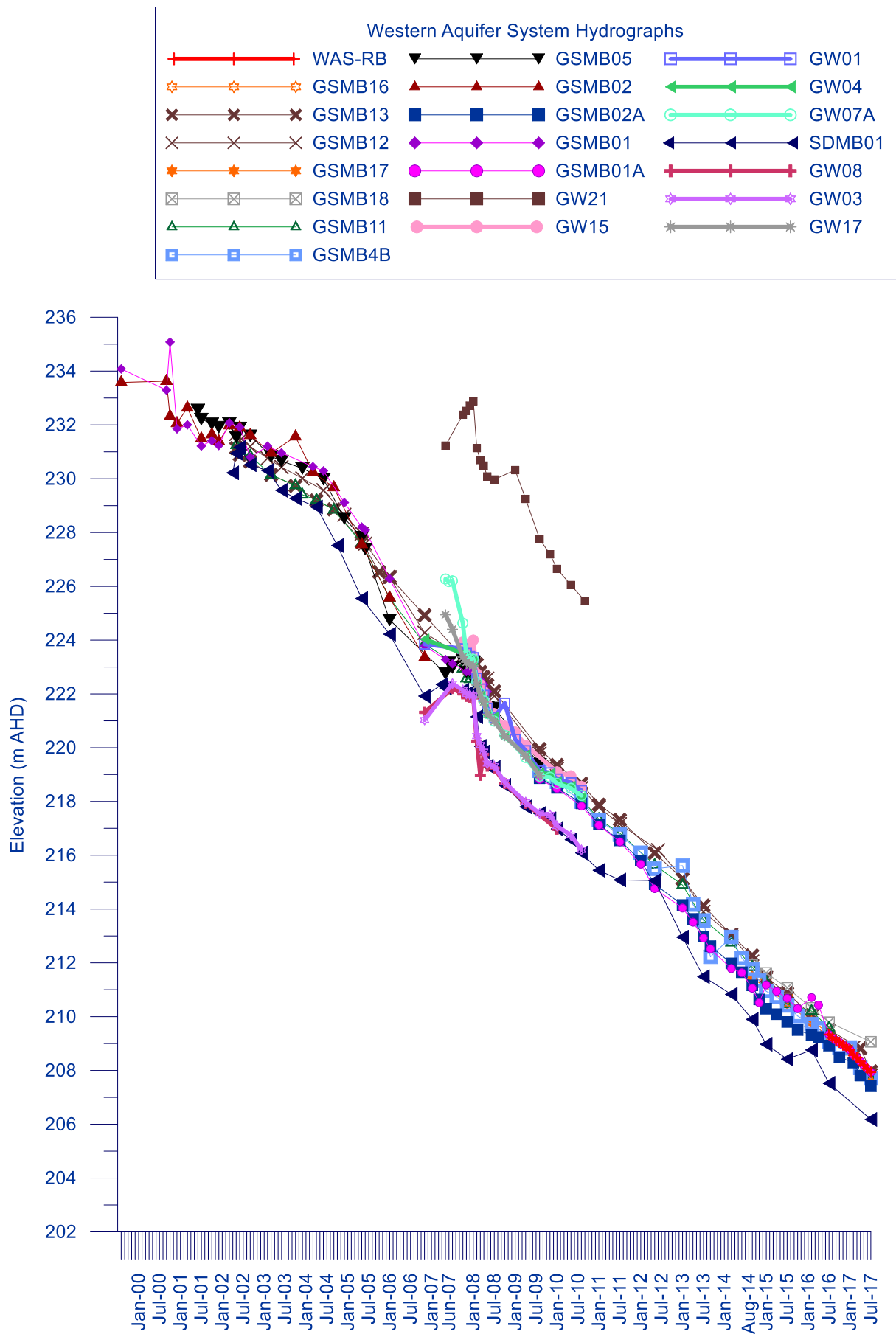
BORE HYDROGRAPHS

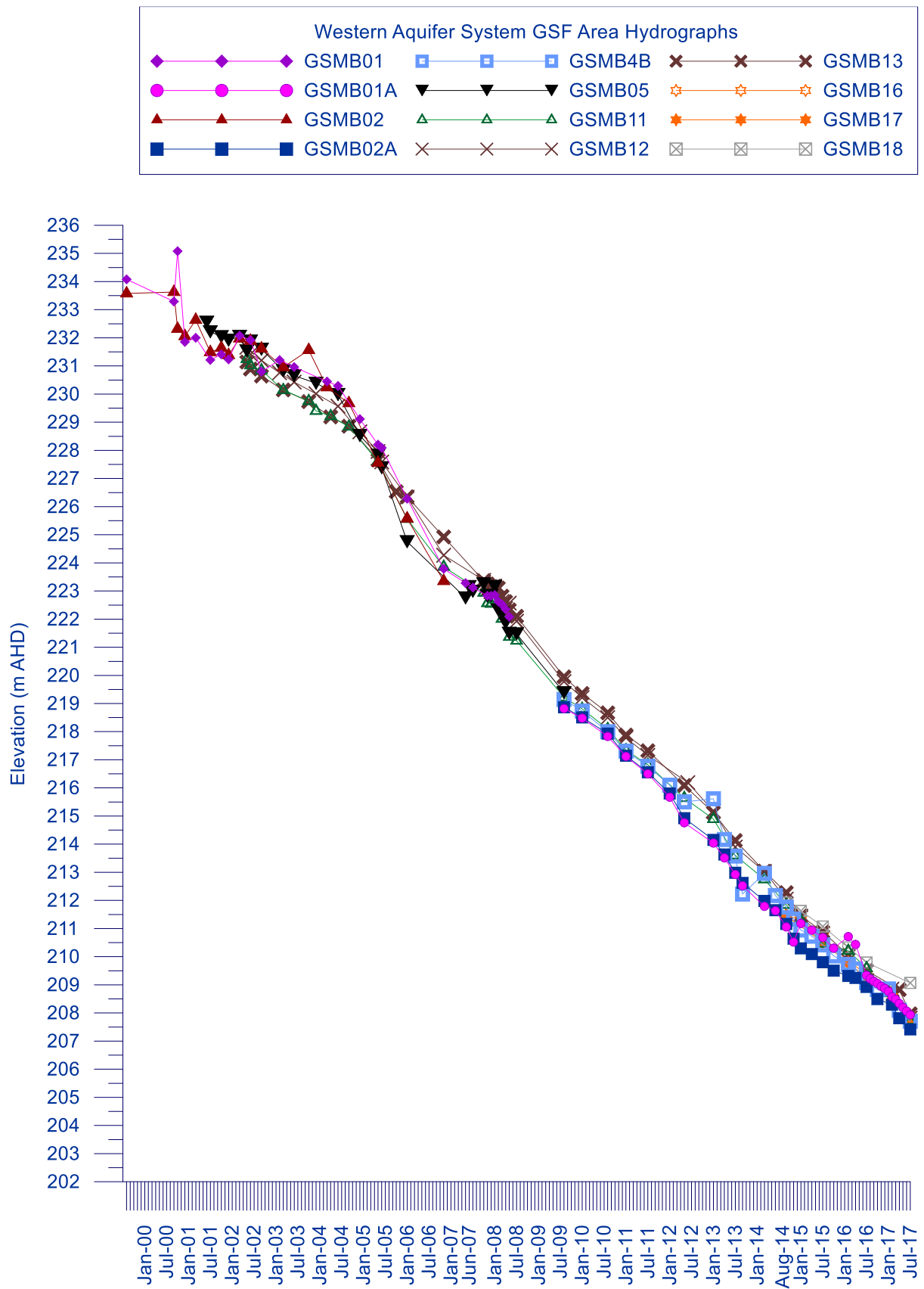


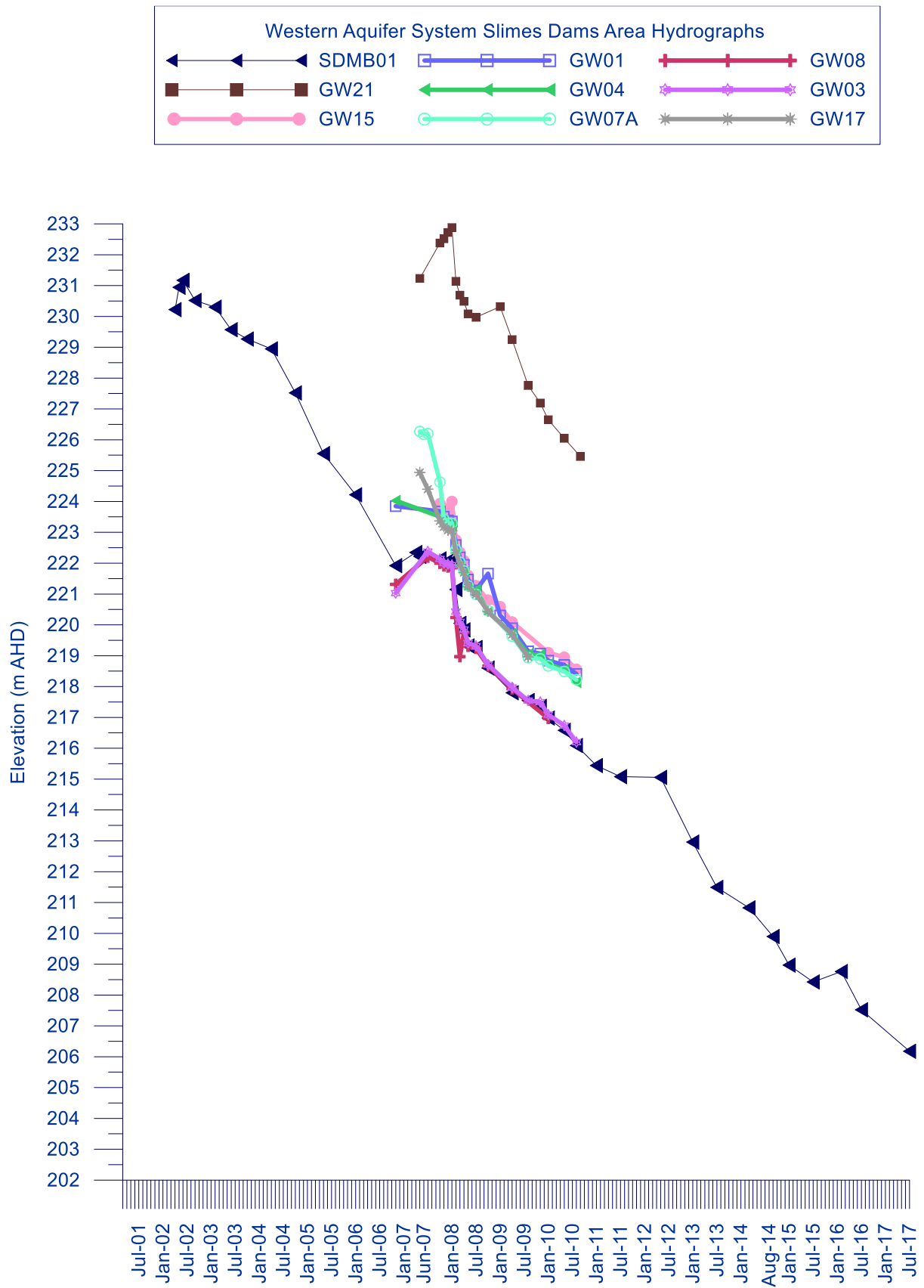












APPENDIX 5

EAS-RB Chemical & Statistical Analysis

Analysis results and statistical analysis

Standard water quality parameters

Dissolved metals

Total metals

Hydrochemical Plots

Piper and Durov diagrams

Time series plots

Box-whisker plots

Table 5.1: EAS-RB Basis Water Quality Parameters and Statistical Analysis

Date sampled	pH (units)	TDS (mg/L)	EC l (µS/cm)	HCO3 (mg/L)	Ca (mg/L)	Cl (mg/L)	F (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	SO4 (mg/L)	NO2+NO3-N (mg/L)	TKN-N (mg/L)	ΣN-N (mg/L)	ΣP-P (mg/L)	R P-P (mg/L)	SS (mg/L)
Jul-16	8.32	668	924	516	98	108	0.6	42	5	57	32	0.12	0.5	0.5	0.3	0.1	368
Aug-16	7.99	566	961	484	100	102	0.7	46	5	66	33	0.22	0.2	0.4	0.3	0.04	327
Sep-16	8.22	560	989	390	89	102	0.5	42	4	61	33	0.18	0.5	0.5	0.2	0.02	254
Oct-16	7.85	550	969	432	79	87	0.5	44	4	66	33	0.26	0.3	0.6	0.11	0.01	134
Nov-16	8.09	535	973	423	110	96	0.7	42	6	65	33	0.27	0.05	0.3	0.33	0.005	493
Dec-16	8.32	533	916	296	59	105	0.6	44	4	62	32	0.34	0.62	0.9	1.82	0.005	1550
Jan-17	7.83	588	908	455	84	90	0.4	46	4	65	33	0.24	0.2	0.4	0.31	0.01	370
Feb-17	8.00	468	967	421	90	94	0.6	48	4	70	31	0.34	0.1	0.4	0.13	0.01	168
Mar-17	8.05	540	955	427	89	94	0.6	46	4	67	34	0.34	0.1	0.4	0.11	0.08	76
Apr-17	8.12	548	877	418	82	95	0.5	47	4	66	34	0.29	0.1	0.4	0.07	0.005	72
May-17	7.83	552	1100	471	91	102	0.6	45	4	67	34	0.34	0.05	0.3	0.03	0.01	34
Jun-17	7.94	542	1020	420	78	91	0.4	44	4	65	33	0.33	0.1	0.4	0.06	0.005	34
Jul-17	7.94	542	981	429	80	91	0.4	46	4	68	34	0.37	0.5	0.5	0.05	0.01	56
Aug-17	7.62	548	799	425	88	94	0.5	46	4	65	34	0.39	0.2	0.6	0.07	0.01	46
Sep-17	7.75	557	939	426	84	98	0.6	46	4	65	35	0.39	0.2	0.6	0.07	0.01	62

Statistic	pH	TDS	EC l	HCO3	Ca	Cl	F	Mg	K	Na	SO4	NO2+NO3-N	TKN-N	ΣN-N	ΣP-P	R P-P	SS
Count	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Min	7.62	468	799	296	59	87	0.40	42	4	57	31	0.12	0.05	0.30	0.03	0.01	34
Max	8.32	668	1100	516	110	108	0.70	48	6	70	35	0.39	0.62	0.90	1.82	0.10	1550
Range	0.70	200	201	220	51	21	0.30	6	2	13	4	0.27	0.57	0.60	1.79	0.10	1516
Ave	7.99	553	952	429	87	97	0.55	45	4	65	33	0.29	0.25	0.48	0.26	0.02	270
SD	0.20	41	67	48	12	6	0.10	1.9	0.59	3.1	1.0	0.08	0.19	0.15	0.44	0.03	384
5th %ile	7.71	514	854	362	72	89	0.40	42.0	4.00	59.8	31.7	0.16	0.05	0.30	0.04	0.01	34
20th %ile	7.83	539	914	419	80	91	0.48	43.6	4.00	64.4	32.8	0.24	0.10	0.40	0.07	0.01	54
25th %ile	7.83	539	914	419	80	91	0.48	43.6	4.00	64.4	32.8	0.24	0.10	0.40	0.07	0.01	54
50th %ile	7.99	548	961	426	88	95	0.60	46.0	4.00	65.0	33.0	0.33	0.20	0.40	0.11	0.01	134
75th %ile	8.11	559	977	443	91	102	0.60	46.0	4.00	66.5	34.0	0.34	0.40	0.55	0.30	0.02	348
80th %ile	8.14	561	983	458	92	102	0.60	46.0	4.20	67.0	34.0	0.35	0.50	0.60	0.30	0.02	368
95th %ile	8.32	612	1044	494	103	106	0.70	47.3	5.30	68.6	34.3	0.39	0.54	0.69	0.78	0.09	810
IQR	0.28	19.50	62.6	24.03	10.70	11.00	0.12	2.40	0.00	2.10	1.20	0.10	0.30	0.15	0.23	0.01	294
IQR * 1.5	0.41	29.25	93.9	36.05	16.05	16.50	0.18	3.60	0.00	3.15	1.80	0.16	0.45	0.23	0.35	0.02	440
Outlier <	7.42	510	821	383	64	75	0.30	40	4	61	31	0.08		0.18			
Outlier >	8.52	588	1071	480	107	119	0.78	50	4	70	36	0.50	0.85	0.78	0.65	0.03	788
No Outliers	0	2	1	3	2	0	0	0	3	0	0	1	0	1	1	2	1

Notes: 1) CO3 as CaCO3 and HCO3 as CaCO3 converted to respective ionic concentrations. 2) SD, Standard Deviation; 3) %ile, percentile; 4) IQR, Interquartile Range (= Q3 – Q1), 4) Outliers in bold font.

Table 5.2: EAS-RB Total Metals Analytical Results and Statistical Analysis

Sampled	ΣAl	ΣAs	ΣCd	ΣCr	ΣCo	ΣCu	ΣPb	ΣHg	ΣNi	ΣSe	ΣU	ΣZn
Jul-16	2.47	0.0020	0.0002	0.0060	0.0040	0.0200	0.0100	0.0001	0.0100	0.0050	0.0080	0.0530
Aug-16	1.72	0.0020	0.0002	0.0040	0.0030	0.0220	0.0070	0.0001	0.0090	0.0050	0.0080	0.0450
Sep-16	2.28	0.0020	0.0002	0.0060	0.0030	0.0300	0.0080	0.0001	0.0080	0.0050	0.0080	0.0580
Oct-16	0.46	0.0010	0.0001	0.0020	0.0010	0.0140	0.0030	0.0001	0.0040	0.0050	0.0080	0.0260
Nov-16	2.65	0.0020	0.0003	0.0070	0.0030	0.0420	0.0150	0.0001	0.0100	0.0050	0.0080	0.0760
Dec-16	6.95	0.0030	0.0004	0.0170	0.0070	0.0620	0.0310	0.0001	0.0240	0.0050	0.0080	0.1450
Jan-17	1.99	0.0020	0.0002	0.0050	0.0030	0.0210	0.0080	0.0001	0.0090	0.0050	0.0080	0.0420
Feb-17	0.72	0.0010	0.0001	0.0030	0.0010	0.0130	0.0050	0.0001	0.0005	0.0050	0.0070	0.0290
Mar-17	0.56	0.0005	0.0001	0.0020	0.0010	0.0100	0.0030	0.0001	0.0040	0.0050	0.0070	0.0300
Apr-17	0.57	0.0005	0.0001	0.0020	0.0005	0.0080	0.0030	0.0001	0.0020	0.0050	0.0070	0.0240
May-17	0.26	0.0005	0.0001	0.0010	0.0005	0.0150	0.0020	0.0001	0.0020	0.0050	0.0070	0.0260
Jun-17	0.33	0.0005	0.0001	0.0010	0.0005	0.0170	0.0020	0.0001	0.0020	0.0050	0.0070	0.0220
Jul-17	0.51	0.0005	0.0001	0.0030	0.0005	0.0070	0.0020	0.0001	0.0020	0.0050	0.0070	0.0160
Aug-17	0.44	0.0005	0.0001	0.0020	0.0005	0.0120	0.0020	0.0001	0.0020	0.0050	0.0070	0.0200
Sep-17	0.63	0.0005	0.0001	0.0020	0.0005	0.0080	0.0020	0.0001	0.0020	0.0050	0.0070	0.0120

Statistic	ΣAl	ΣAs	ΣCd	ΣCr	ΣCo	ΣCu	ΣPb	ΣHg	ΣNi	ΣSe	ΣU	ΣZn
Count	15	15	15	15	15	15	15	15	15	15	15	15
Min	0.26	0.0005	0.0001	0.0010	0.0005	0.0070	0.0020	0.0001	0.0005	0.0050	0.0070	0.0120
Max	6.95	0.0030	0.0004	0.0170	0.0070	0.0620	0.0310	0.0001	0.0240	0.0050	0.0080	0.1450
Range	6.69	0.0025	0.0004	0.0160	0.0065	0.0550	0.0290	0.0000	0.0235	0.0000	0.0010	0.1330
Average	1.50	0.0012	0.0001	0.0042	0.0019	0.0201	0.0069	0.0001	0.0060	0.0050	0.0075	0.0416
SD	1.73	0.0008	0.0001	0.0040	0.0019	0.0149	0.0077	0.0000	0.0060	0.0000	0.0005	0.0335
5th %ile	0.31	0.0005	0.0001	0.0010	0.0005	0.0077	0.0020	0.0001	0.0016	0.0050	0.0070	0.0148
20th %ile	0.46	0.0005	0.0001	0.0020	0.0005	0.0096	0.0020	0.0001	0.0020	0.0050	0.0070	0.0216
25th %ile	0.46	0.0005	0.0001	0.0020	0.0005	0.0096	0.0020	0.0001	0.0020	0.0050	0.0070	0.0216
50th %ile	0.63	0.0010	0.0001	0.0030	0.0010	0.0150	0.0030	0.0001	0.0040	0.0050	0.0070	0.0290
75th %ile	2.14	0.0020	0.0002	0.0055	0.0030	0.0215	0.0080	0.0001	0.0090	0.0050	0.0080	0.0490
80th %ile	2.32	0.0020	0.0002	0.0060	0.0030	0.0236	0.0084	0.0001	0.0092	0.0050	0.0080	0.0540
95th %ile	3.94	0.0023	0.0003	0.0100	0.0049	0.0480	0.0198	0.0001	0.0142	0.0050	0.0080	0.0967
IQR	1.68	0.0015	0.0002	0.0035	0.0025	0.0119	0.0060	0.0000	0.0070	0.0000	0.0010	0.0274
IQR * 1.5	2.52	0.0023	0.0002	0.0053	0.0038	0.0179	0.0090	0.0000	0.0105	0.0000	0.0015	0.0411
Outlier <								0.0001		0.0050	0.0055	
Outlier >	4.65	0.0043	0.0004	0.0108	0.0068	0.0394	0.0170	0.0001	0.0195	0.0050	0.0095	0.0901
No Outliers	1	0	0	1	1	2	1	0	1	0	0	1

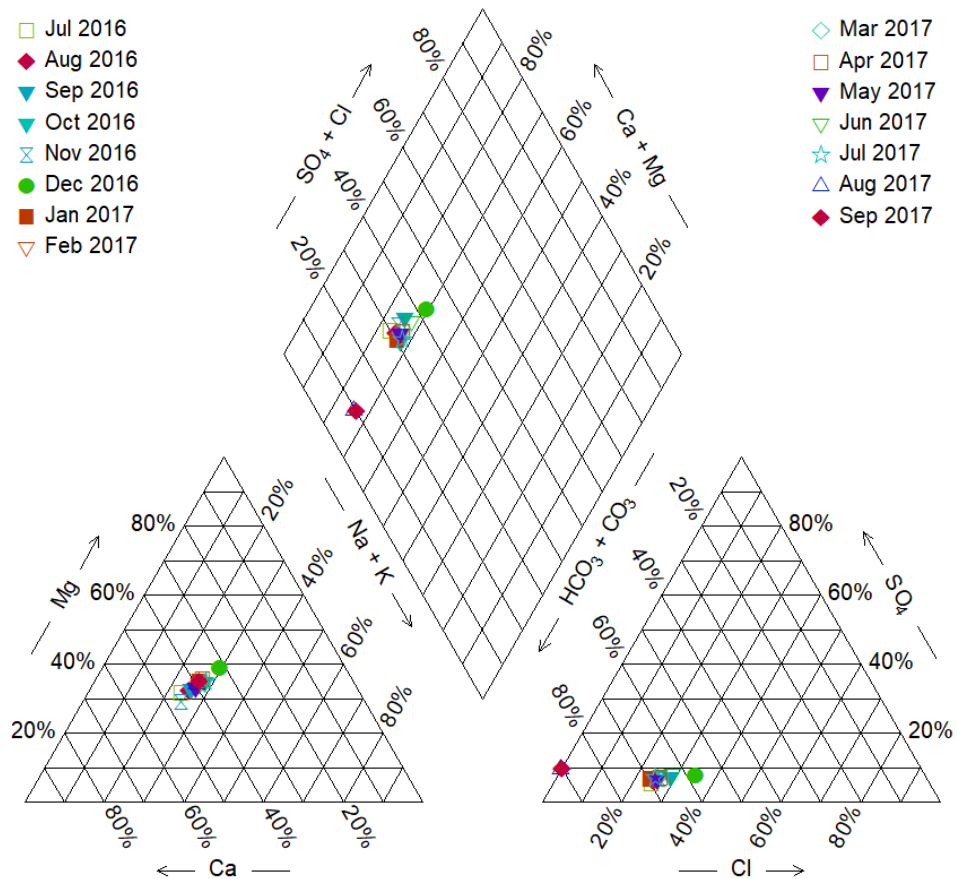
Notes: 1) Non-detects assumed to be half detection limit; 2)) IQR, Interquartile Range (= Q3 – Q1), 3) Outliers in bold font.

Table 5.3: EAS-RB Dissolved Metals Analytical Results and Statistical Analysis

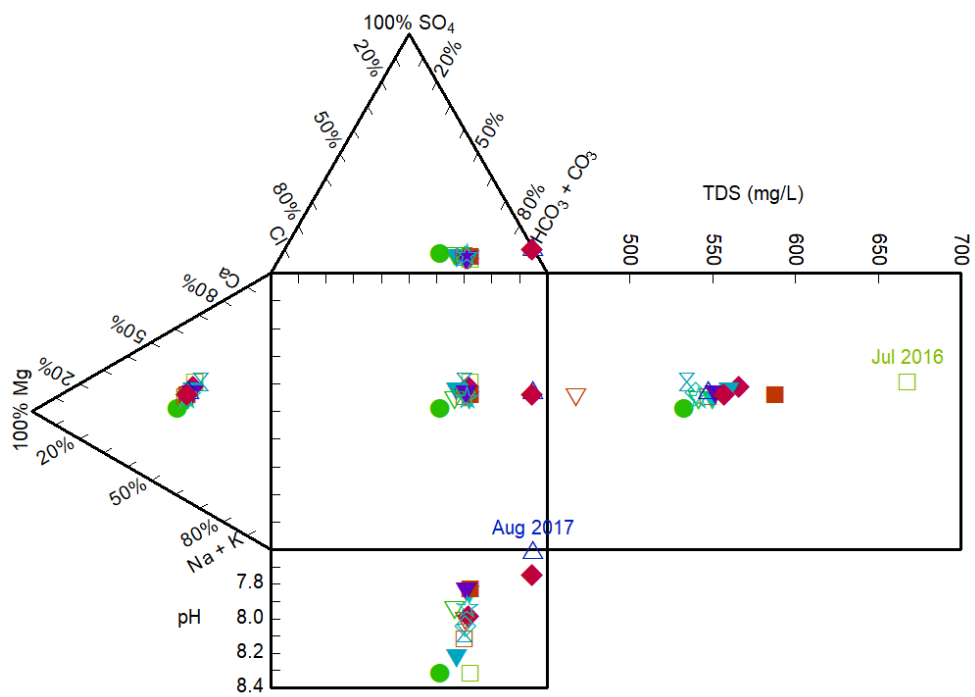
Sampled	D_Al	D_As	D_Cd	D_Cr	D_Co	D_Cu	D_Pb	D_Hg	D_Ni	D_Se	D_U	D_Zn
Jul-16	0.1000	0.0010	0.00005	0.0005	0.0020	0.0080	0.0020	0.00005	0.0040	0.005	0.0070	0.0160
Aug-16	0.0200	0.0005	0.00005	0.0005	0.0005	0.0120	0.0005	0.00005	0.0040	0.005	0.0070	0.0090
Sep-16	0.0050	0.0010	0.00005	0.0005	0.0005	0.0070	0.0005	0.00005	0.0030	0.005	0.0080	0.0140
Oct-16	0.0050	0.0005	0.00005	0.0005	0.0005	0.0070	0.0005	0.00005	0.0005	0.005	0.0070	0.0100
Nov-16	0.0050	0.0005	0.00005	0.0005	0.0005	0.0060	0.0005	0.00005	0.0020	0.005	0.0070	0.0080
Dec-16	0.0050	0.0005	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.005	0.0040	0.0025
Jan-17	0.0050	0.0005	0.00005	0.0005	0.0005	0.0080	0.0005	0.00005	0.0090	0.005	0.0060	0.0080
Feb-17	0.0050	0.0005	0.00010	0.0005	0.0005	0.0110	0.0005	0.00005	0.0030	0.005	0.0070	0.0370
Mar-17	0.0050	0.0005	0.00010	0.0005	0.0005	0.0110	0.0020	0.00020	0.0020	0.005	0.0060	0.0290
Apr-17	0.0050	0.0005	0.00005	0.0005	0.0005	0.0080	0.0005	0.00005	0.0005	0.005	0.0060	0.0130
May-17	0.0050	0.0005	0.00005	0.0005	0.0005	0.0100	0.0005	0.00005	0.0005	0.005	0.0060	0.0090
Jun-17	0.0050	0.0005	0.00005	0.0005	0.0005	0.0100	0.0005	0.00005	0.0010	0.005	0.0060	0.0140
Jul-17	0.0050	0.0005	0.00005	0.0005	0.0005	0.0040	0.0005	0.00005	0.0005	0.005	0.0070	0.0080
Aug-17	0.0050	0.0005	0.00005	0.0005	0.0005	0.0080	0.0005	0.00005	0.0010	0.005	0.0060	0.0110
Sep-17	0.0050	0.0005	0.00005	0.0005	0.0005	0.0040	0.0005	0.00005	0.0005	0.005	0.0060	0.0025

Sampled	D_Al	D_As	D_Cd	D_Cr	D_Co	D_Cu	D_Pb	D_Hg	D_Ni	D_Se	D_U	D_Zn
Count	15	15	15	15	15	15	15	15	15	15	15	15
Min	0.0050	0.0005	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.005	0.0040	0.0025
Max	0.1000	0.0010	0.00010	0.0005	0.0020	0.0120	0.0020	0.00020	0.0090	0.005	0.0080	0.0370
Range	0.0950	0.0005	0.00005	0.0000	0.0015	0.0115	0.0015	0.00015	0.0085	0.000	0.0040	0.0345
Average	0.0123	0.0006	0.00006	0.0005	0.0006	0.0076	0.0007	0.00006	0.0021	0.005	0.0064	0.0127
SD	0.0246	0.0002	0.00002	0.0000	0.0004	0.0031	0.0005	0.00004	0.0023	0.000	0.0009	0.0092
5th %ile	0.0050	0.0005	0.00005	0.0005	0.0005	0.0030	0.0005	0.00005	0.0005	0.005	0.0054	0.0025
20th %ile	0.0050	0.0005	0.00005	0.0005	0.0005	0.0056	0.0005	0.00005	0.0005	0.005	0.0060	0.0080
25th %ile	0.0050	0.0005	0.00005	0.0005	0.0005	0.0056	0.0005	0.00005	0.0005	0.005	0.0060	0.0080
50th %ile	0.0050	0.0005	0.00005	0.0005	0.0005	0.0080	0.0005	0.00005	0.0010	0.005	0.0060	0.0100
75th %ile	0.0050	0.0005	0.00005	0.0005	0.0005	0.0100	0.0005	0.00005	0.0030	0.005	0.0070	0.0140
80th %ile	0.0050	0.0005	0.00005	0.0005	0.0005	0.0102	0.0005	0.00005	0.0032	0.005	0.0070	0.0144
95th %ile	0.0440	0.0010	0.00010	0.0005	0.0009	0.0113	0.0020	0.00009	0.0055	0.005	0.0073	0.0314
IQR	0.0000	0.0000	0.00000	0.0000	0.0000	0.0044	0.0000	0.00000	0.0025	0.000	0.0010	0.0060
IQR * 1.5	0.0000	0.0000	0.00000	0.0000	0.0000	0.0066	0.0000	0.00000	0.0038	0.000	0.0015	0.0090
Outlier <	0.0050	0.0005	0.00005	0.0005	0.0005	-0.0010	0.0005	0.00005	-0.0033	0.005	0.0045	-0.0010
Outlier >	0.0050	0.0005	0.00005	0.0005	0.0005	0.0166	0.0005	0.00005	0.0068	0.005	0.0085	0.0230
No Outliers	2	2	0	0	1	0	2	1	1	0	1	2

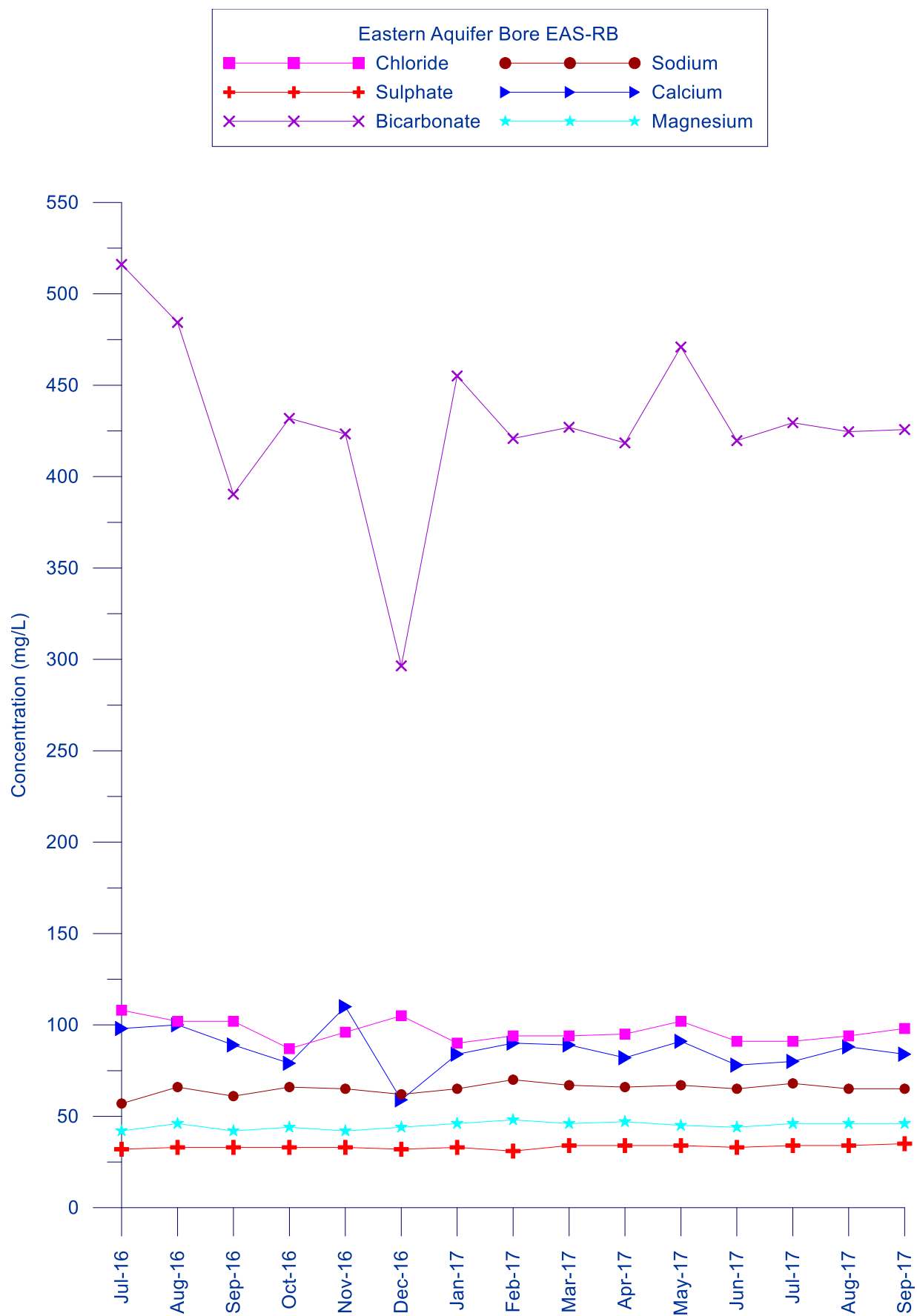
Note: 1) Non-detects assumed to be half detection limit, 2) IQR, Interquartile Range (= Q3 – Q1).



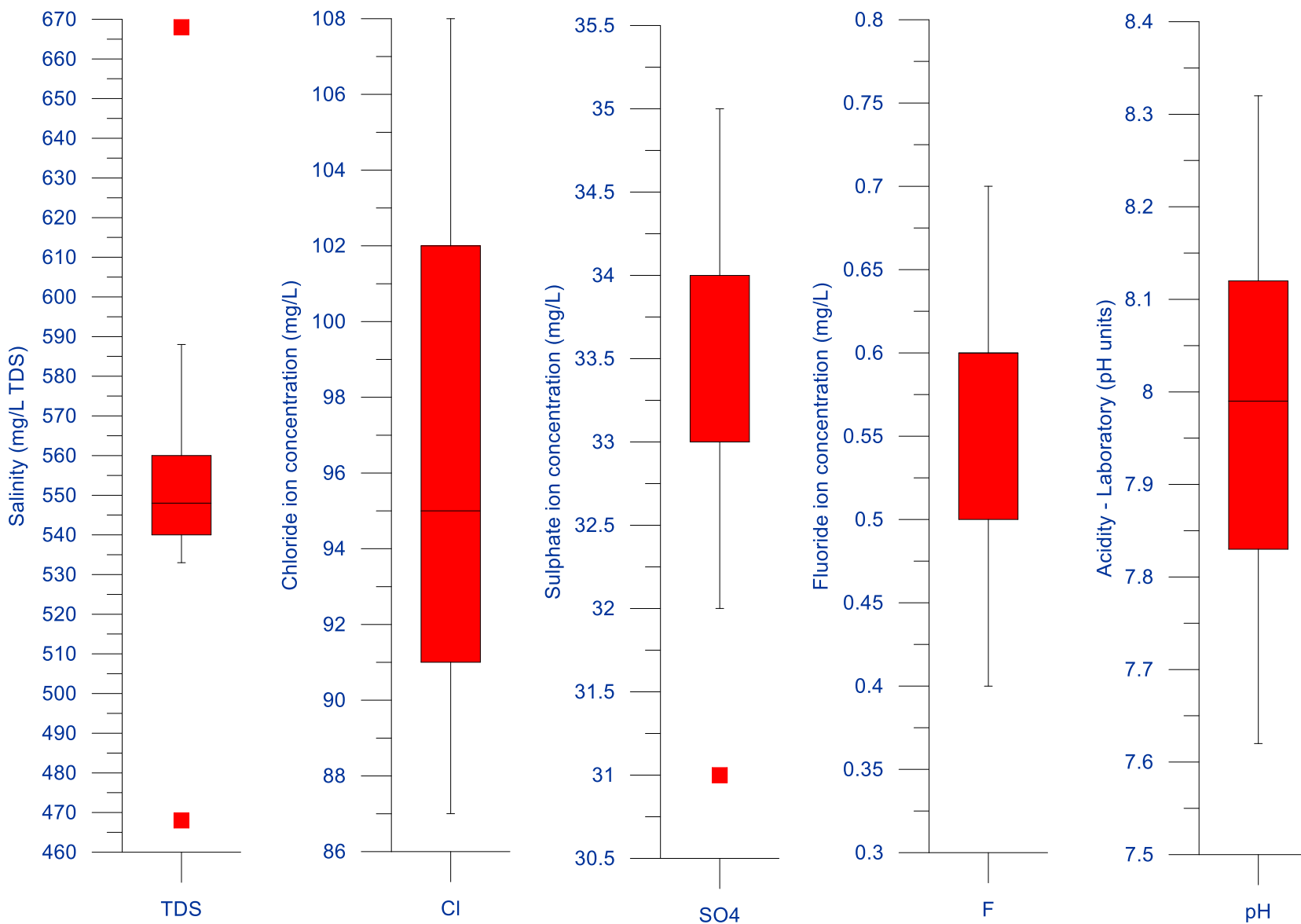
EAS-RB Piper Diagram



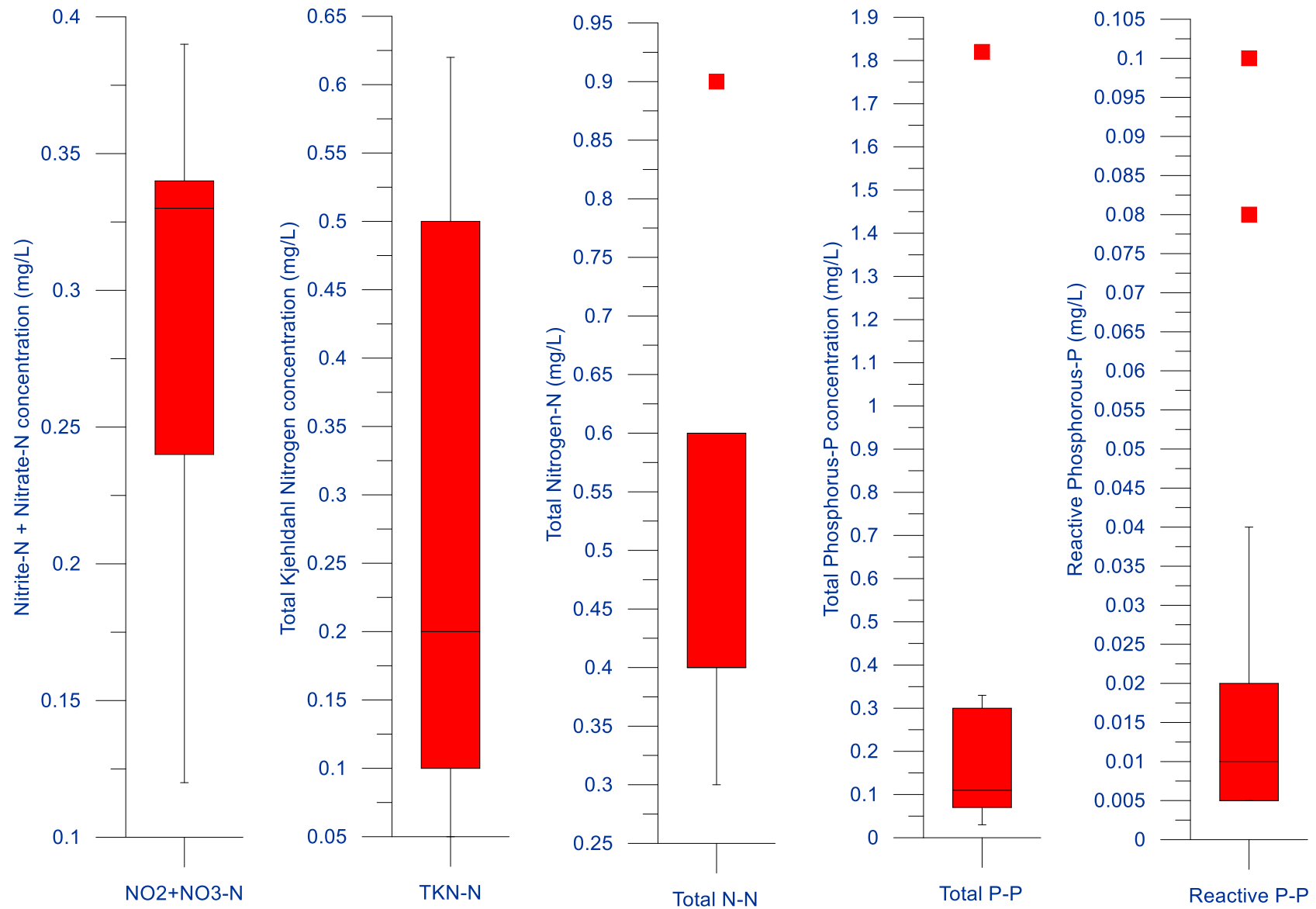
EAS-RB Durov Diagram



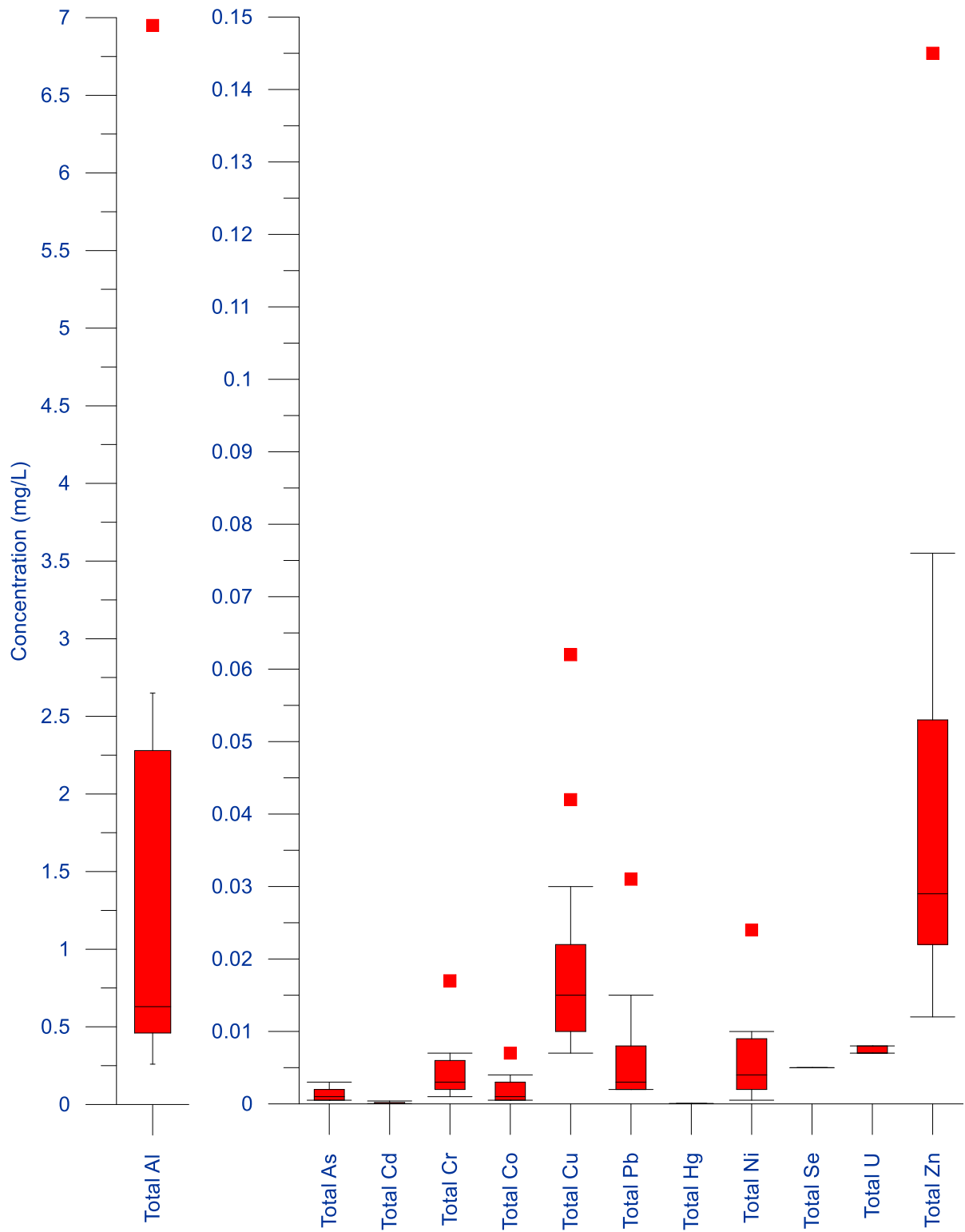
Eastern Aquifer System Bore EAS-RB Standard Water Quality Parameters Concentrations Box-Whisker plots



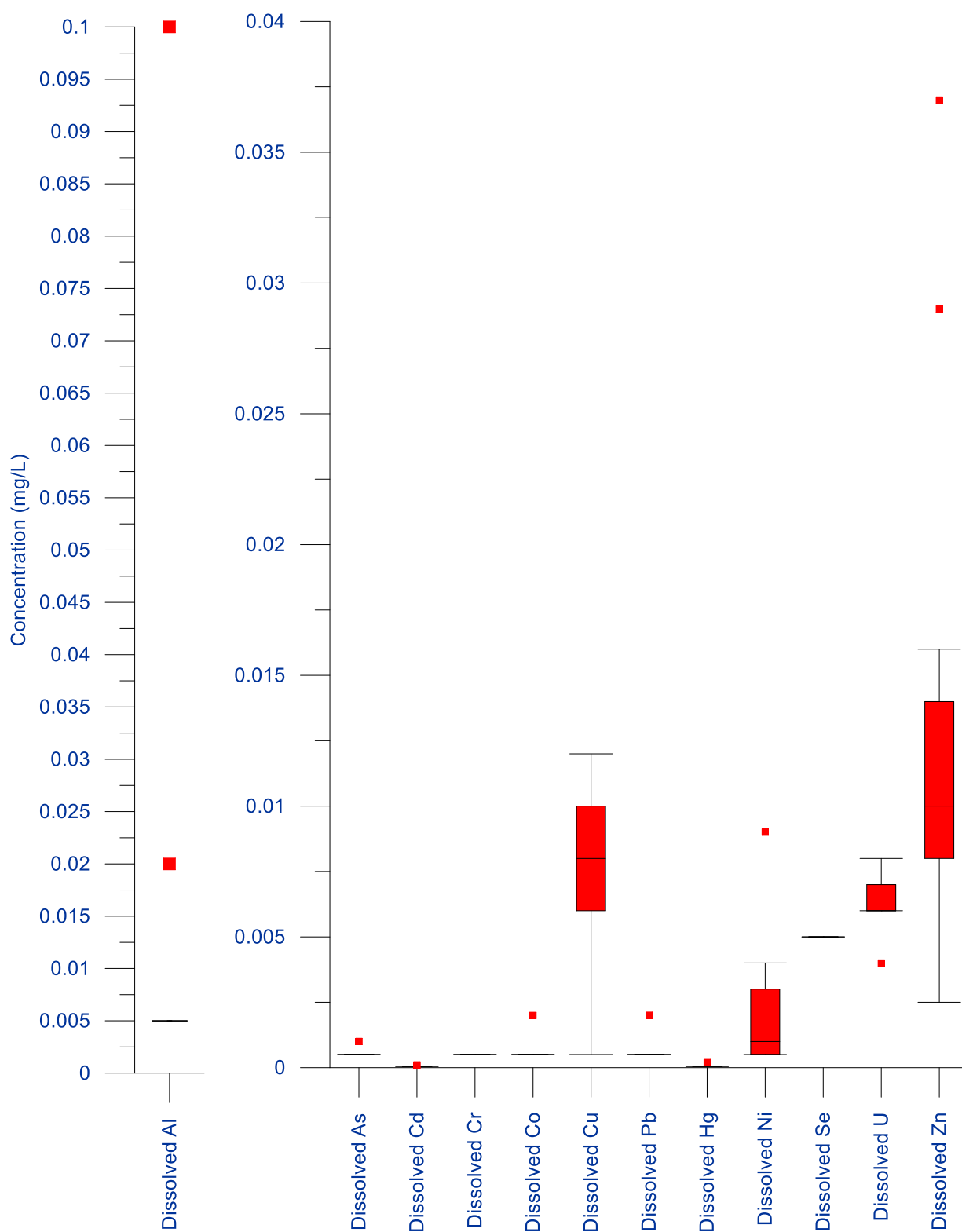
Eastern Aquifer System Bore EAS-RB Nitrogen and Phosphorous Concentrations Box-Whisker Plots



Eastern Aquifer System Bore EAS-RB Total
Metals Concentrations Box-Whisker Plots



Eastern Aquifer System Bore EAS-RB Dissolved Metals Concentrations Box-Whisker Plots



APPENDIX 6

WAS-RB Chemical & Statistical Analysis

Analysis results and statistical analysis

Standard water quality parameters

Dissolved metals

Total metals

Hydrochemical Plots

Piper and Durov diagrams

Time series plots

Box-whisker plots

Table 6.1: WAS-RB Basis Water Quality Parameters and Statistical Analysis

Date sampled	pH (units)	TDS (mg/L)	CO3 (mg/L)	HCO3 (mg/L)	Ca (mg/L)	Cl (mg/L)	F (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	SO4 (mg/L)	NO2+NO3-N (mg/L)	TKN-N (mg/L)	ΣN-N (mg/L)	ΣP-P (mg/L)	R P-P (mg/L)	SS (mg/L)
Jul-16	8.33	802	1460	390	83	288	1.1	40	5	128	32	0.005	0.5	0.5	1.03	0.050	122
Aug-16	7.60	811	1440	373	88	298	1.0	44	6	148	48	0.005	0.2	0.2	1.02	0.005	57
Sep-16	8.37	809	1400	290	85	288	1.0	43	5	148	58	0.005	0.5	0.5	0.15	0.020	22
Oct-16	8.09	822	1410	354	71	271	1.1	40	5	149	61	0.005	0.20	0.20	0.48	0.010	18
Nov-16	8.37	813	1450	340	111	296	1.2	40	7	151	55	0.005	0.20	0.20	0.23	0.020	8
Dec-16	8.08	916	1360	245	78	298	0.9	44	5	146	66	0.010	0.19	0.20	0.46	0.010	41
Jan-17	8.04	844	1390	300	79	266	0.8	43	5	151	77	0.005	0.05	0.05	0.17	0.005	8
Feb-17	8.36	836	1390	284	81	290	1.0	47	6	165	76	0.005	0.05	0.05	0.02	0.005	2.5
Mar-17	8.35	823	1460	321	85	294	1.0	44	6	158	71	0.005	0.05	0.05	0.04	0.005	2.5
Apr-17	8.26	830	1460	331	78	265	1.0	44	5	156	68	0.005	0.10	0.10	0.84	0.010	50
May-17	8.29	832	1360	370	80	293	1.2	42	5	152	62	0.005	0.20	0.20	0.21	0.020	28
Jun-17	8.26	816	1440	331	70	263	1.0	40	5	146	65	0.020	0.30	0.30	0.29	0.010	16
Jul-17	8.12	832	1450	323	81	258	0.9	42	5	154	72	0.020	0.50	0.50	0.14	0.005	20
Aug-17	8.04	790	1420	309	78	263	1.0	42	5	147	76	0.030	0.30	0.30	0.03	0.005	10
Sep-17	8.11	794	1390	306	72	294	1.2	42	5	149	71	0.005	0.10	0.10	0.19	0.010	16

Statistic	pH	TDS	EC	HCO3	Ca	Cl	F	Mg	K	Na	SO4	NO2+NO3-N	TKN-N	ΣN-N	ΣP-P	R P-P	SS
Count	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Min	7.60	790	1360	245	70	258	0.80	40	5	128	32	0.005	0.05	0.05	0.02	0.005	3
Max	8.37	916	1460	390	111	298	1.20	47	7	165	77	0.030	0.50	0.50	1.03	0.050	122
Range	0.77	126	100	145	41	40	0.40	7	2	37	45	0.025	0.45	0.45	1.01	0.045	120
Ave	8.18	825	1419	325	81	282	1.03	42	5	150	64	0.009	0.23	0.23	0.35	0.013	28
SD	0.20	30	36	38	10	15	0.12	2	1	8	12	0.008	0.16	0.16	0.35	0.012	31
5th %ile	7.91	793	1360	273	71	262	0.87	40	5	141	43	0.005	0.05	0.05	0.03	0.005	3
20th %ile	8.07	808	1390	298	77	265	0.98	40	5	147	57	0.005	0.09	0.09	0.12	0.005	8
25th %ile	8.07	808	1390	298	77	265	0.98	40	5	147	57	0.005	0.09	0.09	0.12	0.005	8
50th %ile	8.26	822	1420	323	80	288	1.00	42	5	149	66	0.005	0.20	0.20	0.21	0.010	18
75th %ile	8.34	832	1450	347	84	294	1.10	44	6	153	72	0.008	0.30	0.30	0.47	0.015	35
80th %ile	8.35	833	1452	357	85	294	1.12	44	6	154	73	0.012	0.34	0.34	0.55	0.020	43
95th %ile	8.37	866	1460	378	95	298	1.20	45	6	160	76	0.023	0.50	0.50	1.02	0.029	76
IQR	0.27	24	60	49	7	29	0.12	4	1	6	14	0.003	0.21	0.21	0.35	0.010	27
IQR * 1.5	0.40	37	90	73	11	44	0.18	6	1	9	21	0.004	0.32	0.32	0.53	0.015	40
Outlier <	7.67	771	1300	225	66	221	0.80	34	4	138	36	0.001					
Outlier >	8.74	869	1540	420	95	338	1.28	50	6	162	93	0.011	0.62	0.62	1.00	0.030	74
No outliers	1	1	0	0	1	0	1	0	1	2	1	3	0	0	0	0	1

Notes: 1) CO3 as CaCO3 and HCO3 as CaCO3 converted to respective ionic concentrations. 2) SD, Standard Deviation; 3) %ile, percentile; 4) IQR, Interquartile Range (= Q3 – Q1); Outliers in bold font.

Table 6.2: WAS-RB Total Metals Analytical Results and Statistical Analysis

Sampled	ΣAl	ΣAs	ΣCd	ΣCr	ΣCo	ΣCu	ΣPb	ΣHg	ΣNi	ΣSe	ΣU	ΣZn
Jul-16	0.780	0.005	0.00005	0.0020	0.0020	0.0130	0.0040	0.00005	0.0120	0.0050	0.0030	0.0650
Aug-16	0.440	0.004	0.00005	0.0110	0.0020	0.0150	0.0020	0.00005	0.0370	0.0050	0.0060	0.0610
Sep-16	0.120	0.003	0.00005	0.0005	0.0005	0.0050	0.0005	0.00005	0.0020	0.0050	0.0030	0.0170
Oct-16	0.310	0.003	0.00005	0.0010	0.0005	0.0120	0.0020	0.00005	0.0050	0.0050	0.0050	0.0340
Nov-16	0.090	0.004	0.00005	0.0005	0.0005	0.0070	0.0005	0.00005	0.0020	0.0050	0.0030	0.0240
Dec-16	0.200	0.003	0.00005	0.0005	0.0005	0.0090	0.0020	0.00005	0.0180	0.0050	0.0050	0.0430
Jan-17	0.050	0.006	0.00005	0.0005	0.0005	0.0040	0.0005	0.00005	0.0040	0.0050	0.0060	0.0140
Feb-17	0.120	0.003	0.00005	0.0005	0.0005	0.0050	0.0010	0.00005	0.0005	0.0050	0.0050	0.0180
Mar-17	0.020	0.006	0.00005	0.0005	0.0005	0.0040	0.0005	0.00005	0.0020	0.0050	0.0050	0.0140
Apr-17	0.320	0.003	0.00005	0.0020	0.0010	0.0090	0.0020	0.00005	0.0040	0.0050	0.0030	0.0540
May-17	0.320	0.002	0.00005	0.0005	0.0010	0.0100	0.0010	0.00005	0.0040	0.0050	0.0020	0.0190
Jun-17	0.210	0.004	0.00005	0.0020	0.0030	0.0120	0.0020	0.00005	0.0100	0.0050	0.0030	0.0360
Jul-17	0.080	0.002	0.00005	0.0005	0.0005	0.0060	0.0005	0.00005	0.0040	0.0050	0.0050	0.0260
Aug-17	0.050	0.002	0.00005	0.0005	0.0005	0.0050	0.0005	0.00005	0.0030	0.0050	0.0060	0.0190
Sep-17	0.170	0.001	0.00005	0.0005	0.0005	0.0090	0.0010	0.00005	0.0030	0.0050	0.0040	0.0200

Statistic	ΣAl	ΣAs	ΣCd	ΣCr	ΣCo	ΣCu	ΣPb	ΣHg	ΣNi	ΣSe	ΣU	ΣZn
Count	15	15	15	15	15	15	15	15	15	15	15	15
Min	0.020	0.001	0.0001	0.0005	0.0005	0.0040	0.0005	0.0001	0.0005	0.0050	0.0020	0.0140
Max	0.780	0.006	0.0001	0.0110	0.0030	0.0150	0.0040	0.0001	0.0370	0.0050	0.0060	0.0650
Range	0.760	0.005	0.0000	0.0105	0.0025	0.0110	0.0035	0.0000	0.0365	0.0000	0.0040	0.0510
Average	0.219	0.003	0.0001	0.0015	0.0009	0.0083	0.0013	0.0001	0.0074	0.0050	0.0043	0.0309
SD	0.198	0.001	0.0000	0.0027	0.0008	0.0035	0.0010	0.0000	0.0094	0.0000	0.0013	0.0173
5th %ile	0.041	0.002	0.0001	0.0005	0.0005	0.0040	0.0005	0.0001	0.0016	0.0050	0.0027	0.0140
20th %ile	0.074	0.002	0.0001	0.0005	0.0005	0.0050	0.0005	0.0001	0.0020	0.0050	0.0030	0.0178
25th %ile	0.074	0.002	0.0001	0.0005	0.0005	0.0050	0.0005	0.0001	0.0020	0.0050	0.0030	0.0178
50th %ile	0.170	0.003	0.0001	0.0005	0.0005	0.0090	0.0010	0.0001	0.0040	0.0050	0.0050	0.0240
75th %ile	0.315	0.004	0.0001	0.0015	0.0010	0.0110	0.0020	0.0001	0.0075	0.0050	0.0050	0.0395
80th %ile	0.320	0.004	0.0001	0.0020	0.0012	0.0120	0.0020	0.0001	0.0104	0.0050	0.0052	0.0452
95th %ile	0.542	0.006	0.0001	0.0047	0.0023	0.0136	0.0026	0.0001	0.0237	0.0050	0.0060	0.0622
IQR	0.241	0.002	0.0000	0.0010	0.0005	0.0060	0.0015	0.0000	0.0055	0.0000	0.0020	0.0217
IQR * 1.5	0.362	0.003	0.0000	0.0015	0.0008	0.0090	0.0023	0.0000	0.0083	0.0000	0.0030	0.0326
Outlier <	-0.288	-0.001	0.0001	-0.0010	-0.0003	-0.0040	-0.0018	0.0001	-0.0063	0.0050	0.0000	-0.0148
Outlier >	0.677	0.007	0.0001	0.0030	0.0018	0.0200	0.0043	0.0001	0.0158	0.0050	0.0080	0.0721
No Outliers	1	0	0	1	2	0	0	0	1	0	0	0

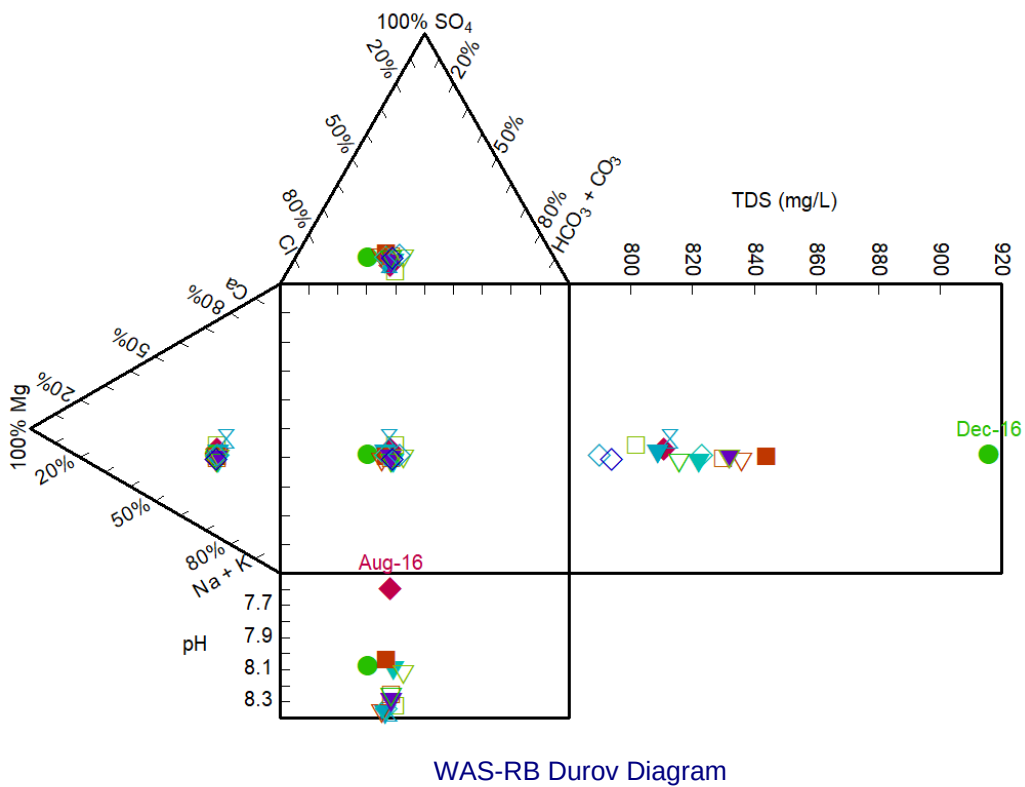
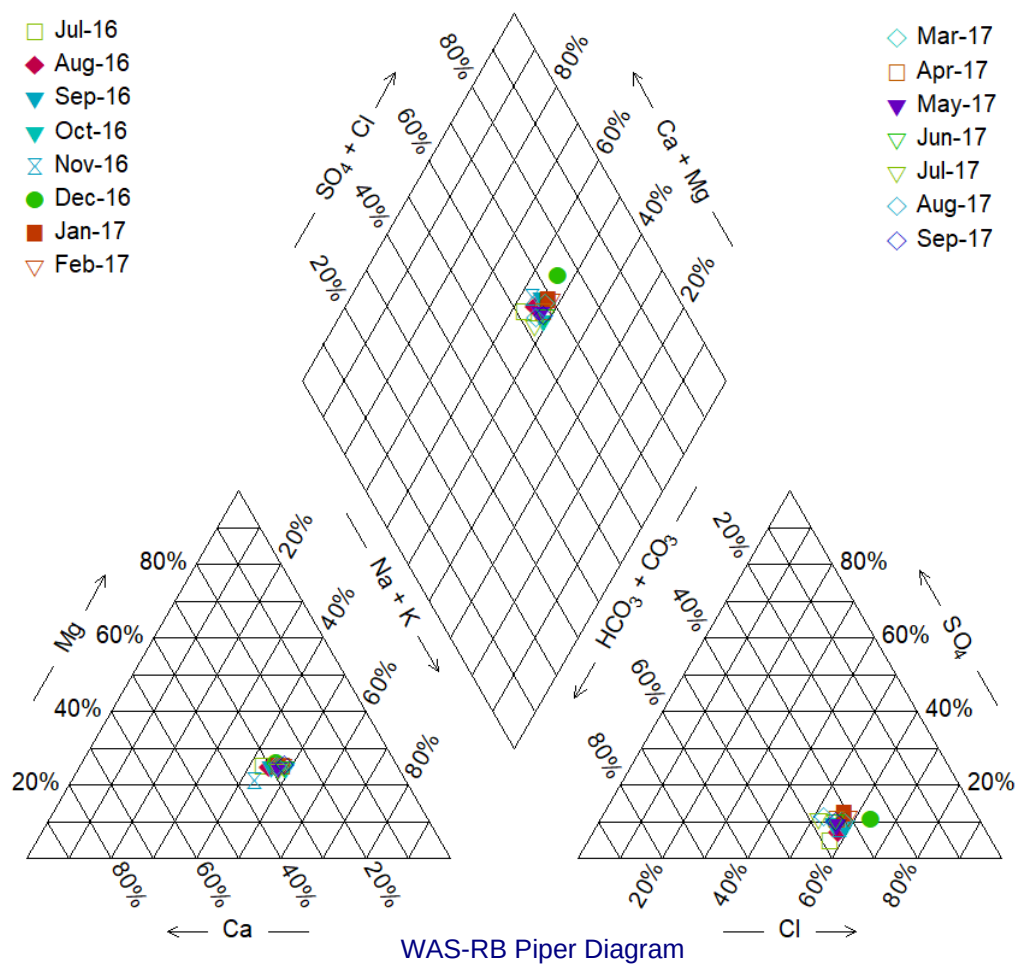
Notes: 1) Non-detects assumed to be half detection limit; 2)) IQR, Interquartile Range (= Q3 – Q1).

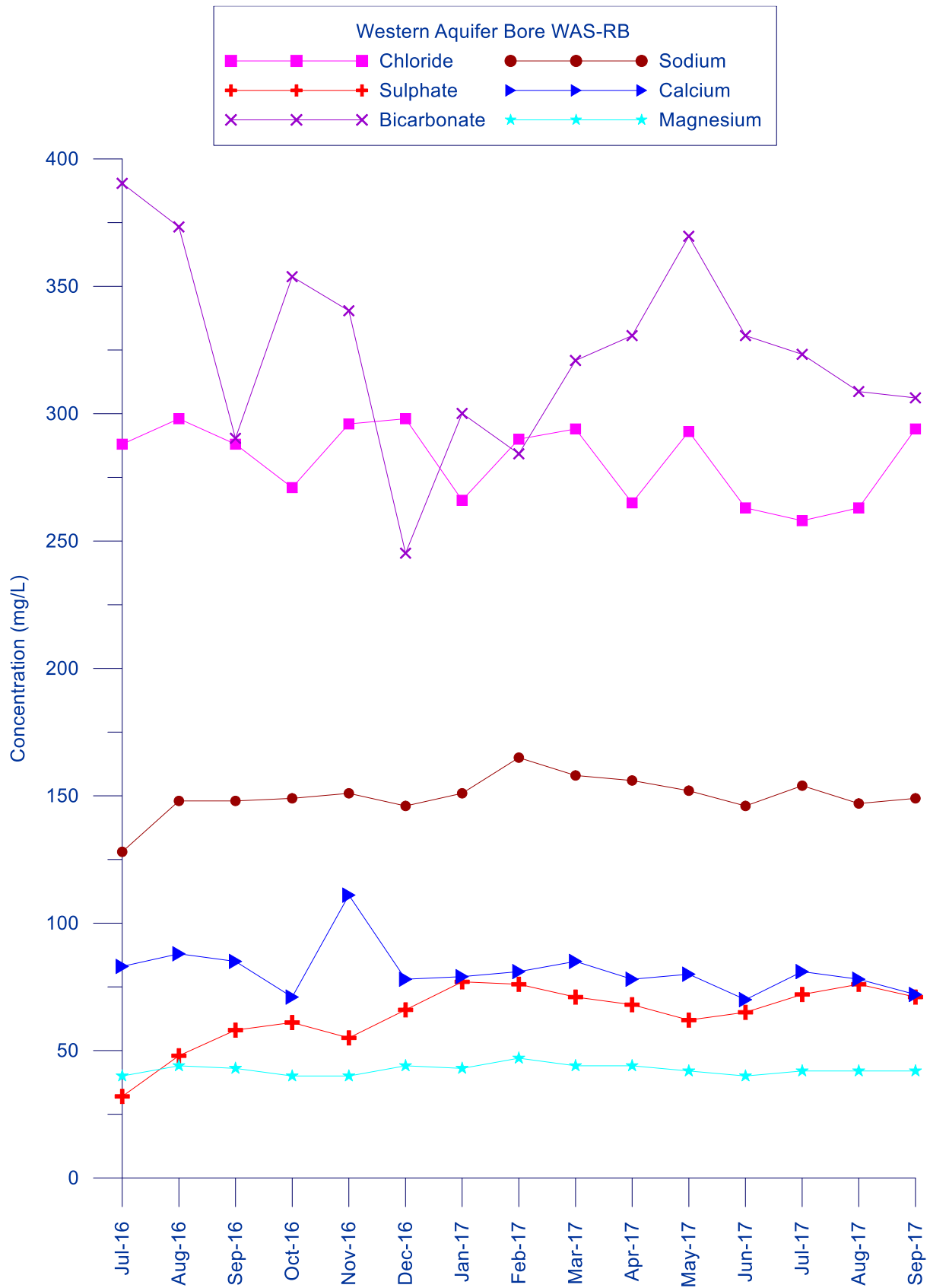
Table 6.3: WAS-RB Dissolved Metals Analytical Results and Statistical Analysis

Sampled	D_Al	D_As	D_Cd	D_Cr	D_Co	D_Cu	D_Pb	D_Hg	D_Ni	D_Se	D_U	D_Zn
Jul-16	0.200	0.004	0.00005	0.0005	0.0020	0.0090	0.0030	0.00005	0.0080	0.0050	0.0020	0.0540
Aug-16	0.005	0.003	0.00005	0.0005	0.0005	0.0030	0.0005	0.00005	0.0140	0.0050	0.0040	0.1070
Sep-16	0.005	0.002	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0010	0.0050	0.0030	0.0025
Oct-16	0.005	0.003	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0020	0.0050	0.0040	0.0025
Nov-16	0.005	0.003	0.00005	0.0005	0.0005	0.0010	0.0005	0.00005	0.0010	0.0050	0.0030	0.0050
Dec-16	0.005	0.002	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0140	0.0050	0.0040	0.0025
Jan-17	0.005	0.006	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0040	0.0050	0.0050	0.0025
Feb-17	0.005	0.003	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0020	0.0050	0.0050	0.0060
Mar-17	0.005	0.006	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0020	0.0050	0.0050	0.0070
Apr-17	0.005	0.002	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.0050	0.0020	0.0050
May-17	0.005	0.001	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.0050	0.0020	0.0025
Jun-17	0.005	0.002	0.00005	0.0005	0.0020	0.0020	0.0005	0.00005	0.0010	0.0050	0.0020	0.0070
Jul-17	0.005	0.001	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.0050	0.0040	0.0060
Aug-17	0.005	0.001	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0020	0.0050	0.0050	0.0025
Sep-17	0.005	0.0005	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.0050	0.0040	0.0025

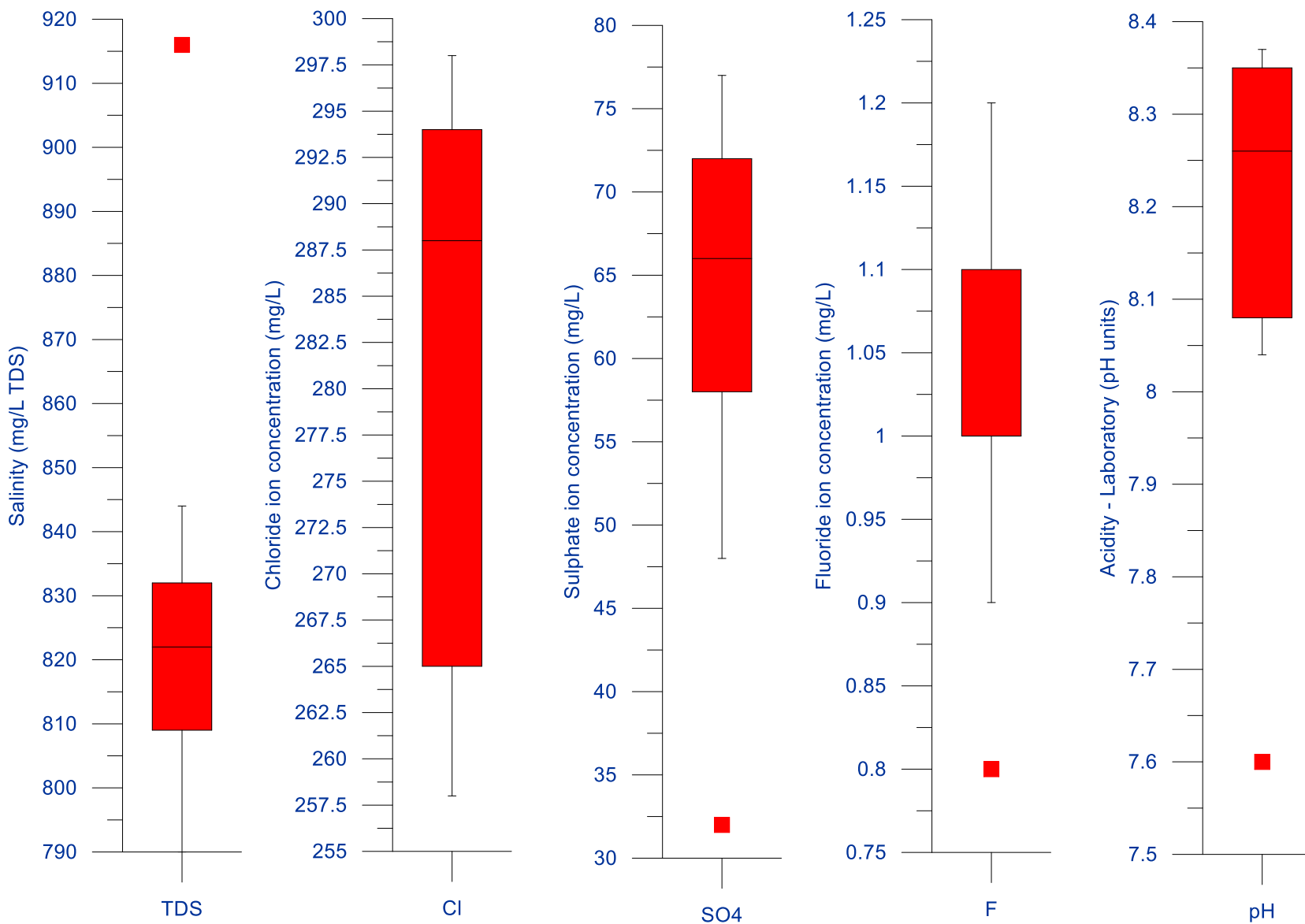
Sampled	D_Al	D_As	D_Cd	D_Cr	D_Co	D_Cu	D_Pb	D_Hg	D_Ni	D_Se	D_U	D_Zn
Count	15	15	15	15	15	15	15	15	15	15	15	15
Min	0.005	0.001	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.0050	0.0020	0.0025
Max	0.200	0.006	0.00005	0.0005	0.0020	0.0090	0.0030	0.00005	0.0140	0.0050	0.0050	0.1070
Range	0.195	0.006	0.00000	0.0000	0.0015	0.0085	0.0025	0.00000	0.0135	0.0000	0.0030	0.1045
Average	0.018	0.003	0.00005	0.0005	0.0007	0.0014	0.0007	0.00005	0.0035	0.0050	0.0036	0.0143
SD	0.050	0.002	0.00000	0.0000	0.0005	0.0022	0.0006	0.00000	0.0047	0.0000	0.0012	0.0287
5th %ile	0.005	0.001	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.0050	0.0020	0.0025
20th %ile	0.005	0.001	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.0050	0.0020	0.0025
25th %ile	0.005	0.001	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005	0.0050	0.0020	0.0025
50th %ile	0.005	0.002	0.00005	0.0005	0.0005	0.0005	0.0005	0.00005	0.0020	0.0050	0.0040	0.0050
75th %ile	0.005	0.003	0.00005	0.0005	0.0005	0.0008	0.0005	0.00005	0.0030	0.0050	0.0045	0.0065
80th %ile	0.005	0.003	0.00005	0.0005	0.0005	0.0012	0.0005	0.00005	0.0048	0.0050	0.0050	0.0070
95th %ile	0.063	0.006	0.00005	0.0005	0.0020	0.0048	0.0013	0.00005	0.0140	0.0050	0.0050	0.0699
IQR	0.000	0.002	0.00000	0.0000	0.0000	0.0003	0.0000	0.00000	0.0025	0.0000	0.0025	0.0040
IQR * 1.5	0.000	0.003	0.00000	0.0000	0.0000	0.0004	0.0000	0.00000	0.0038	0.0000	0.0038	0.0060
Outlier <	0.005	-0.002	0.00005	0.0005	0.0005	0.0001	0.0005	0.00005		0.0050		
Outlier >	0.005	0.006	0.00005	0.0005	0.0005	0.0011	0.0005	0.00005	0.0068	0.0050	0.0083	0.0125
No Outliers	1	0	0	0	2	3	1	0	3	0	0	2

Note: 1) Non-detects assumed to be half detection limit, 2) IQR, Interquartile Range (= Q3 – Q1).

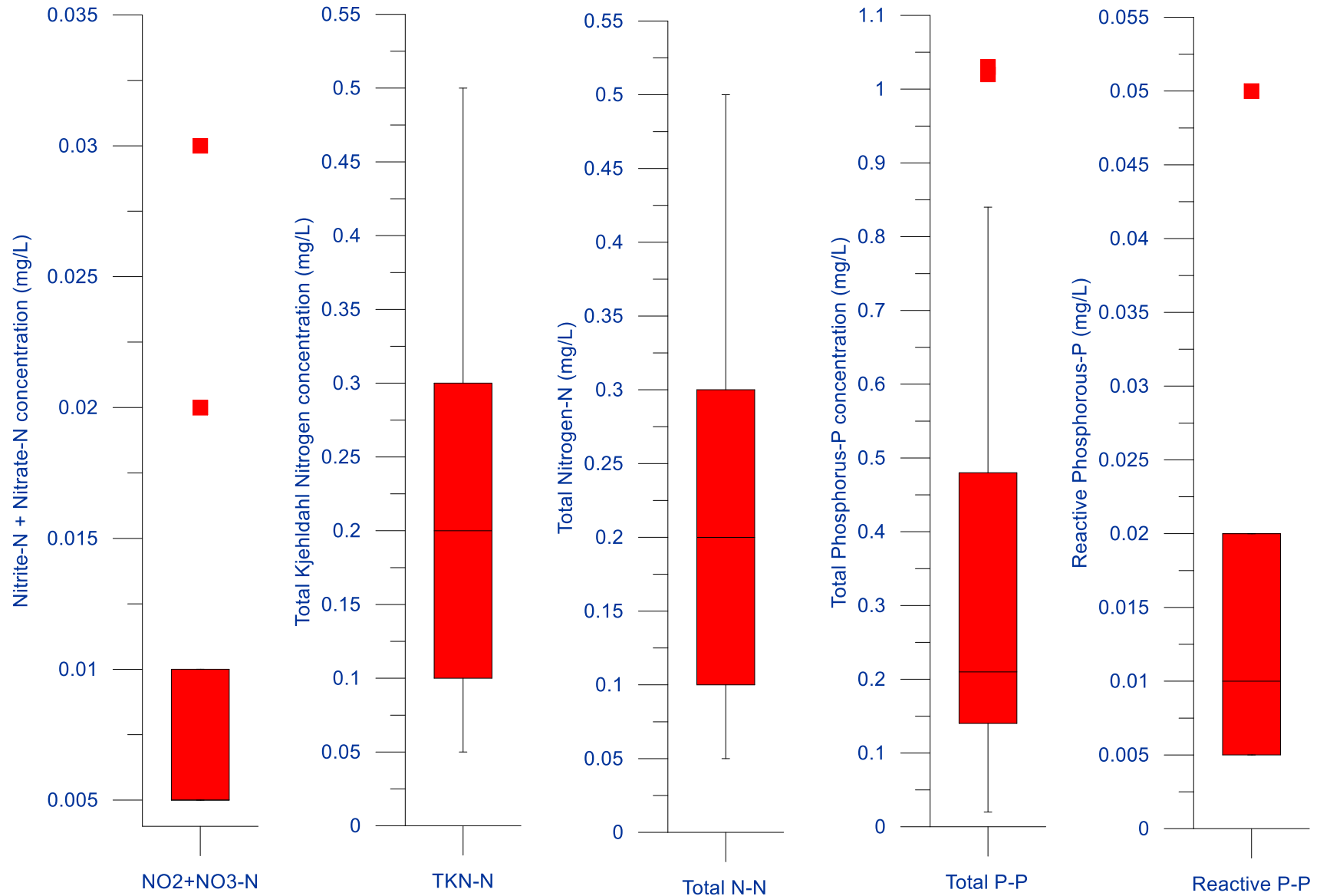




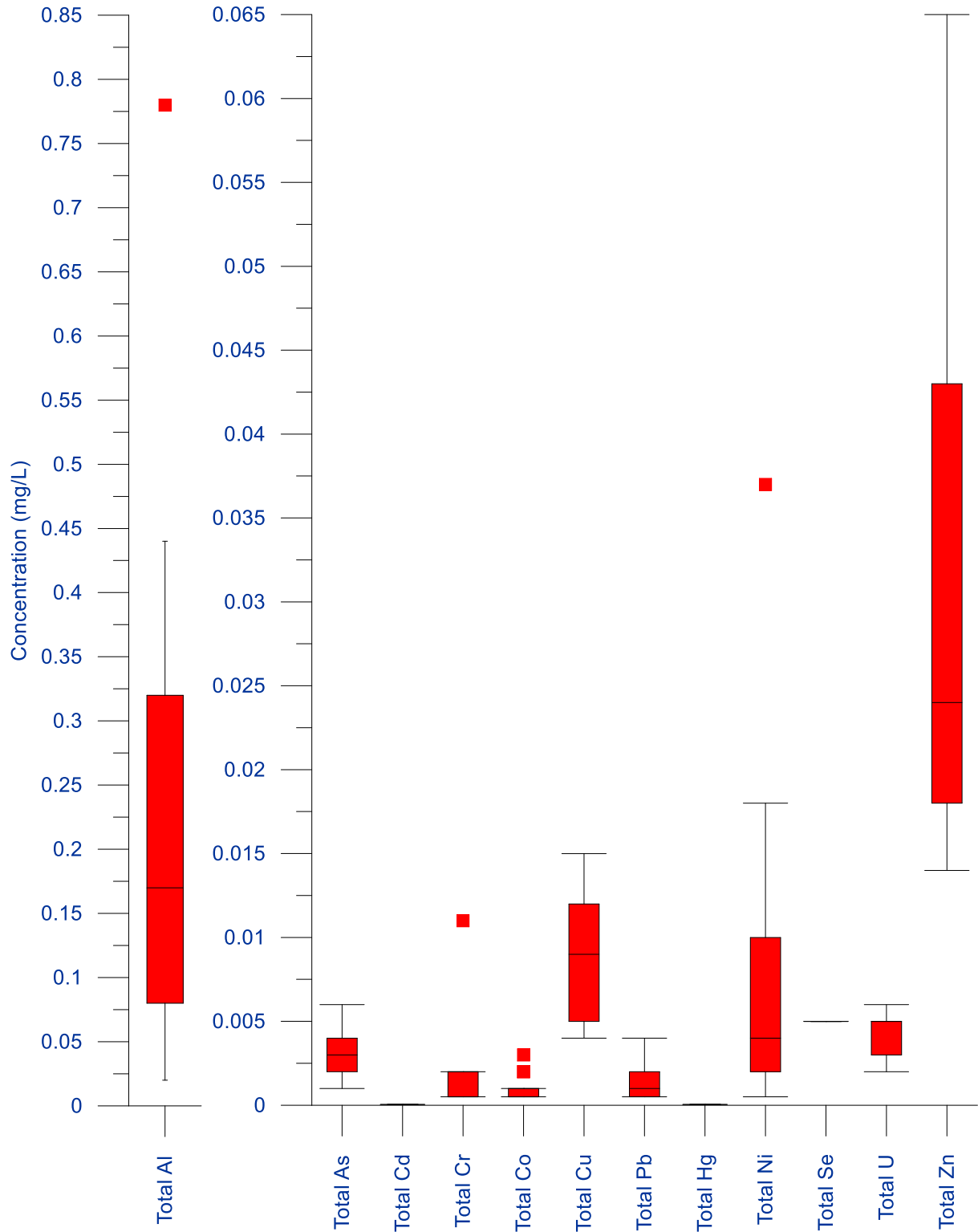
Western Aquifer System Bore WAS-RB Standard Water Quality Parameters Concentrations Box-Whisker plots



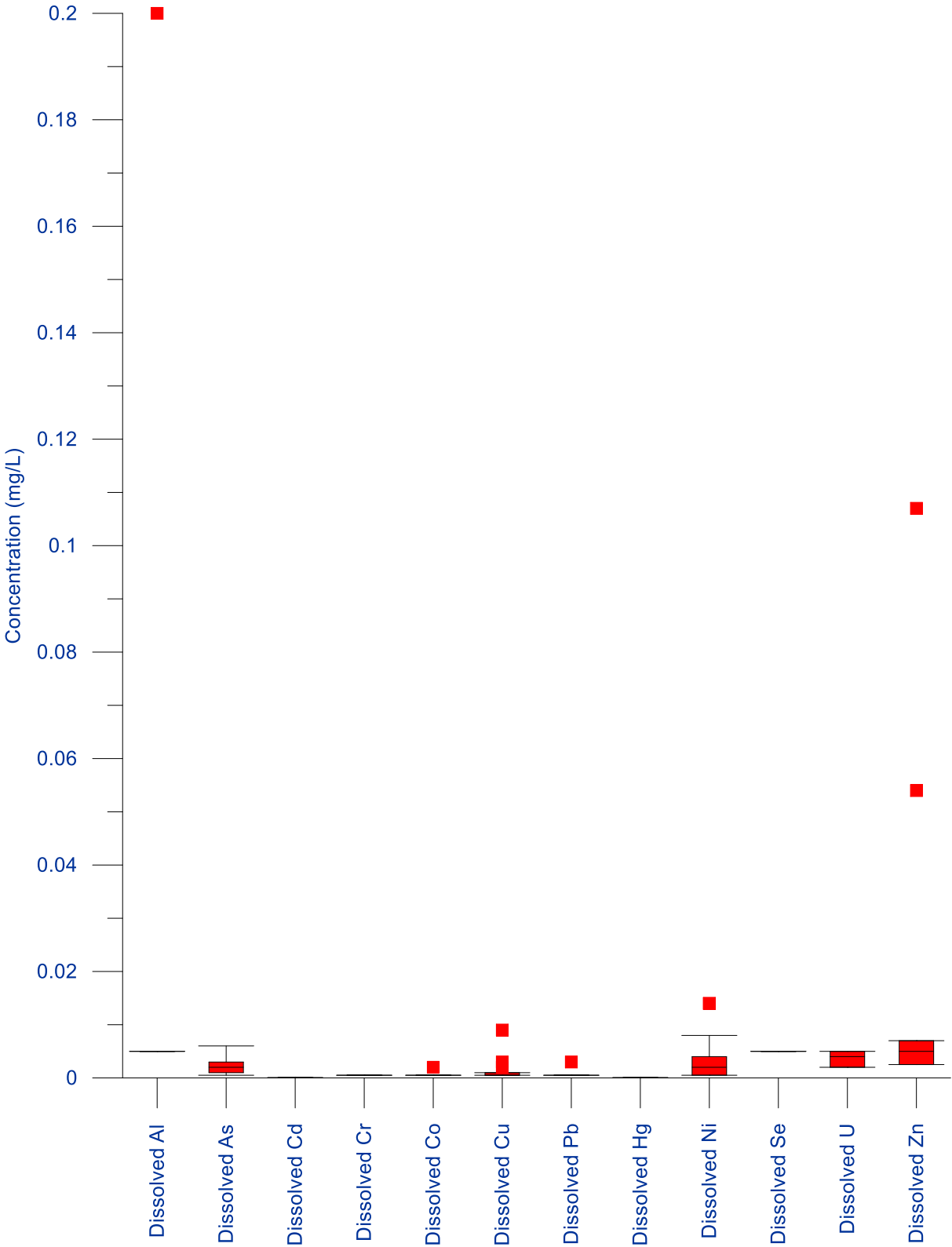
Western Aquifer System Bore WAS-RB Nitrogen and Phosphorous Concentration Box-Whisker Plots



Western Aquifer System Bore WAS-RB Total Metals Concentrations Box-Whisker Plots



Western Aquifer System Bore WAS-RB
Dissolved Metals Concentrations
Box-Whisker Plots



APPENDIX 7

EAS Hydrochemical Analysis

7A) July 2017 Piper Diagrams

7B) Individual Bore Piper Diagrams

7C) Analyte Concentration Time Series Plots

7C1 By Analyte

7C2 By Bore

7D) Box-Whisker Plots

APPENDIX 7A

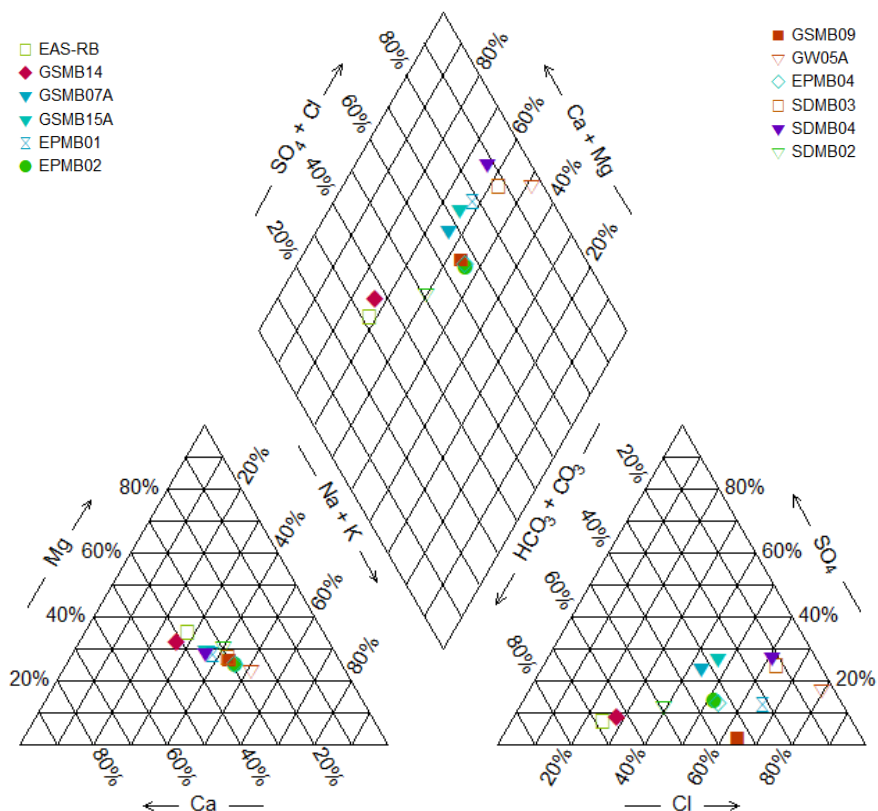
July 2017 Piper Diagrams

EAS GSF area bores

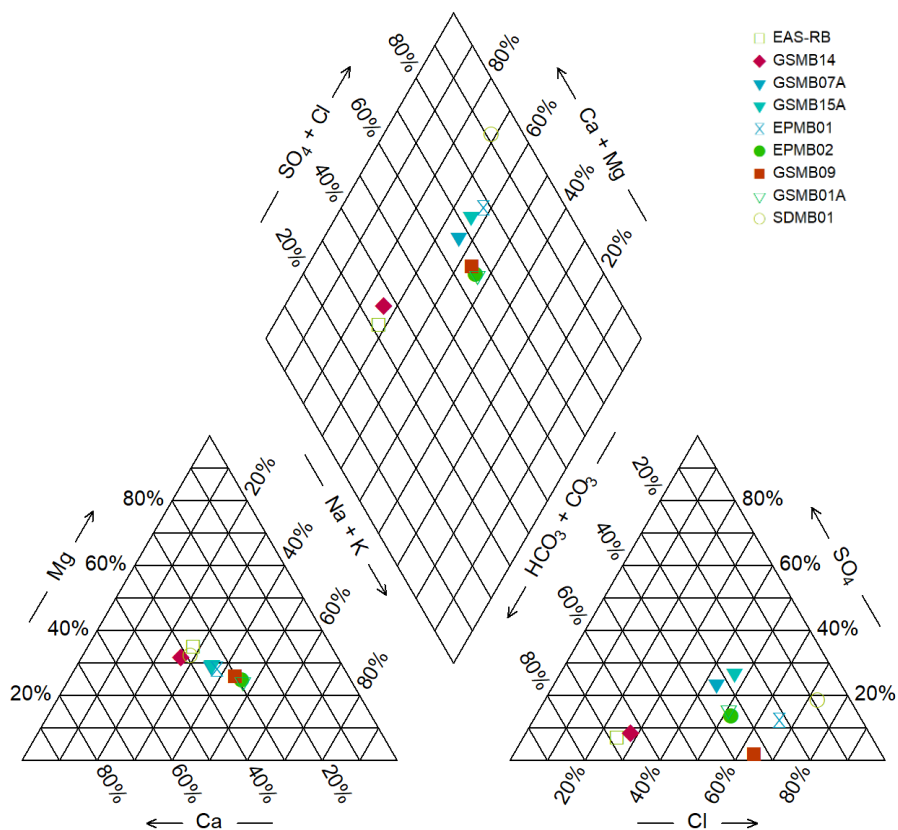
EAS Plant area bores

EAS Slimes Dams area bores

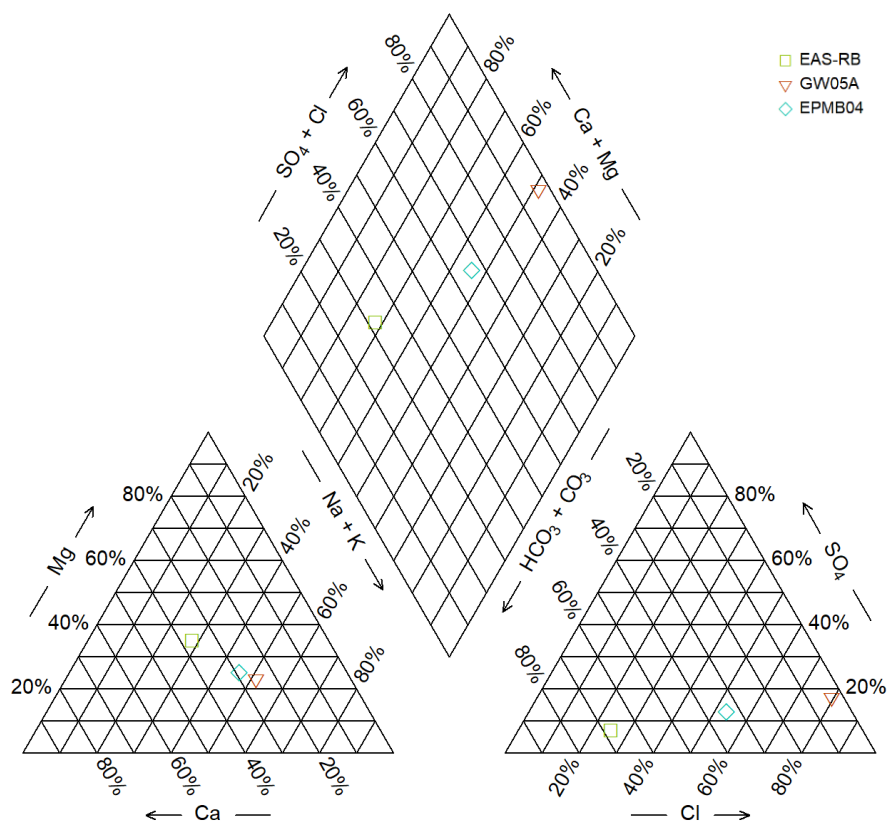
July 2017 Piper Diagram All EAS Bores



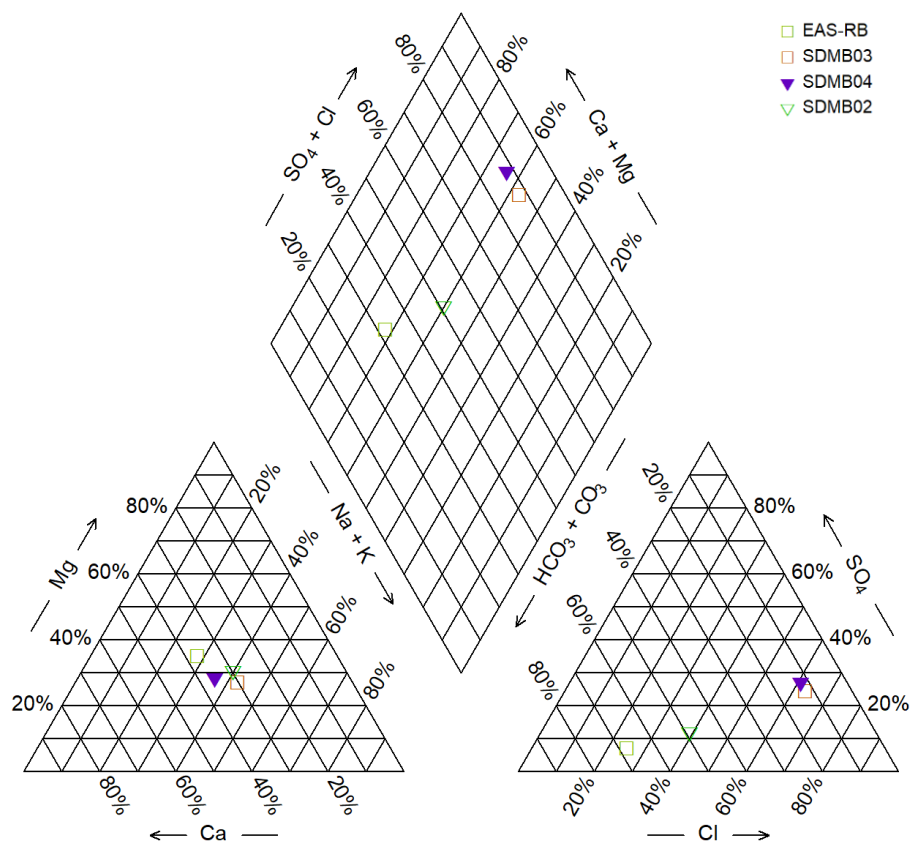
EAS GSF Area July 2017 Piper Diagram



EAS Plant Area July 2017 Piper Diagram



EAS Slime Dams Area July 2017 Piper Diagram

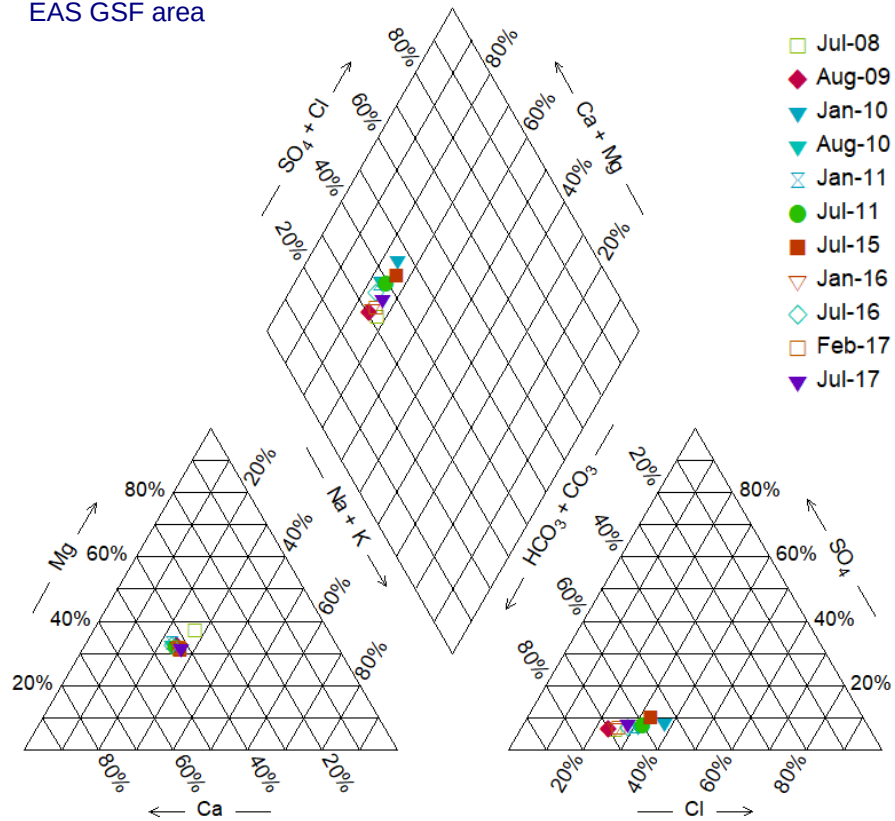


APPENDIX 7B

**Piper Diagrams Individual EAS Bores
(arranged from north to south)**

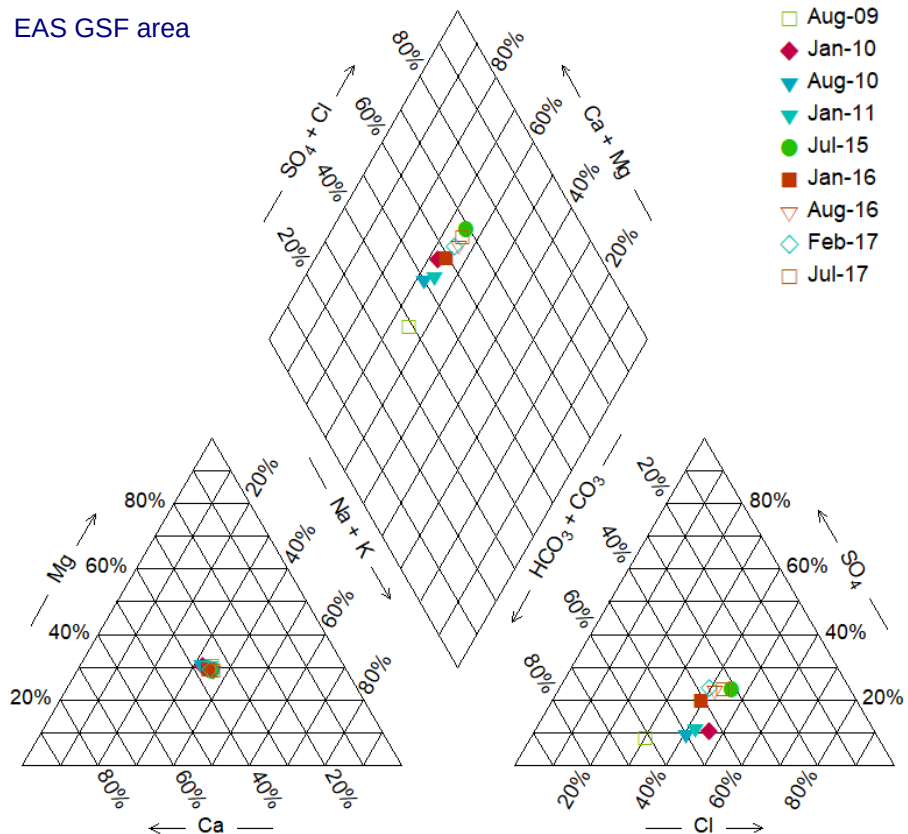
GSMB14 Piper Diagram

EAS GSF area

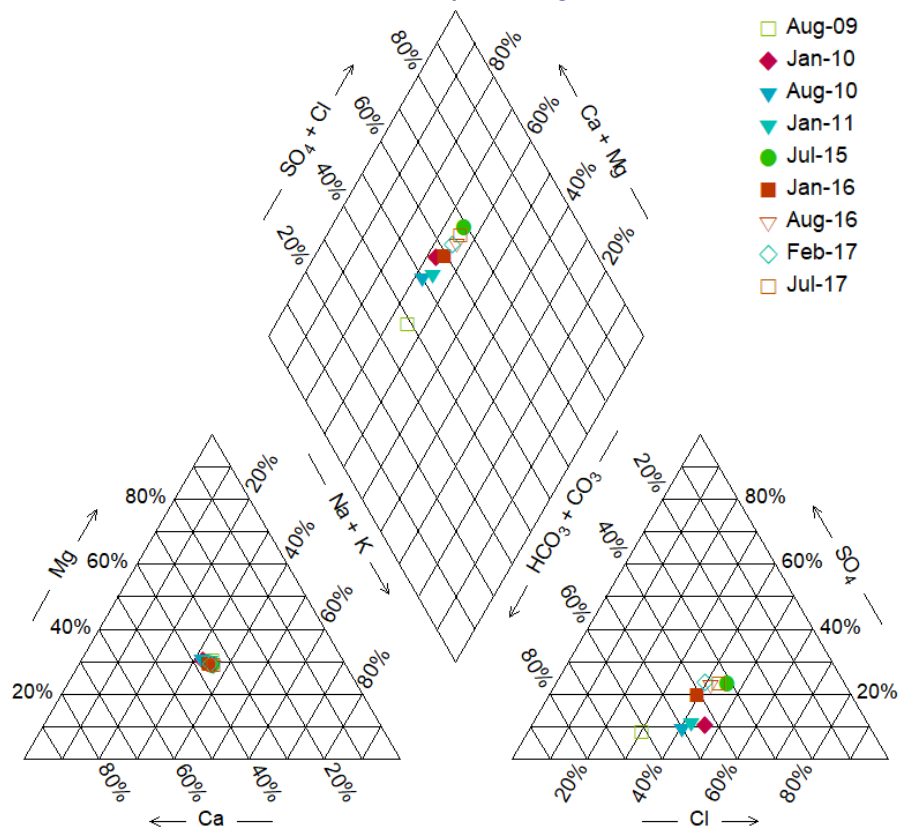


GSMB07A Piper Diagram

EAS GSF area

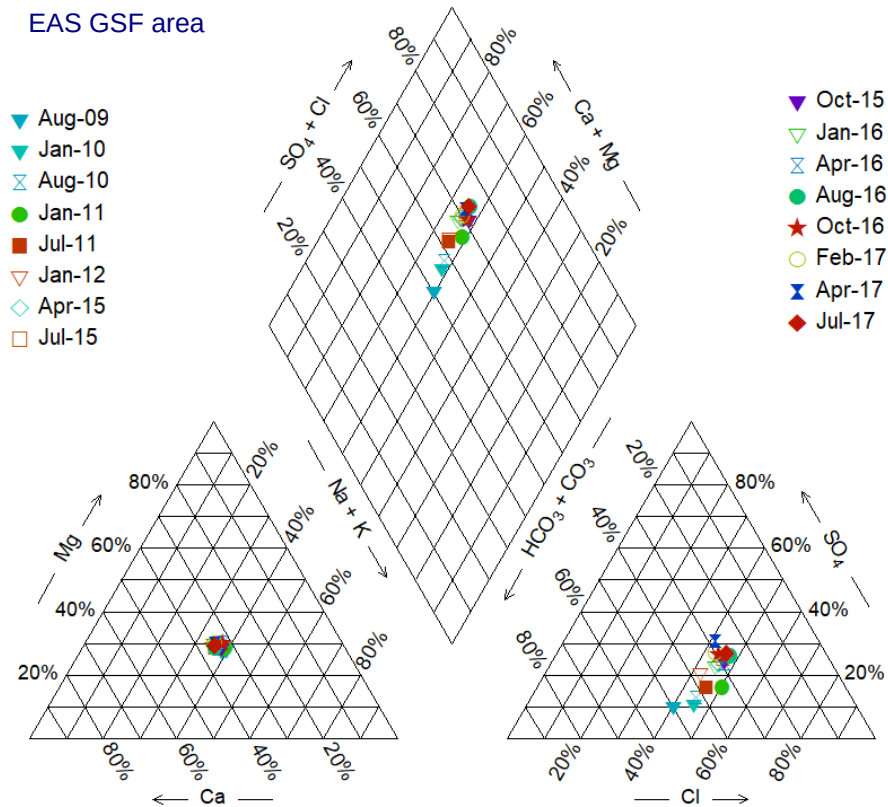


GSMB07A Piper Diagram



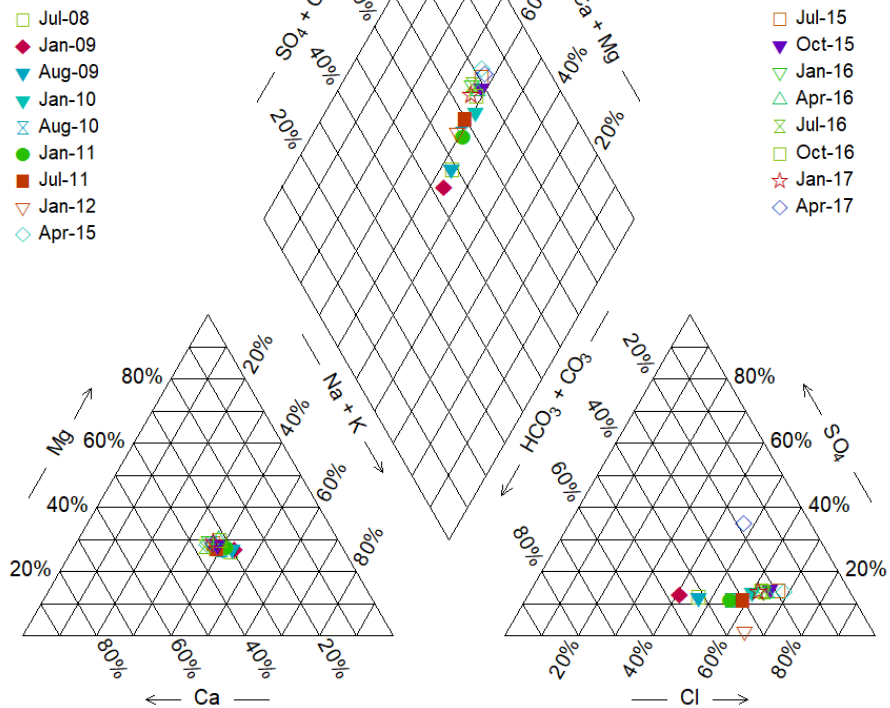
GSMB15A Piper Diagram

EAS GSF area



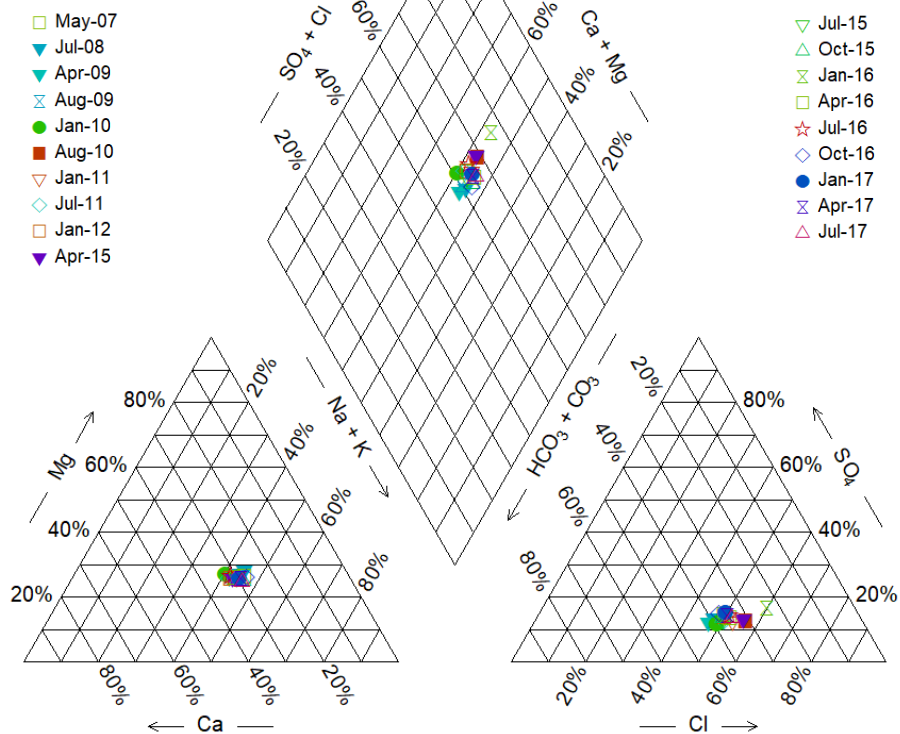
EPMB01 Piper Diagram

EAS GSF area



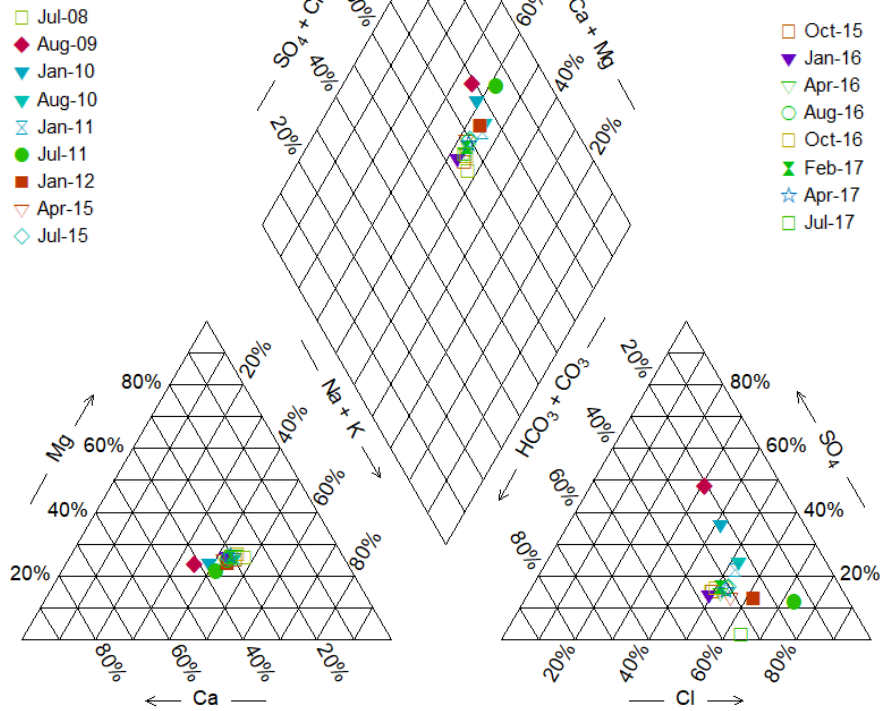
EPMB02 Piper Diagram

EAS GSF area



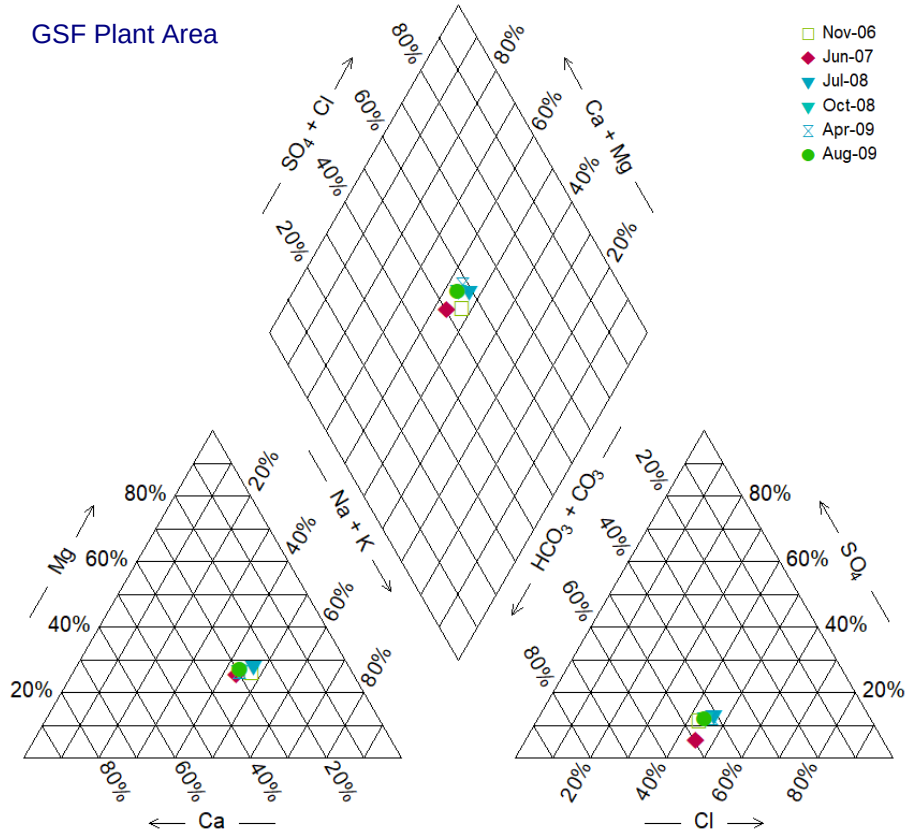
GSMB09 Piper Diagram

EAS GSF area



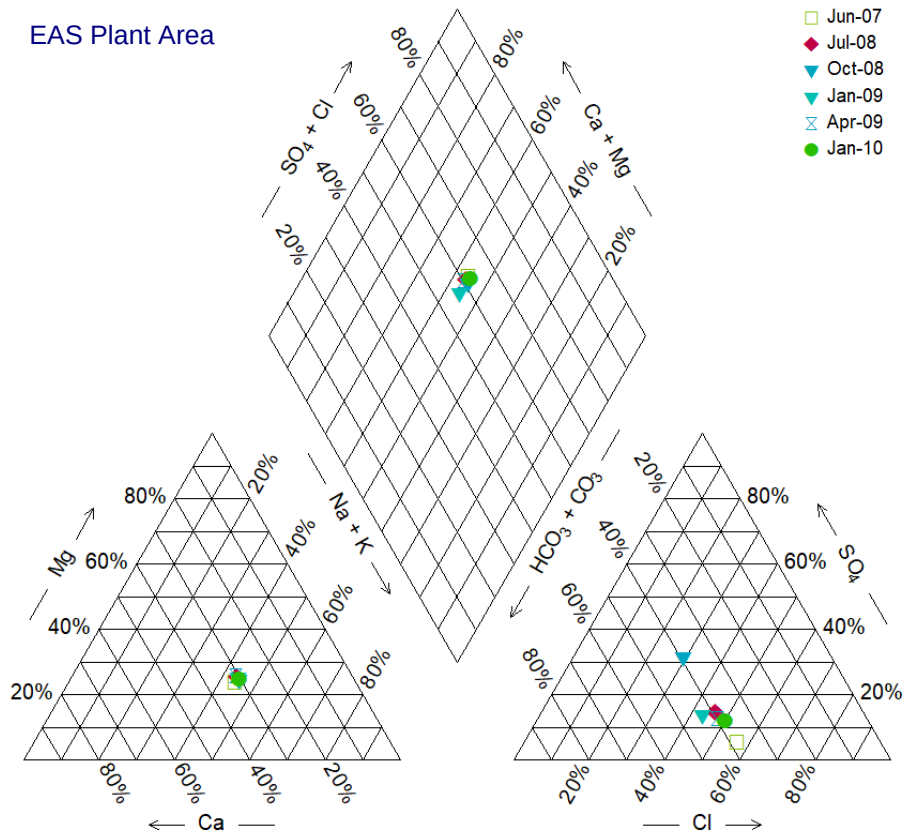
GW06 Piper Diagram

GSF Plant Area



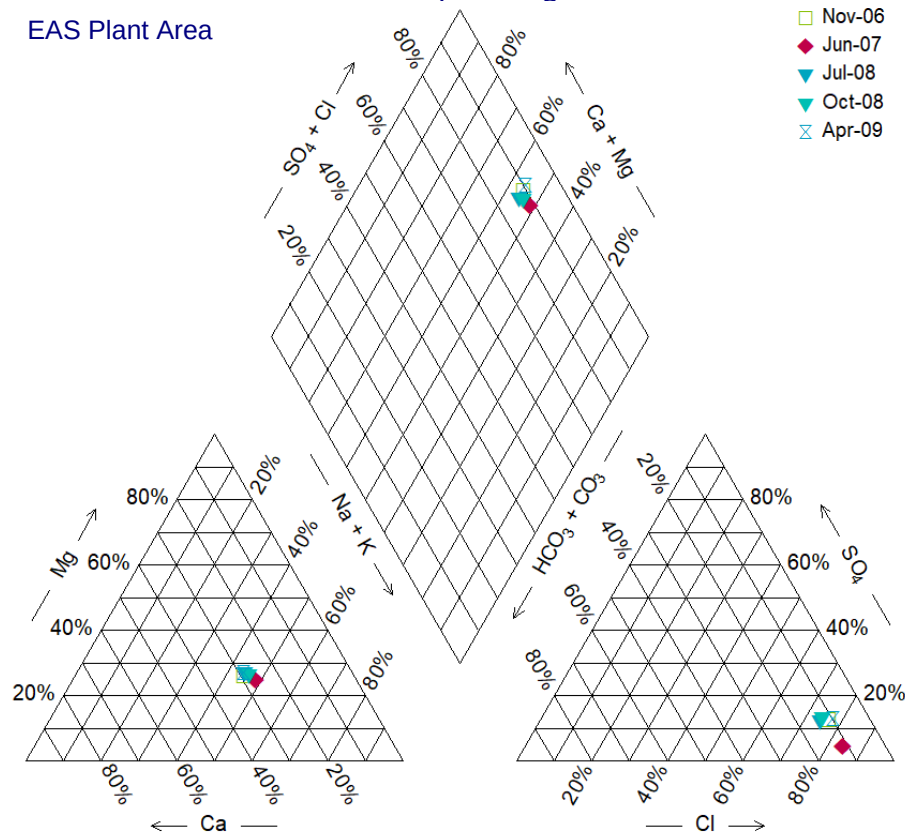
GW23 Piper Diagram

EAS Plant Area



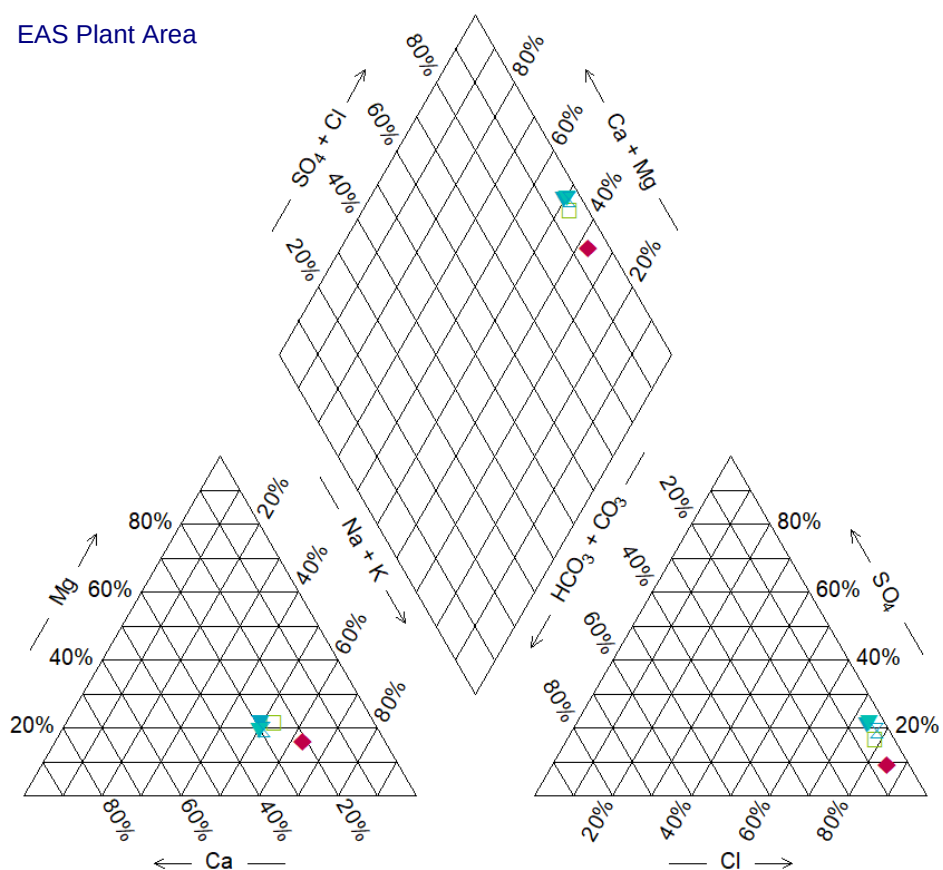
GW13 Piper Diagram

EAS Plant Area



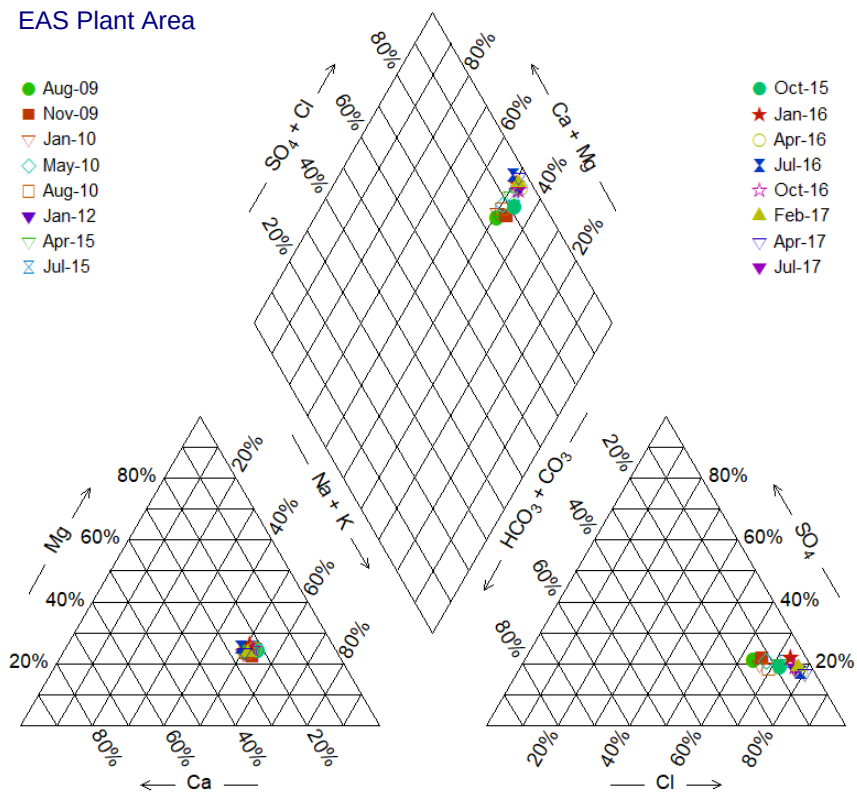
GW05 Piper Diagram

EAS Plant Area



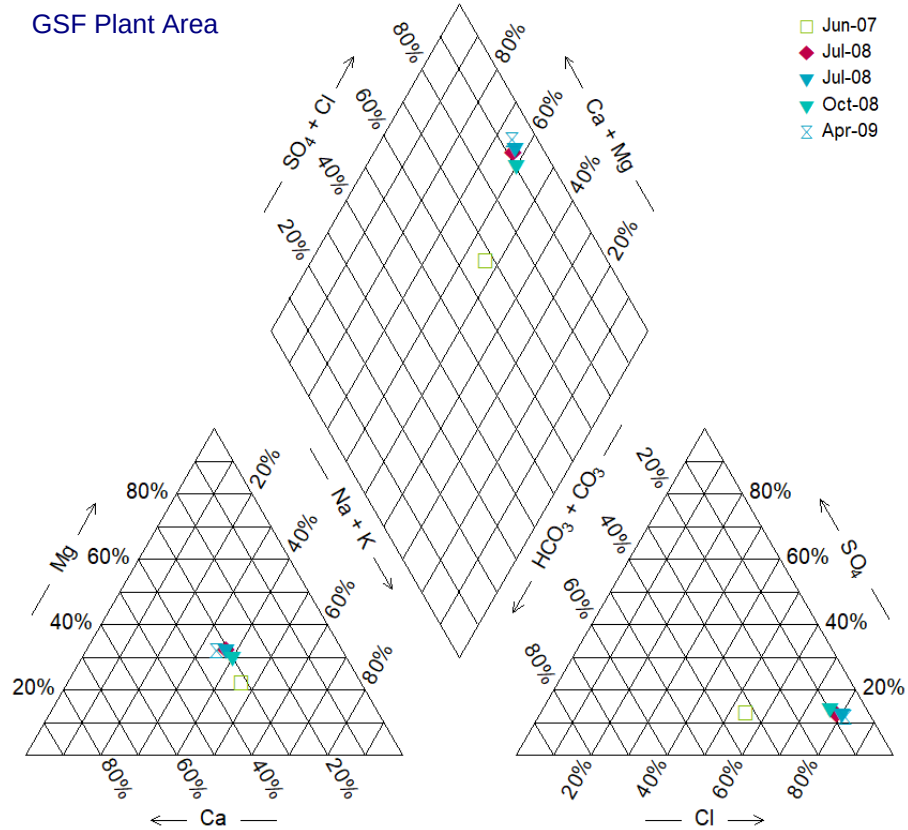
GW05A Piper Diagram

EAS Plant Area



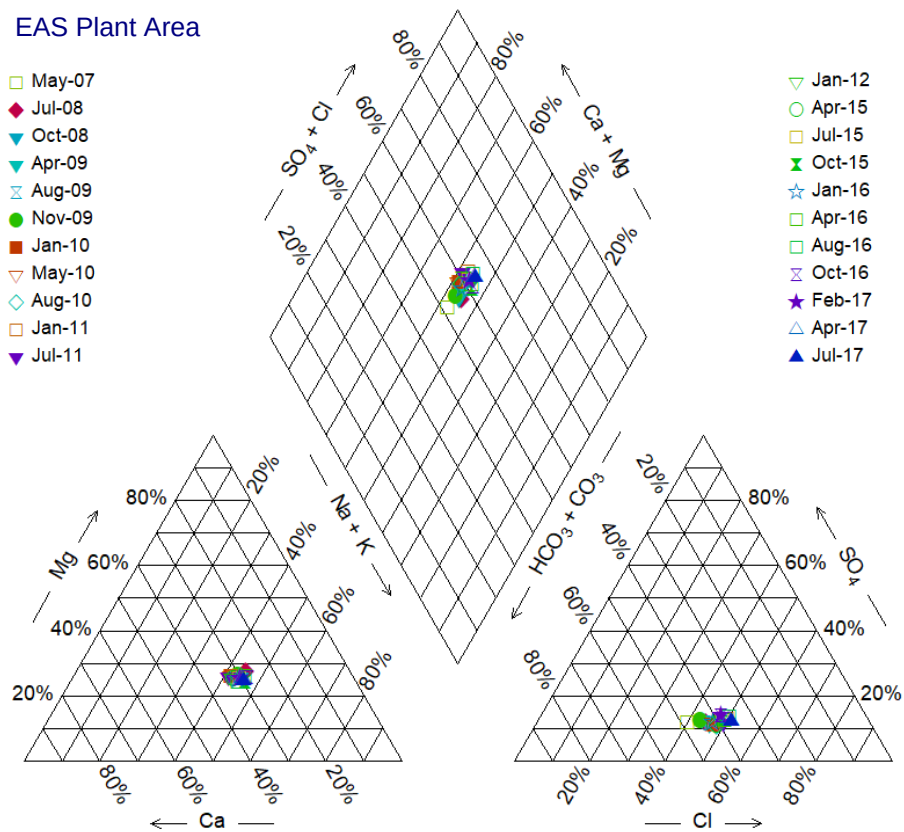
GW19 Piper Diagram

GSF Plant Area



EPMB04 Piper Diagram

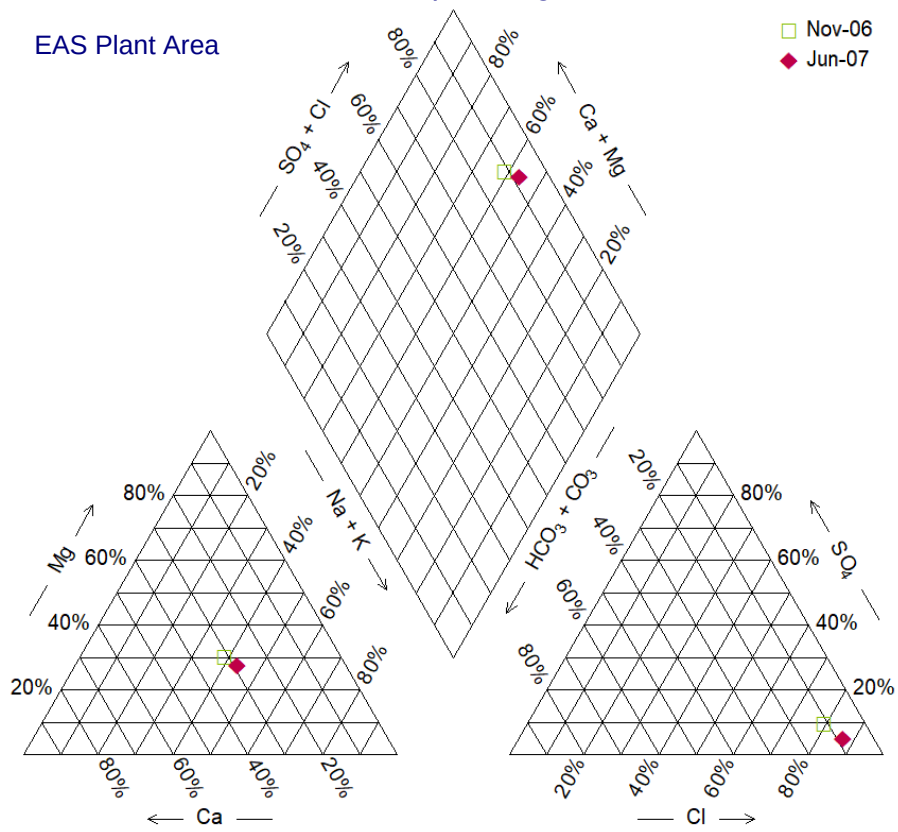
EAS Plant Area



GW14 Piper Diagram

EAS Plant Area

□ Nov-06
◆ Jun-07



APPENDIX 7C1

EAS Analyte Concentration Time Series Plots – By Analyte

EAS GSF Area

**Salinity
Chloride
Sulphate
Calcium
Sodium
Bicarbonate
Fluoride
Acidity**

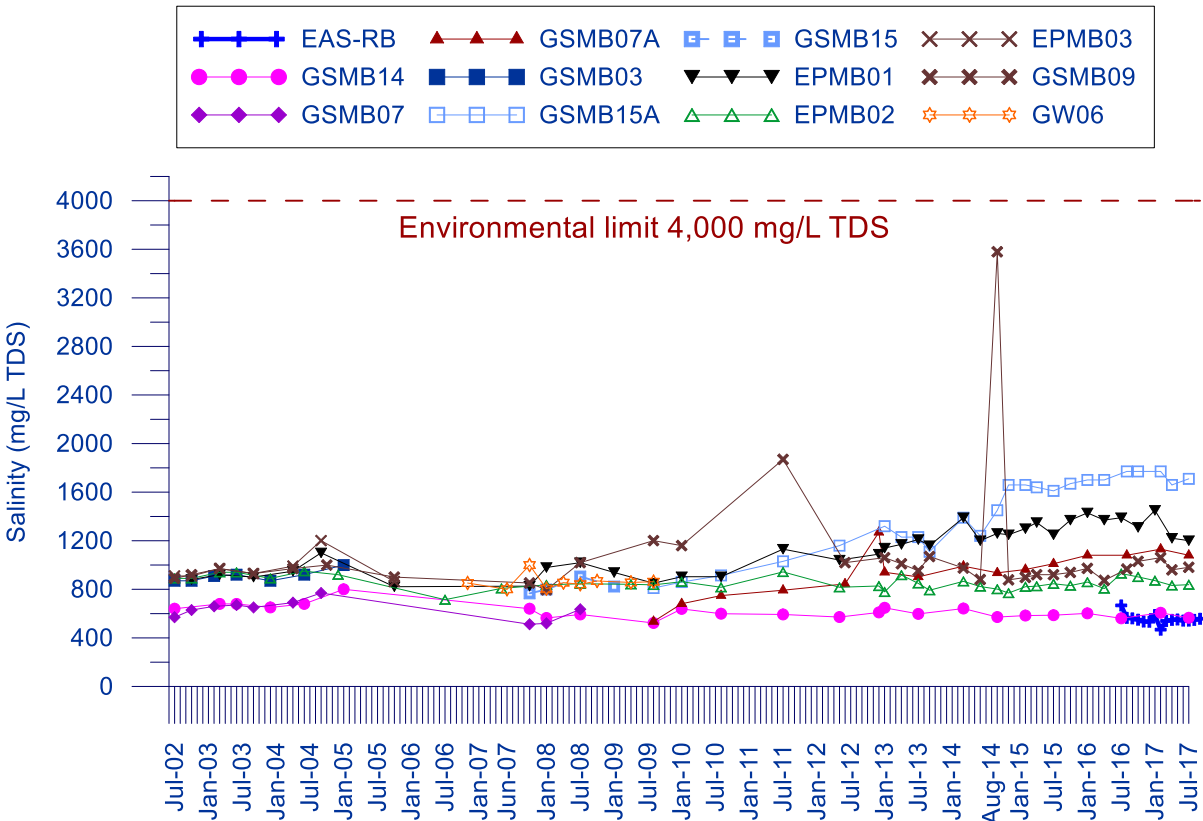
EAS Plant Area

**Salinity
Chloride
Sulphate
Calcium
Sodium
Bicarbonate
Fluoride
Acidity**

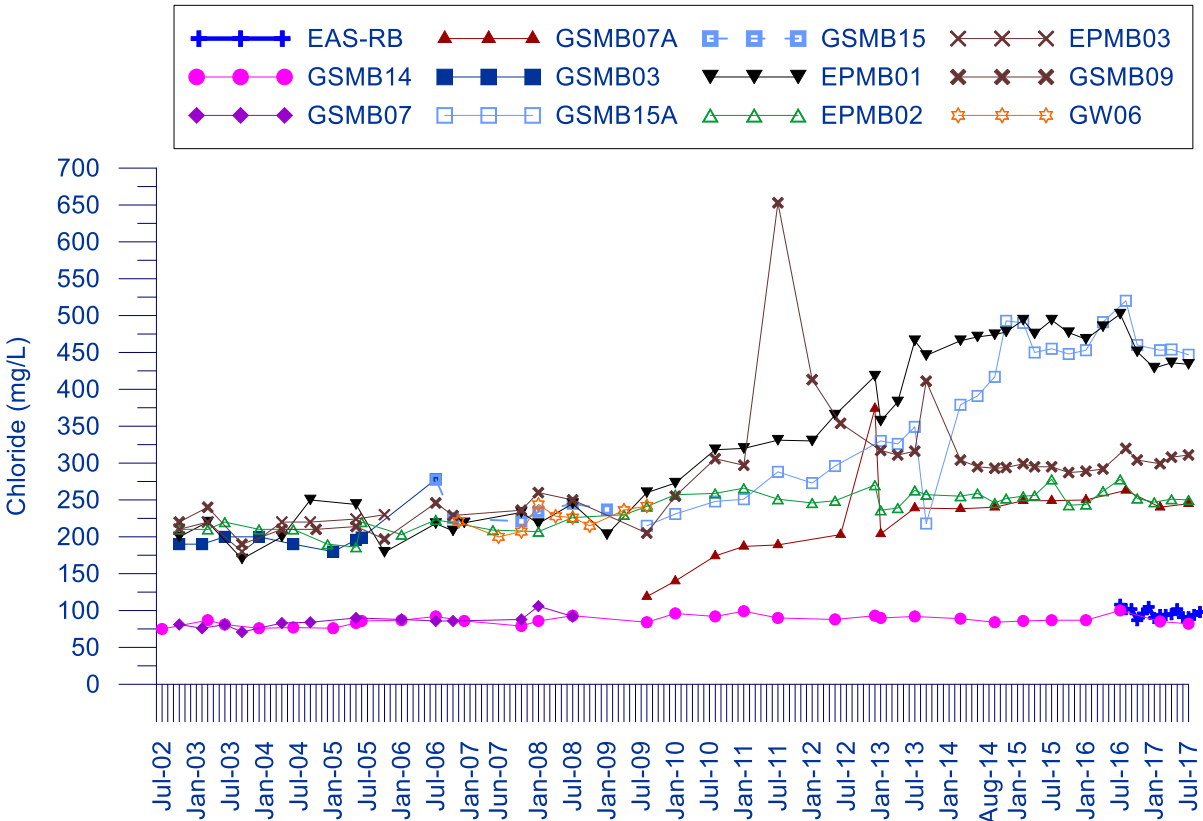
EAS Slimes Dams Area

**Salinity
Chloride
Sulphate
Calcium
Sodium
Bicarbonate
Fluoride
Acidity**

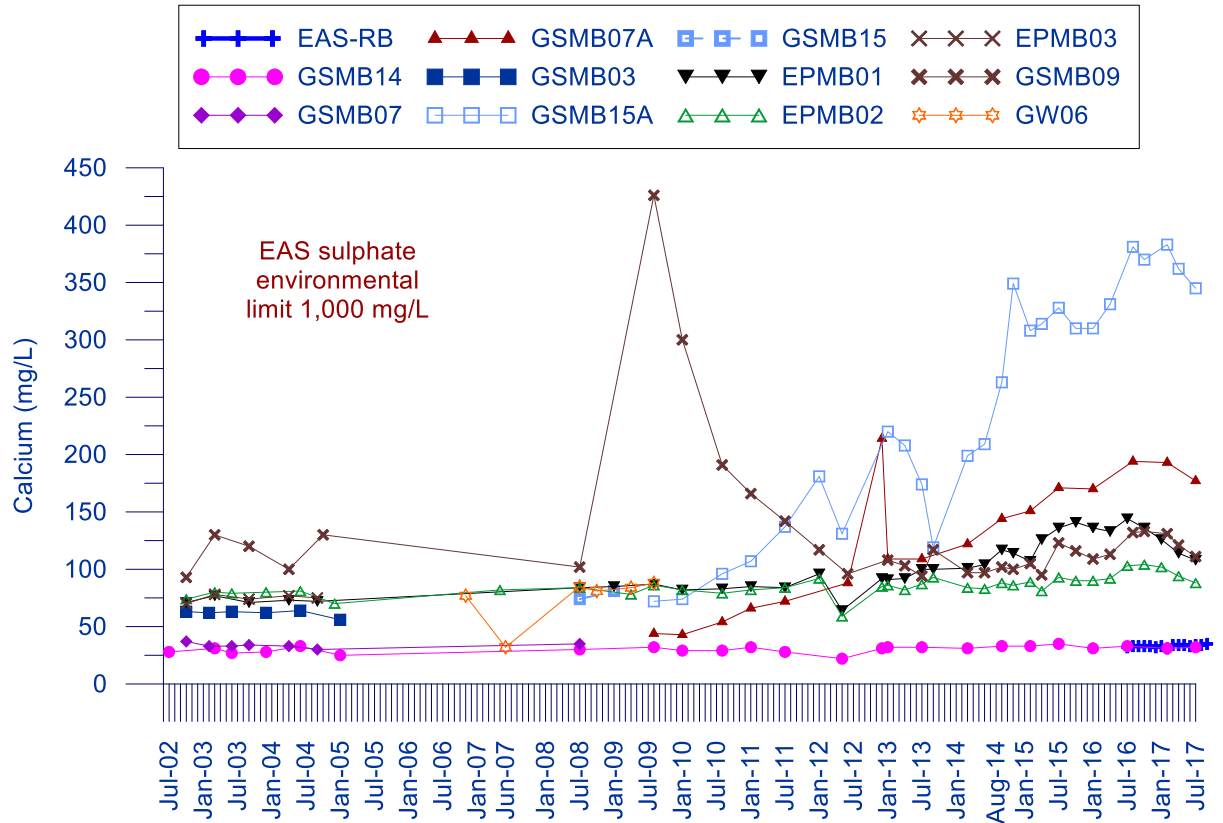
Eastern Aquifer System GSF Area Salinity



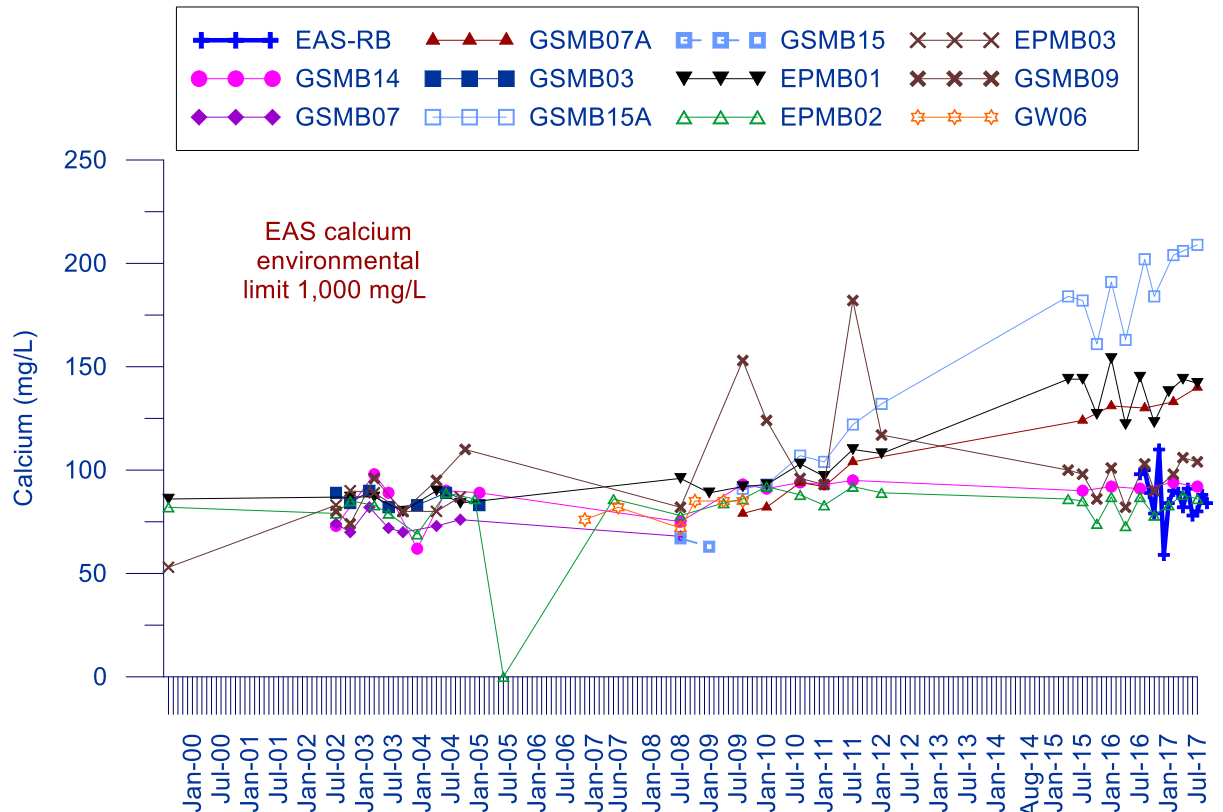
Eastern Aquifer System GSF Area Chloride



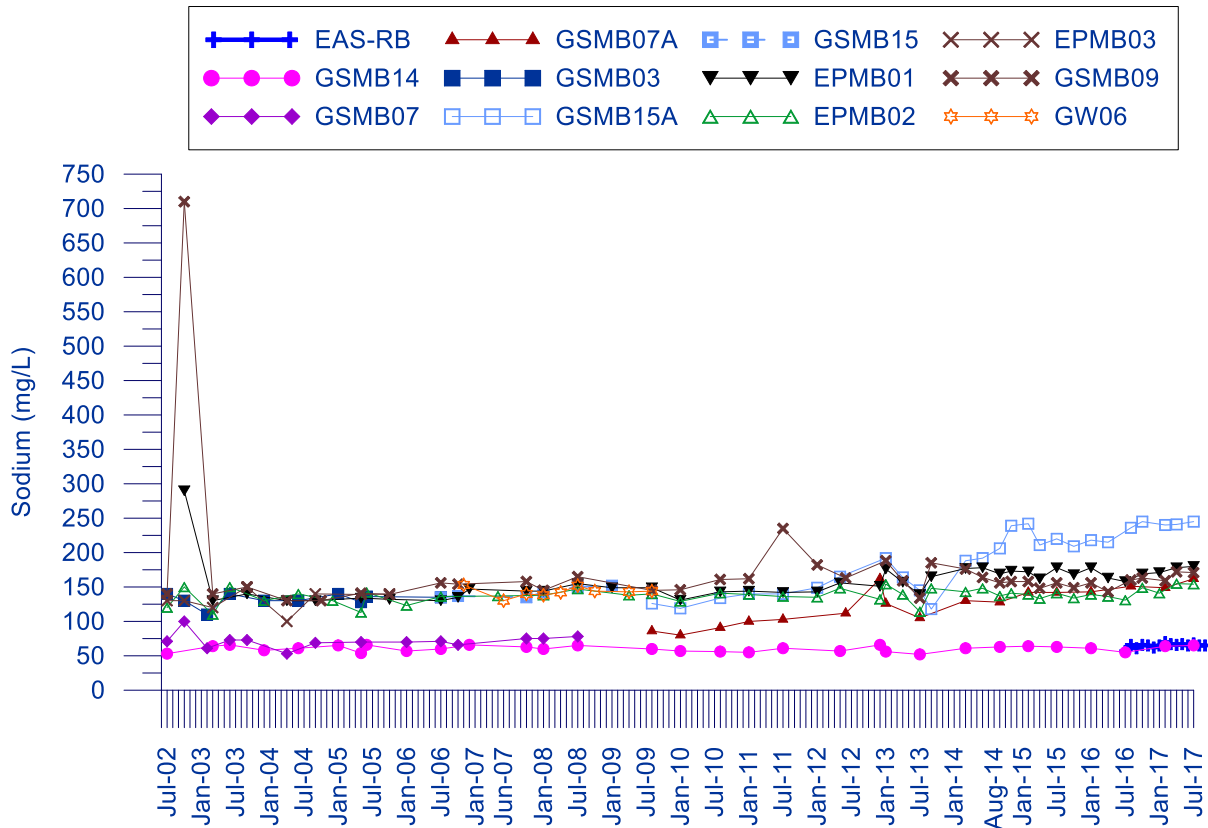
Eastern Aquifer System GSF Area Sulphate



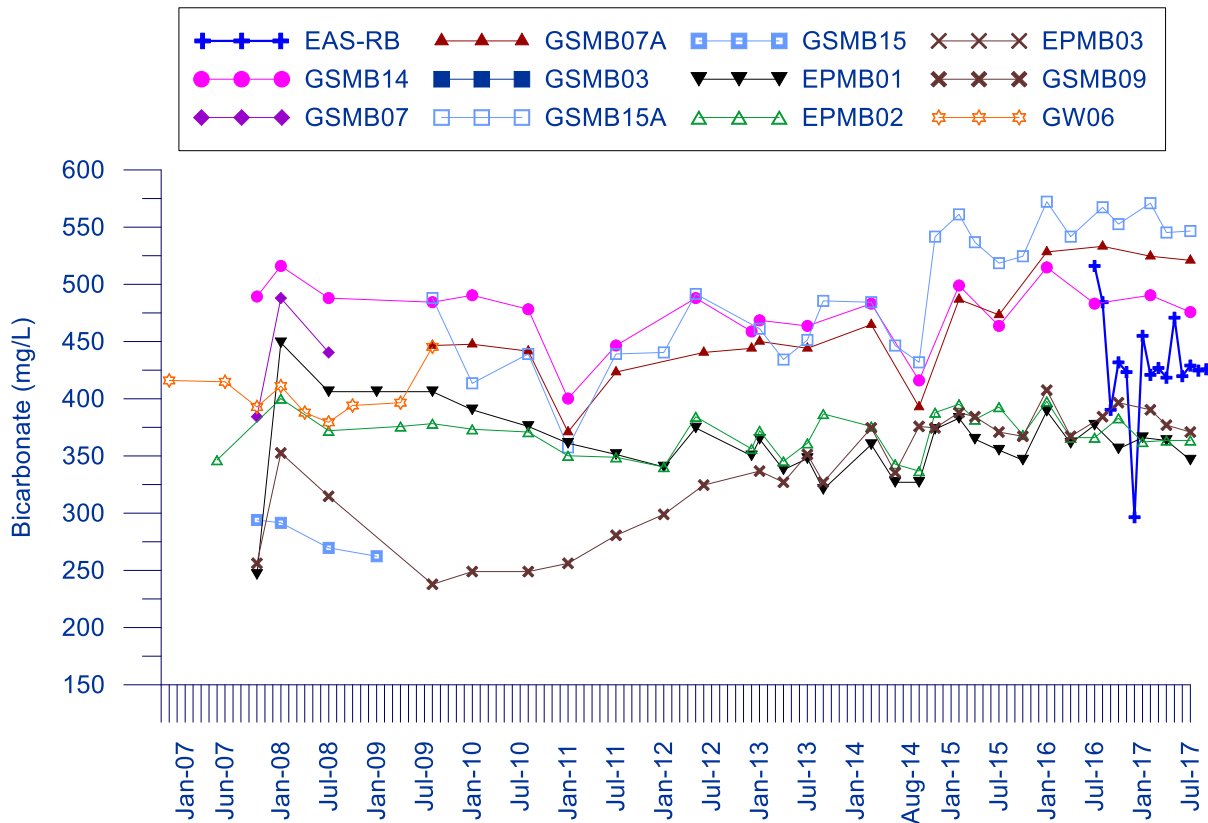
Eastern Aquifer System GSF Area Calcium



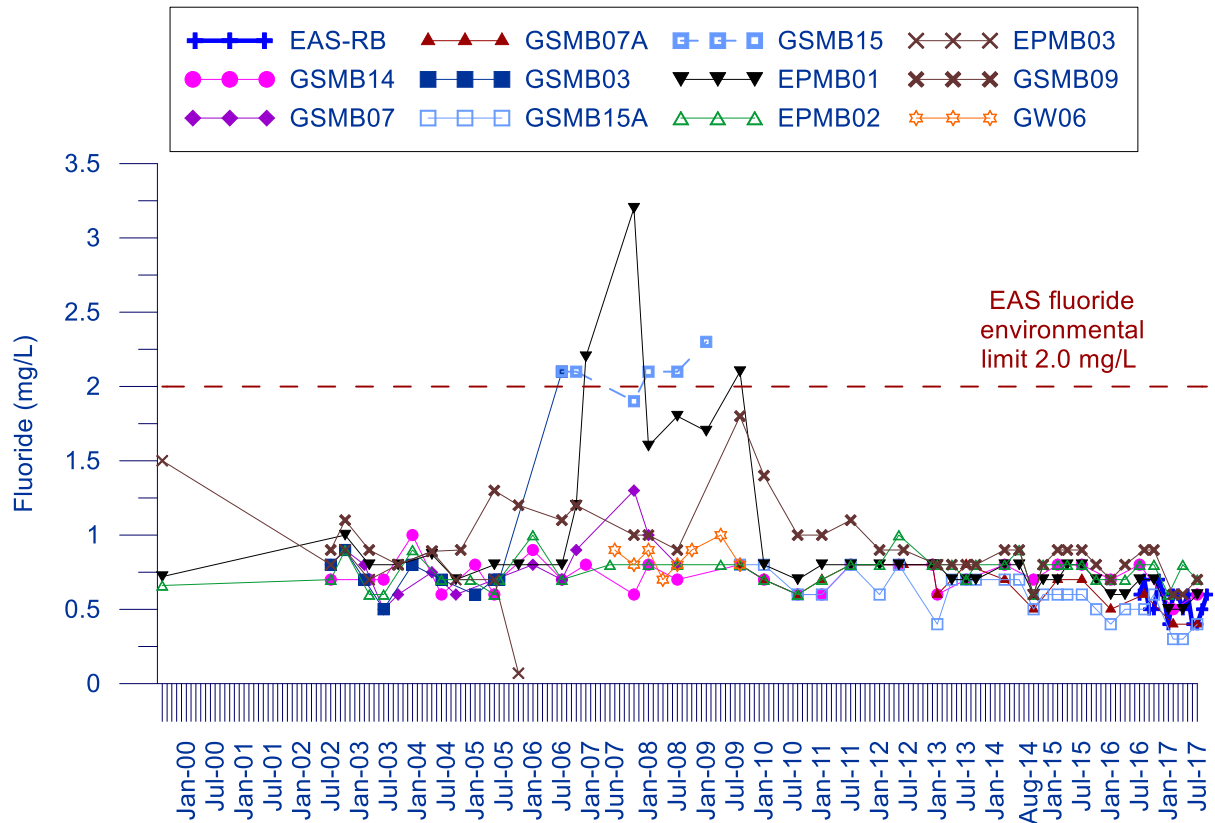
Eastern Aquifer System GSF Area Sodium



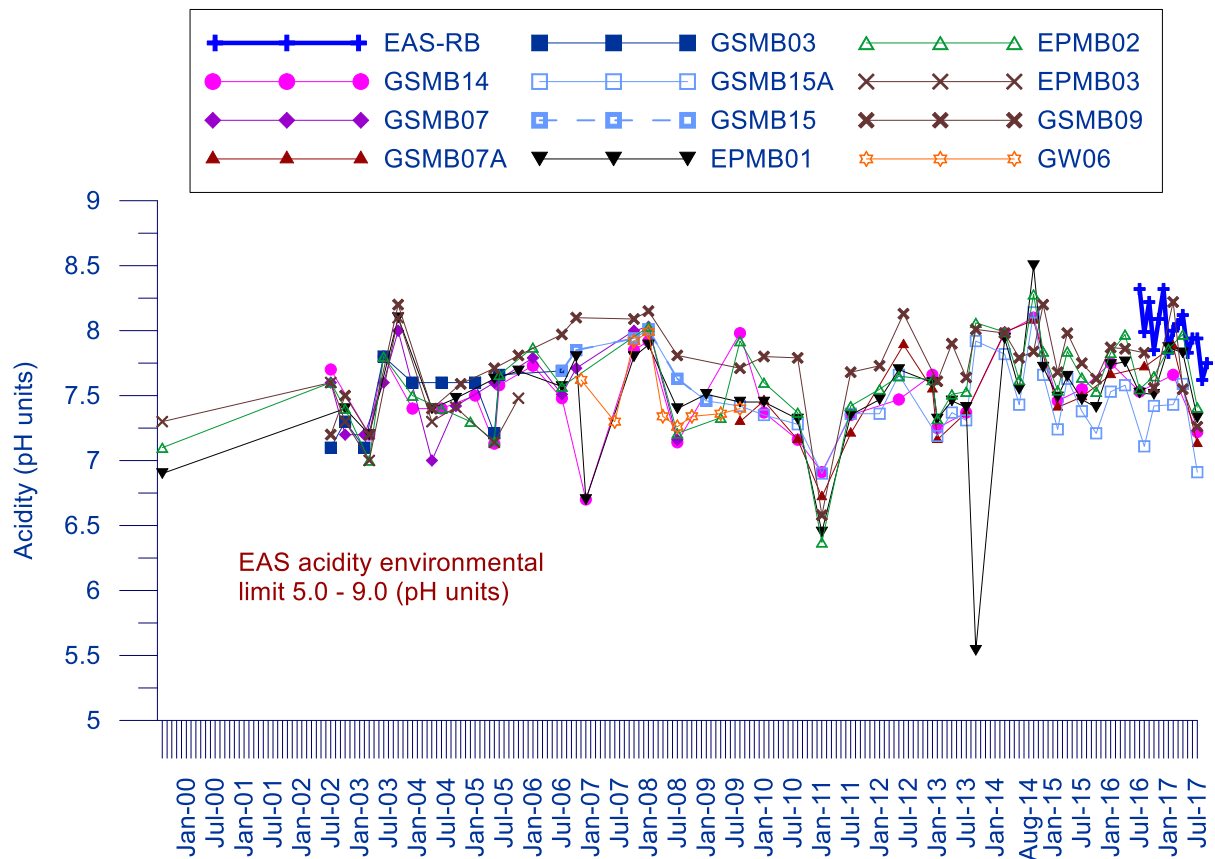
Eastern Aquifer System GSF Area Bicarbonate



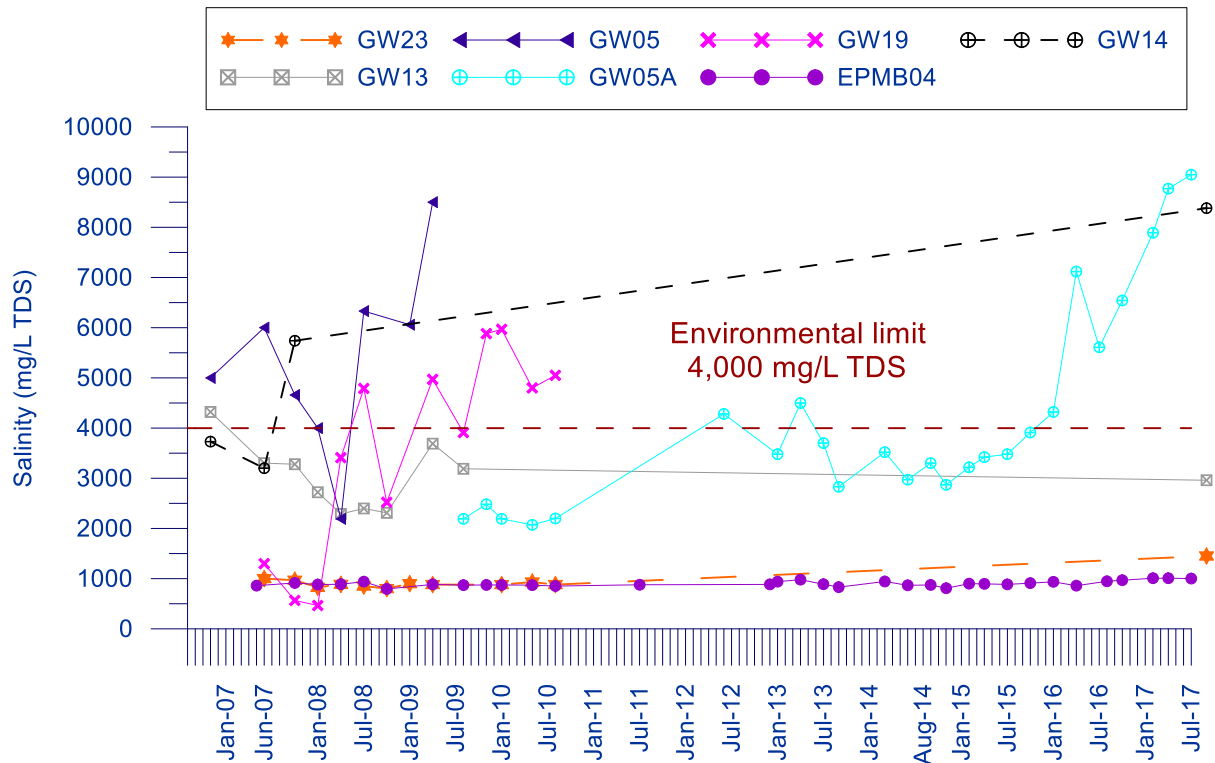
Eastern Aquifer System GSF Area Fluoride



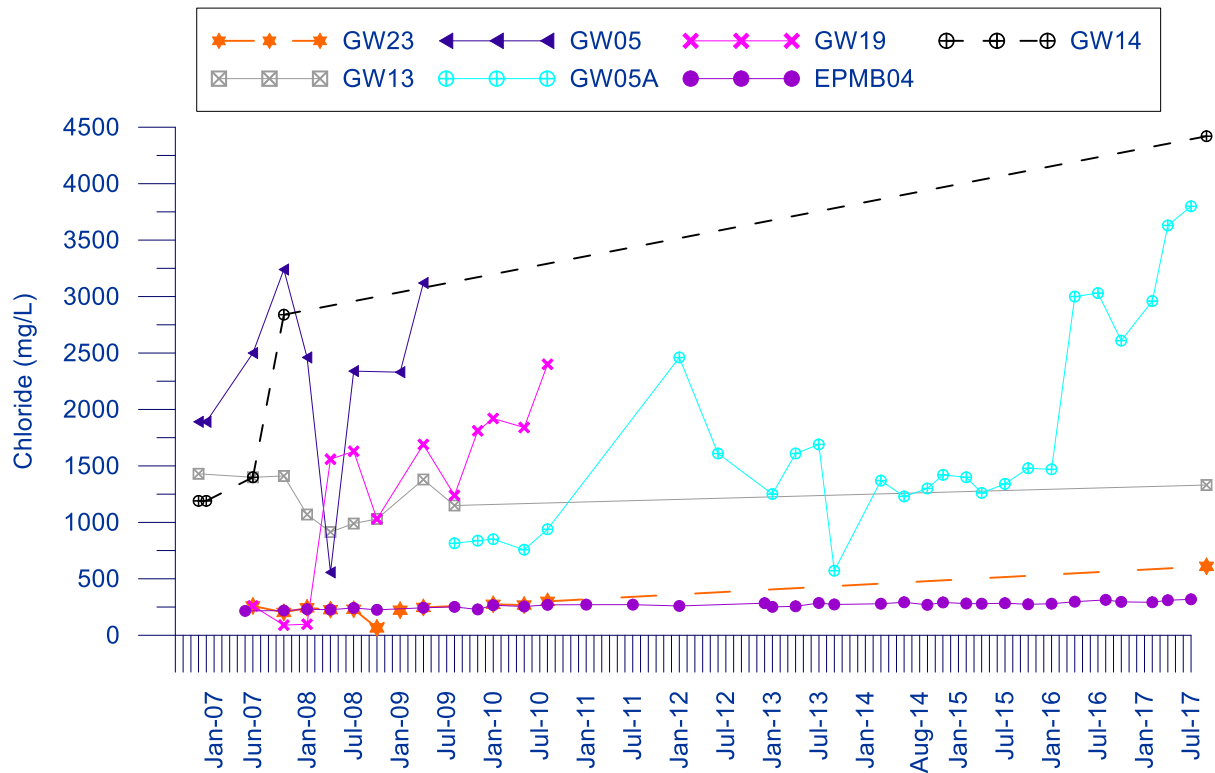
Eastern Aquifer System GSF Area Acidity



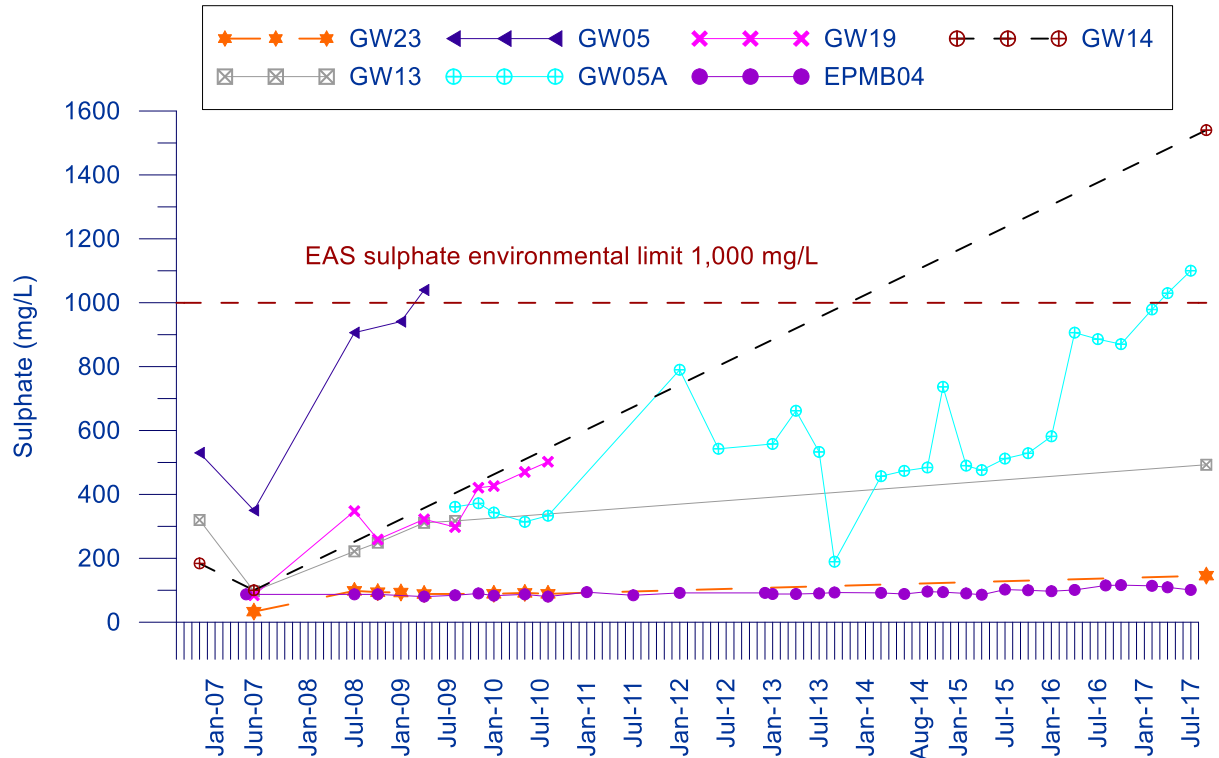
Eastern Aquifer System Plant Area Salinity



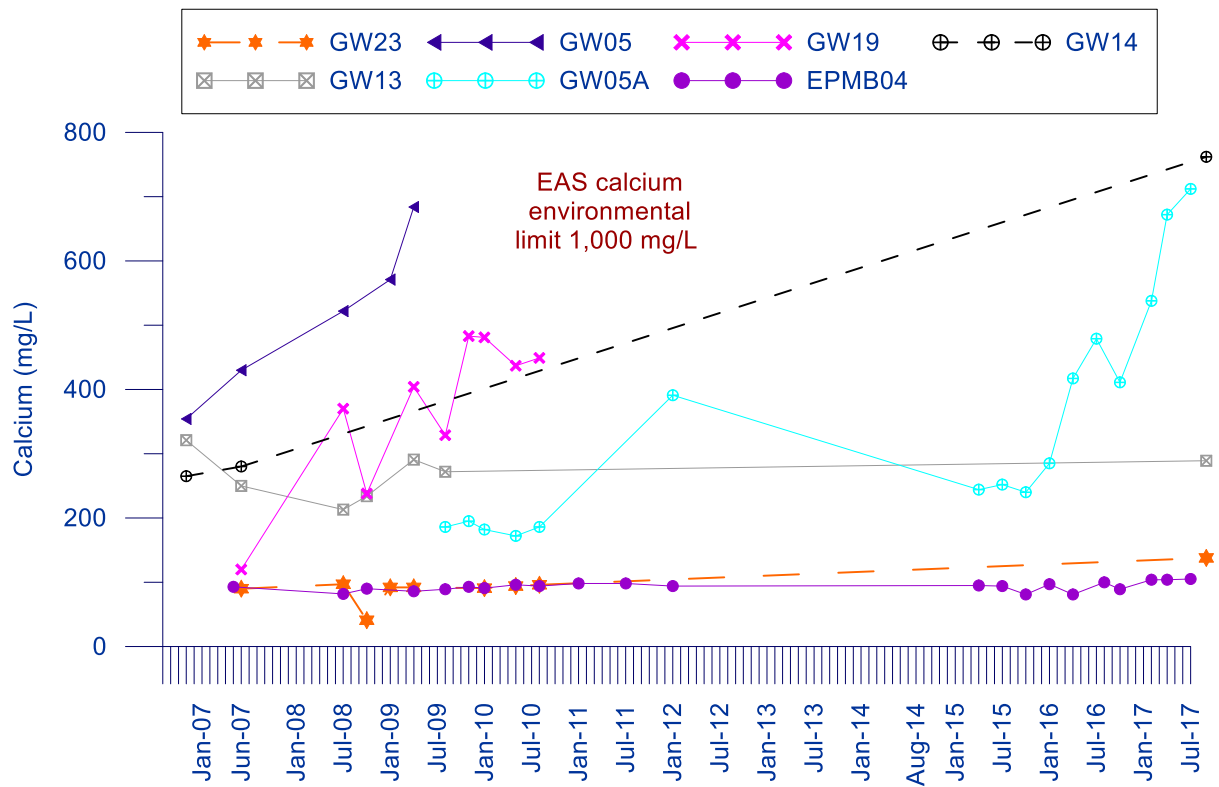
Eastern Aquifer System Plant Area Chloride



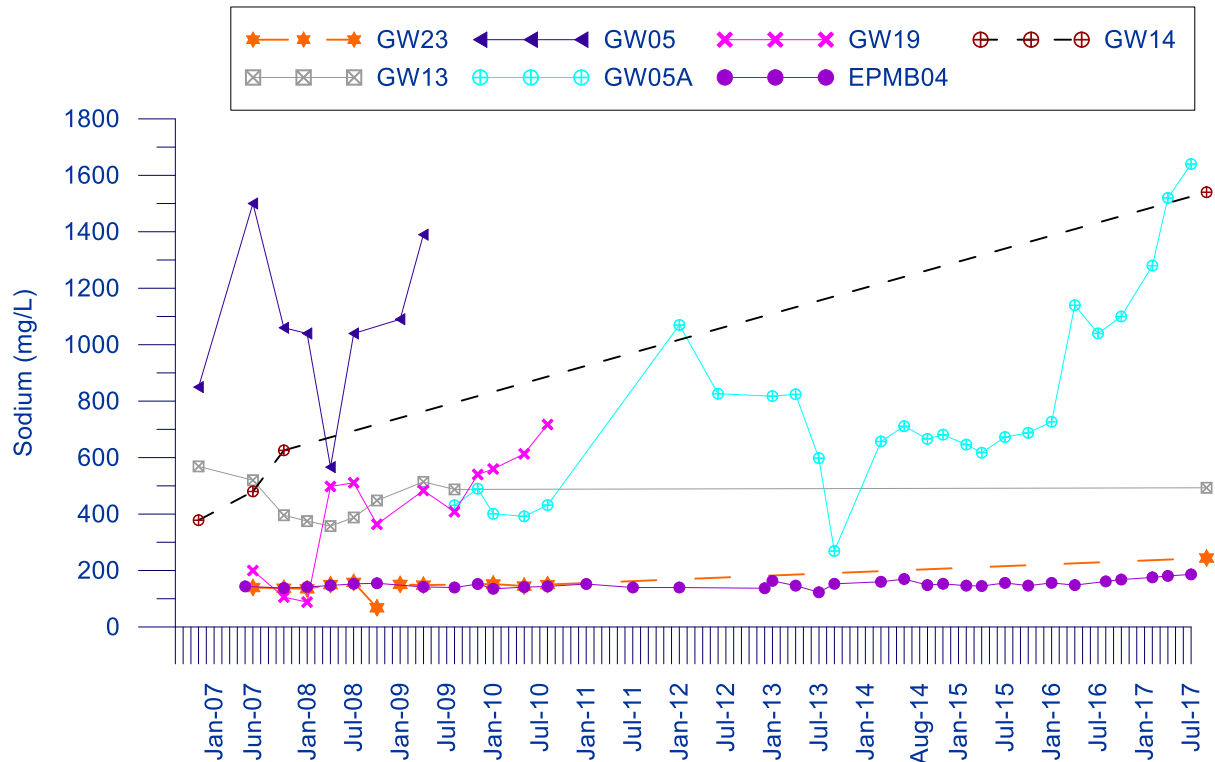
Eastern Aquifer System Plant Area Sulphate



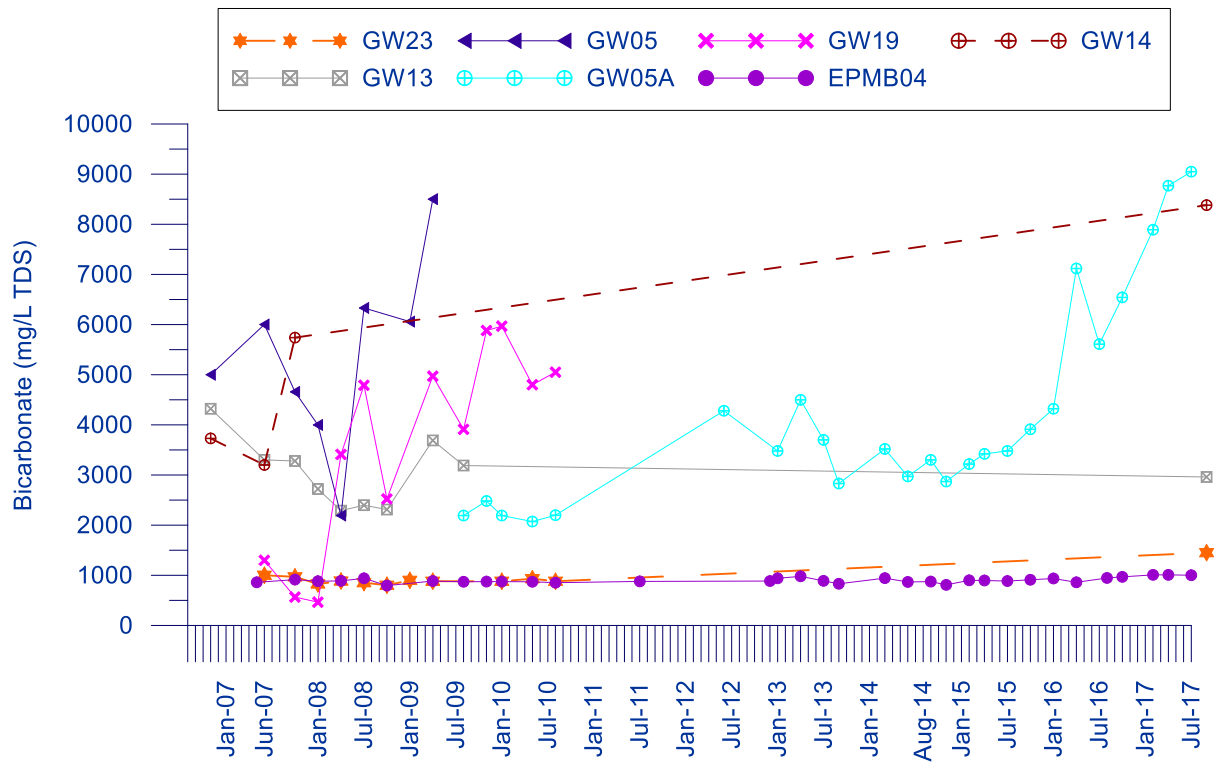
Eastern Aquifer System Plant Area Calcium



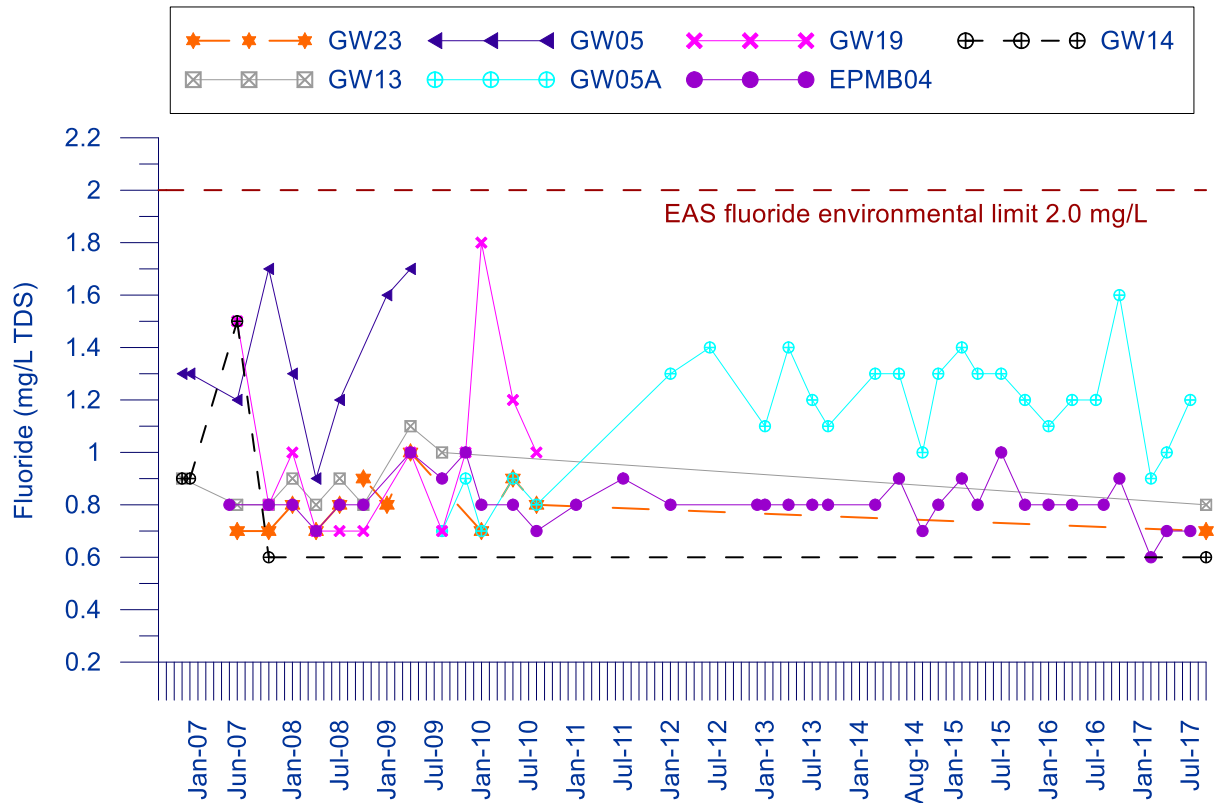
Eastern Aquifer System Plant Area Sodium



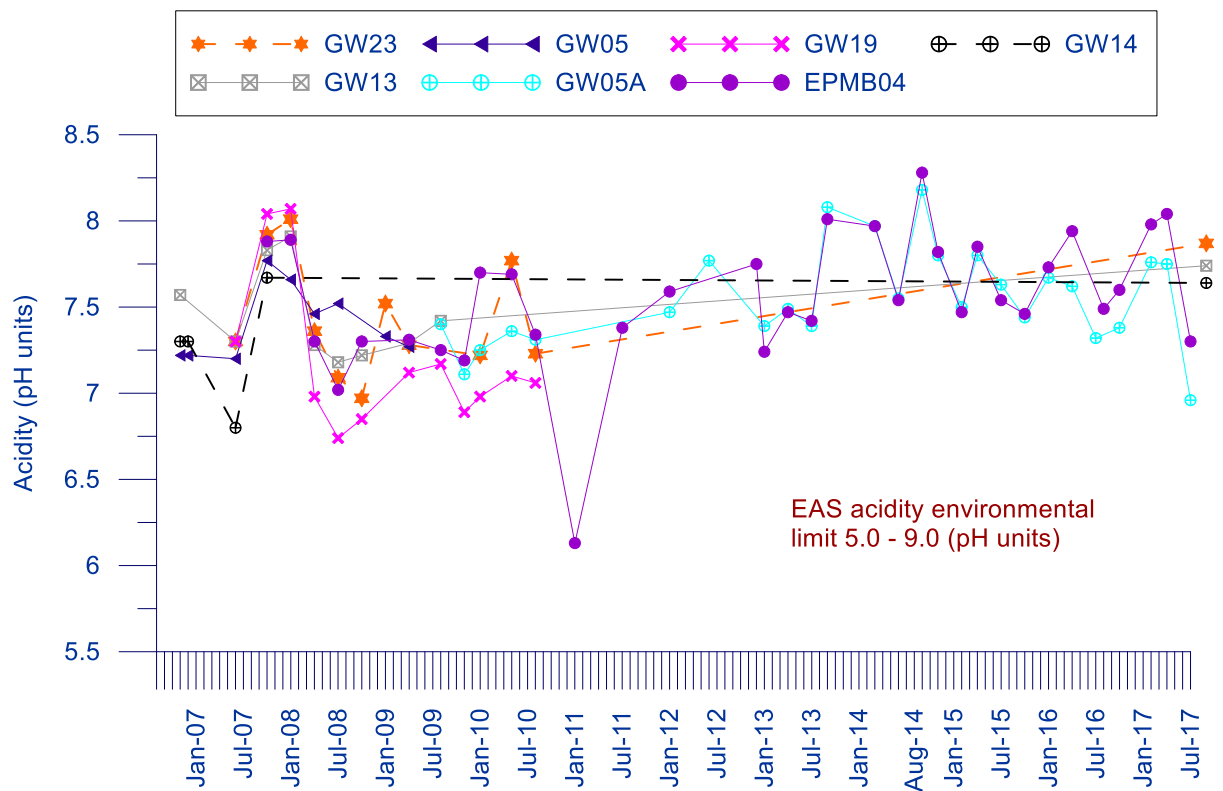
Eastern Aquifer System Plant Area Bicarbonate



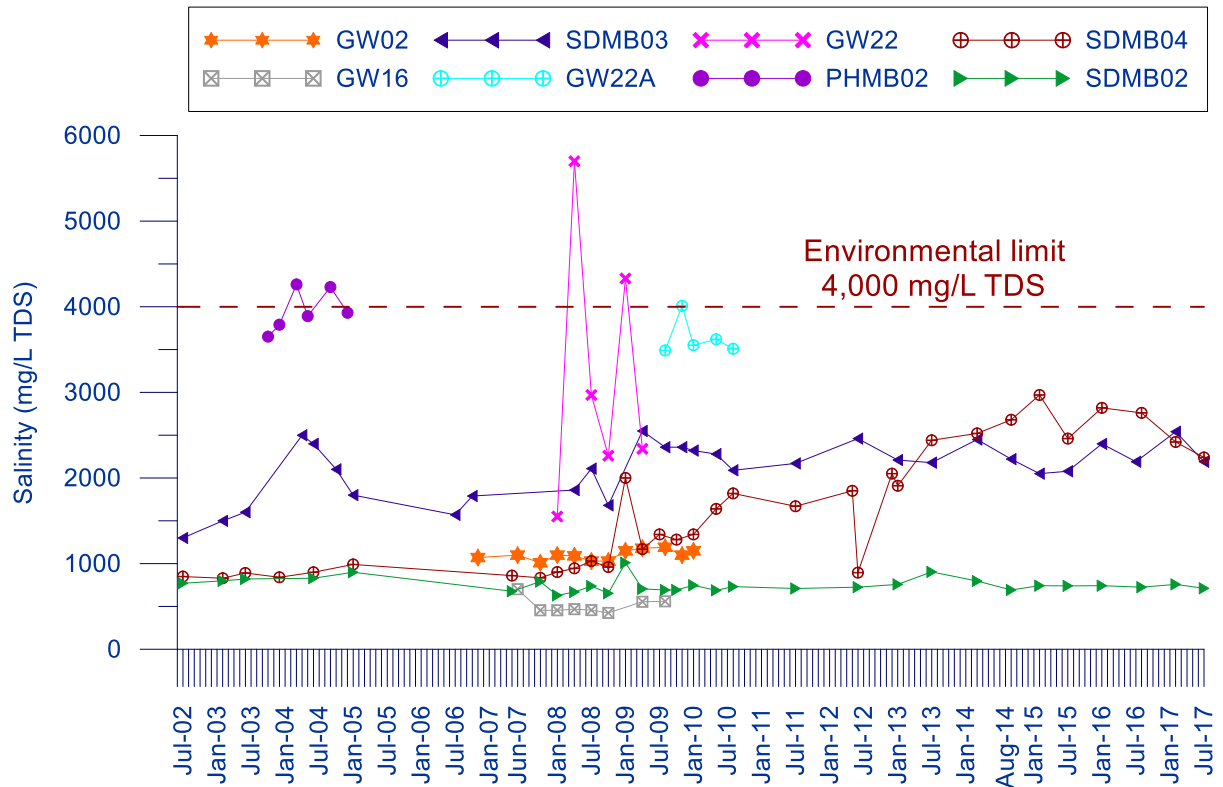
Eastern Aquifer System Plant Area Fluoride



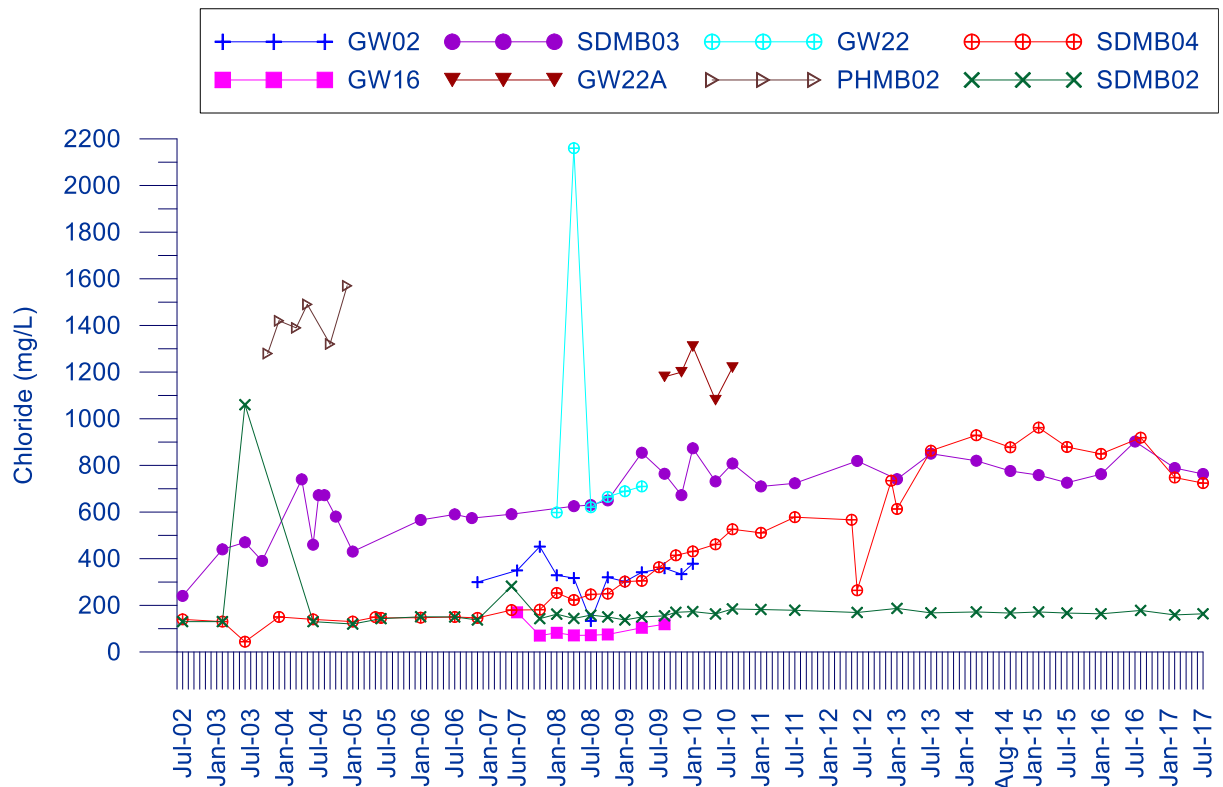
Eastern Aquifer System Plant Area Acidity



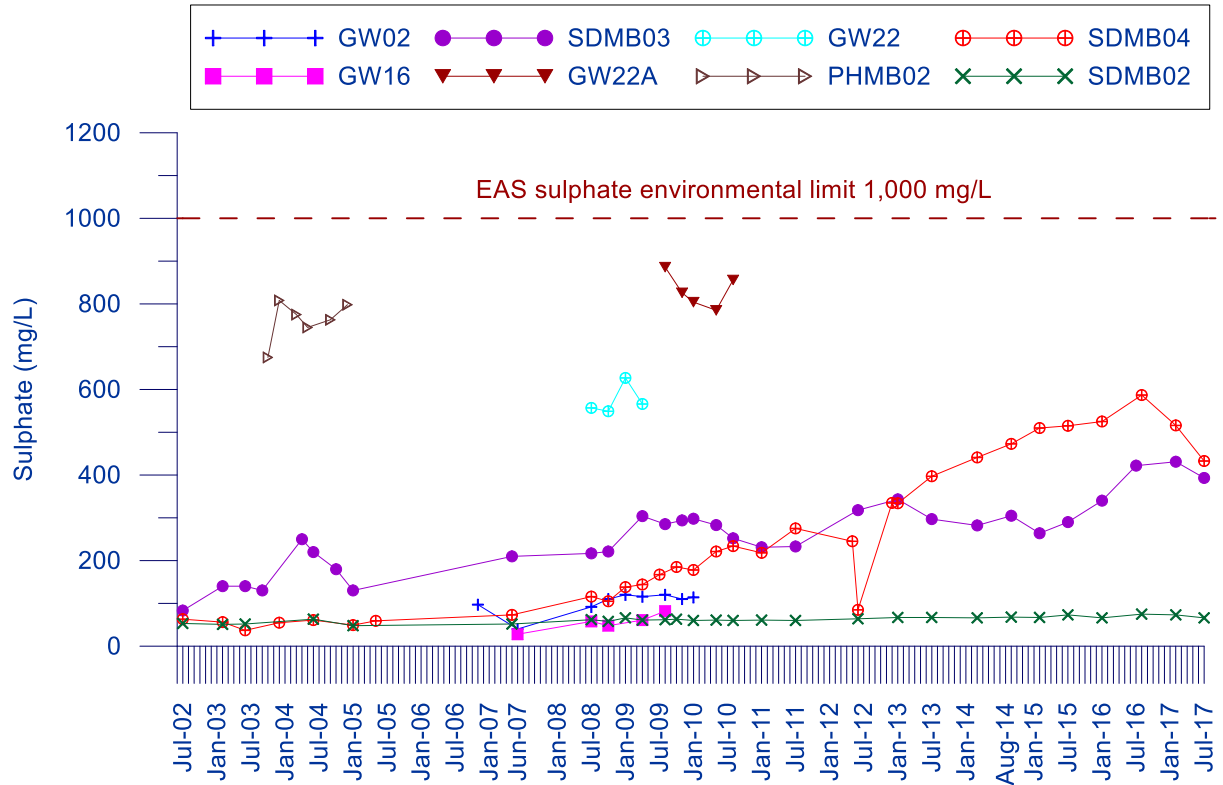
Eastern Aquifer System Slimes Dams Area Salinity



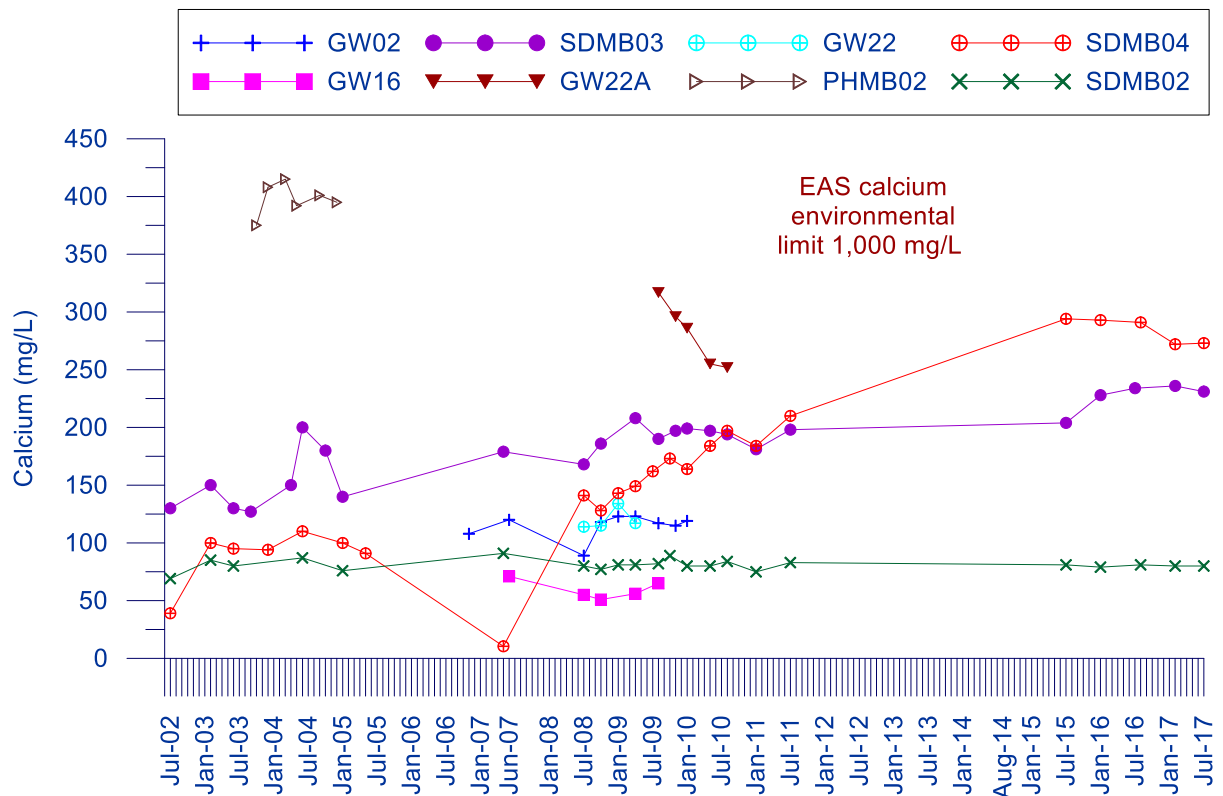
Eastern Aquifer System Slimes Dams Area Chloride



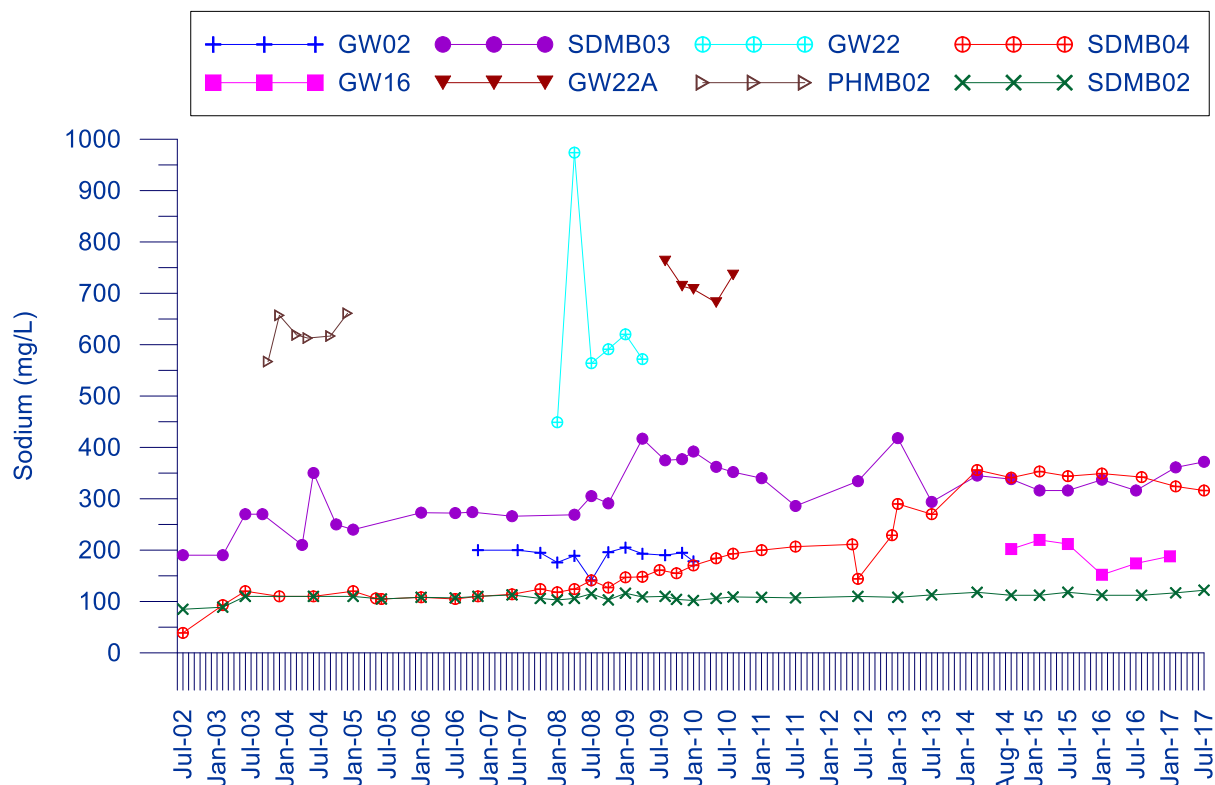
Eastern Aquifer System Slimes Dams Area Sulphate



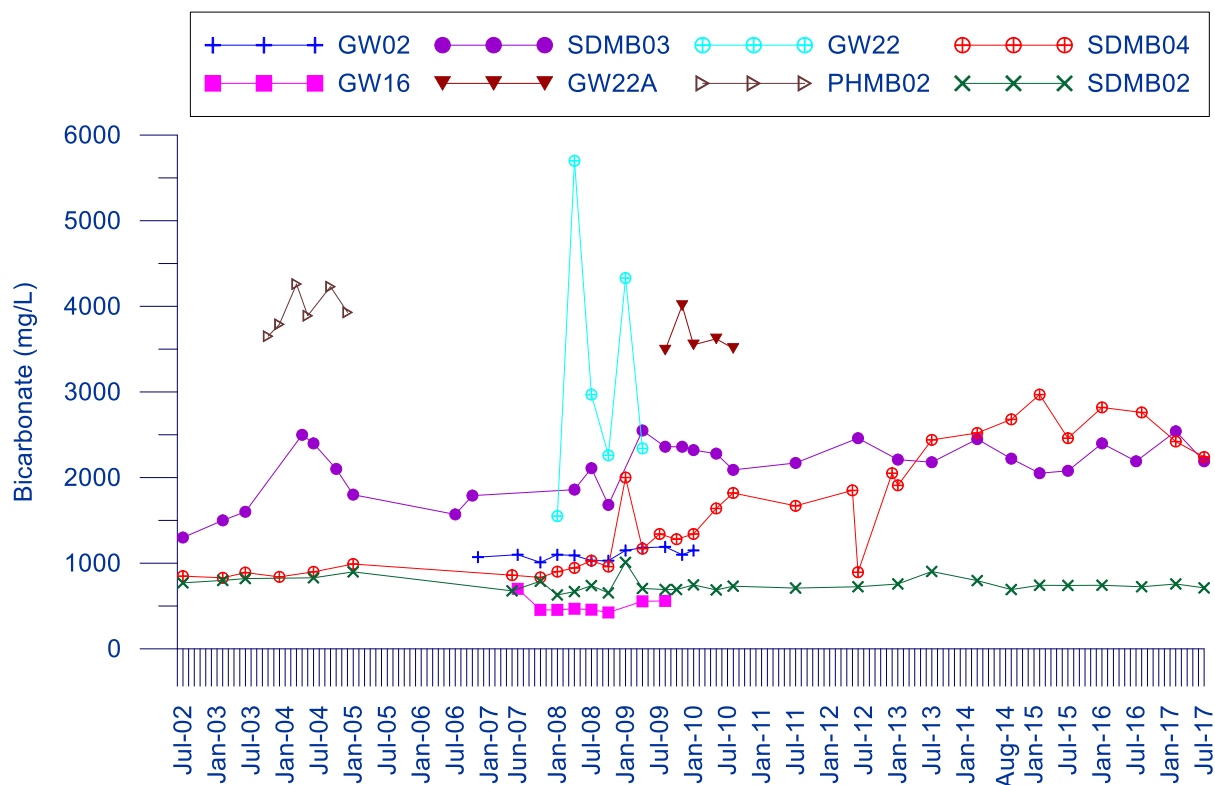
Eastern Aquifer System Slimes Dams Area Calcium



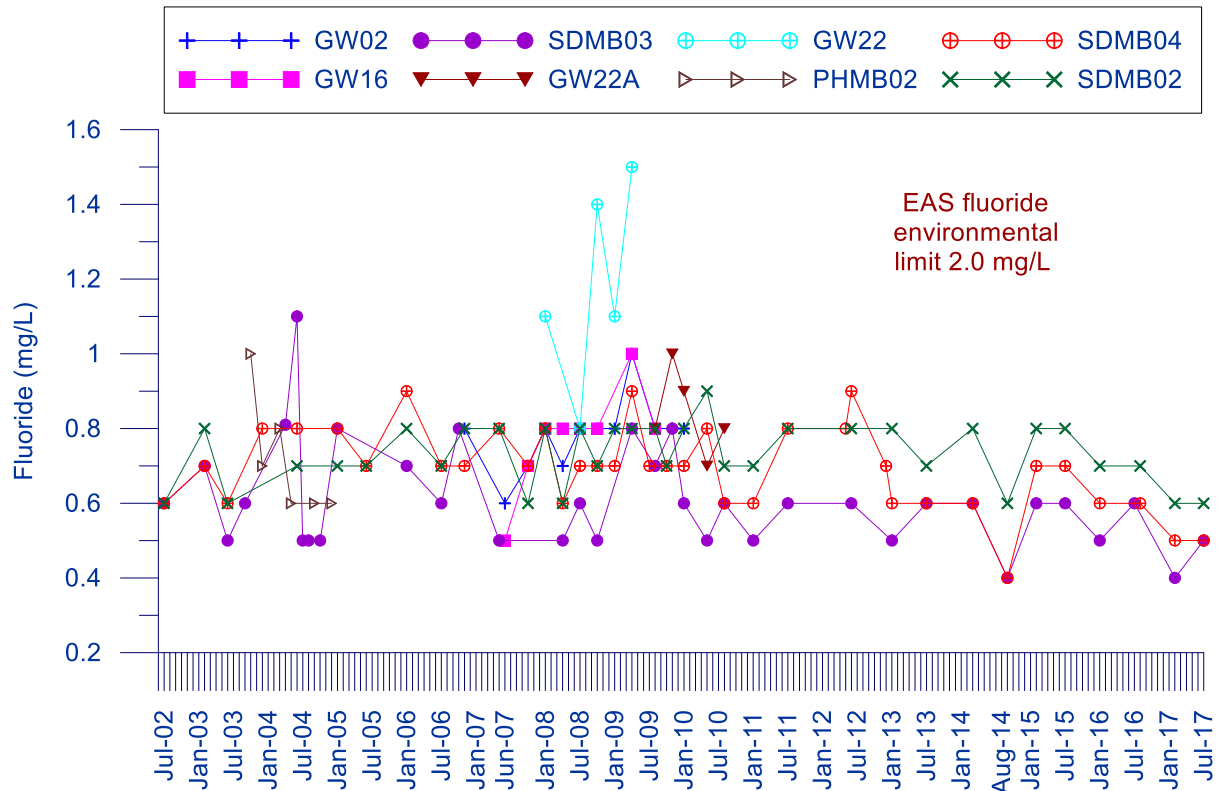
Eastern Aquifer System Slimes Dams Area Sodium



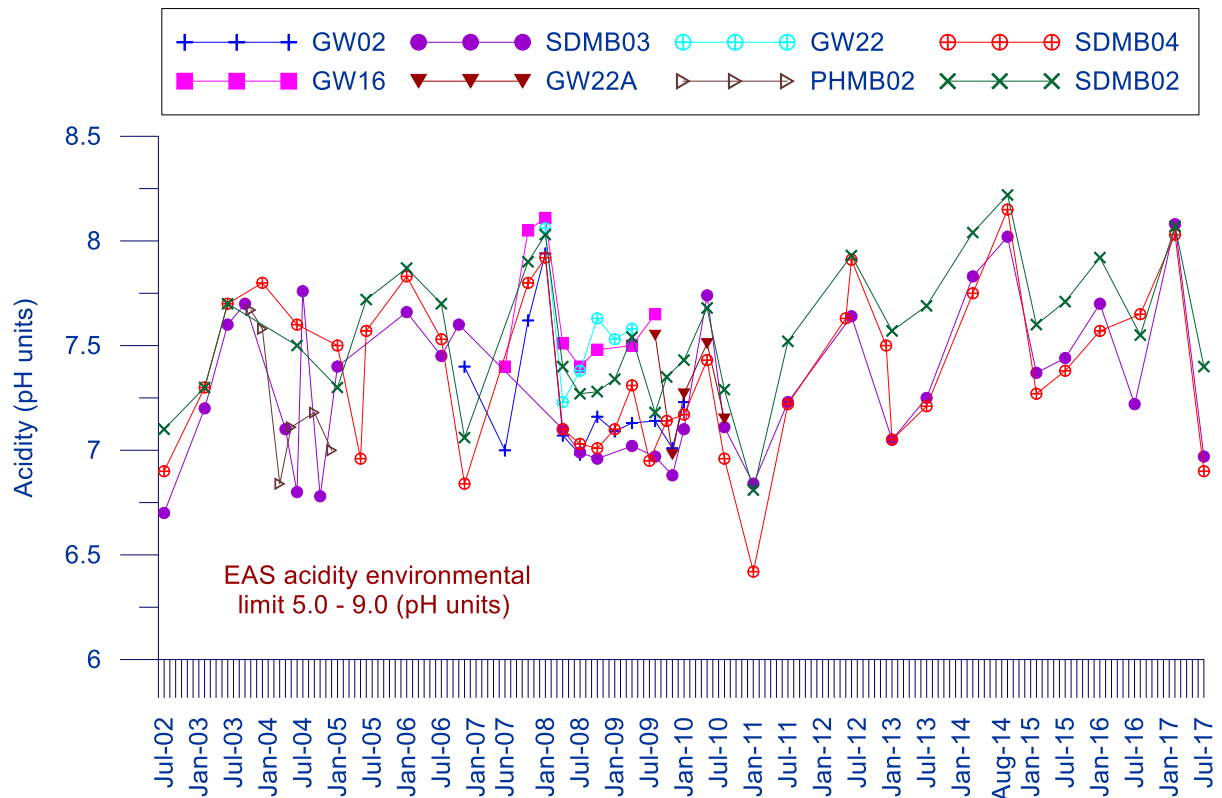
Eastern Aquifer System Slimes Dams Area Bicarbonate



Eastern Aquifer System Slimes Dams Area Fluoride



Eastern Aquifer System Slimes Dams Area Acidity



APPENDIX 7C2

EAS Analyte Concentration Time Series Plots – By Bore (arranged from north to south)

EAS GSF Area

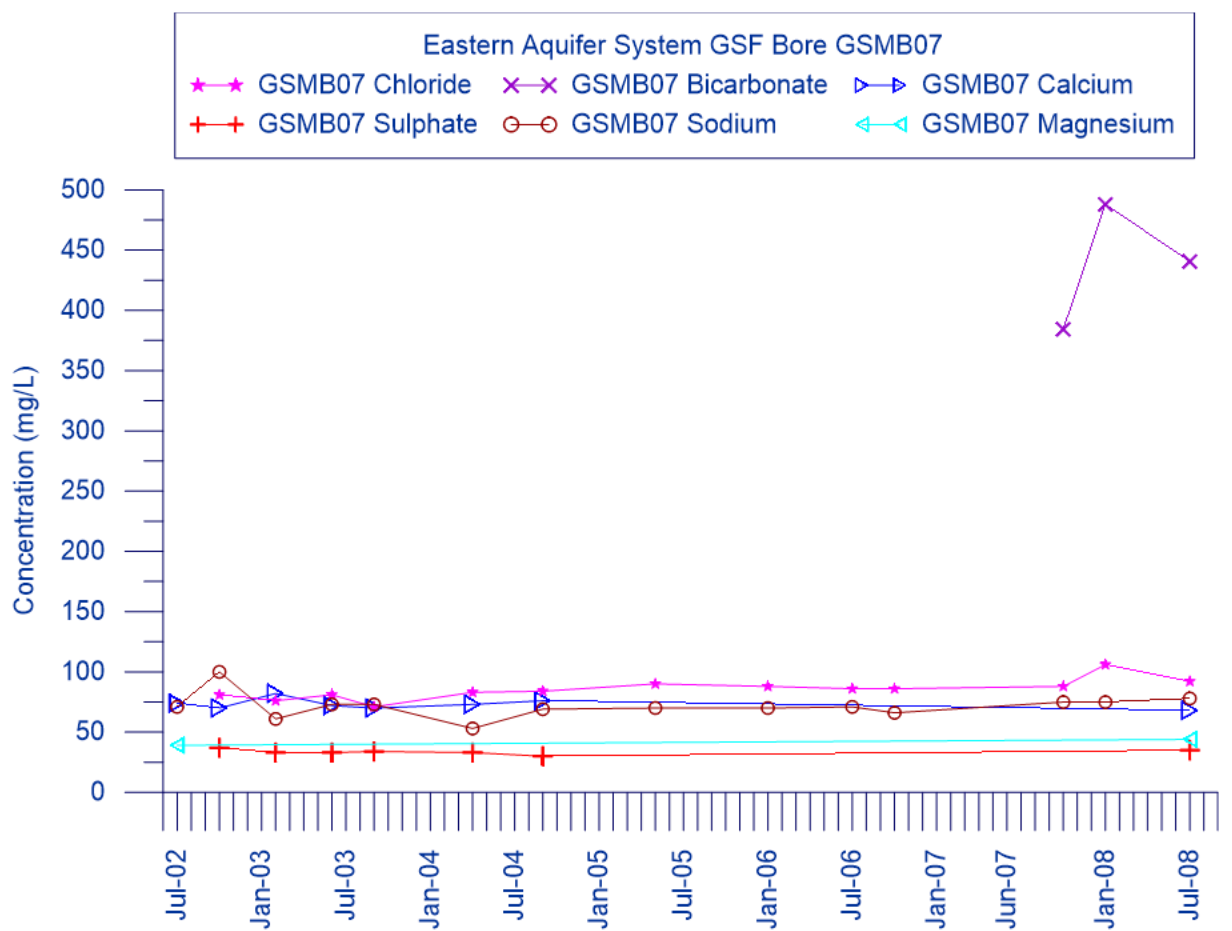
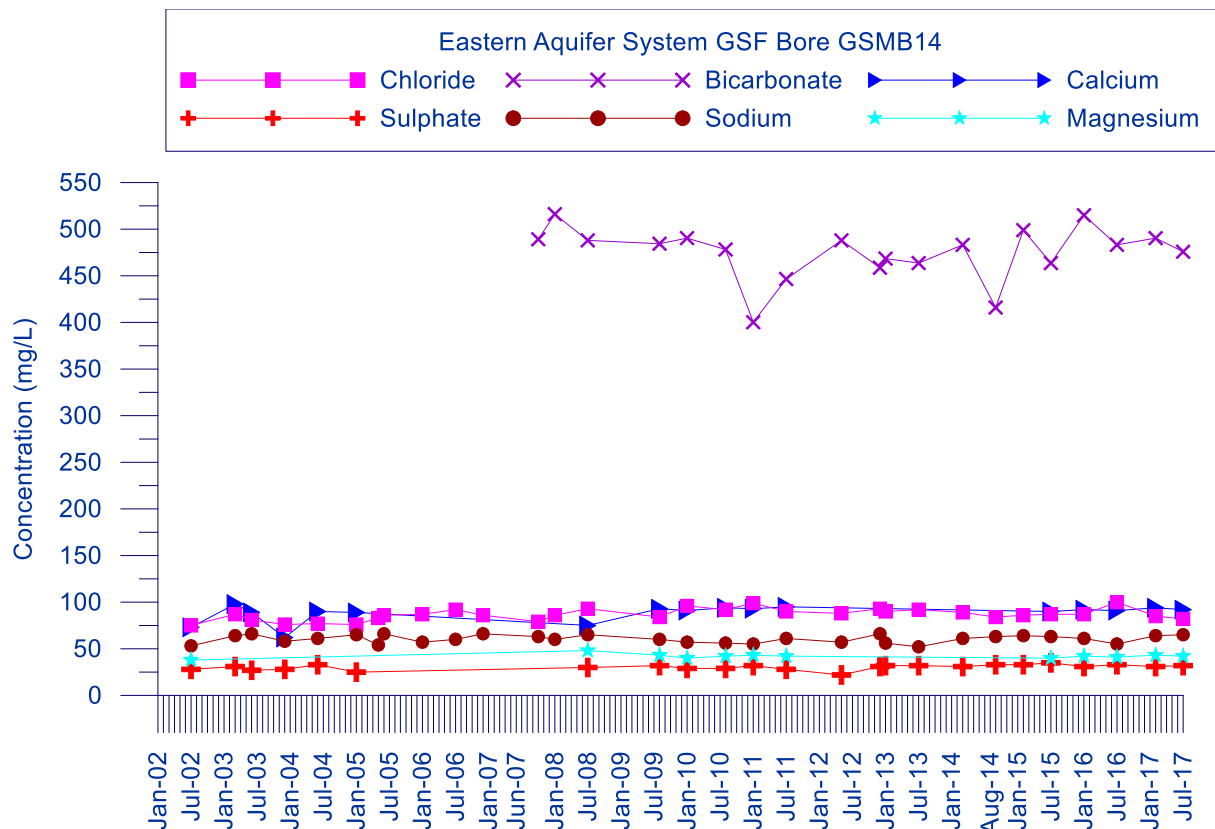
**GSMB14
GSMB07
GSMB07A
GSMB03
GSMB15A
GSMB15
EPMB01
EPMB02
EPMB03
GSMB09
GW06**

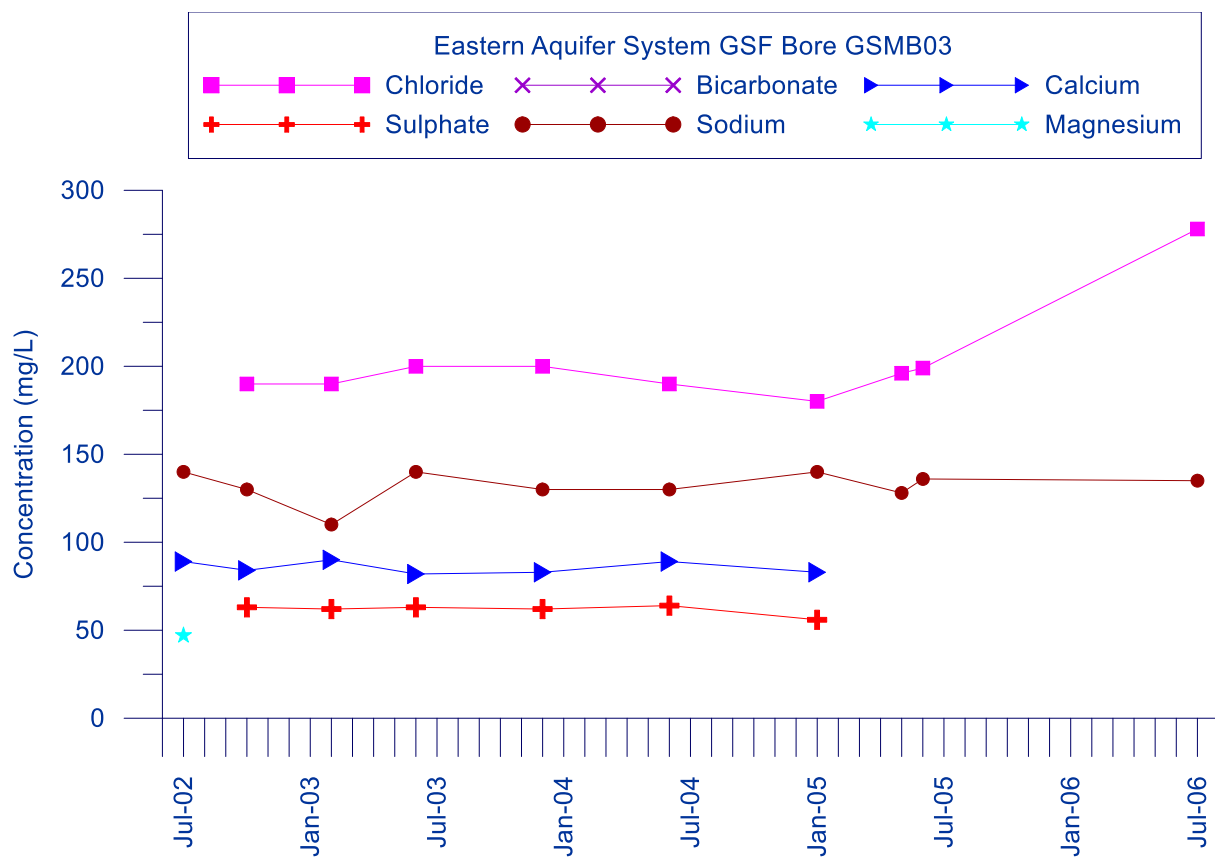
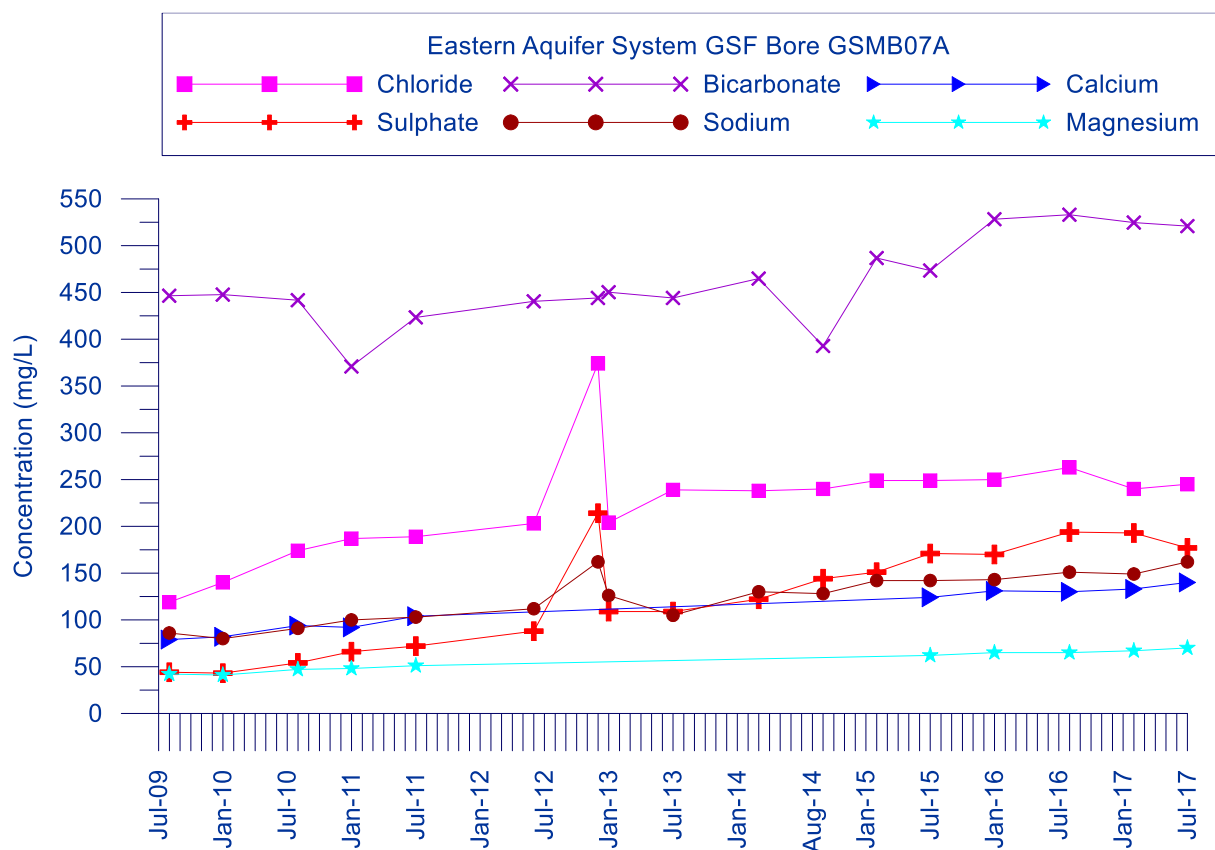
EAS Plant Area

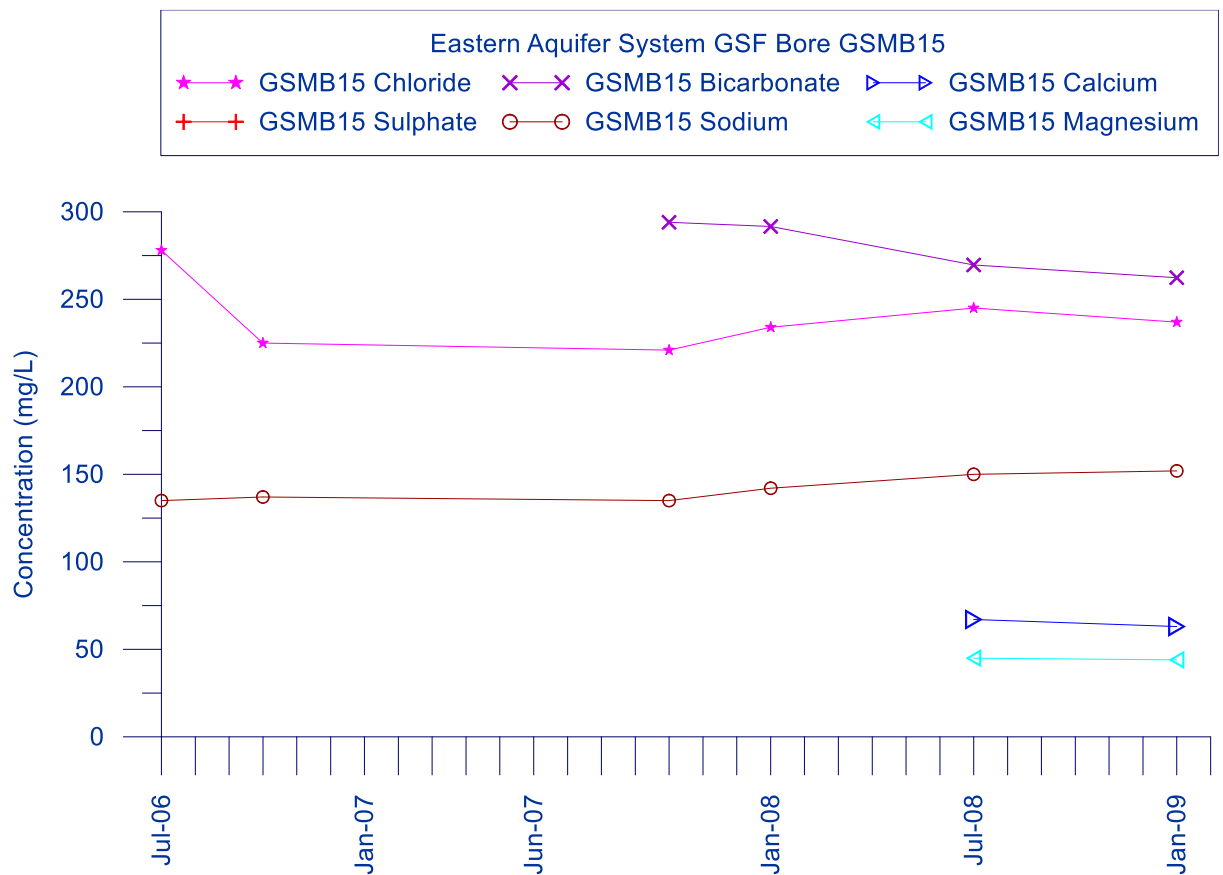
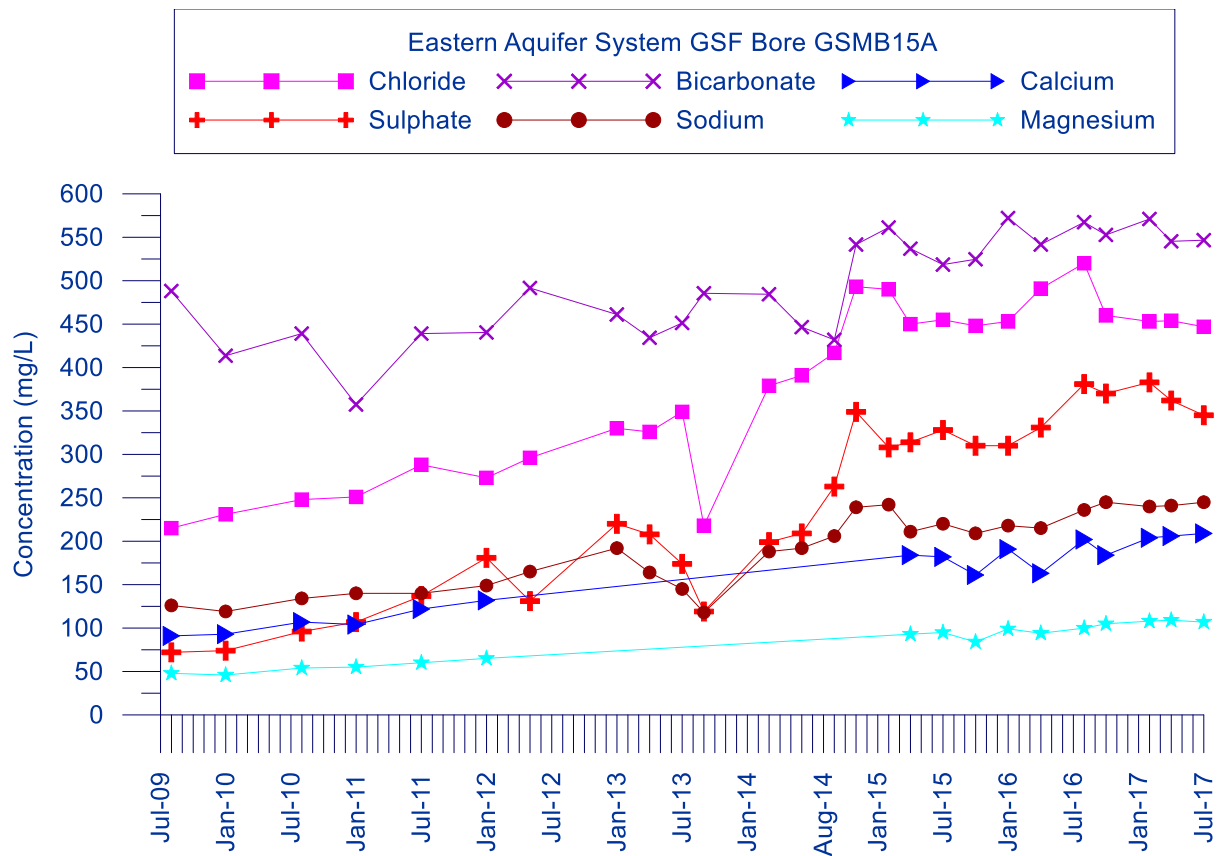
**GW23
GW13
GW05
GW05A
GW19
EPMB04
GW14**

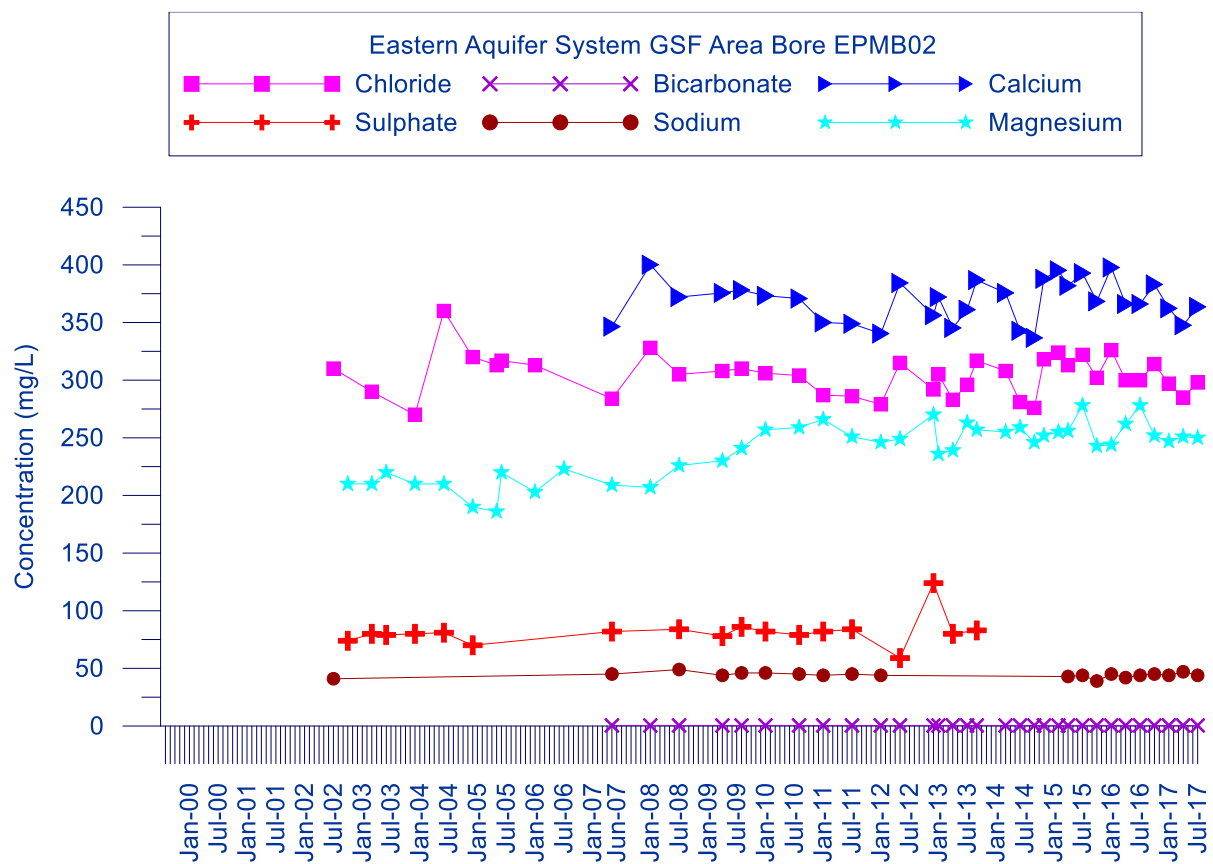
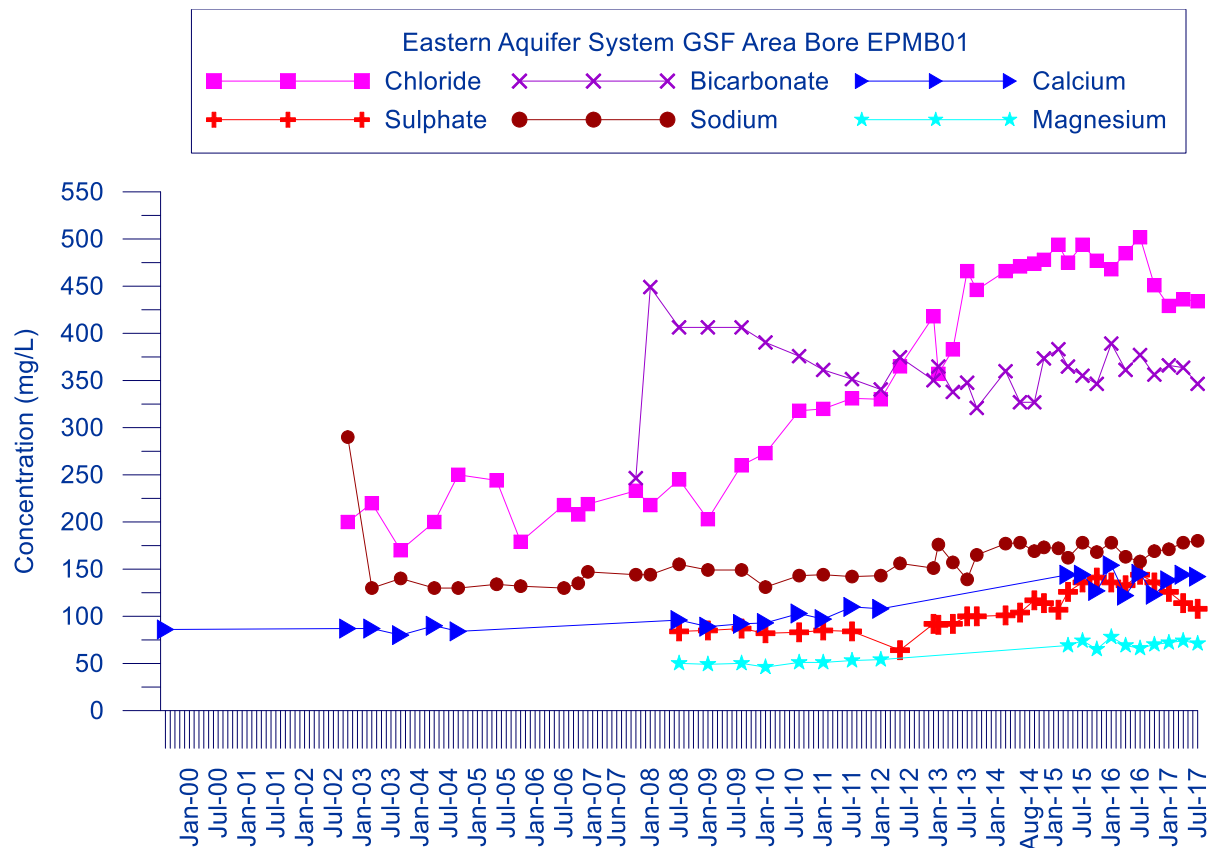
EAS Slimes Dams Area

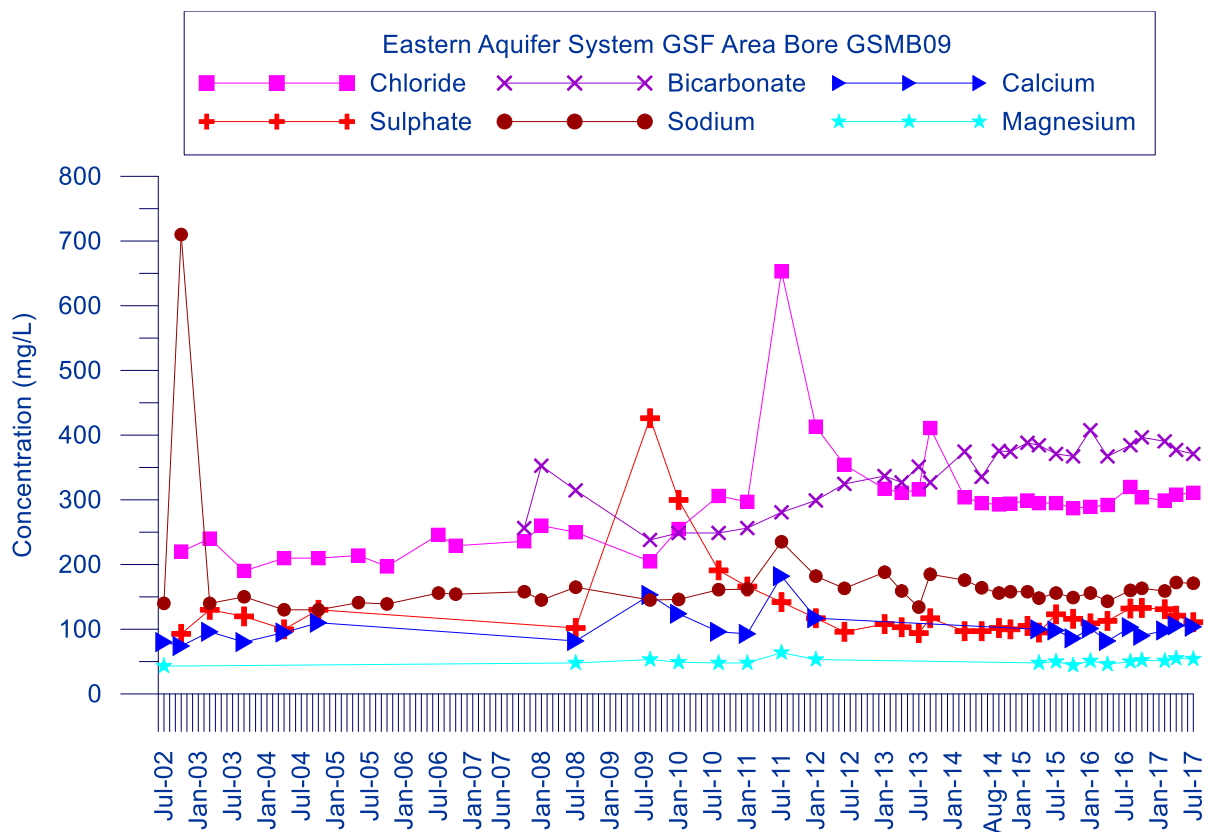
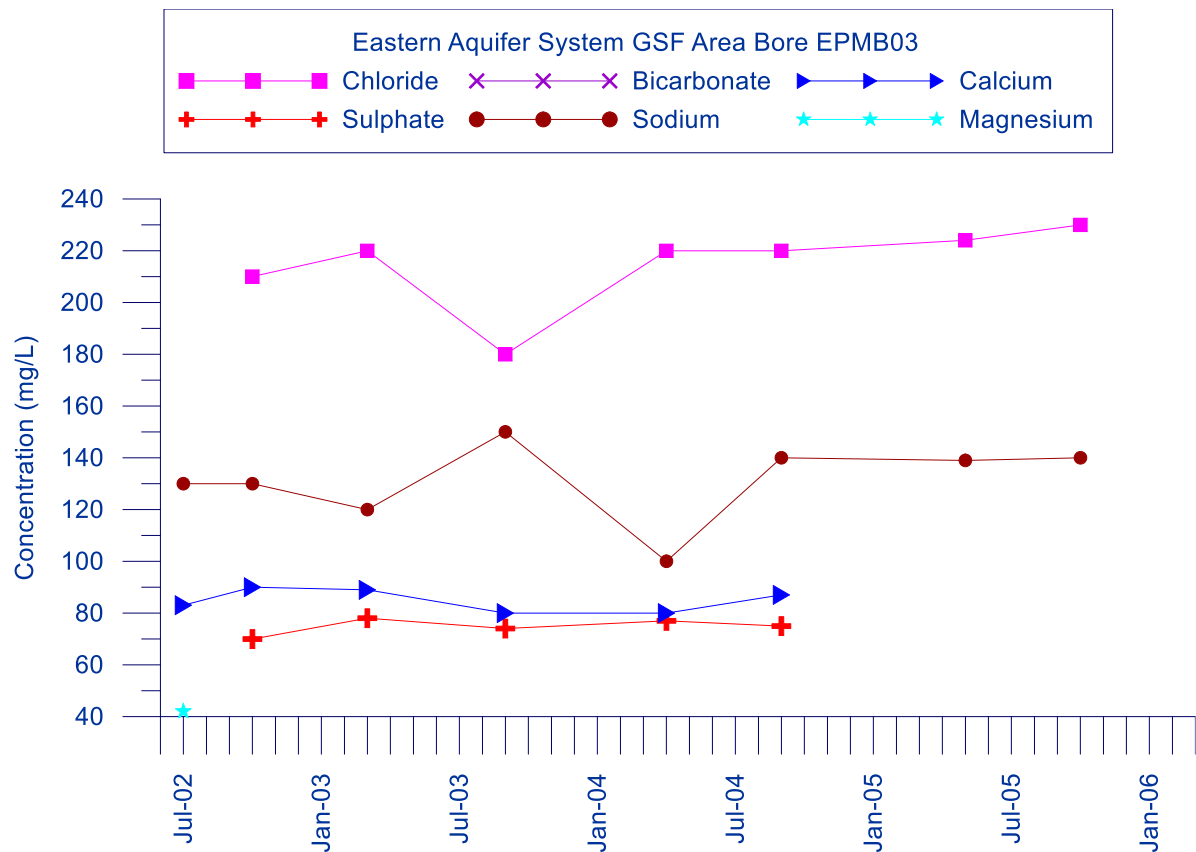
**GW02
GW16
SDMB03
GW22A
GW22
PHMB02
SDMB04
SDMB02**



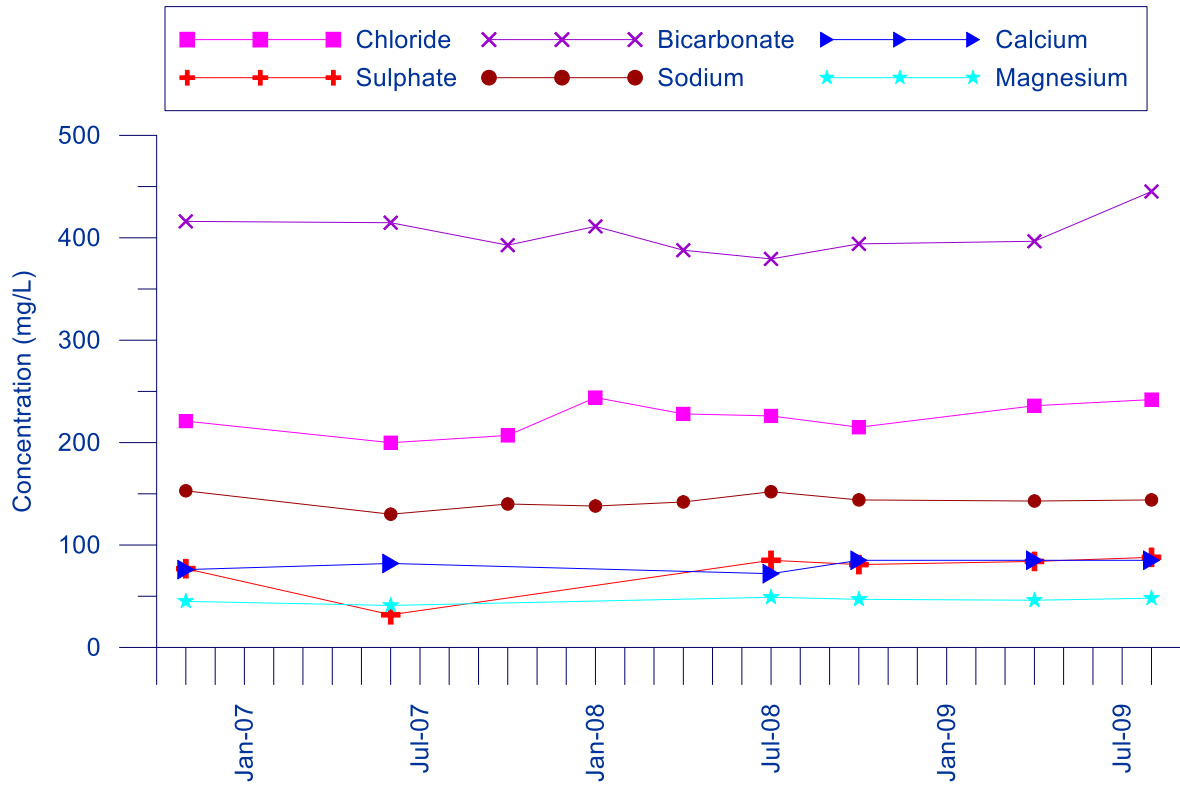




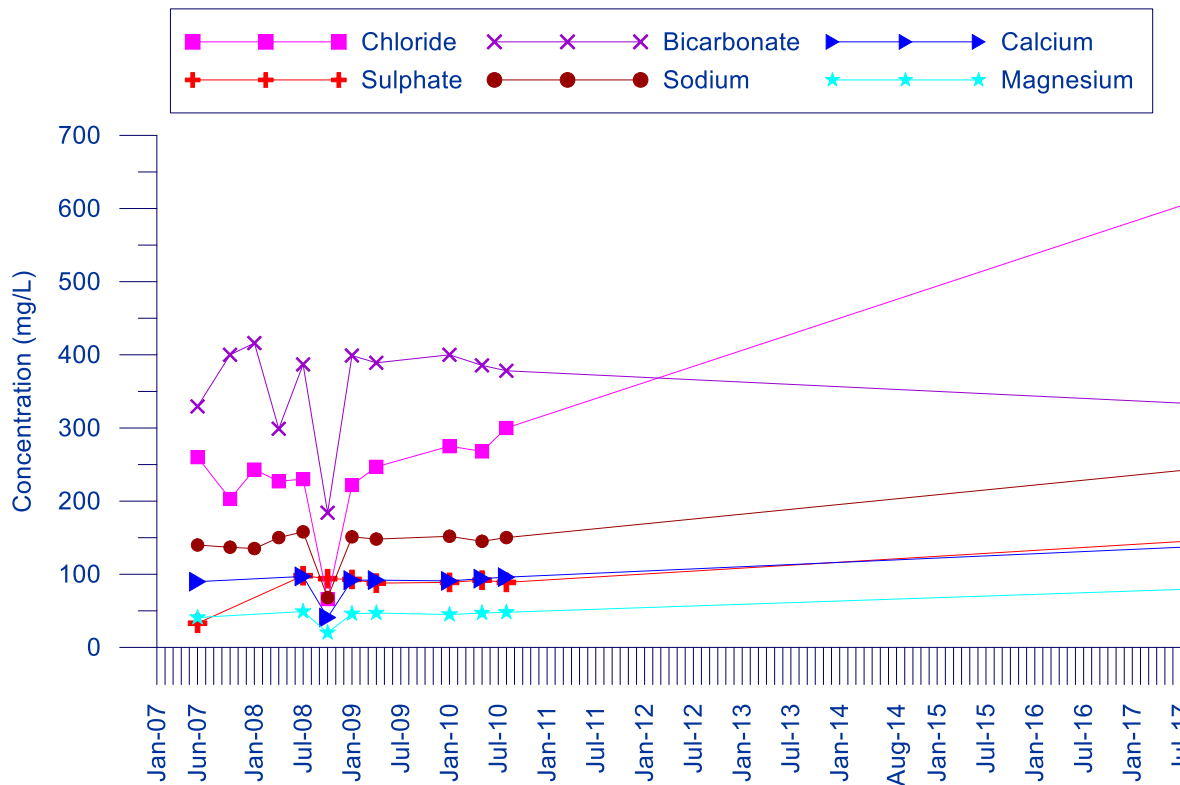




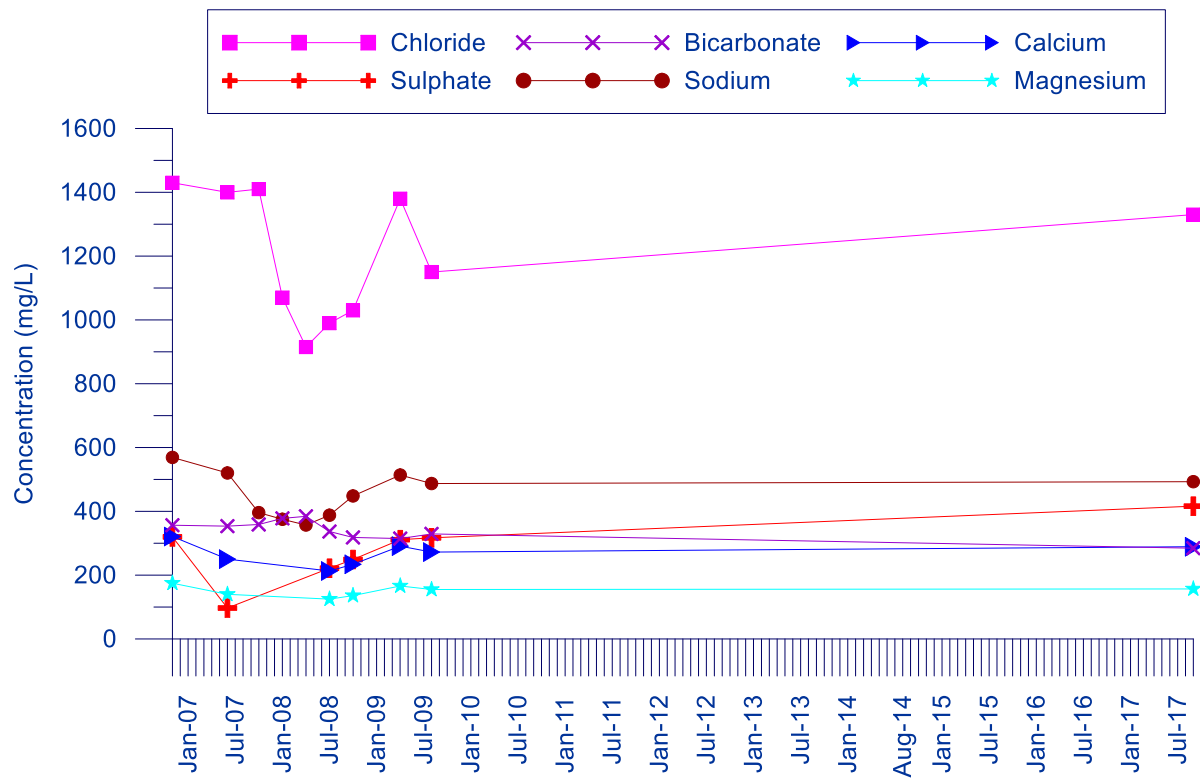
Eastern Aquifer System GSF Area Bore GW06



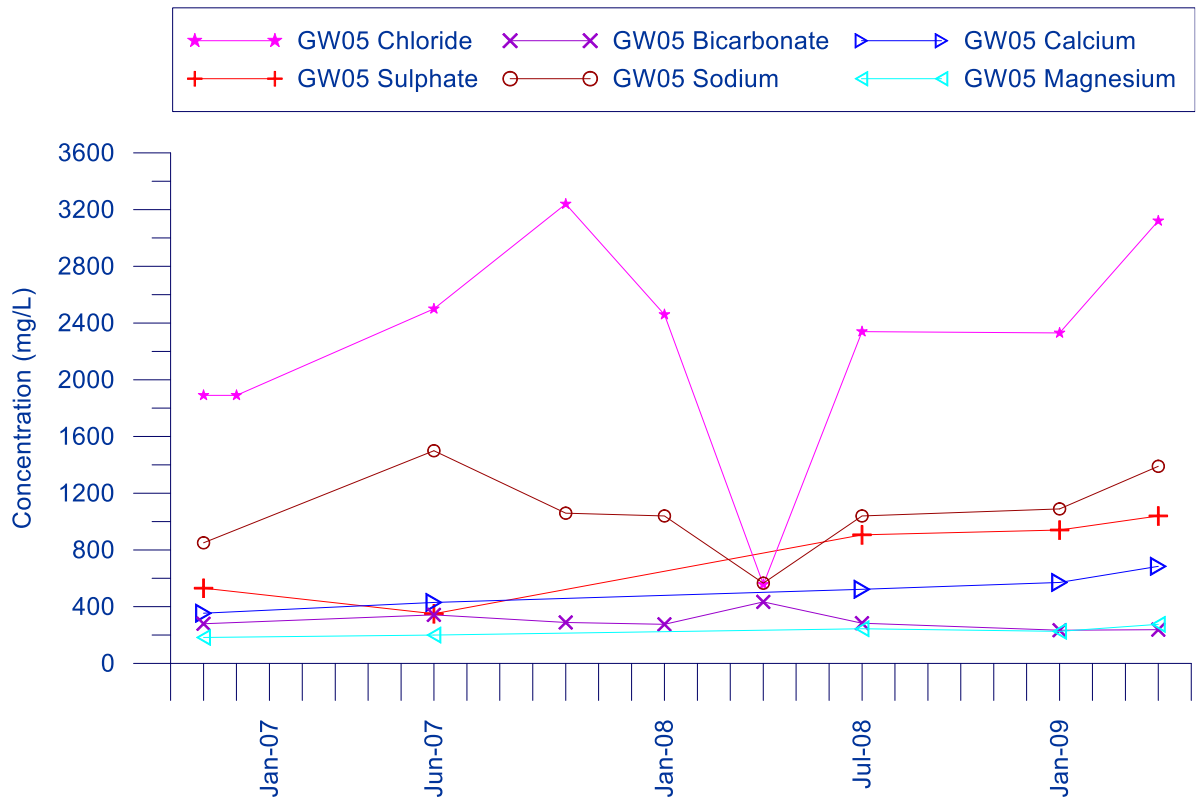
Eastern Aquifer System Plant Area Bore GW23



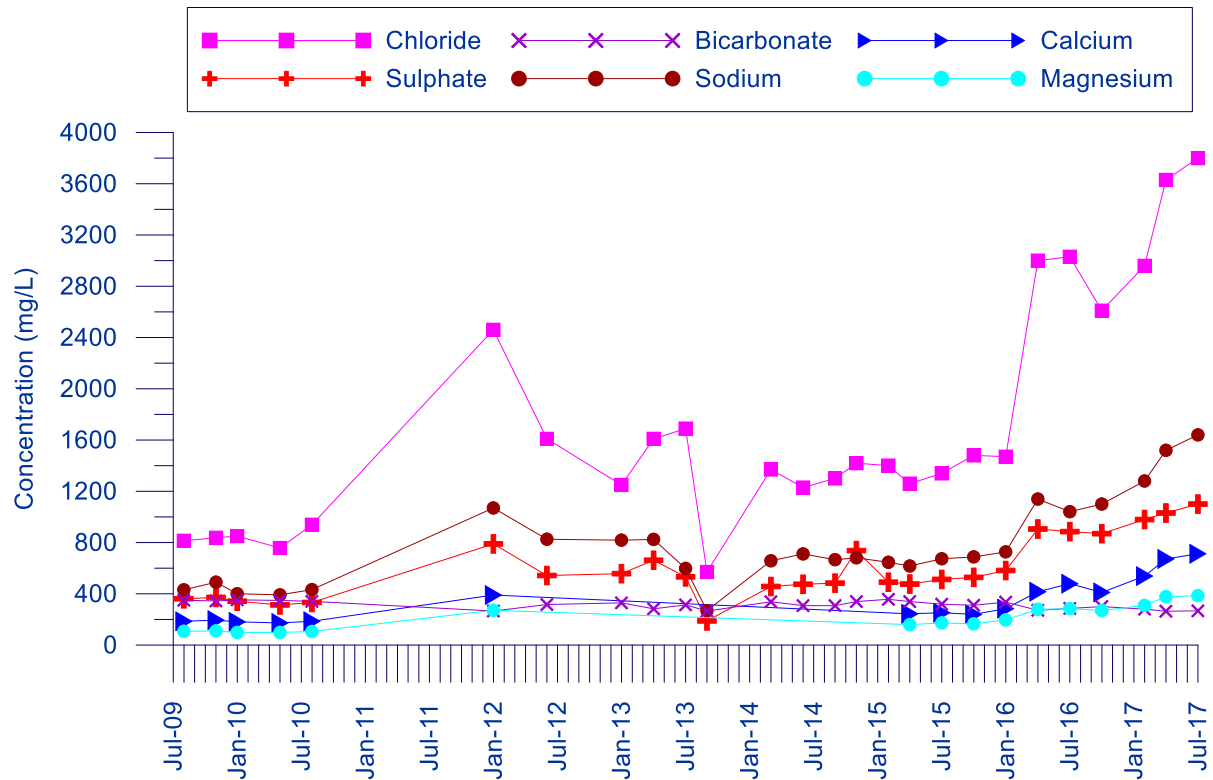
Eastern Aquifer System Plant Area Bore GW13



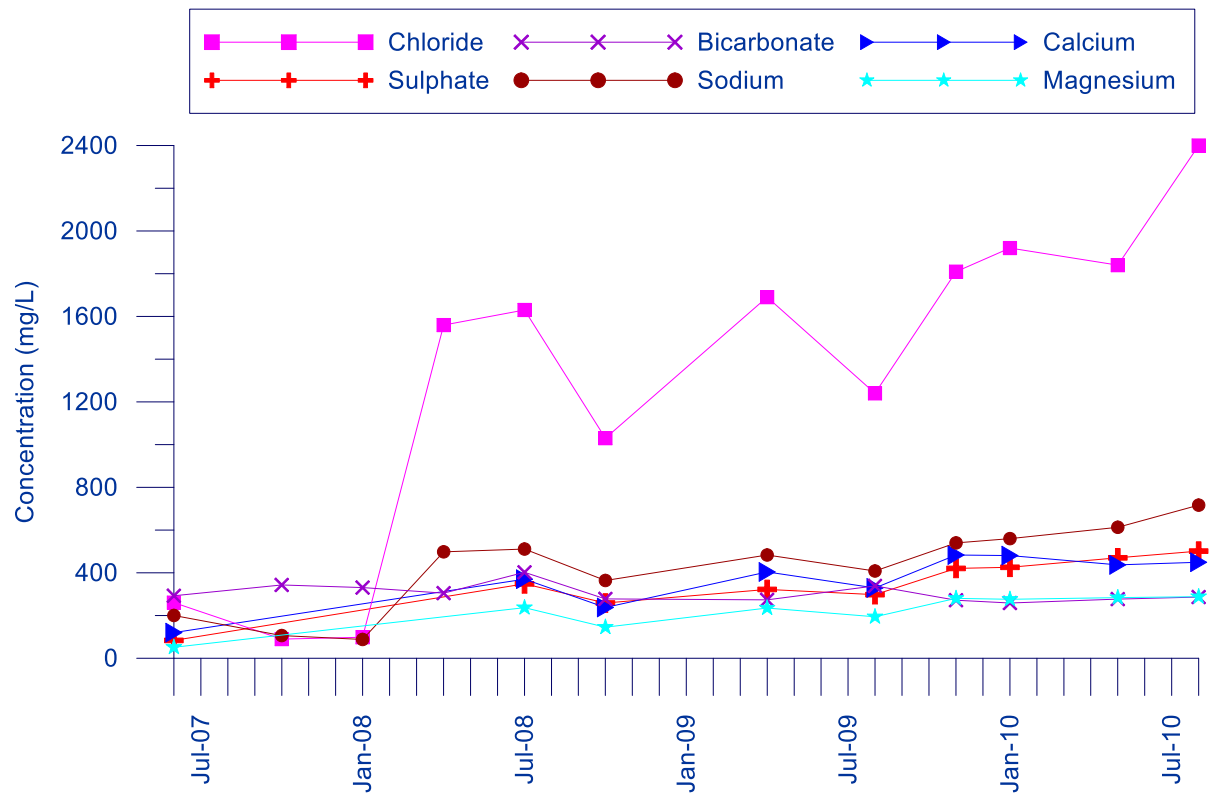
Eastern Aquifer System Plant Area Bore GW05



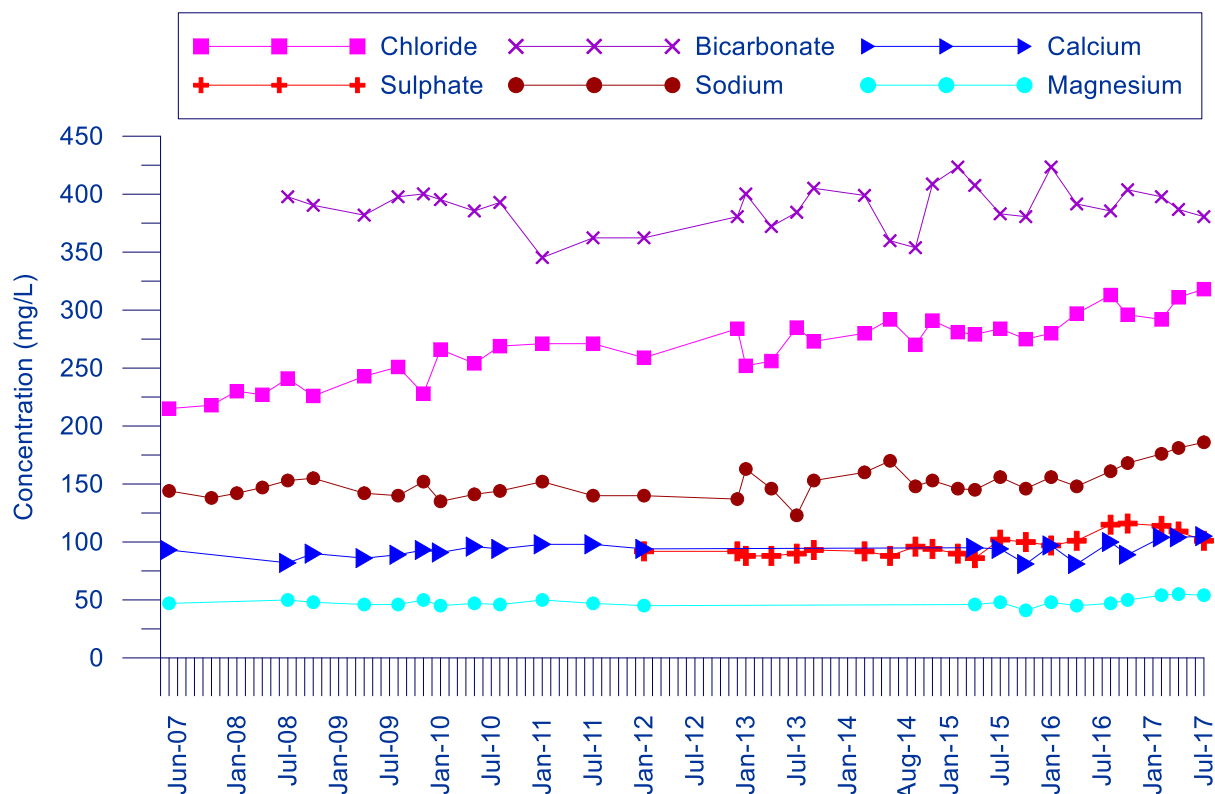
Eastern Aquifer System Plant Area Bore GW05A



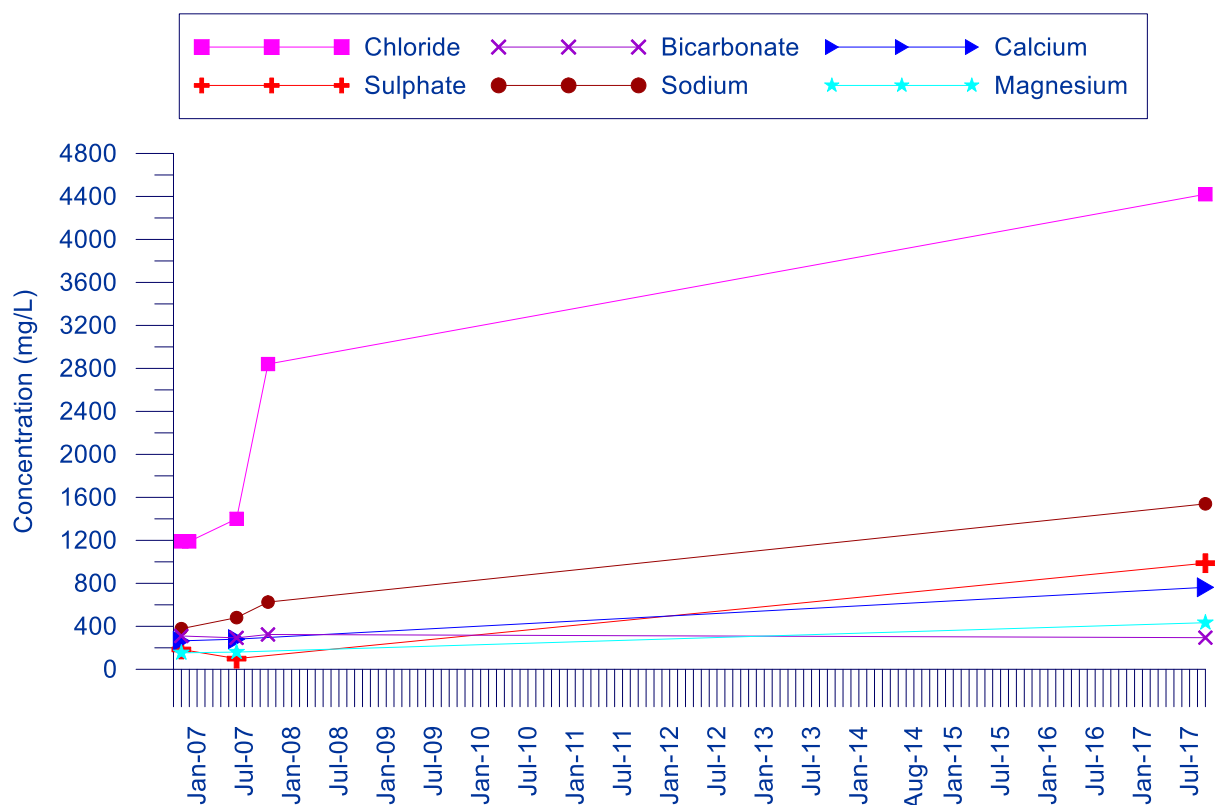
Eastern Aquifer System Plant Area Bore GW19



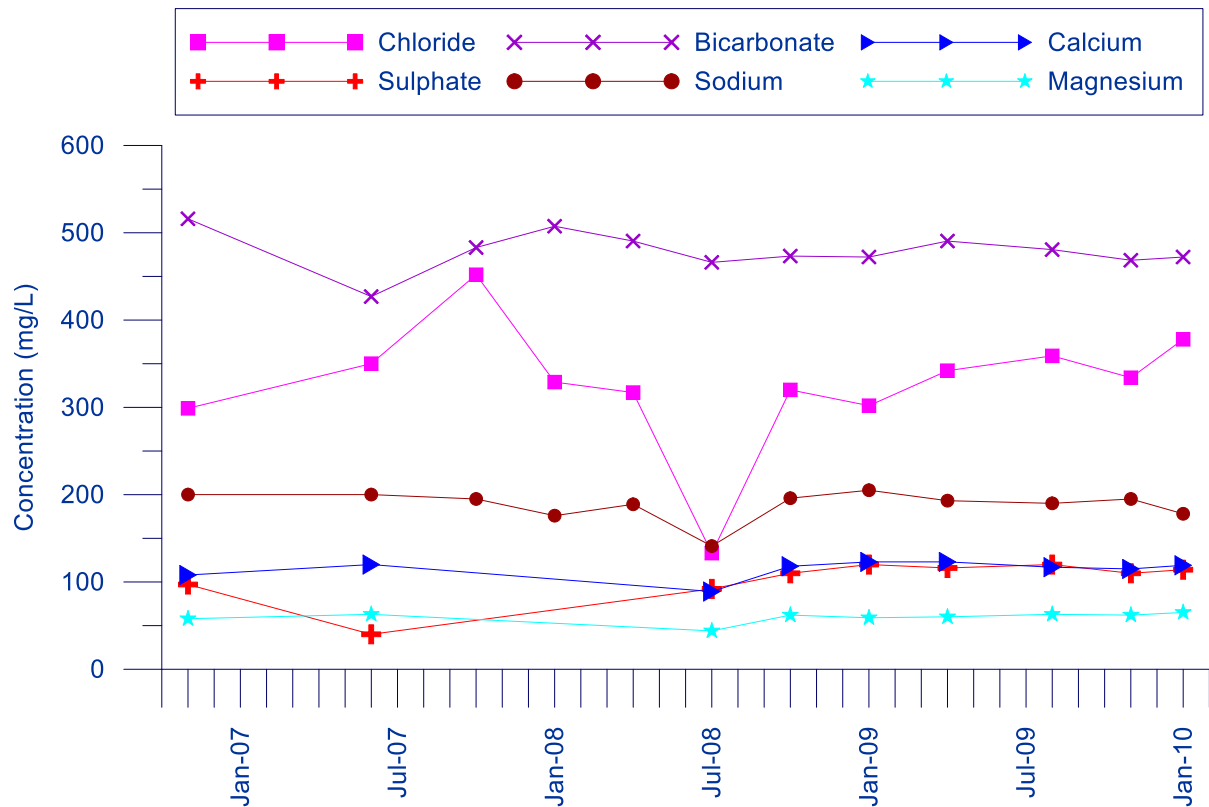
Eastern Aquifer System Plant Area Bore EPMB04



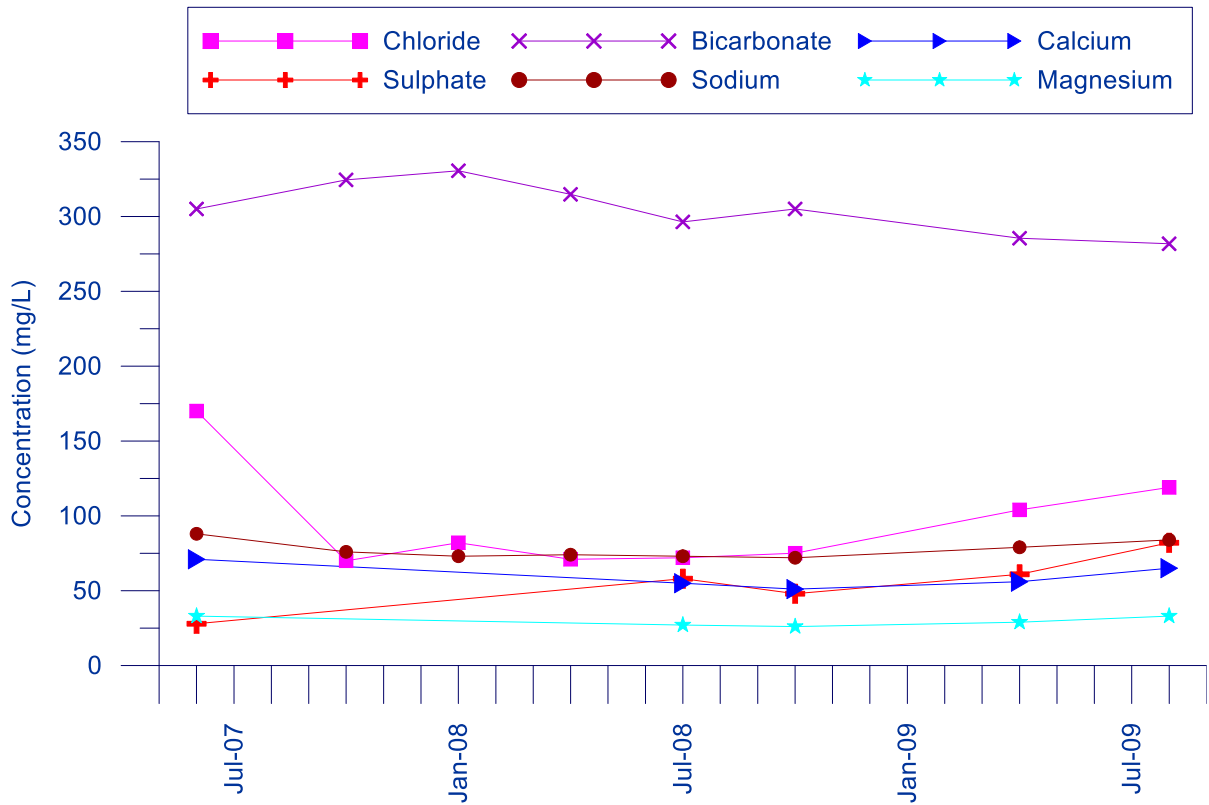
Eastern Aquifer System Plant Area Bore GW14



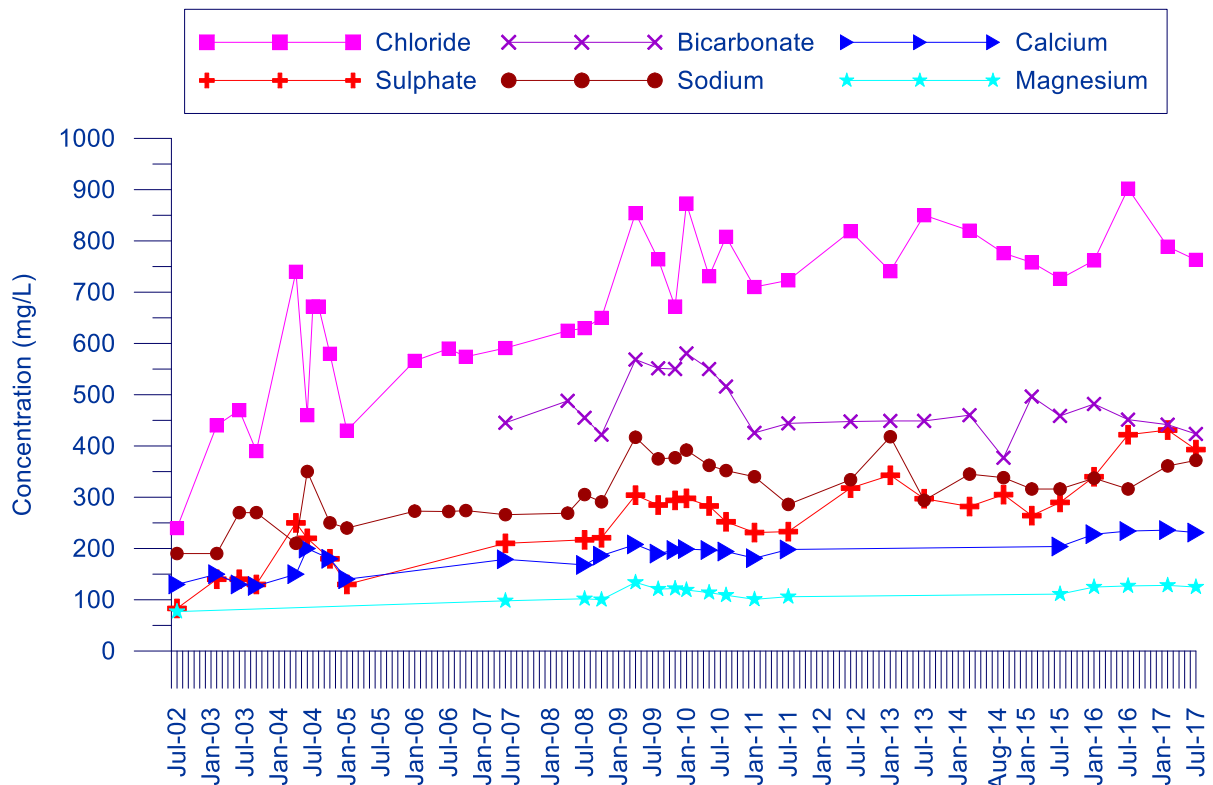
Eastern Aquifer System Slimes Dam Area Bore GW02



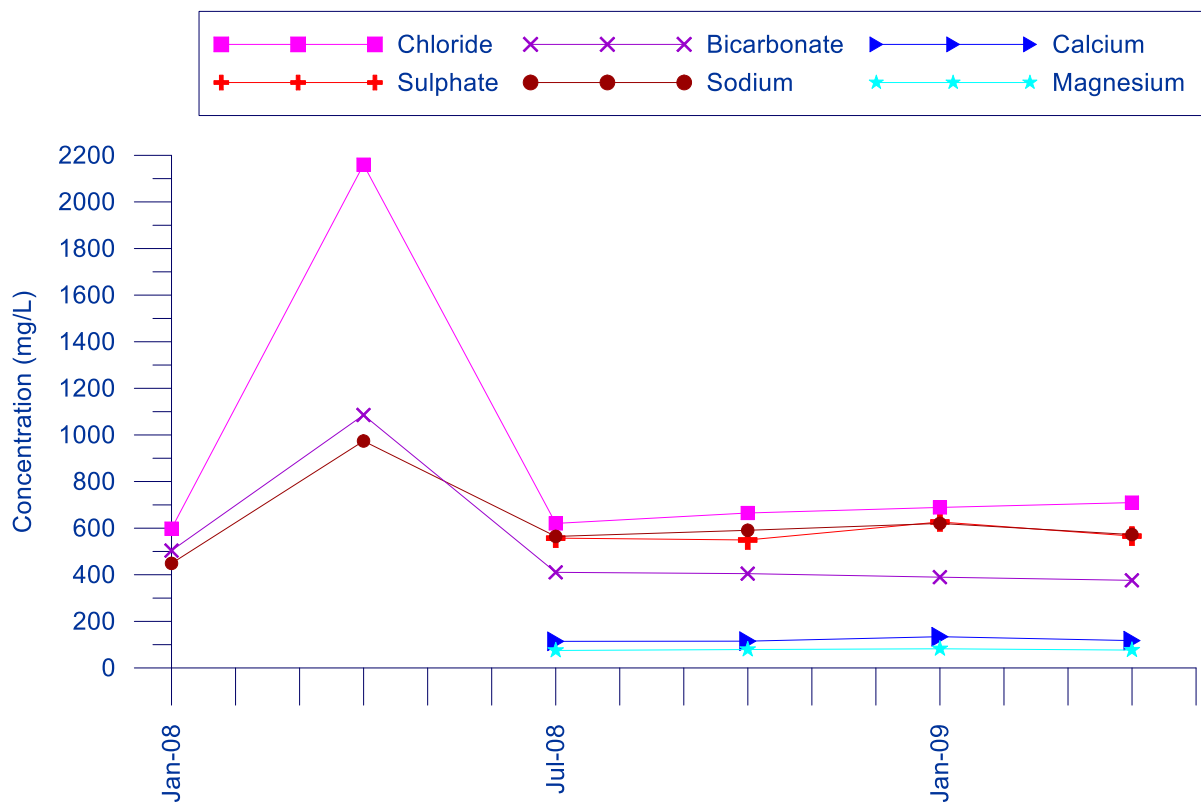
Eastern Aquifer System Slimes Dam Area Bore GW16



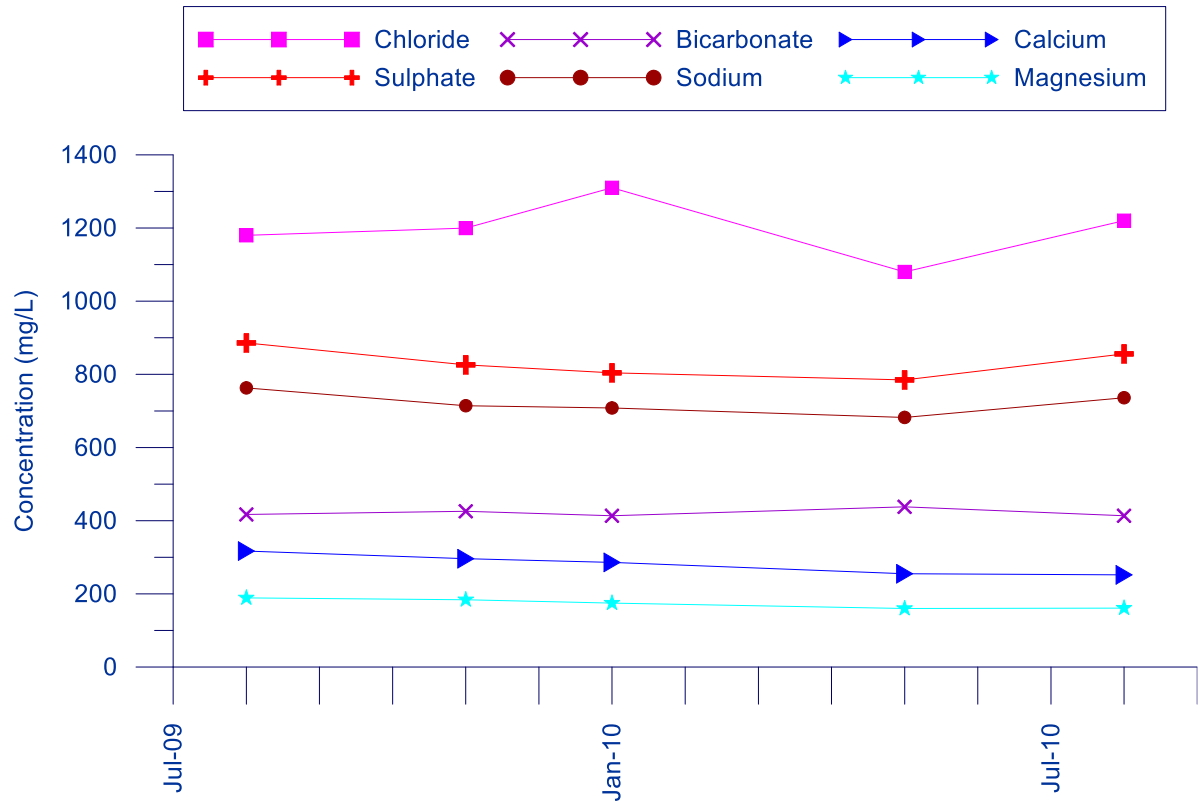
Eastern Aquifer System Slimes Dam Area Bore SDMB03



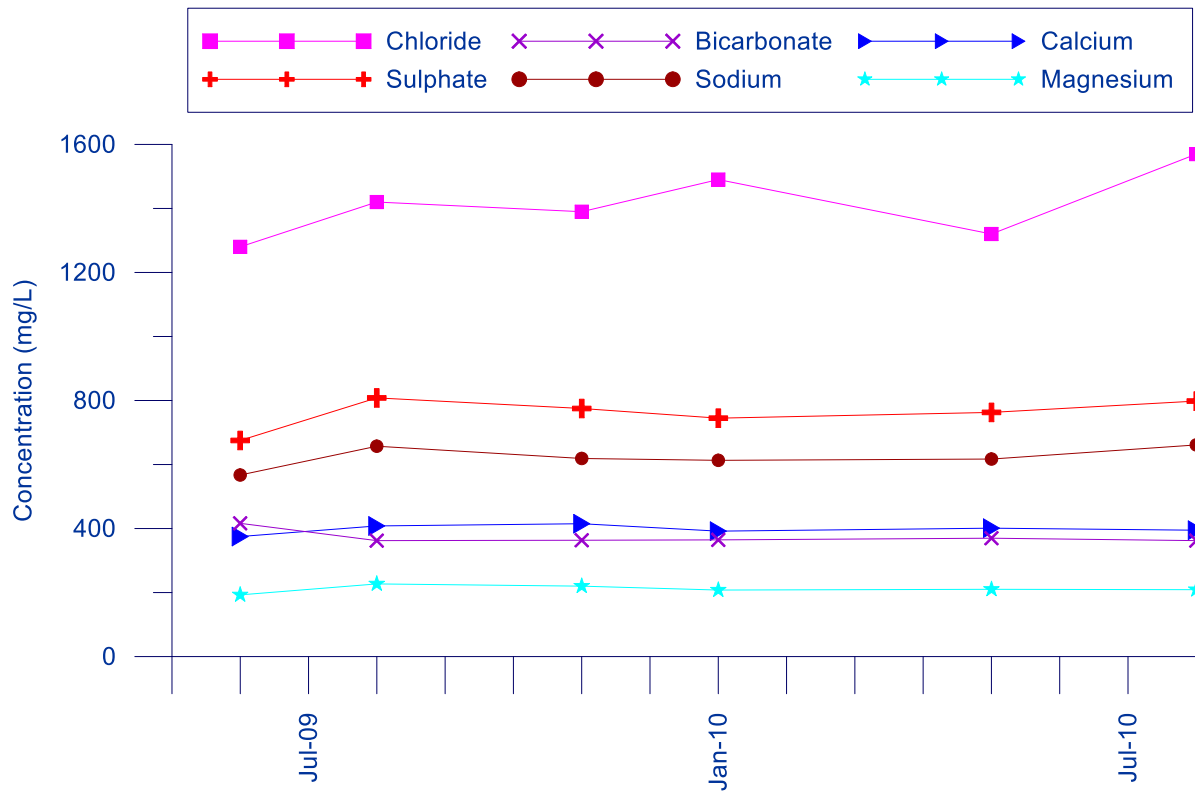
Eastern Aquifer System Slimes Dam Area Bore GW22



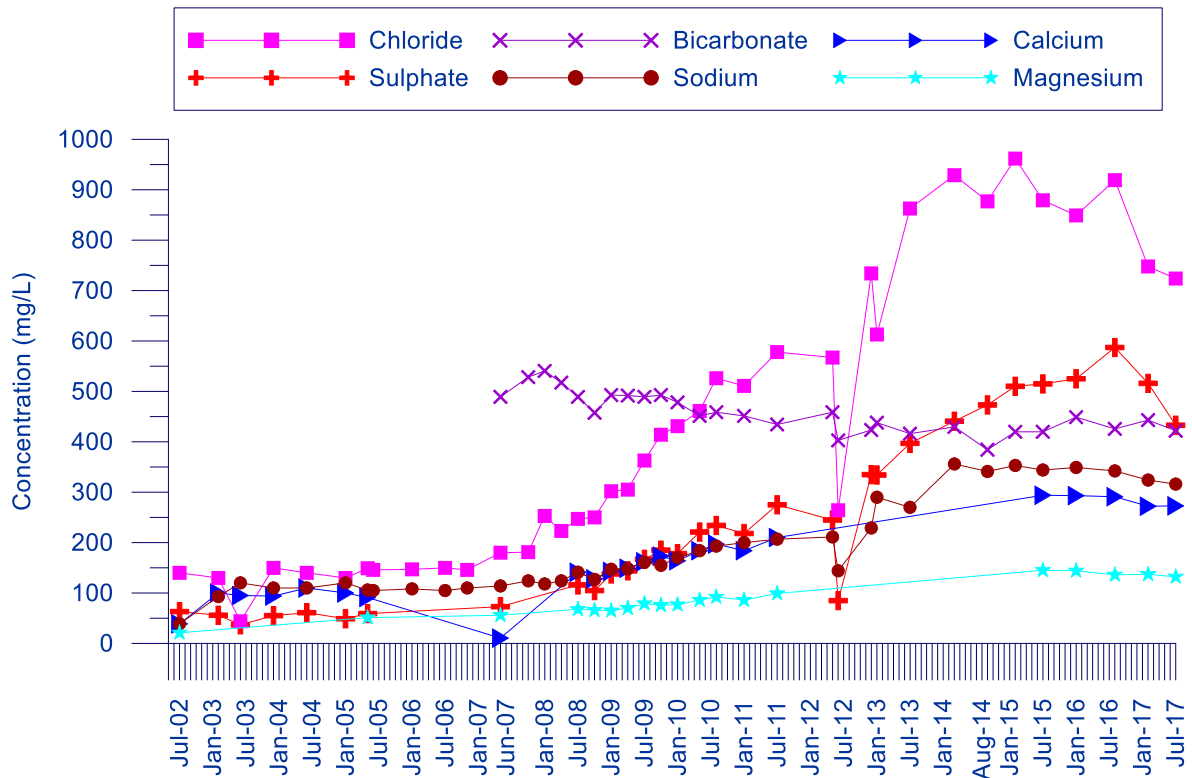
Eastern Aquifer System Slimes Dam Area Bore GW22A



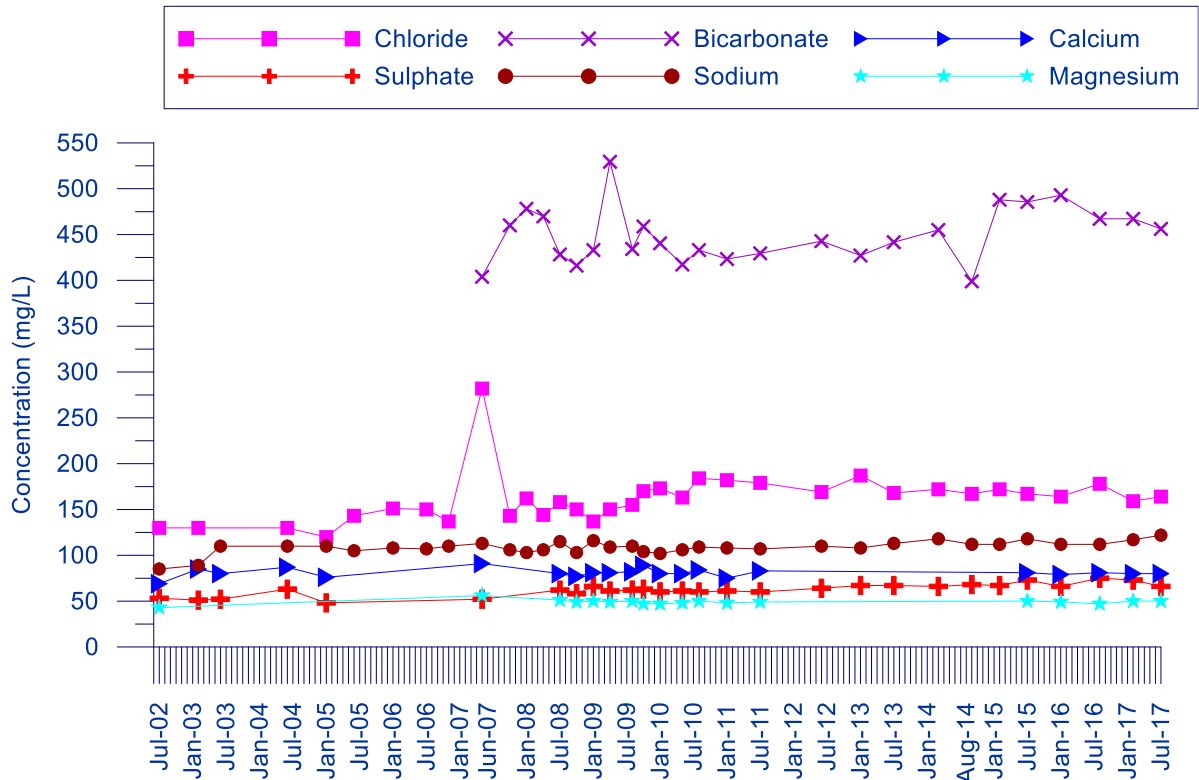
Eastern Aquifer System Plant Area Bore PHMB02



Eastern Aquifer System Plant Area Bore SDMB04



Eastern Aquifer System Plant Area Bore SDMB02



APPENDIX 7D

EAS Box-Whisker Plots

Salinity

Chloride

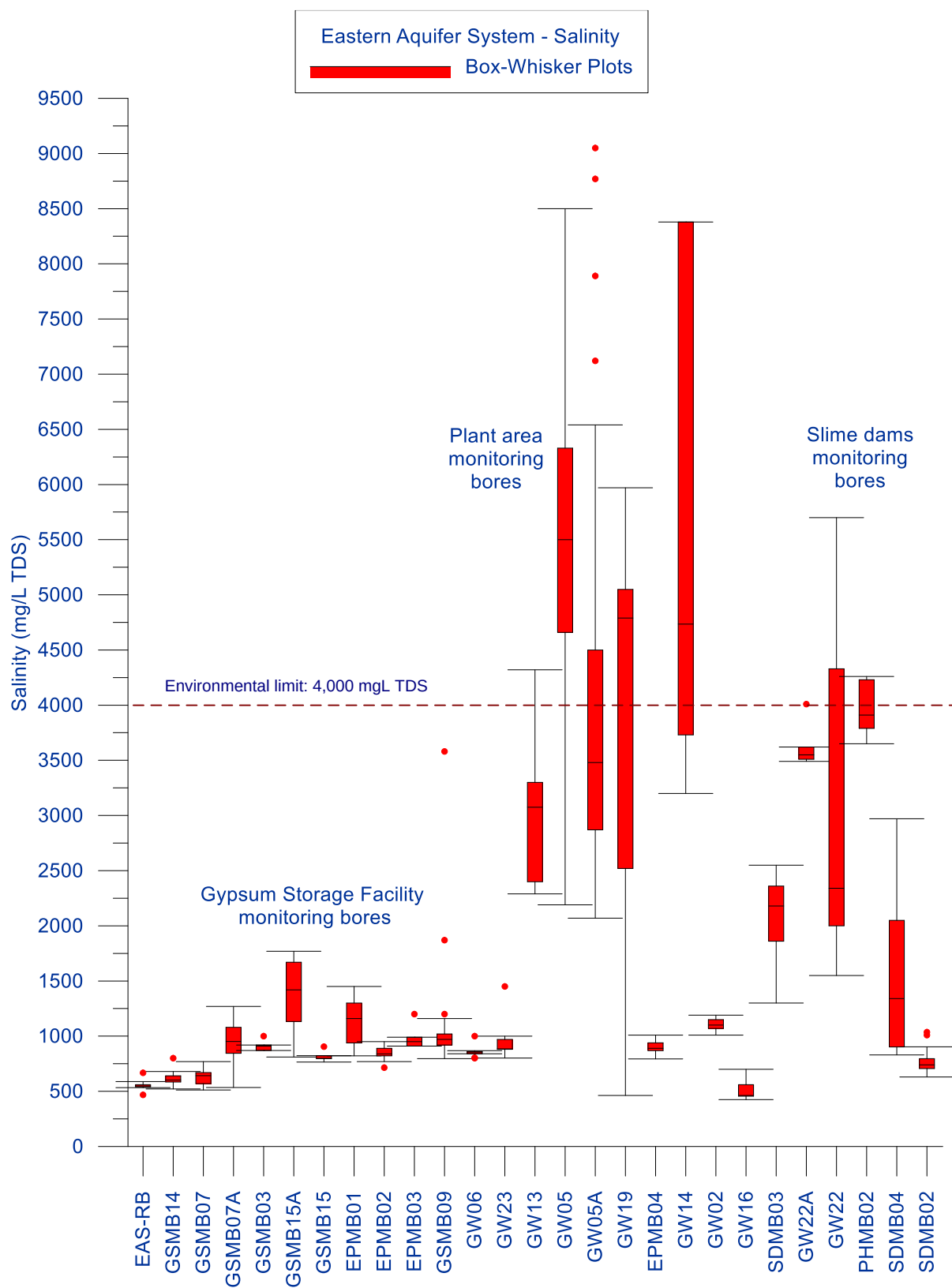
Sulphate

Fluoride

Acidity (laboratory measurements)

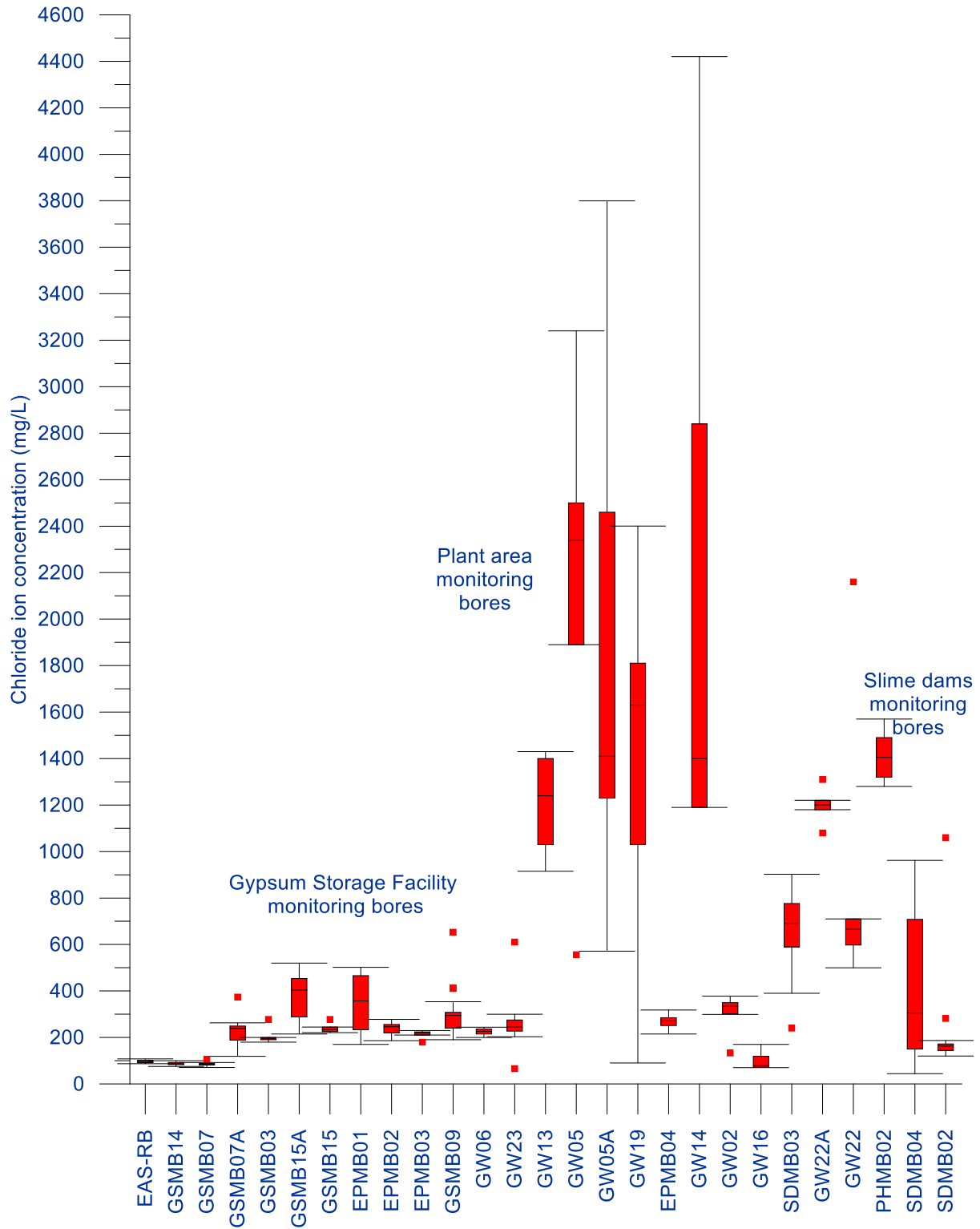
Total Nitrogen-N

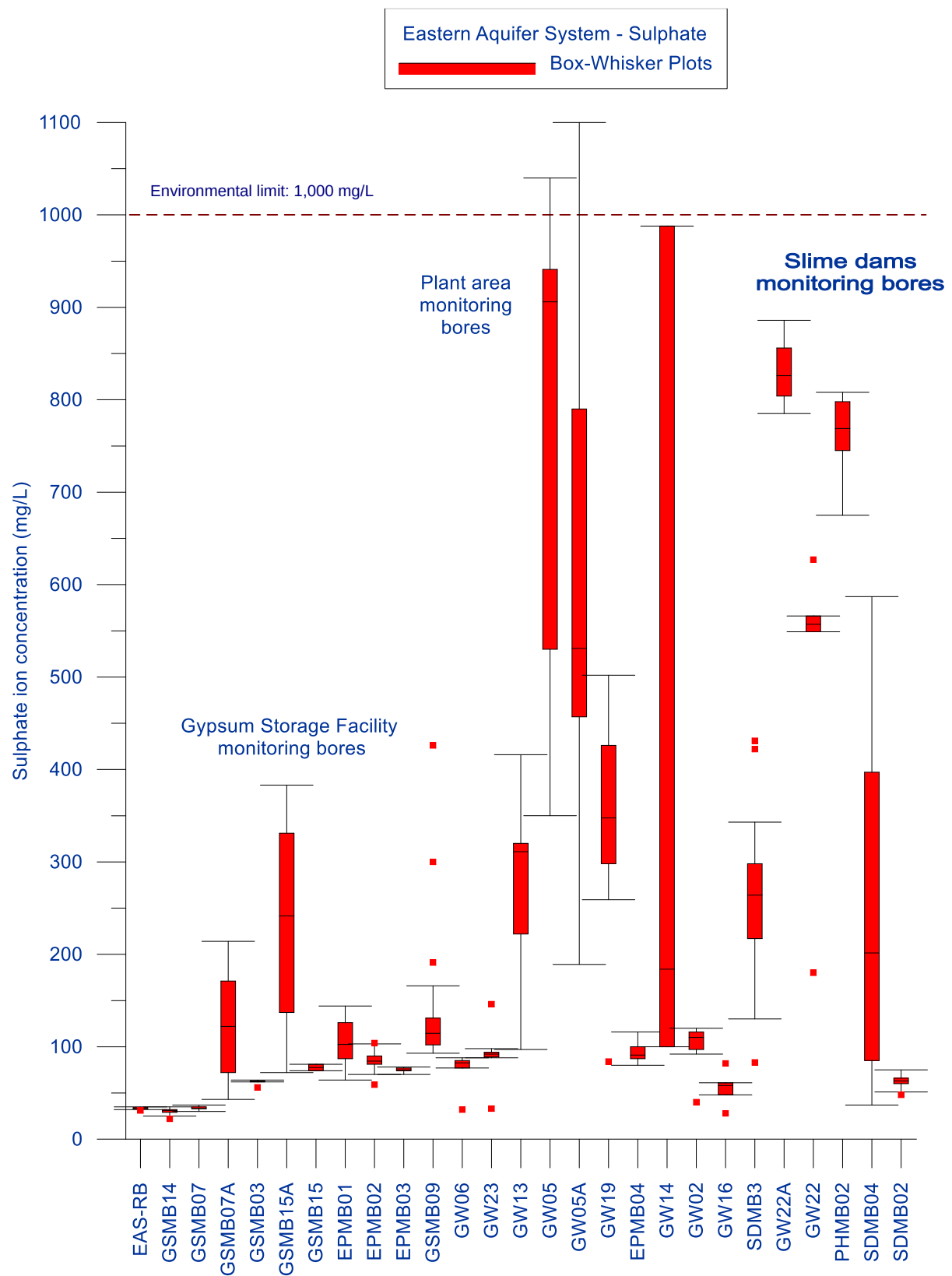
Total Phosphorous-P

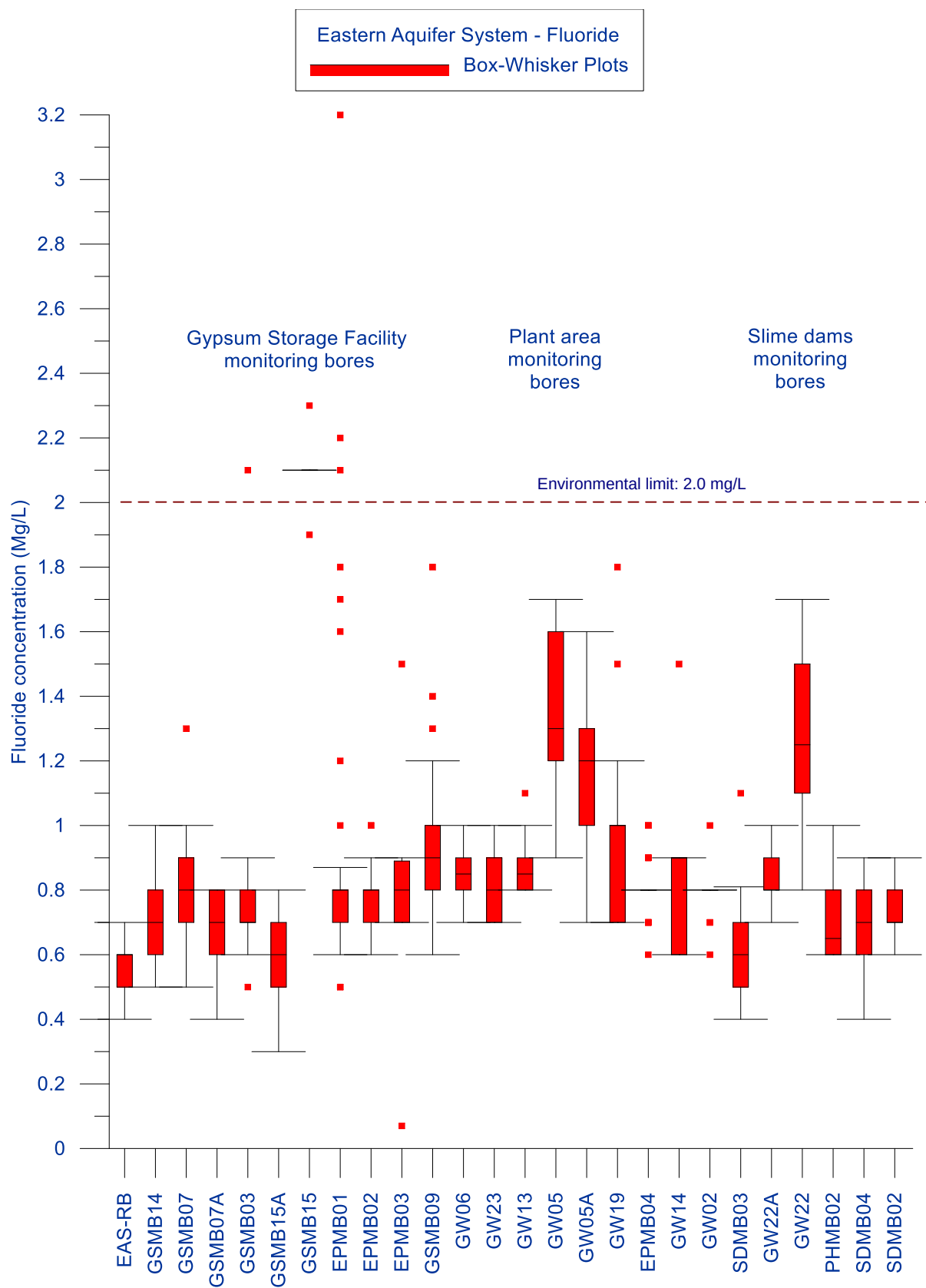


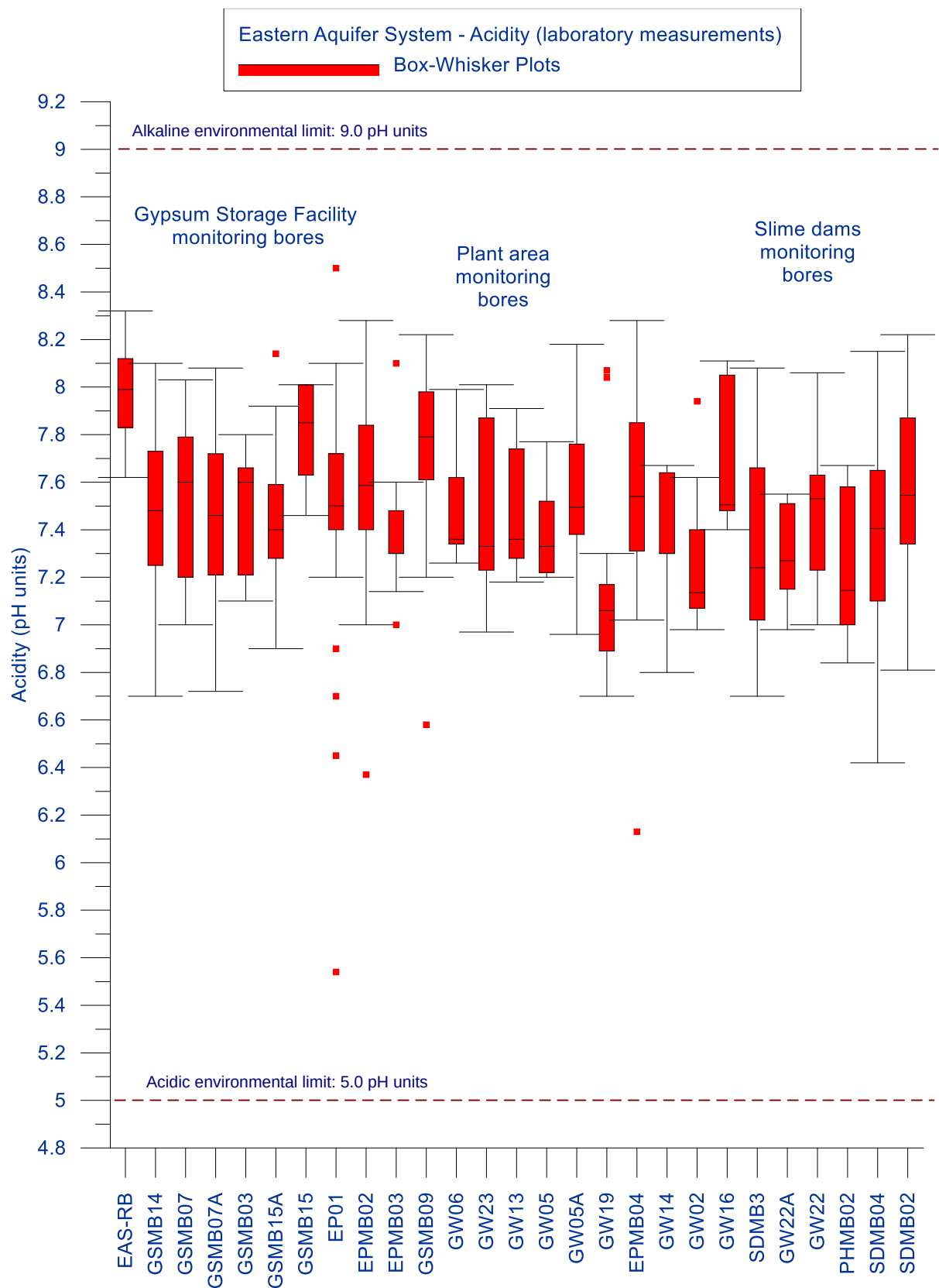
Eastern Aquifer System - Chloride

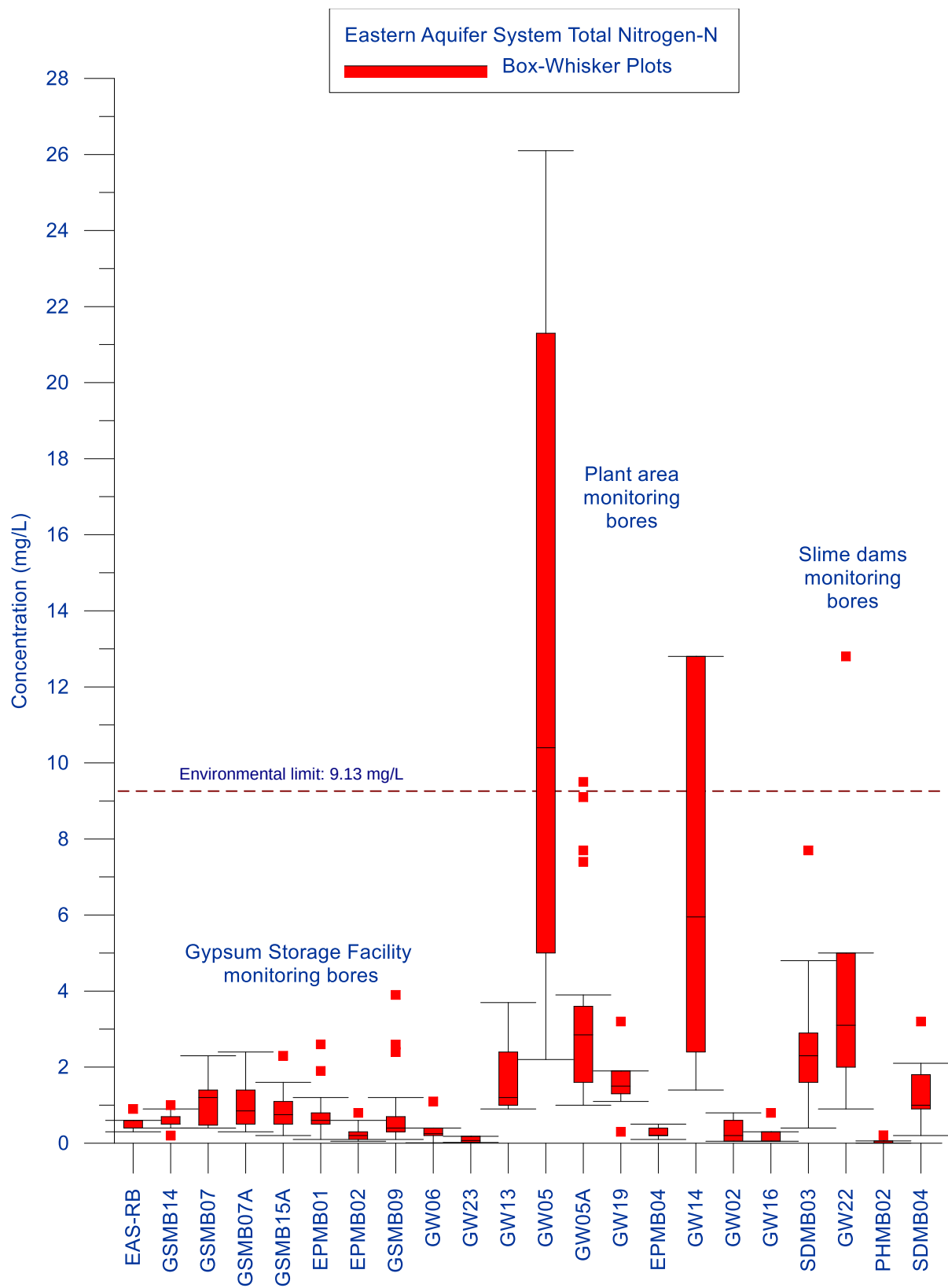
Box-Whisker Plots

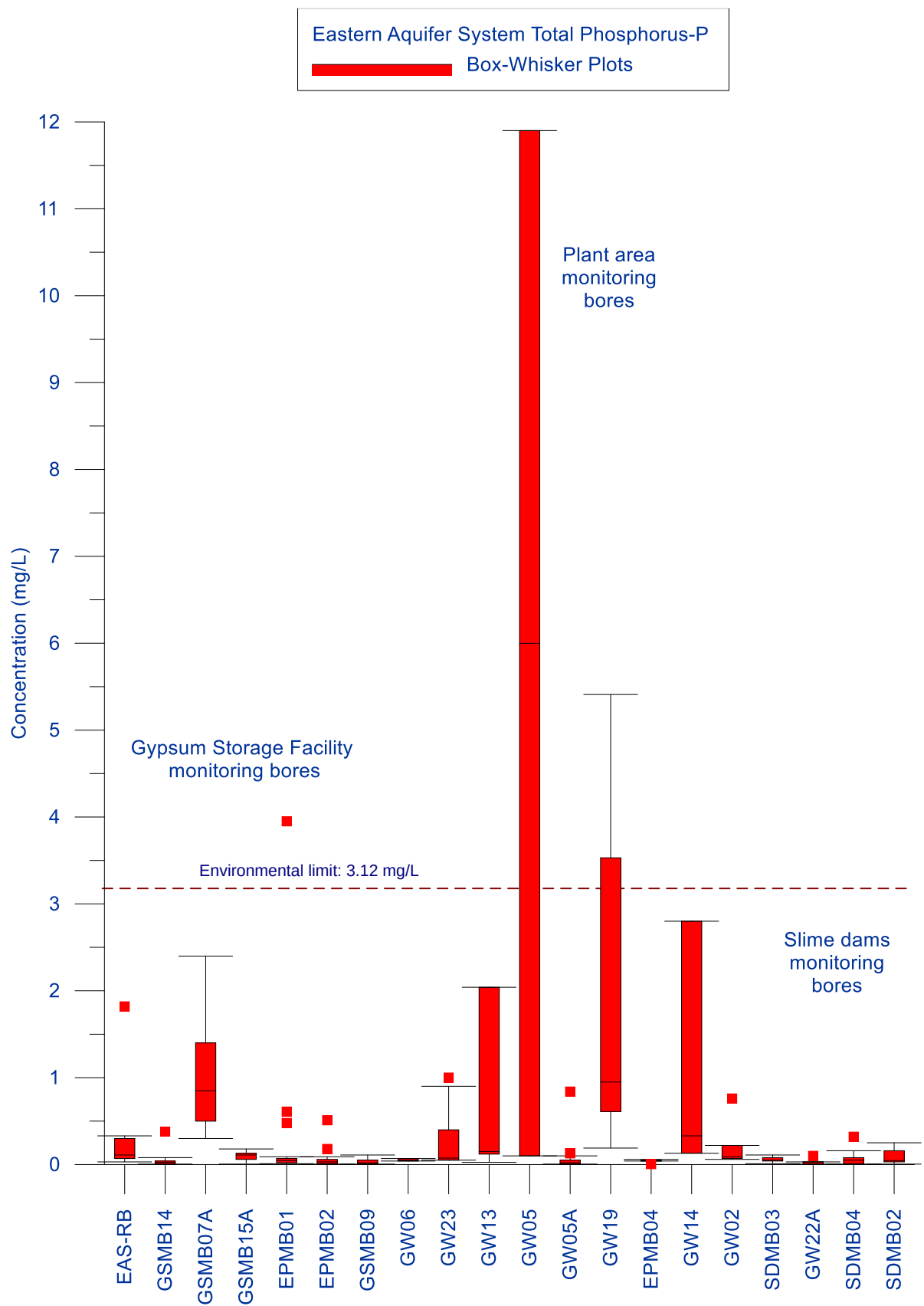












APPENDIX 8

WAS Hydrochemical Analysis

8A) July 2017 Piper Diagrams

8B) Individual Bore Piper Diagrams

8C) Analyte Concentration Time Series Plots

8C1 By Analyte

8C2 By Bore

8D) Box-Whisker Plots

APPENDIX 8A

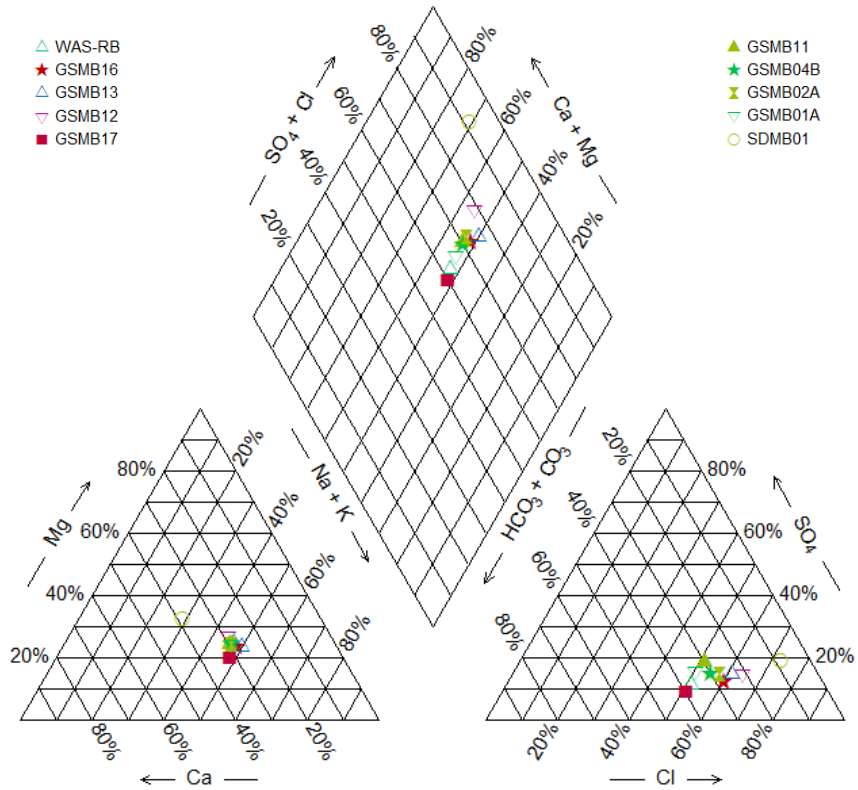
July 2017 Piper Diagrams

WAS GSF area bores

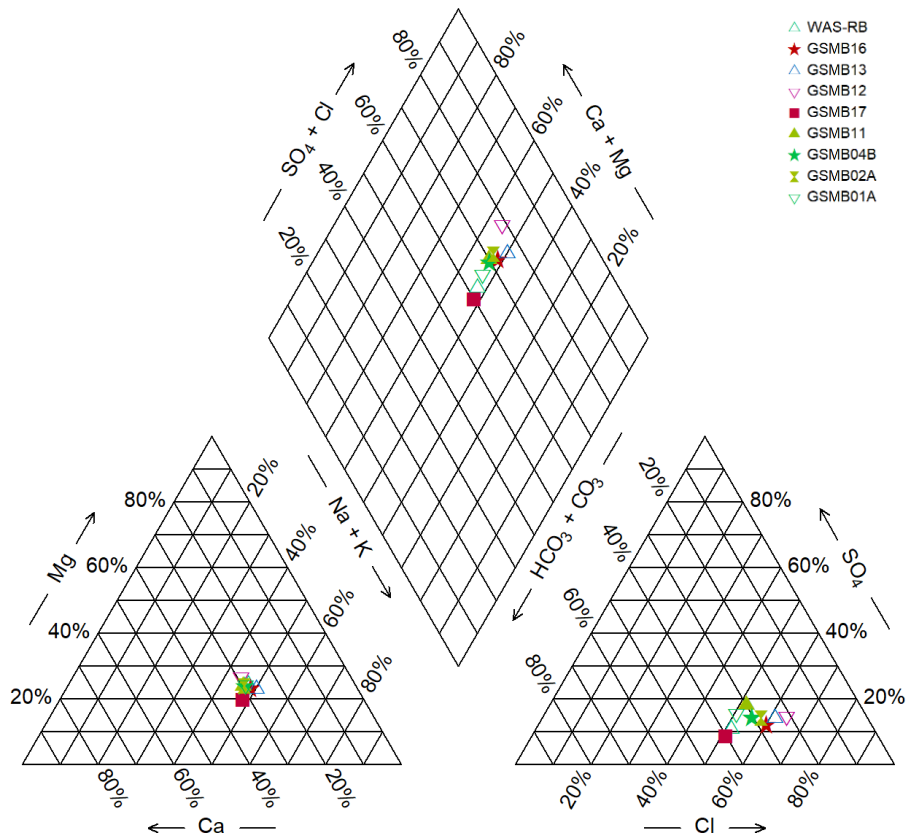
WAS Plant area bores

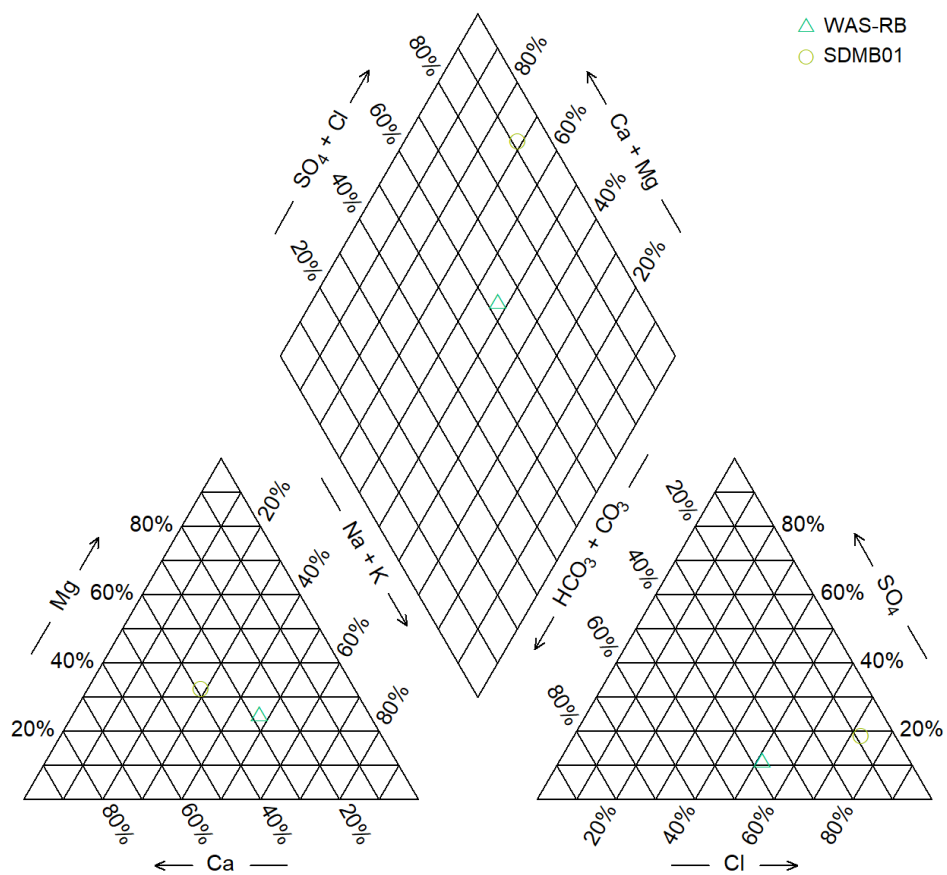
WAS Slimes Dams area bores

July 2017 Piper Diagram All WAS Bores



WAS GSF Area July 2017 Piper Diagram



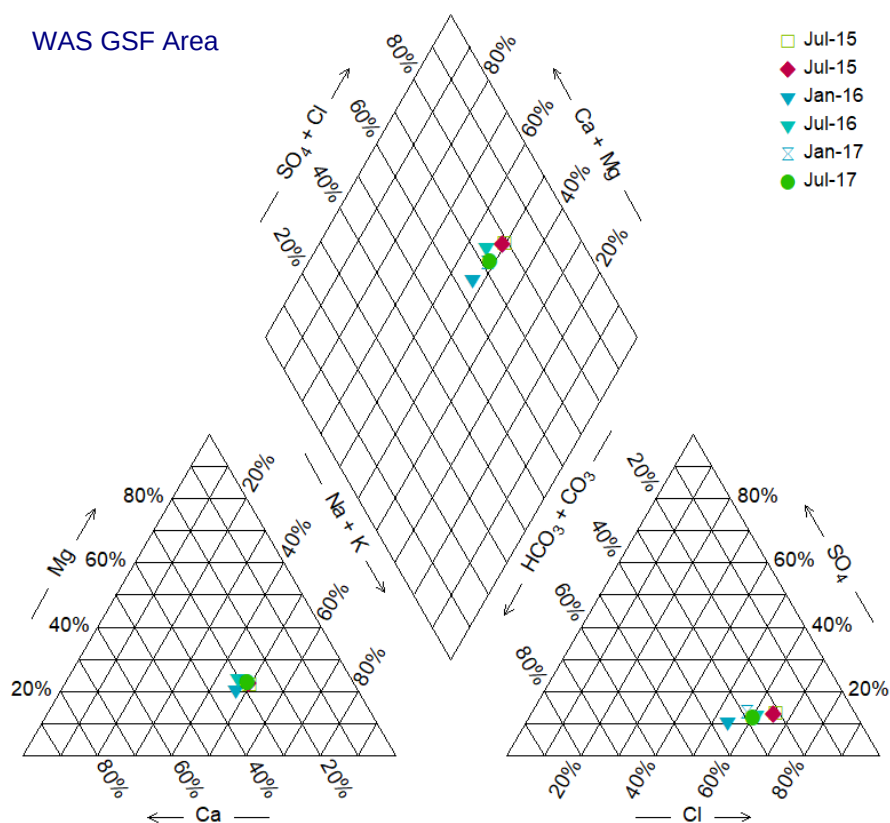


APPENDIX 8B

**Piper Diagrams Individual WAS Bores
(arranged from north to south)**

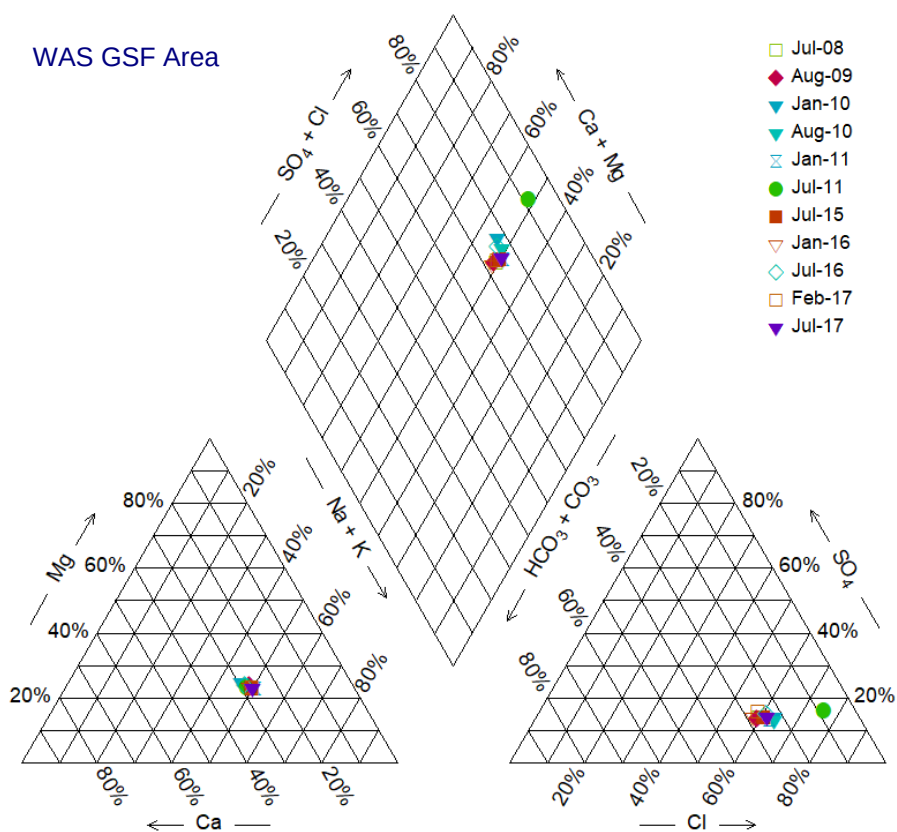
GSMB16 Piper Diagram

WAS GSF Area



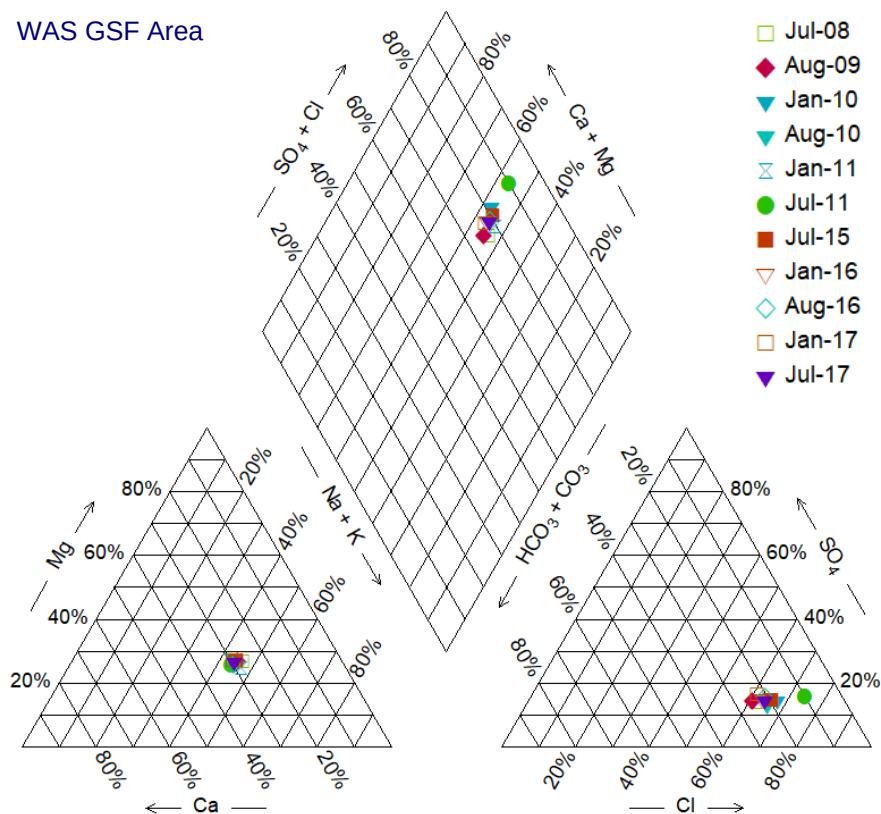
GSMB13 Piper Diagram

WAS GSF Area



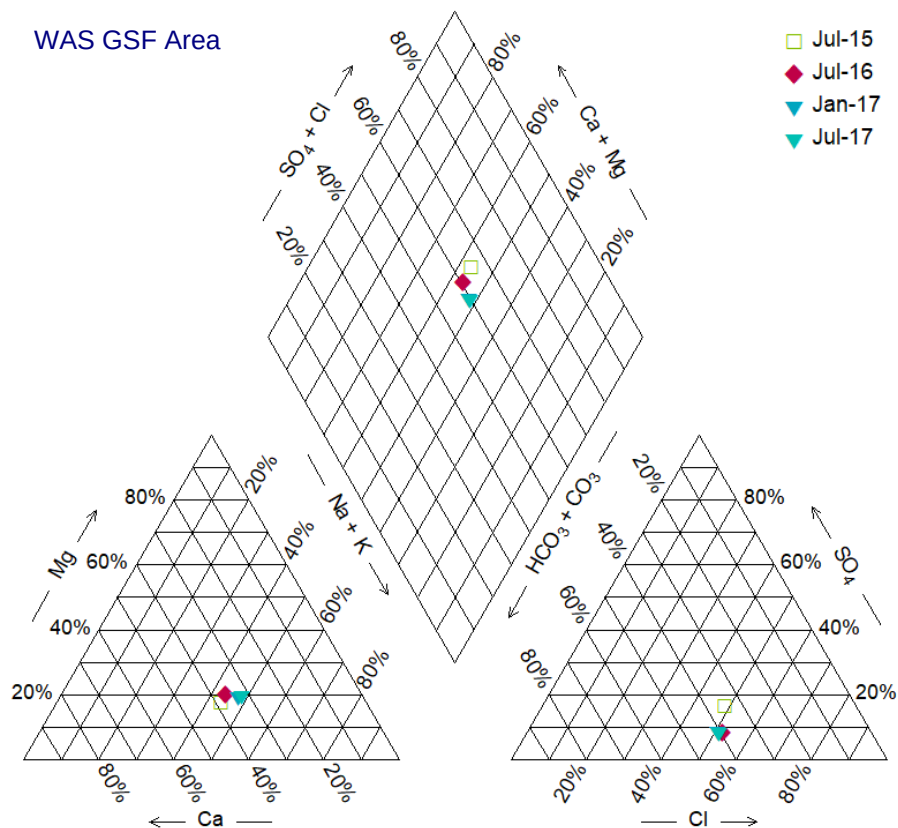
GSMB12 Piper Diagram

WAS GSF Area



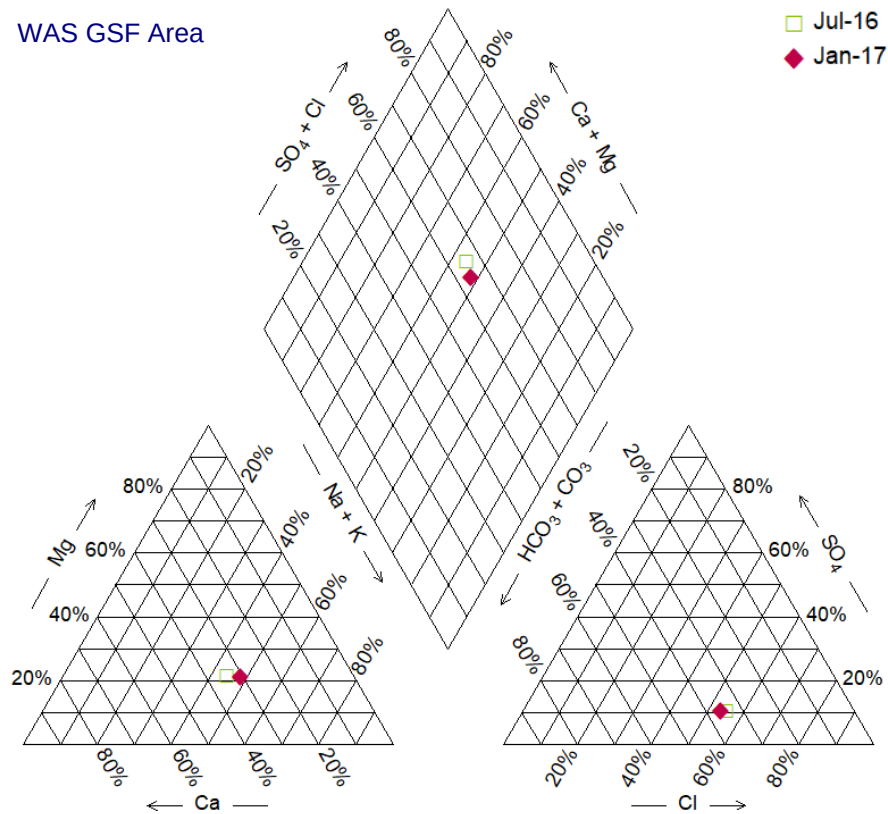
GSMB17 Piper Diagram

WAS GSF Area



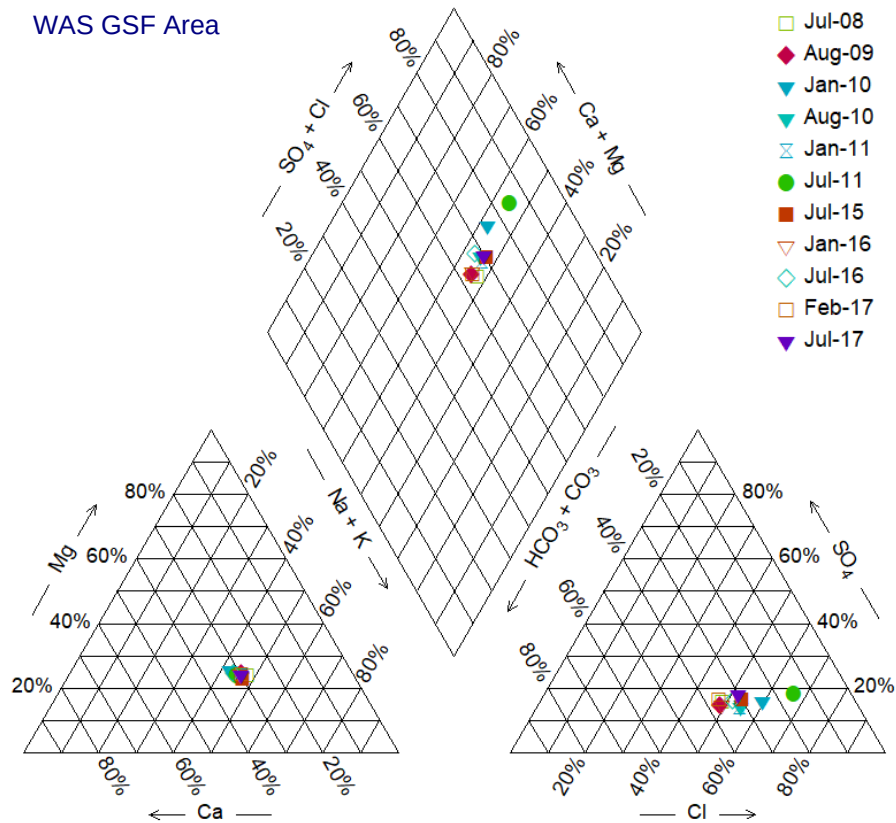
GSMB18 Piper Diagram

WAS GSF Area



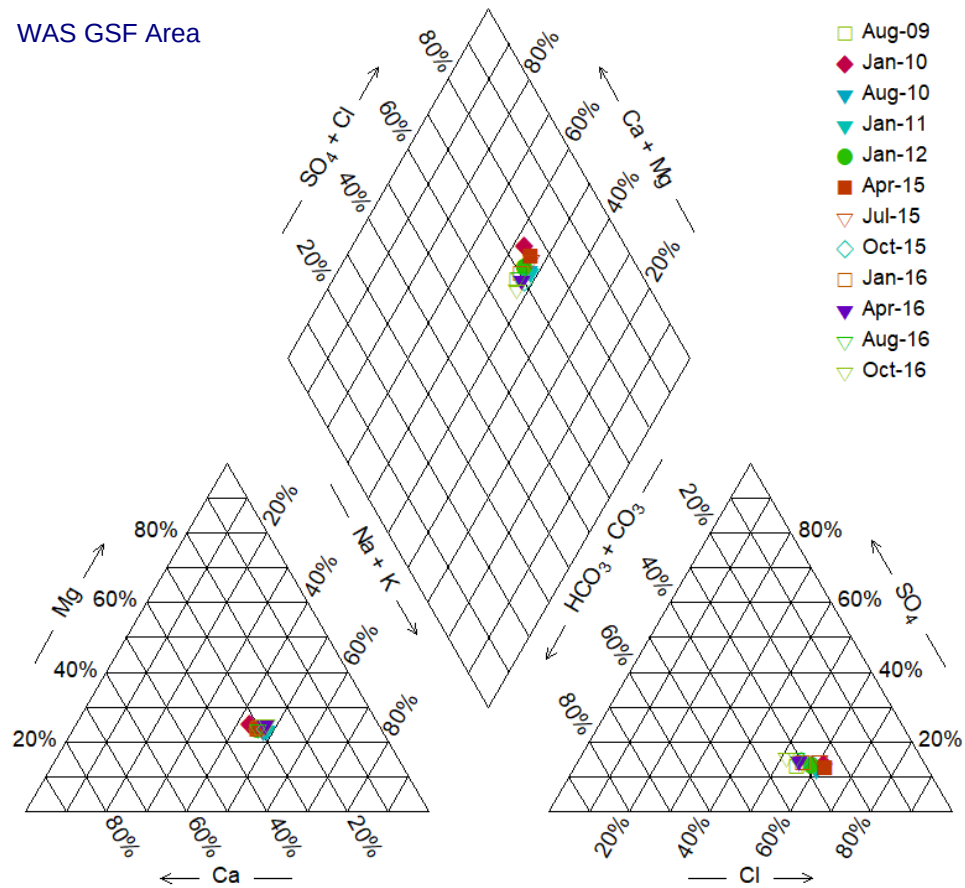
GSMB11 Piper Diagram

WAS GSF Area



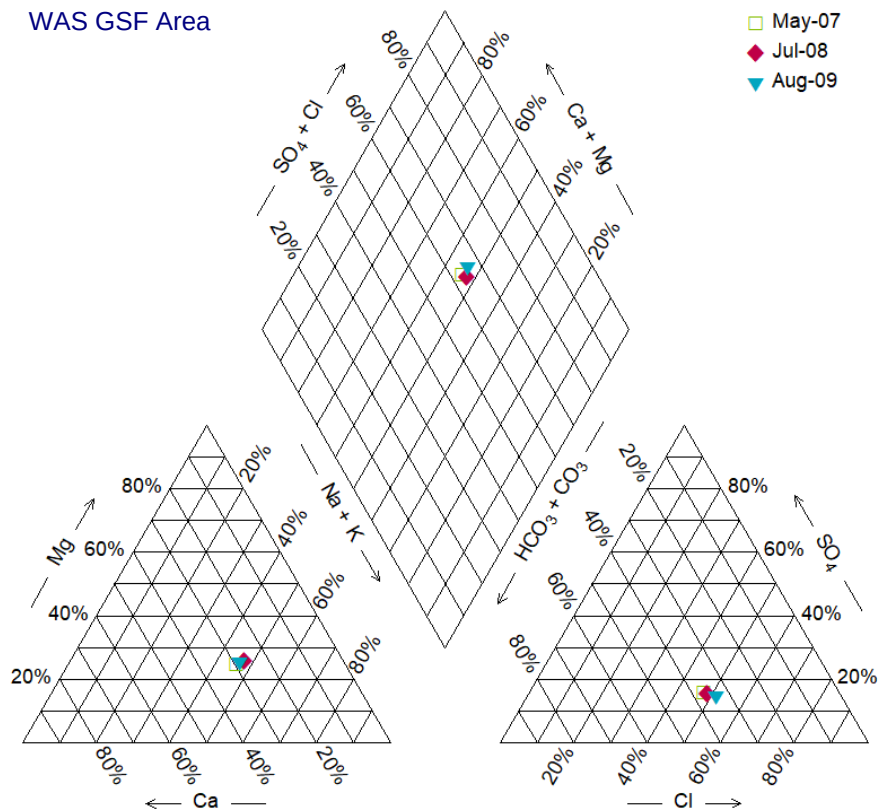
GSMB04B Piper Diagram

WAS GSF Area



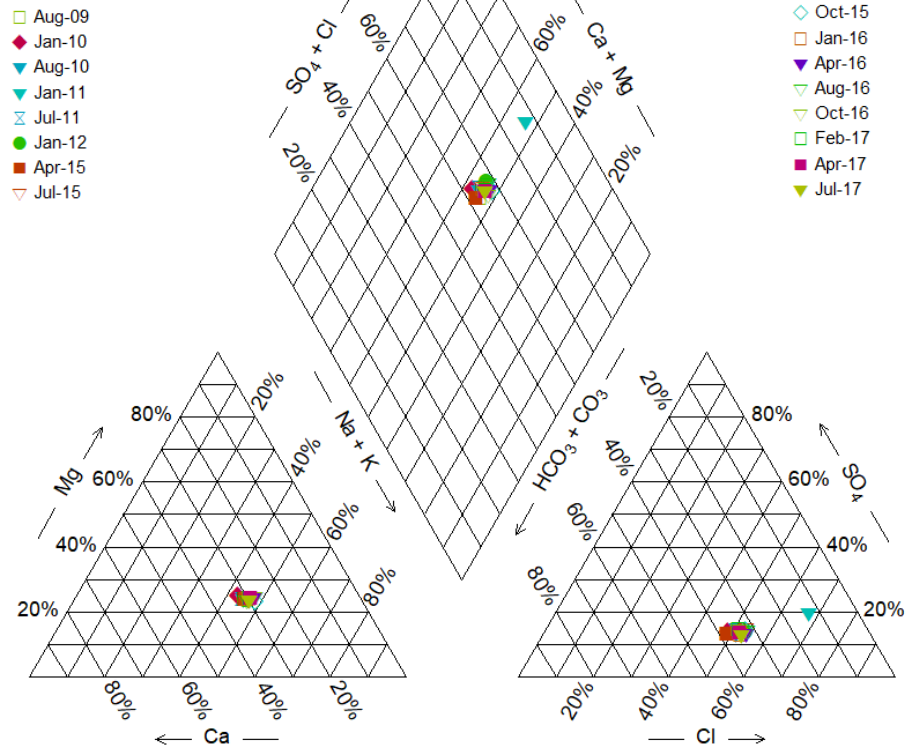
GSMB05 Piper Diagram

WAS GSF Area



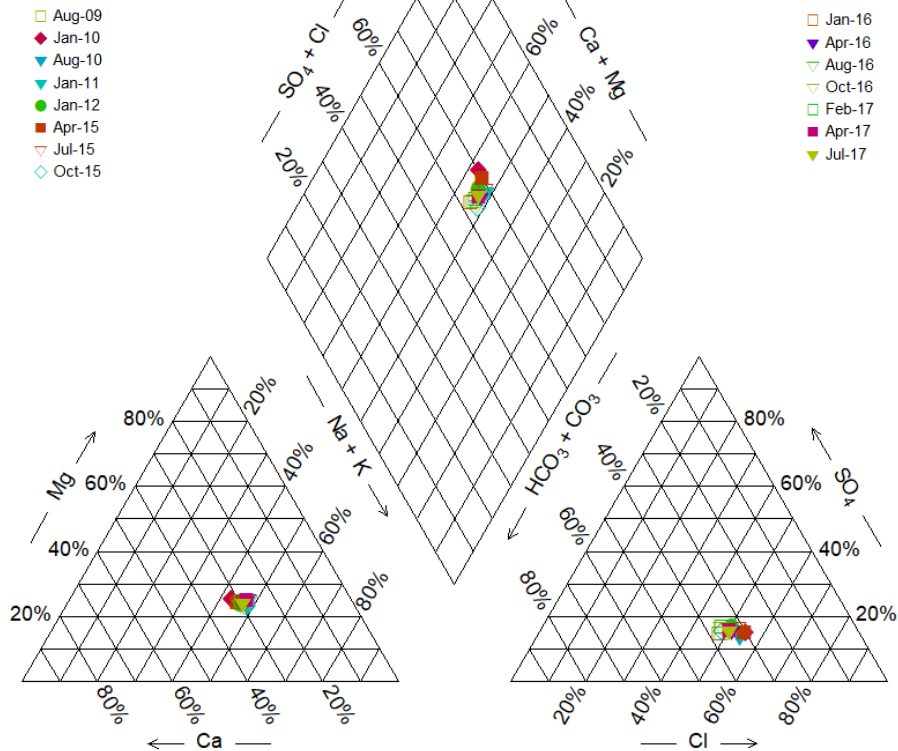
GSMB02A Piper Diagram

WAS GSF Area



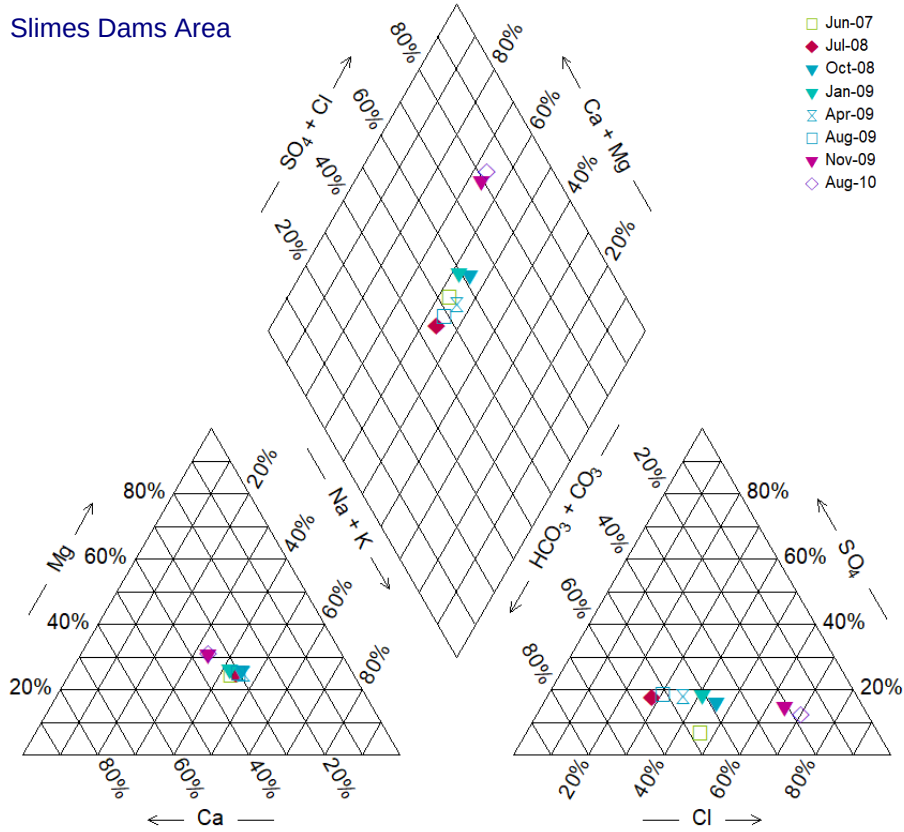
GSMB01A Piper Diagram

WAS GSF Area



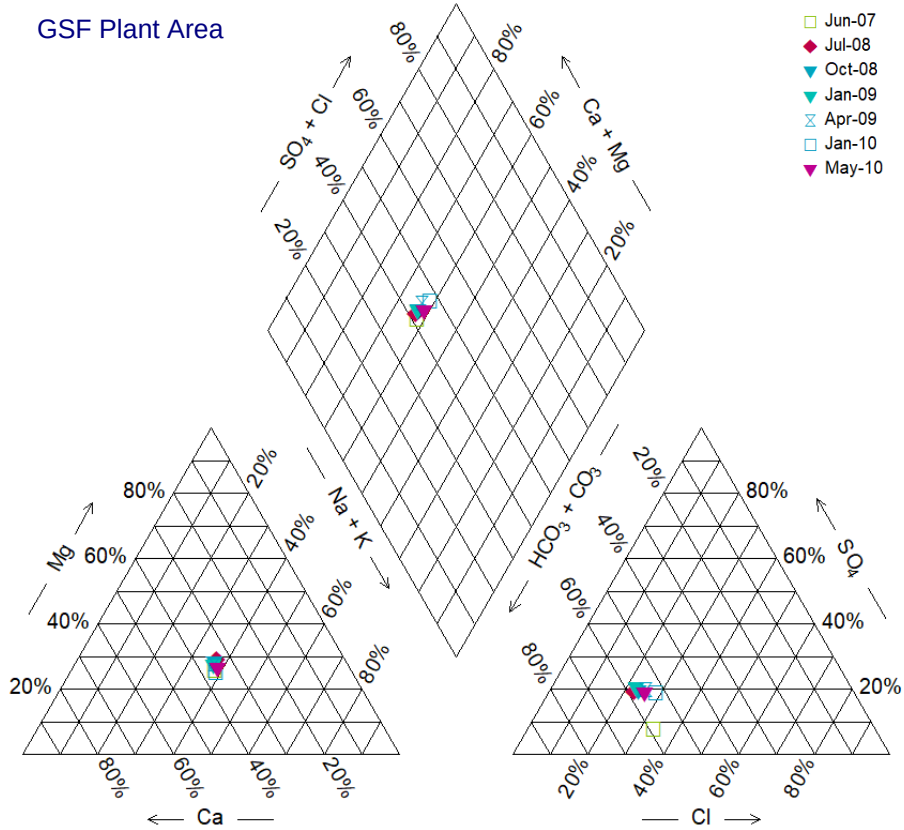
GW21 Piper Diagram

Slimes Dams Area



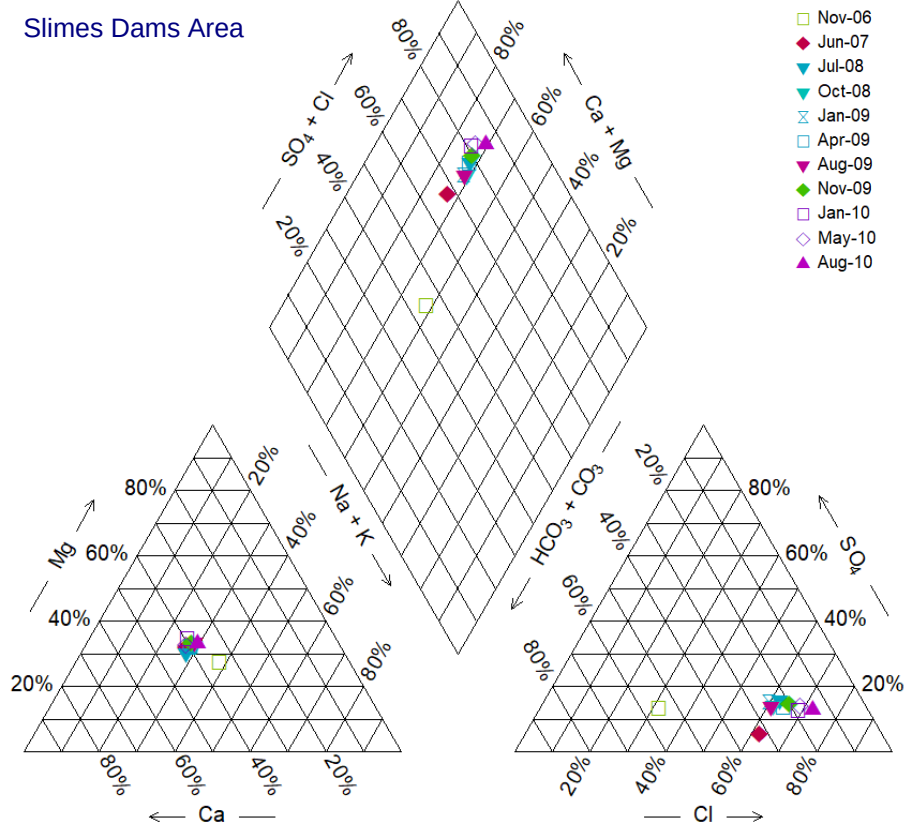
GW15 Piper Diagram

GSF Plant Area



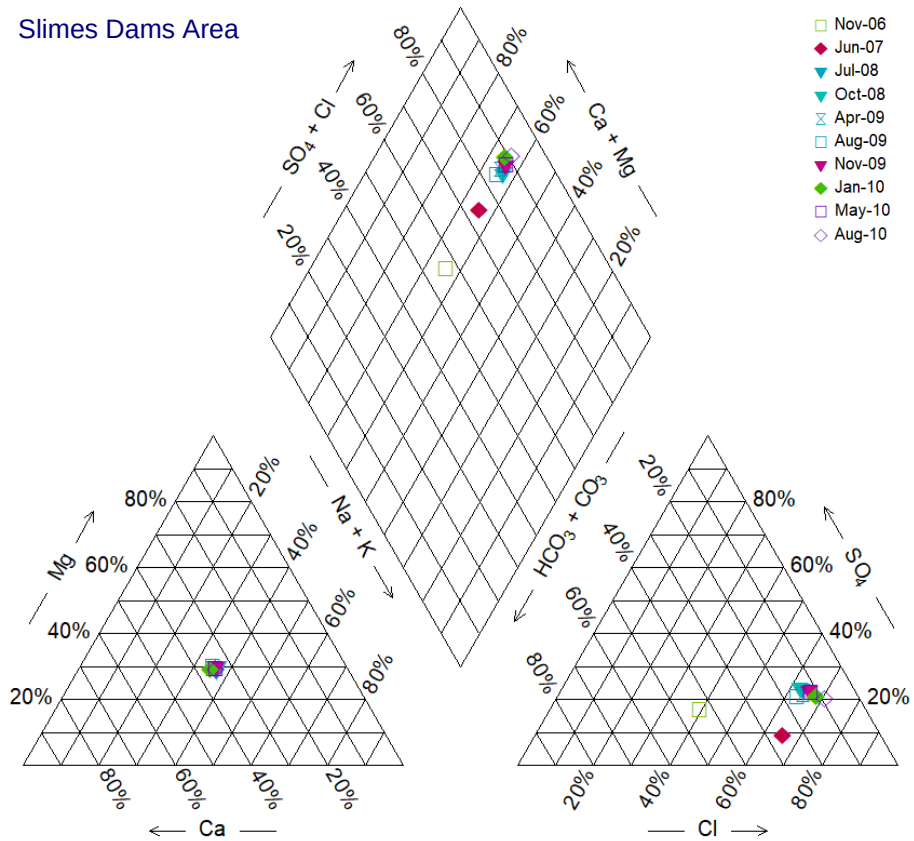
GW01 Piper Diagram

Slimes Dams Area



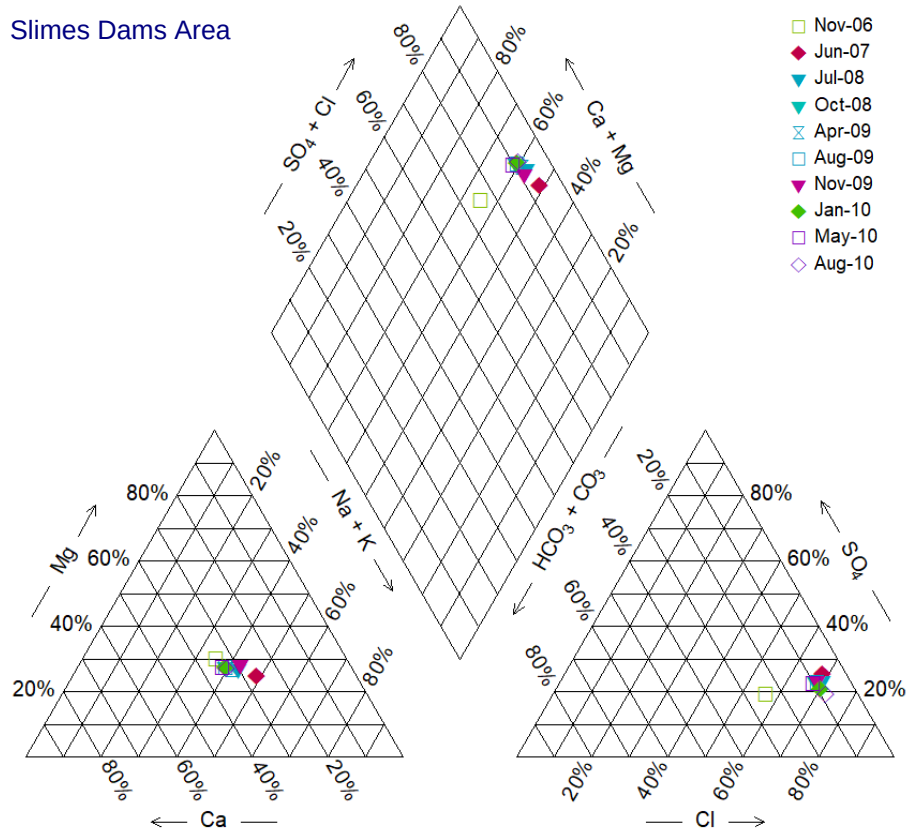
GW04 Piper Diagram

Slimes Dams Area



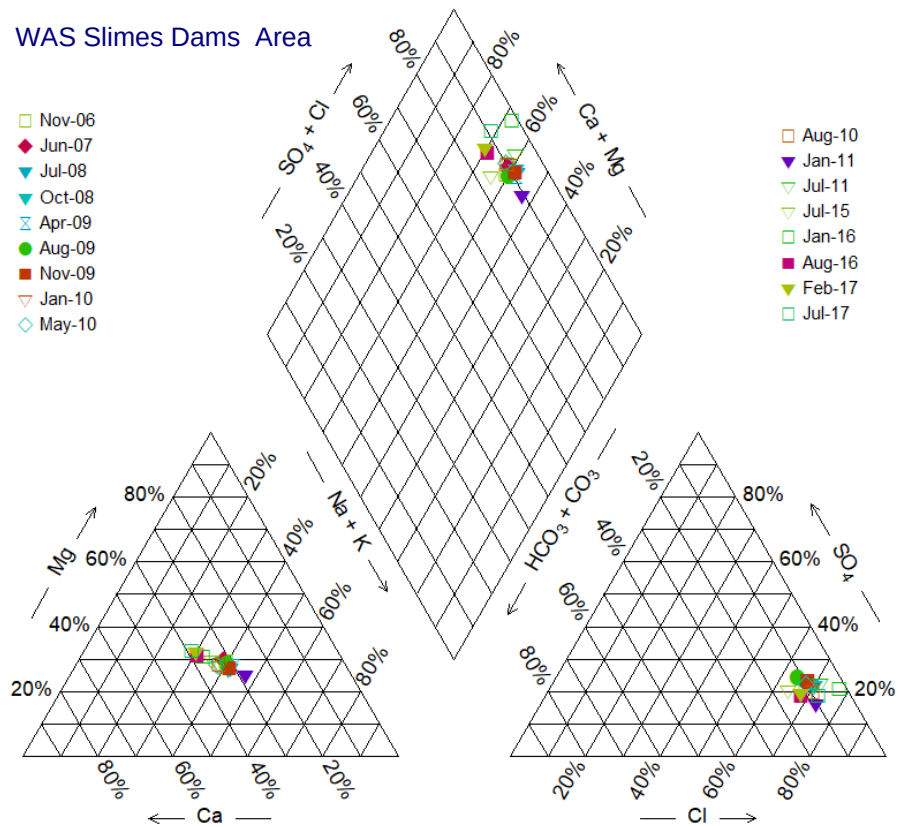
GW07A Piper Diagram

Slimes Dams Area



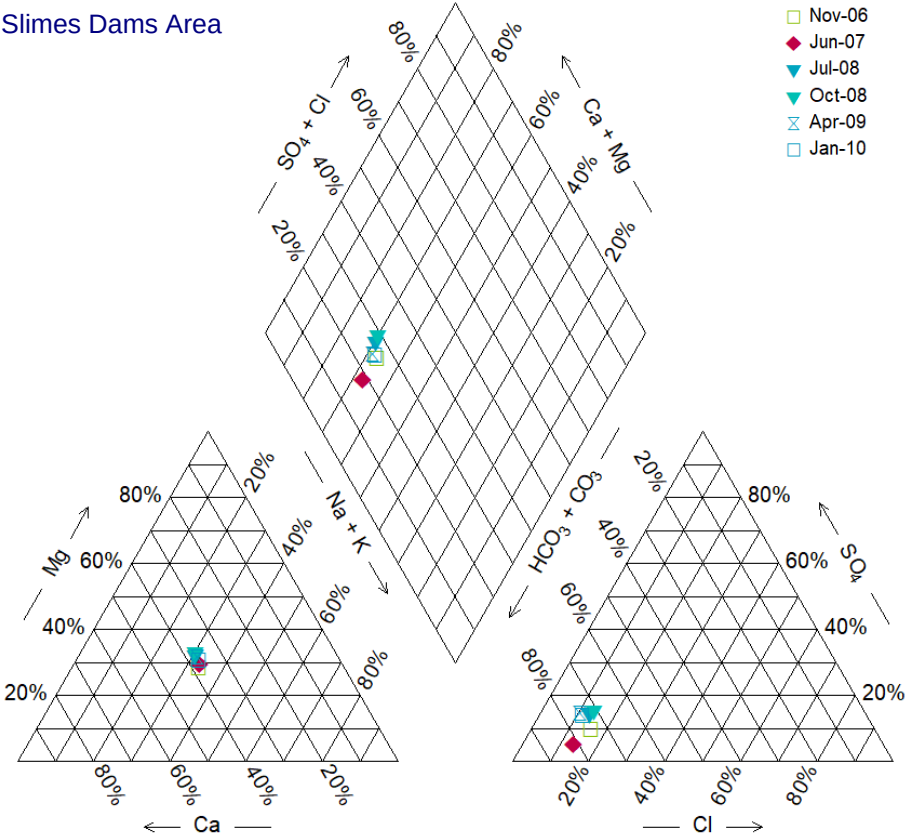
SDMB01 Piper Diagram

WAS Slimes Dams Area



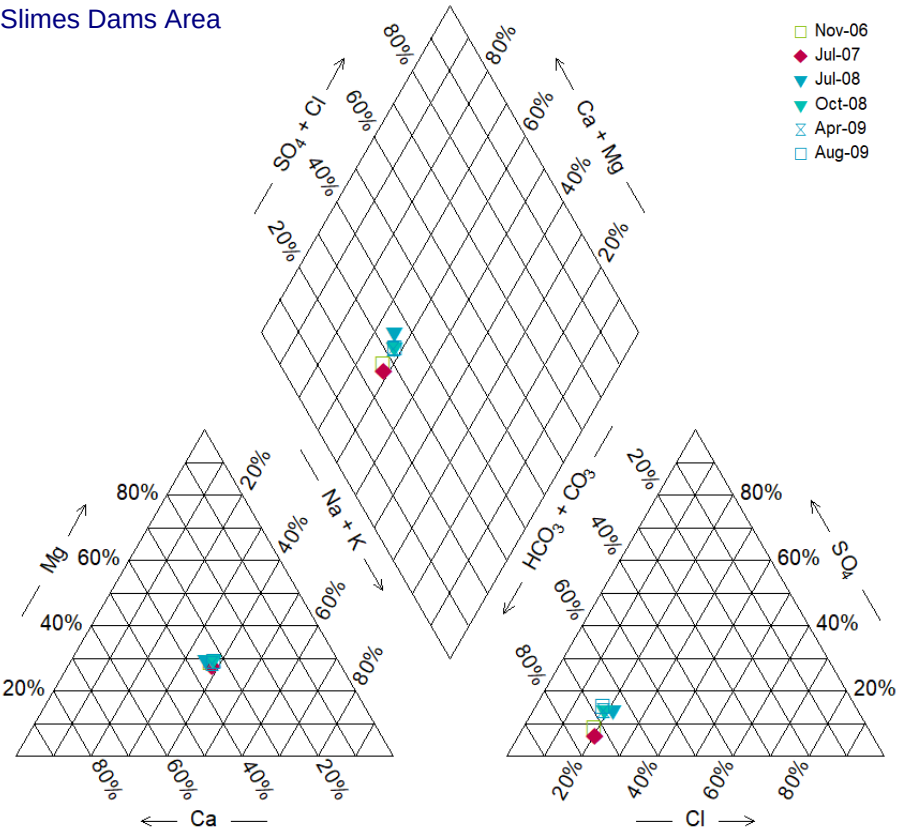
GW08 Piper Diagram

Slimes Dams Area



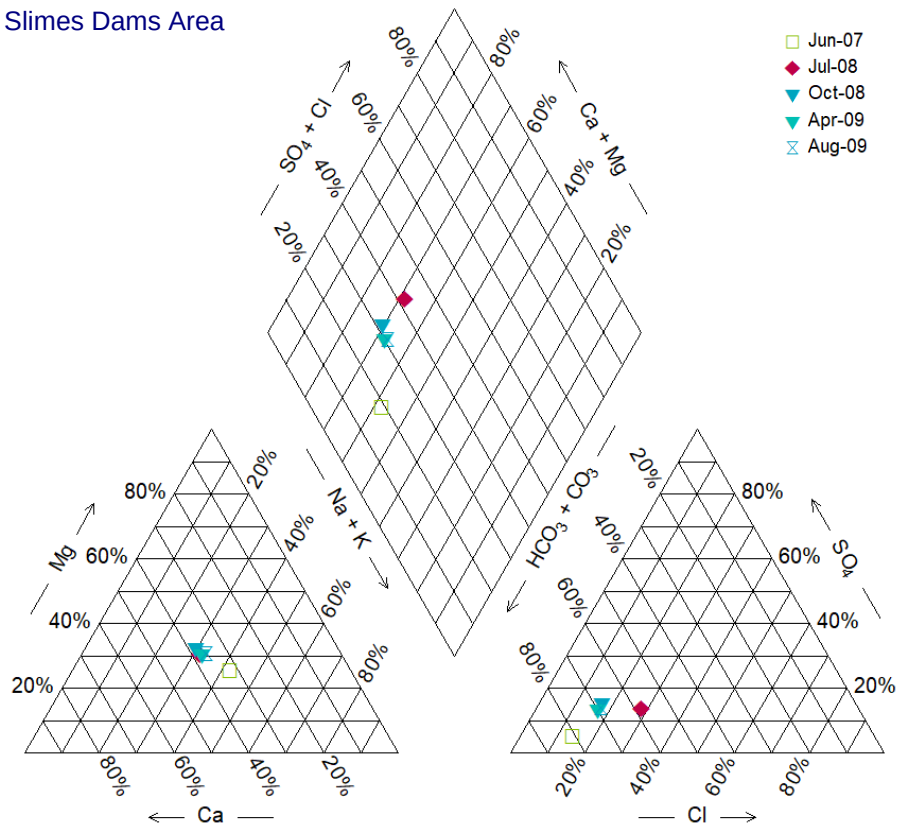
GW03 Piper Diagram

Slimes Dams Area



GW17 Piper Diagram

Slimes Dams Area



APPENDIX 8C1

WAS Analyte Concentration Time Series Plots – By Analyte

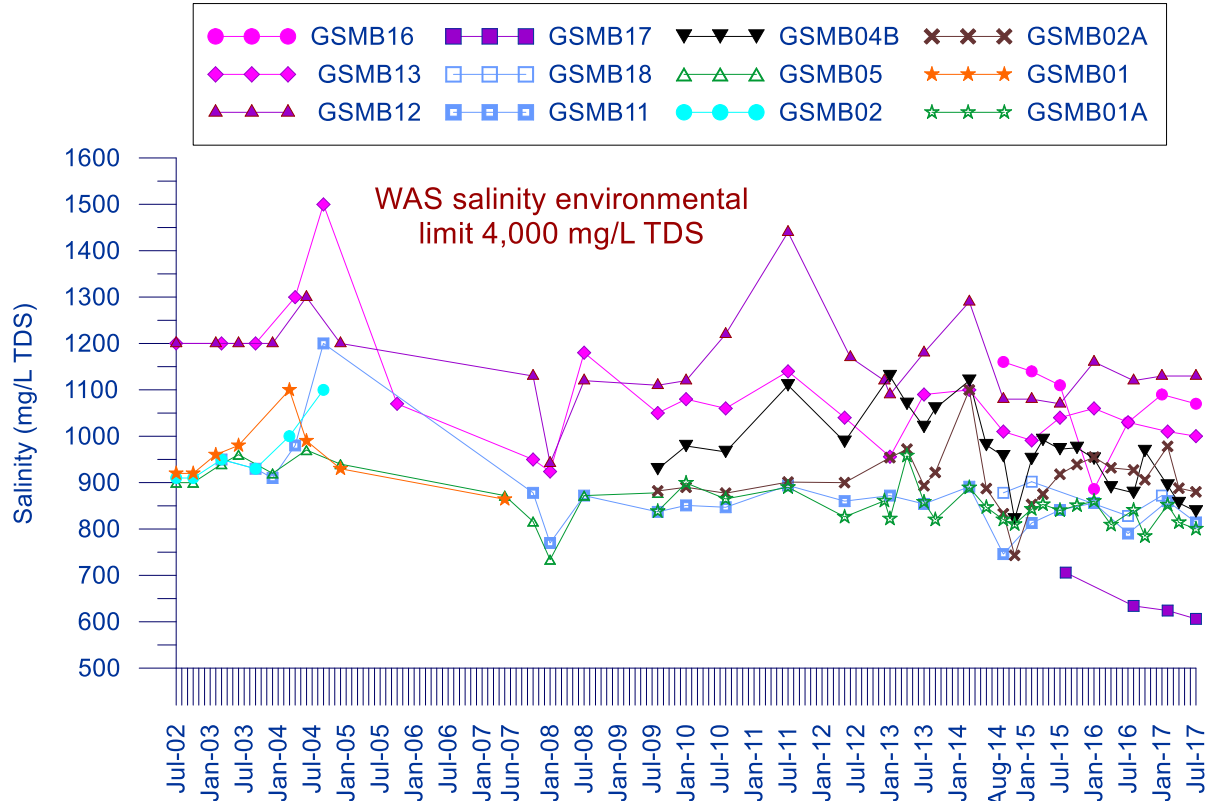
WAS GSF Area

Salinity
Chloride
Sulphate
Calcium
Sodium
Bicarbonate
Fluoride
Acidity

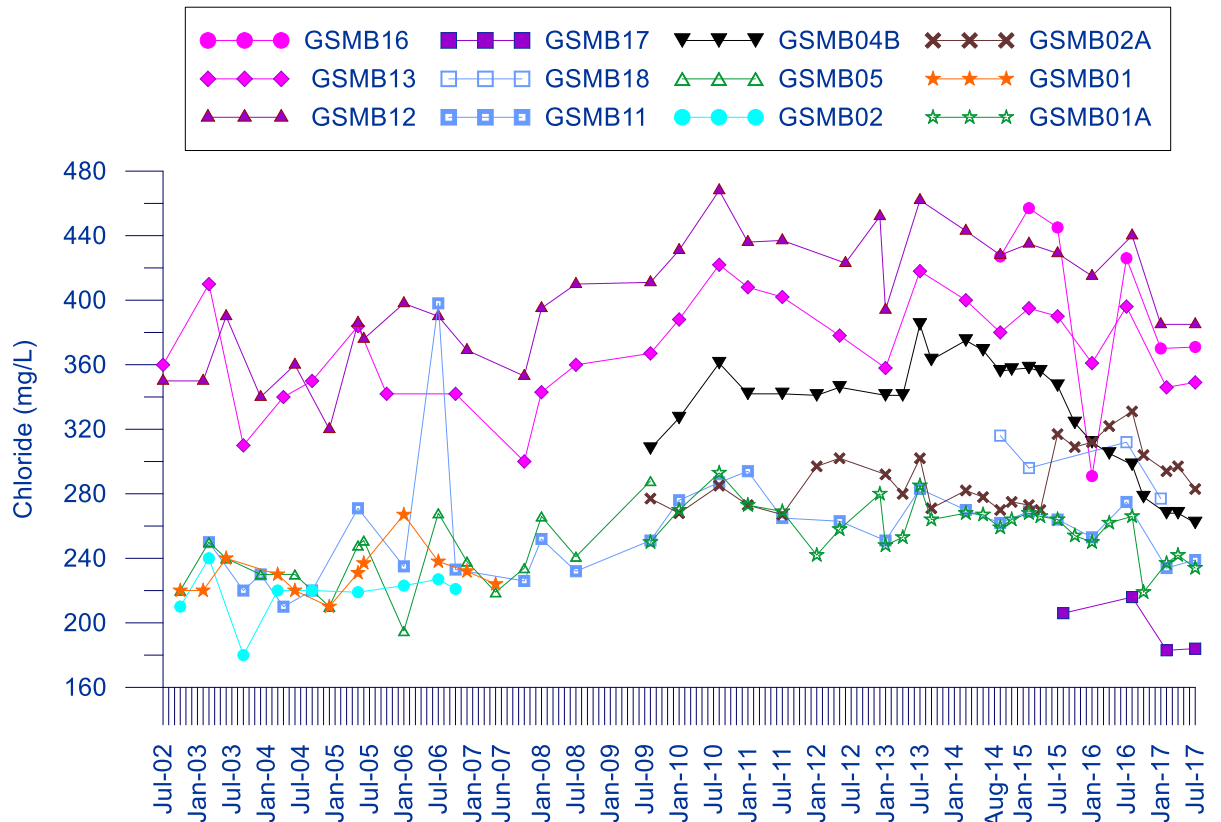
WAS Slimes Dams Area

Salinity
Chloride
Sulphate
Calcium
Sodium
Bicarbonate
Fluoride
Acidity

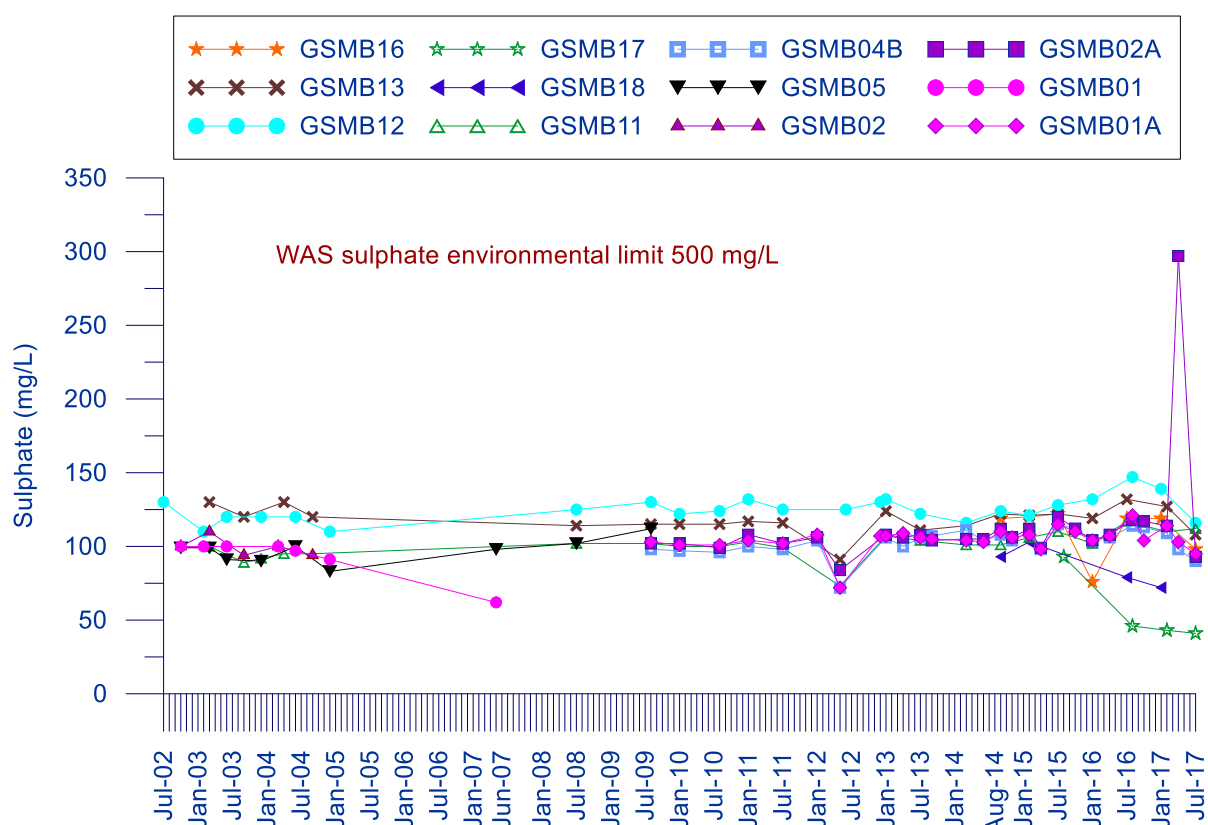
Western Aquifer System GSF Area Salinity



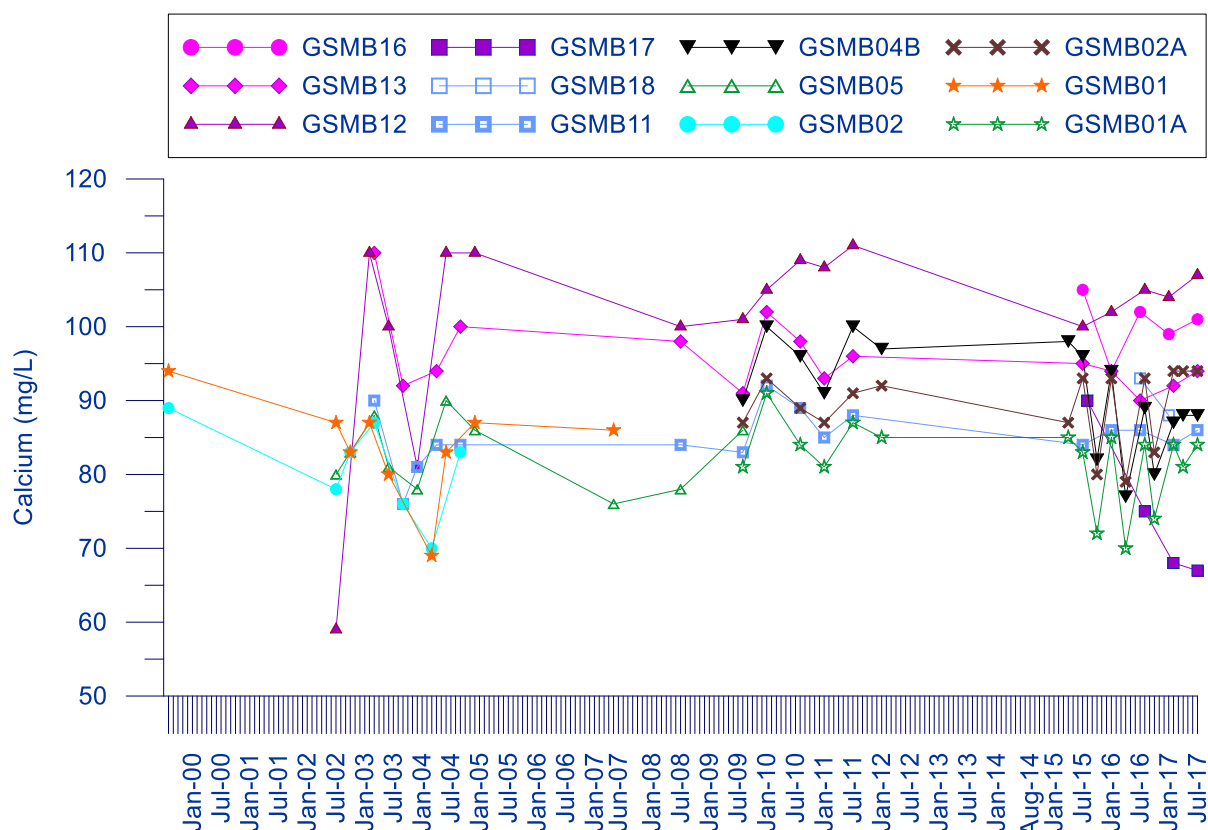
Western Aquifer System GSF Area Chloride



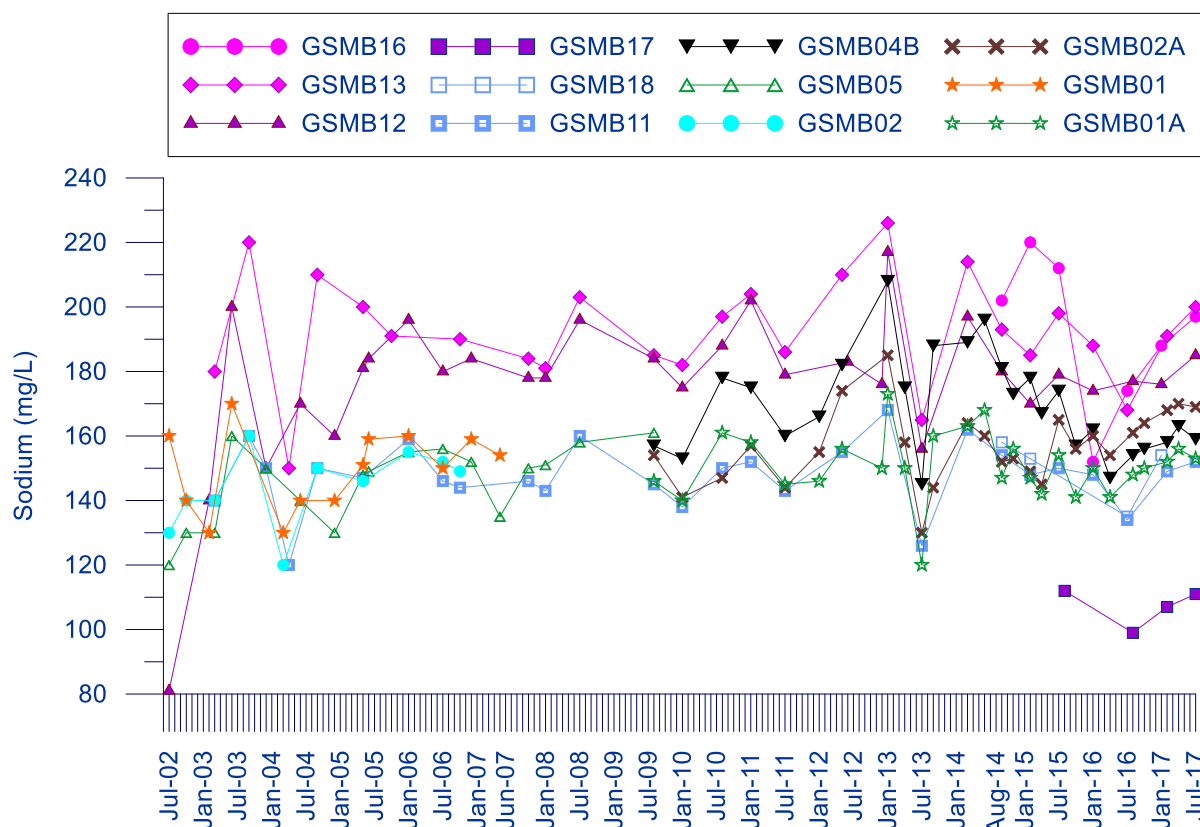
Western Aquifer System GSF Area Sulphate



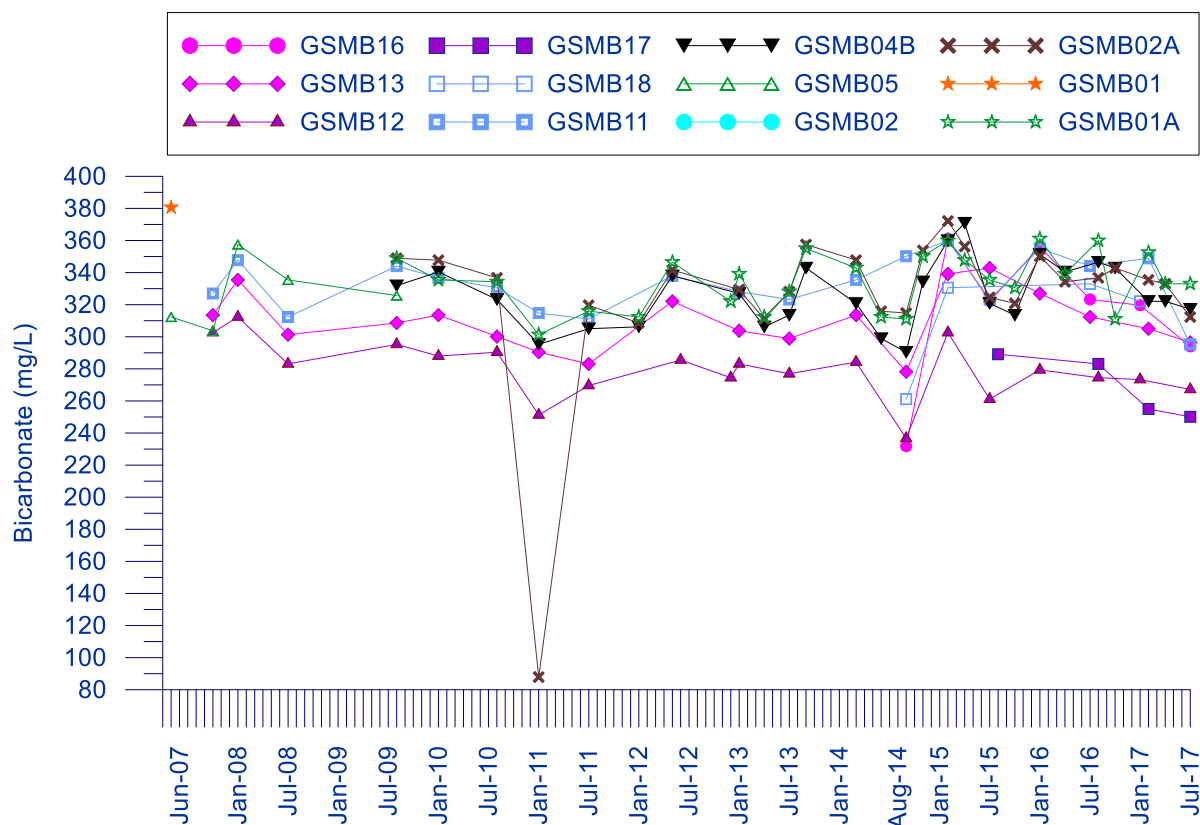
Western Aquifer System GSF Area Calcium



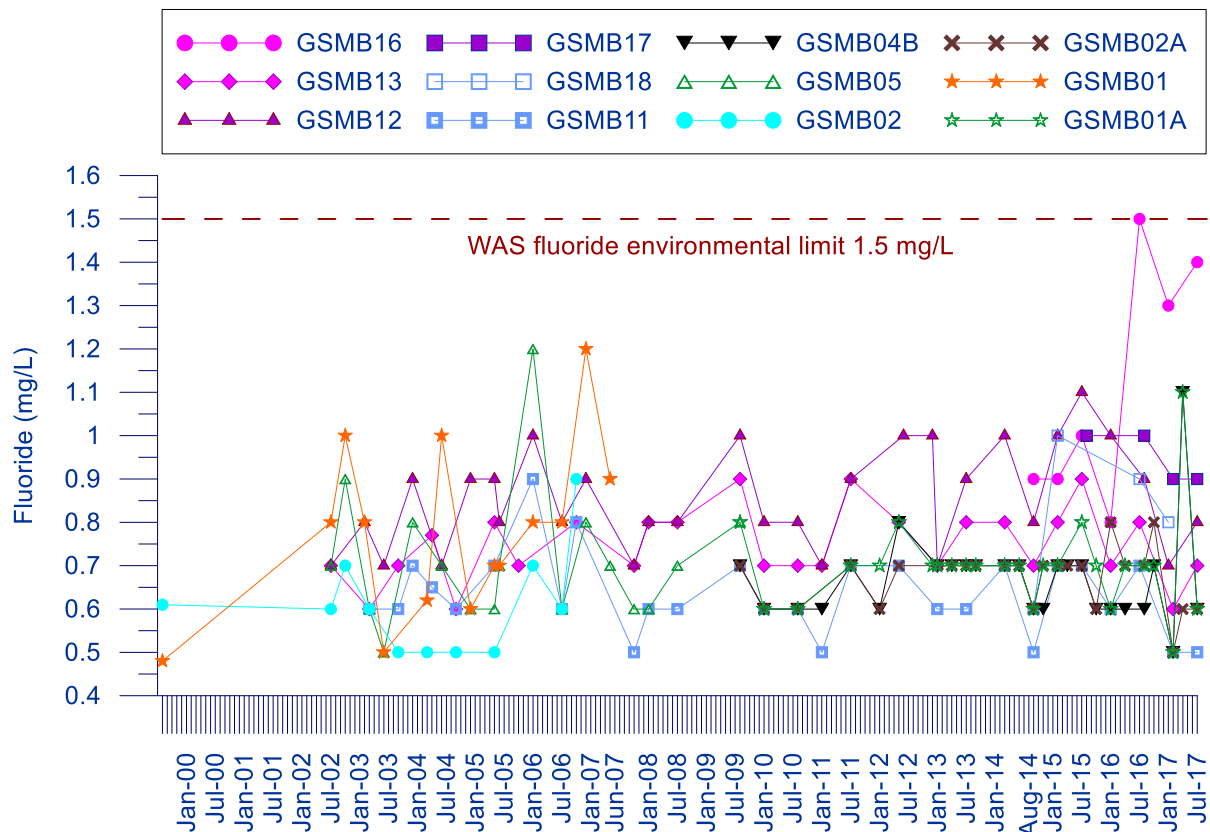
Western Aquifer System GSF Area Sodium



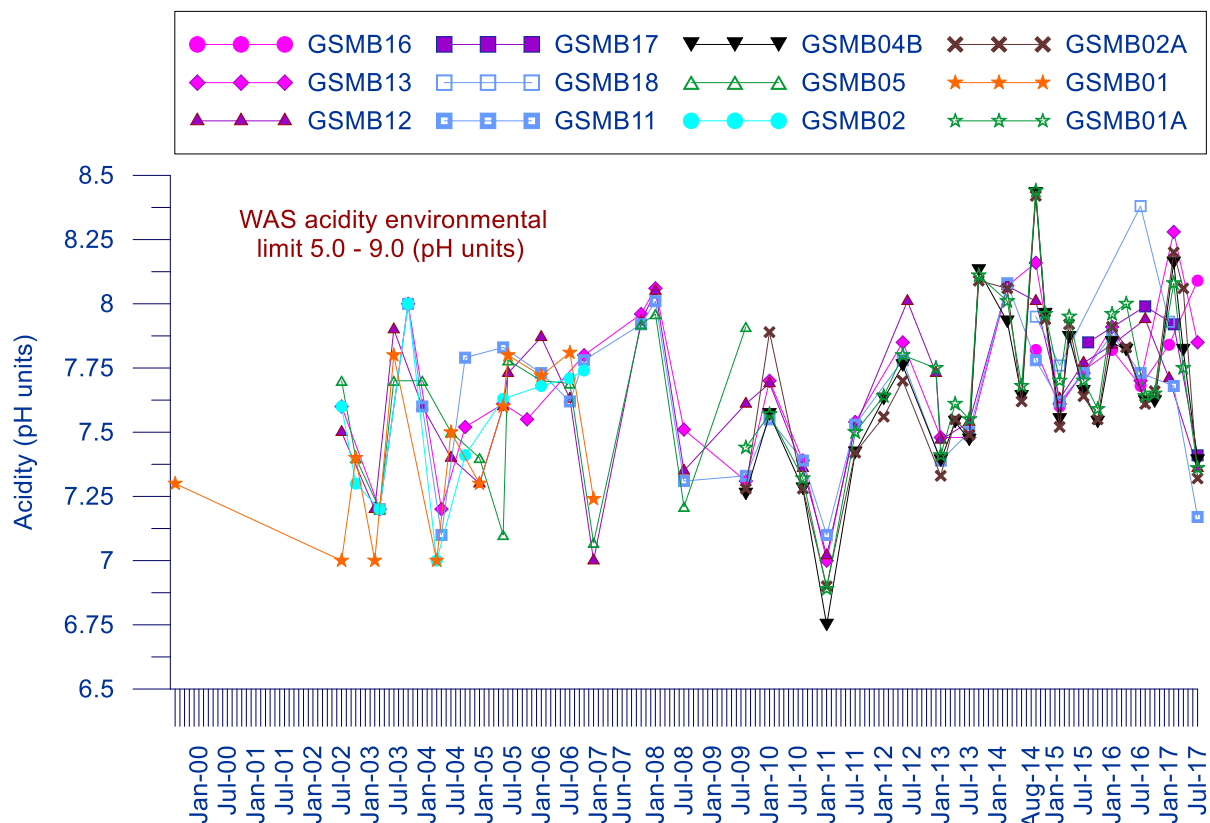
Western Aquifer System GSF Area Bicarbonate



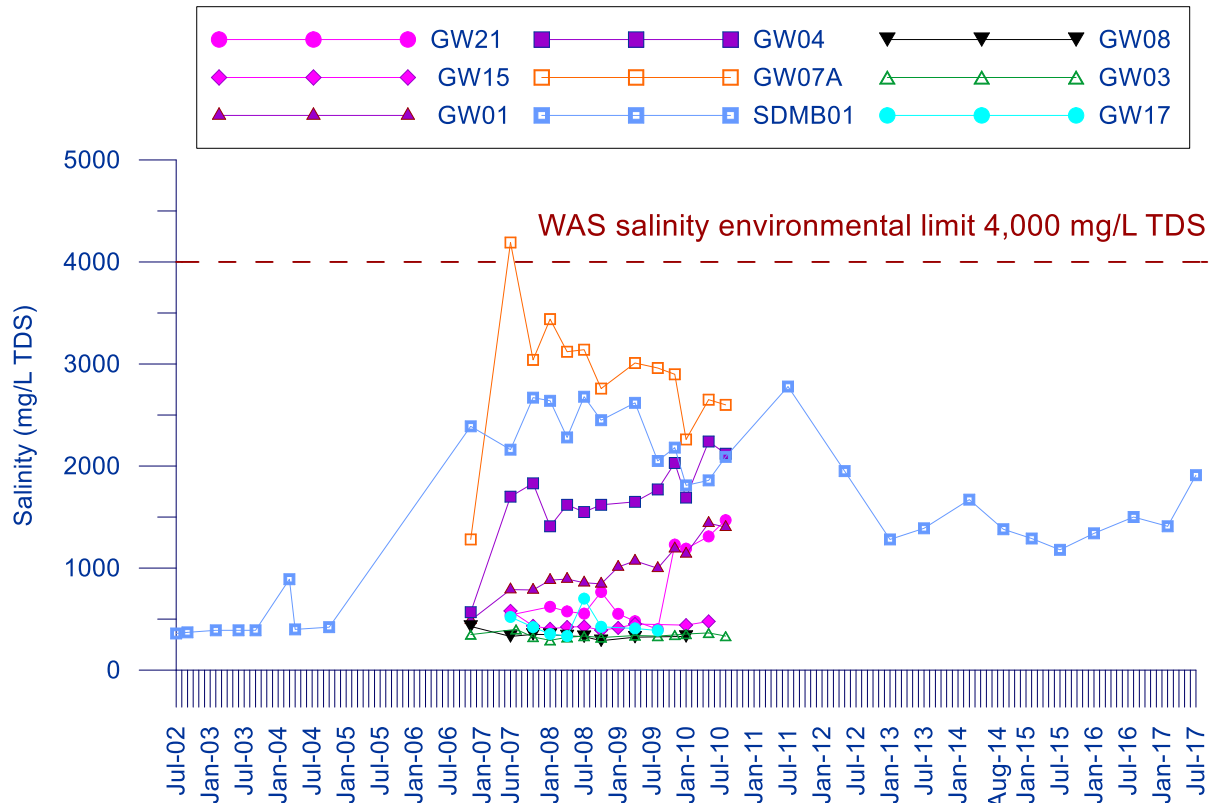
Western Aquifer System GSF Area Fluoride



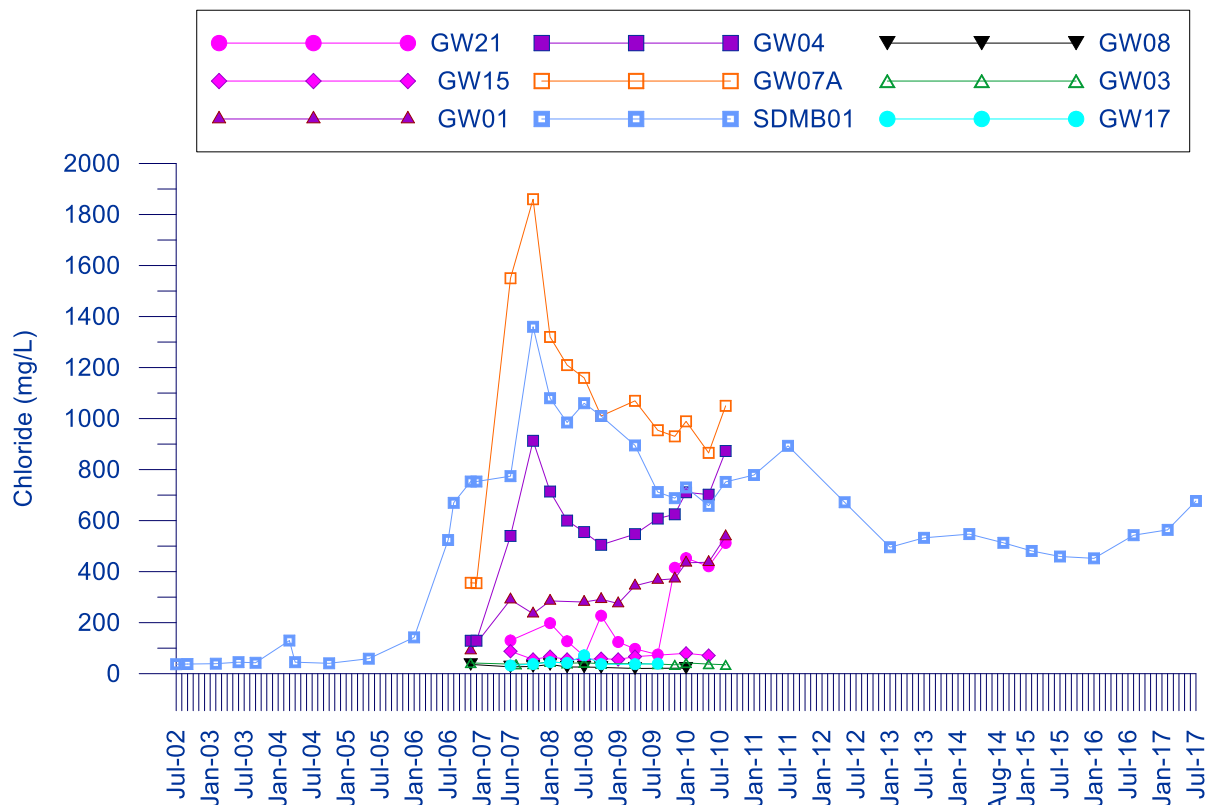
Western Aquifer System GSF Area Acidity



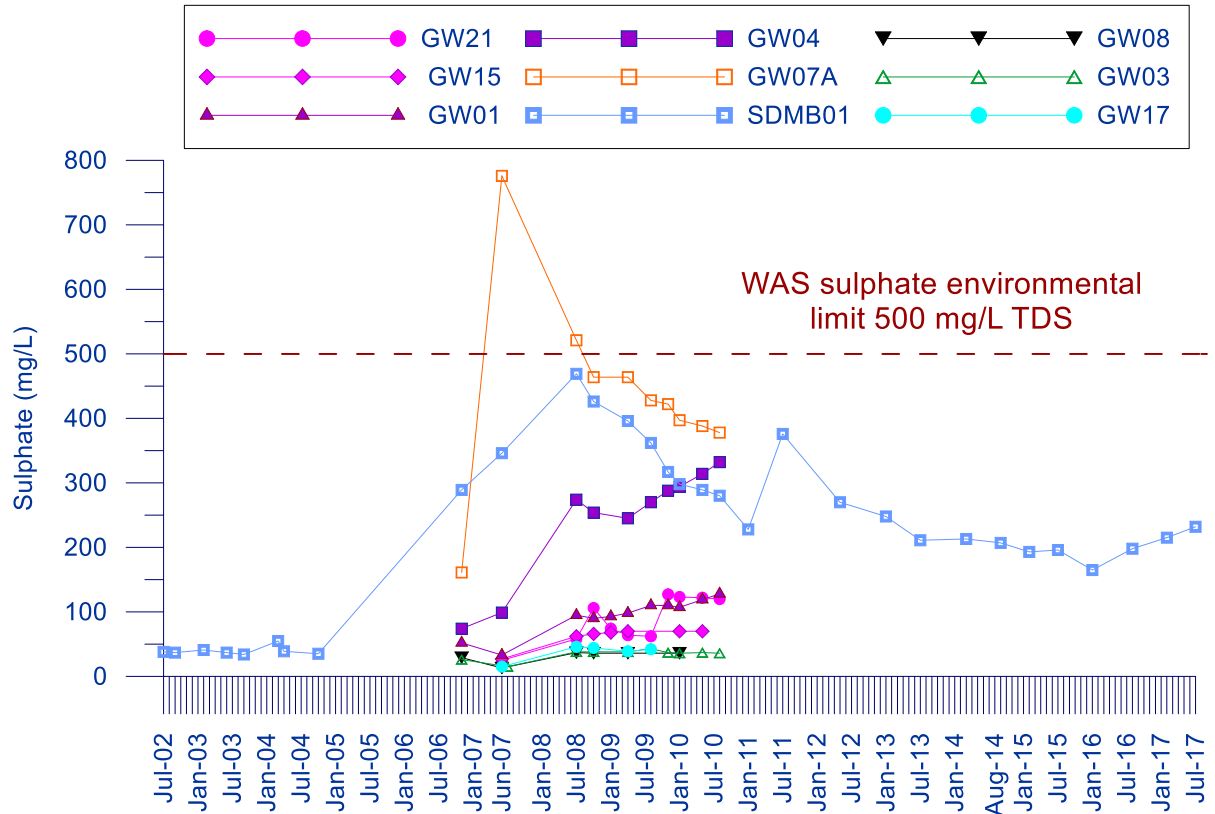
Western Aquifer System Slimes Dams Area Salinity



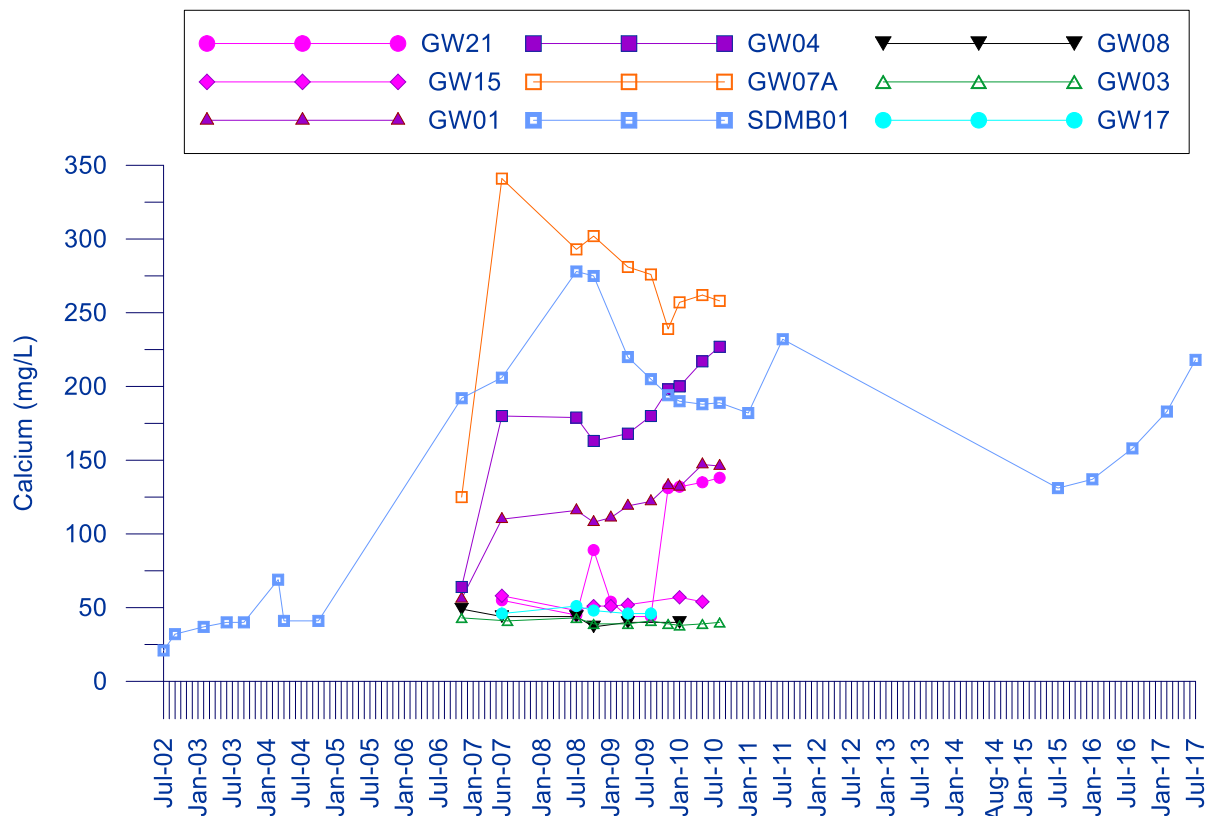
Western Aquifer System Slimes Dams Area Chloride



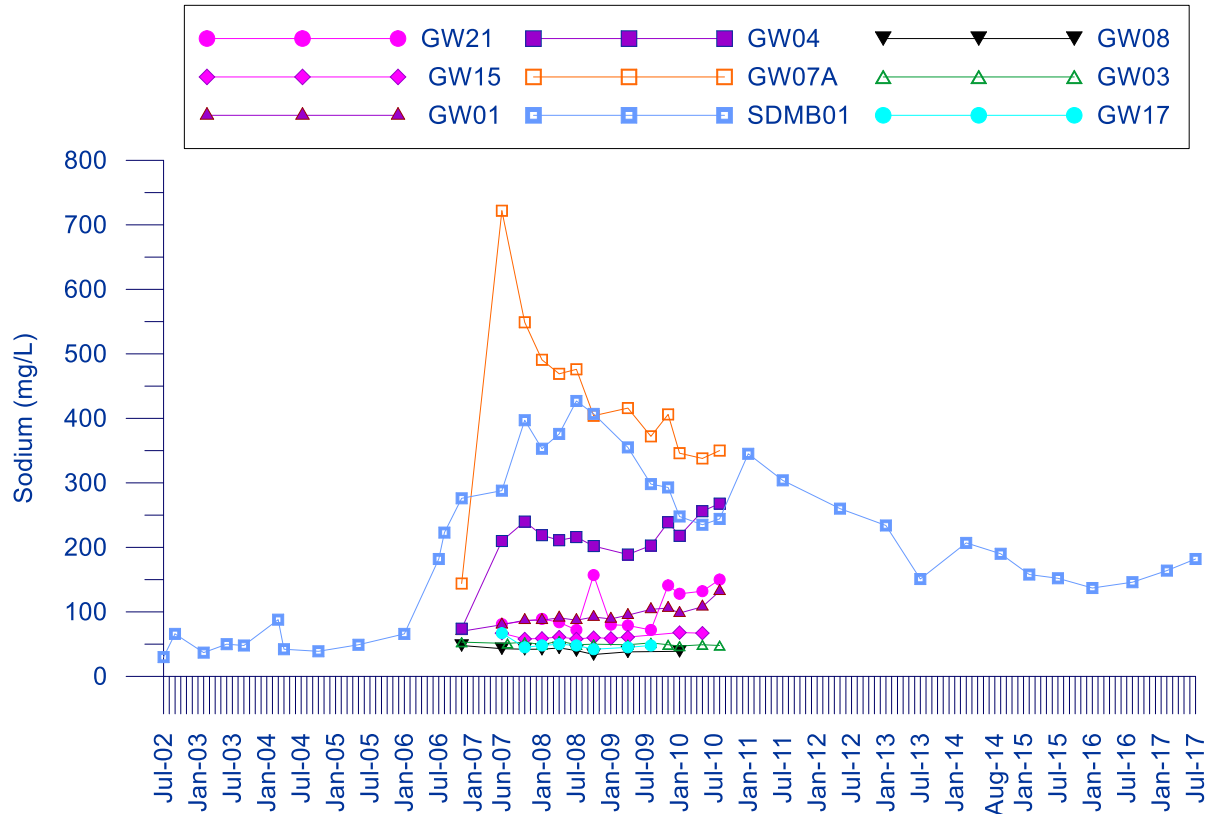
Western Aquifer System Slimes Dams Area Sulphate



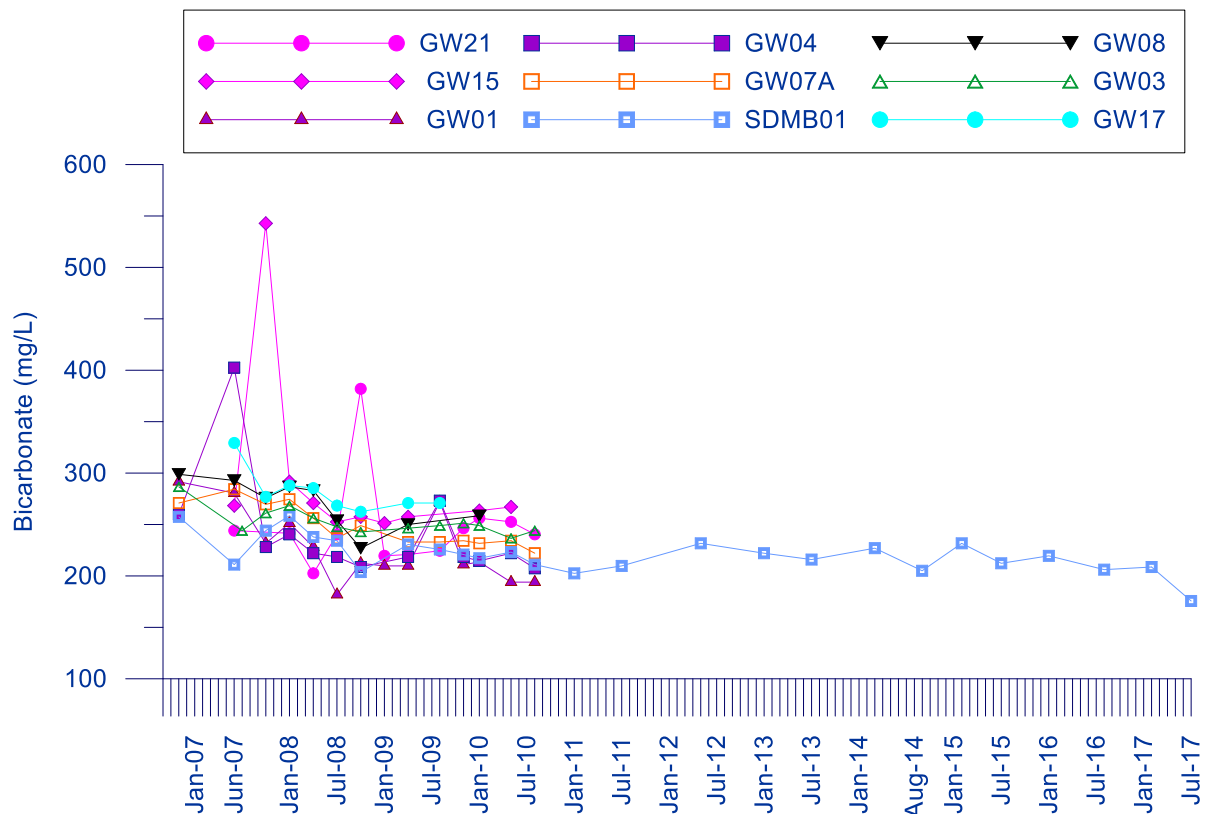
Western Aquifer System Slimes Dams Area Calcium



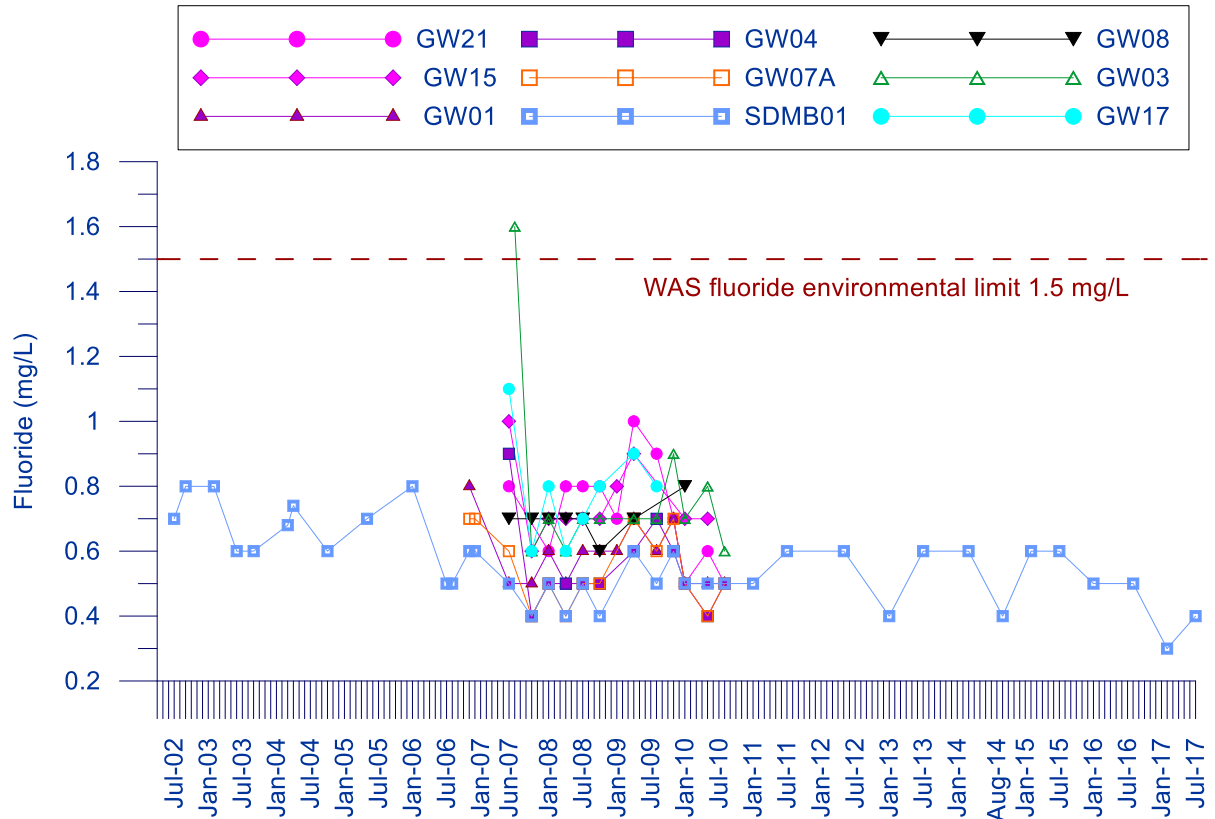
Western Aquifer System Slimes Dams Area Sodium



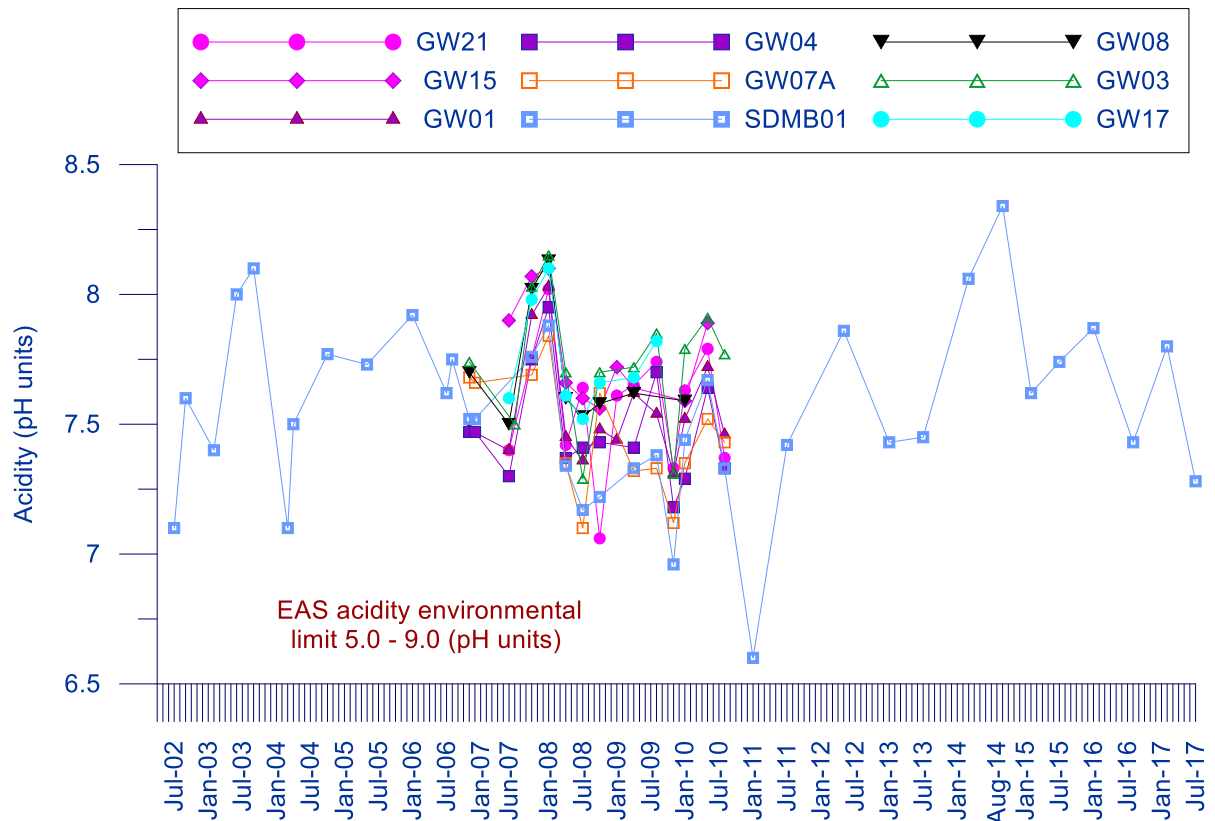
Western Aquifer System Slimes Dams Area Bicarbonate



Western Aquifer System Slimes Dams Area Fluoride



Western Aquifer System Slimes Dams Area Acidity



APPENDIX 8C2

WAS Analyte Concentration Time Series Plots – By Bore (arranged from north to south)

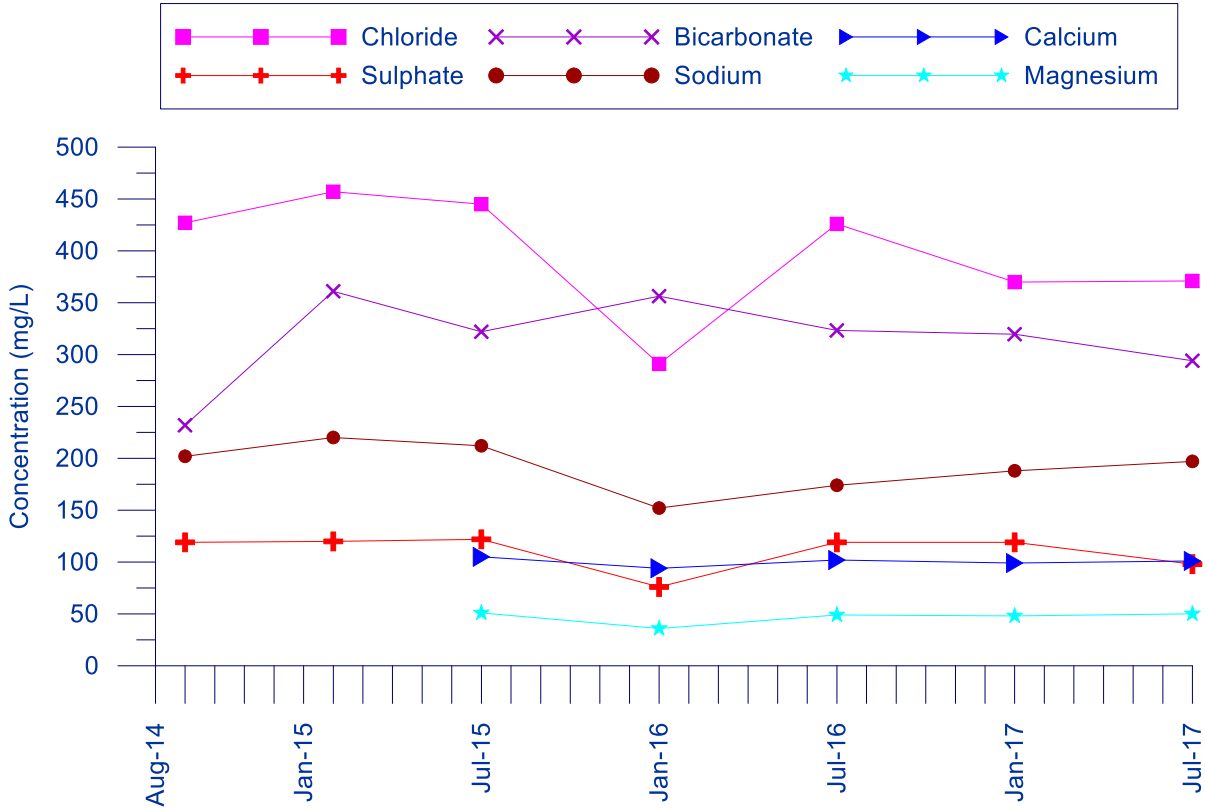
WAS GSF Area

**GSMB16
GSMB13
GSMB12
GSMB18
GSMB11
GSMB04B
GSMB05
GSMB02
GSMB02A
GSMB01
GSMB01A**

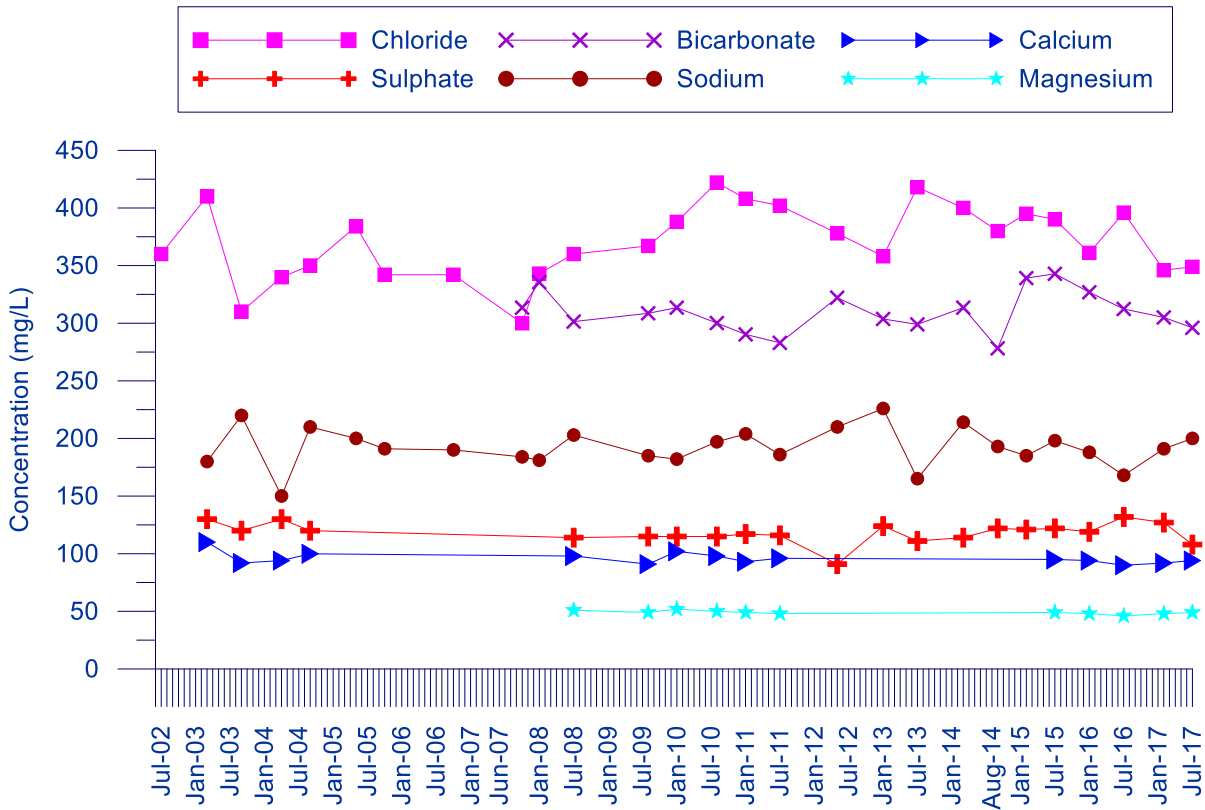
WAS Slimes Dams Area

**GW21
GW15
GW01
GW04
GW07A
GW08
GW03
GW17**

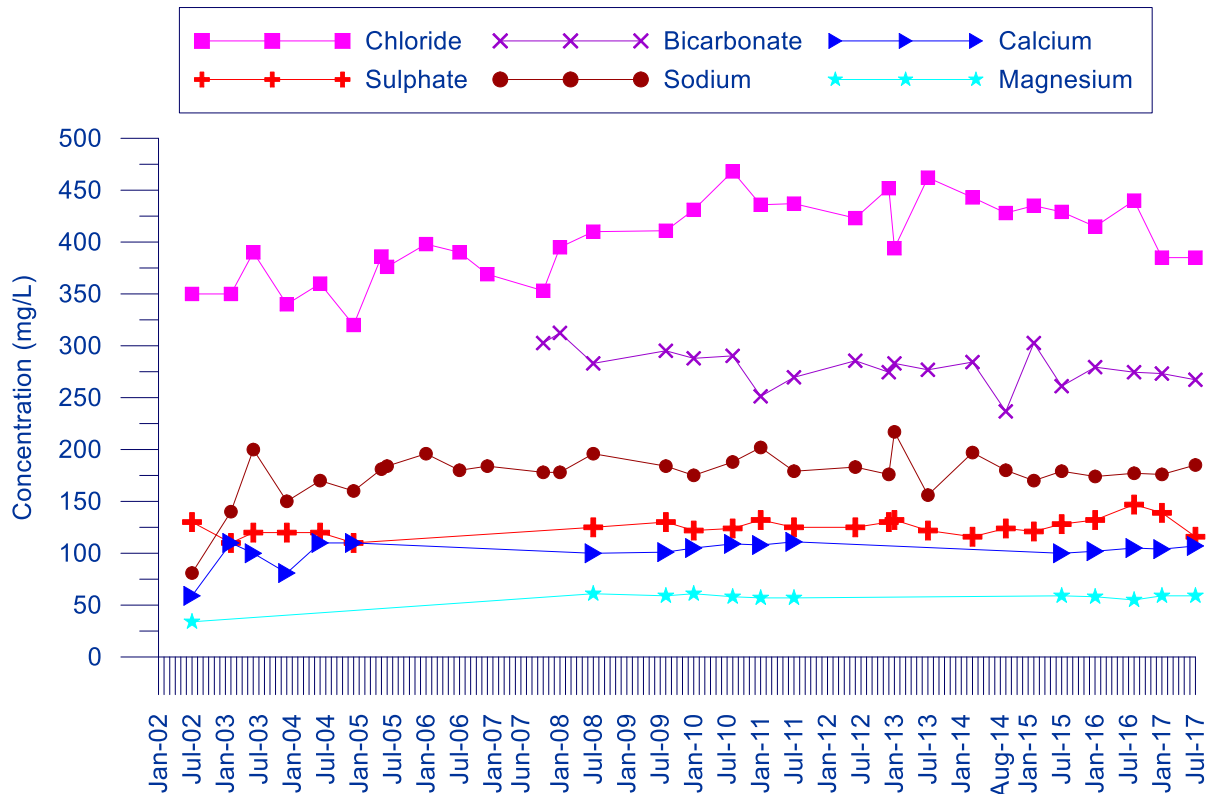
Western Aquifer System GSF Area Bore GSMB16



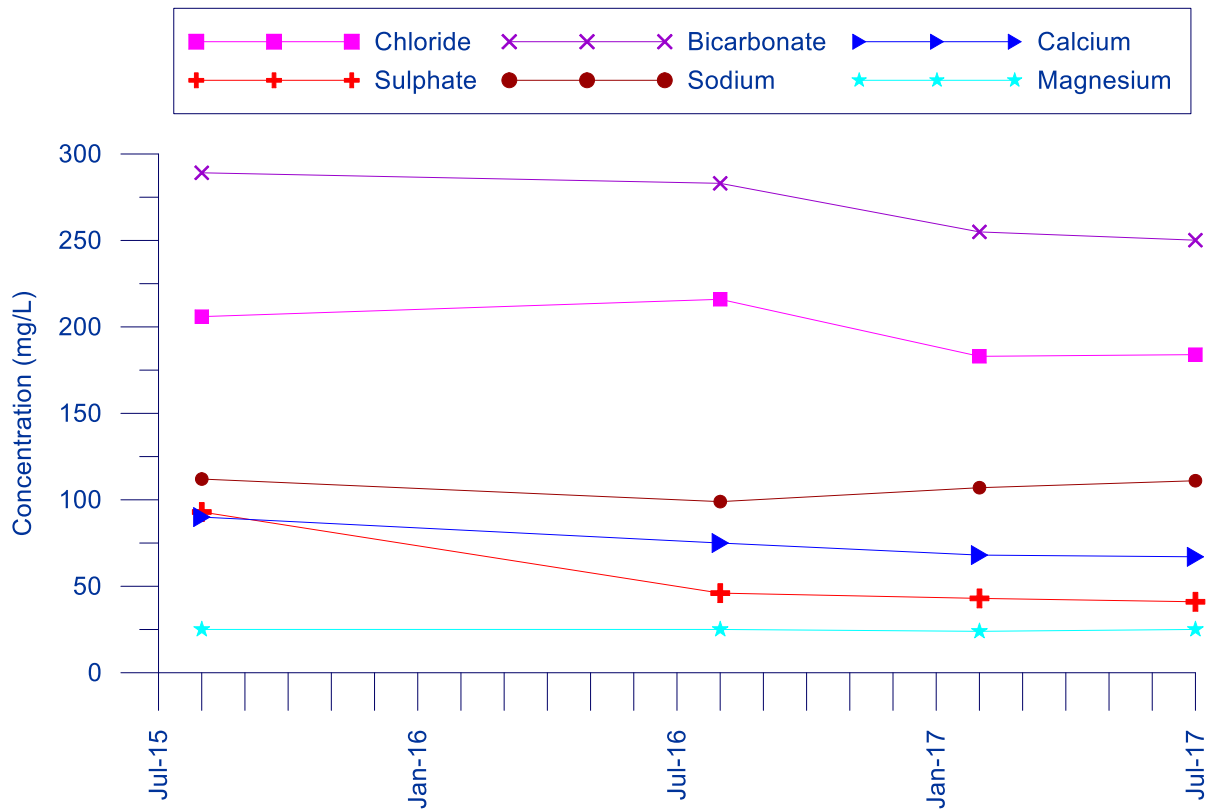
Western Aquifer System GSF Area Bore GSMB13



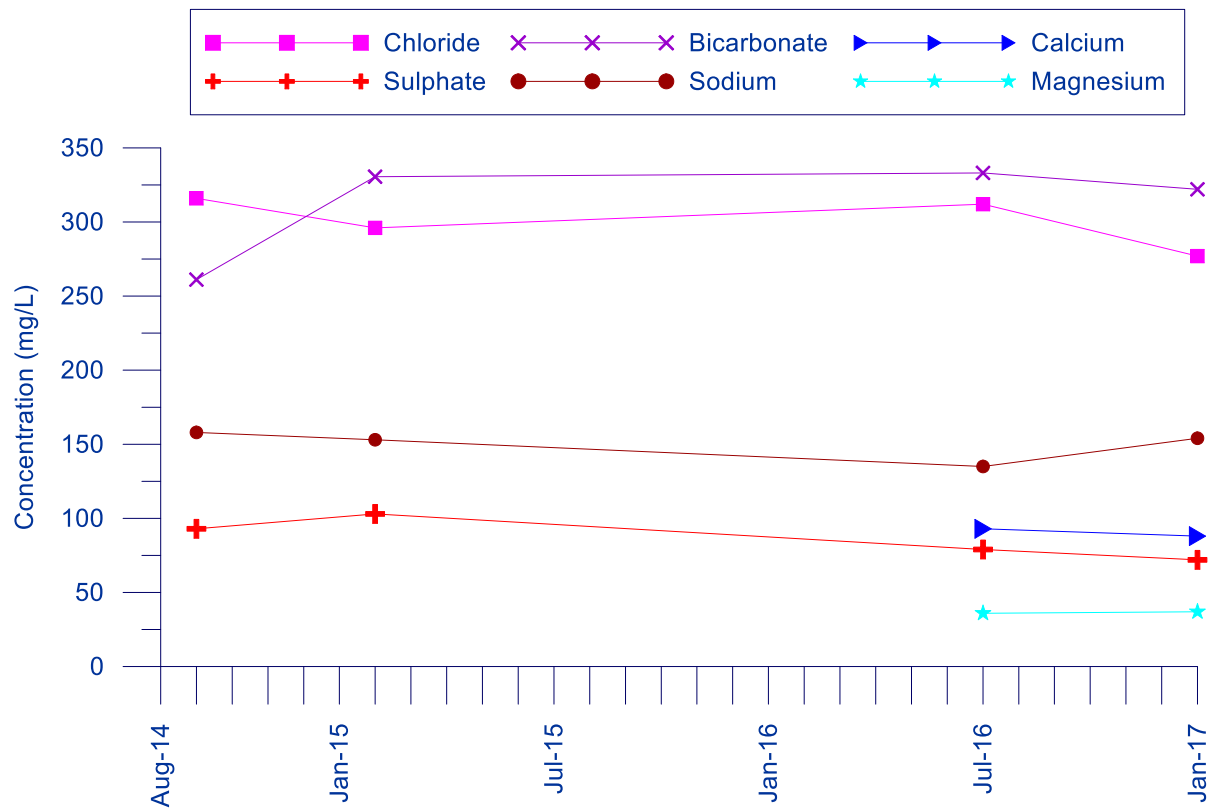
Western Aquifer System GSF Area Bore GSMB12



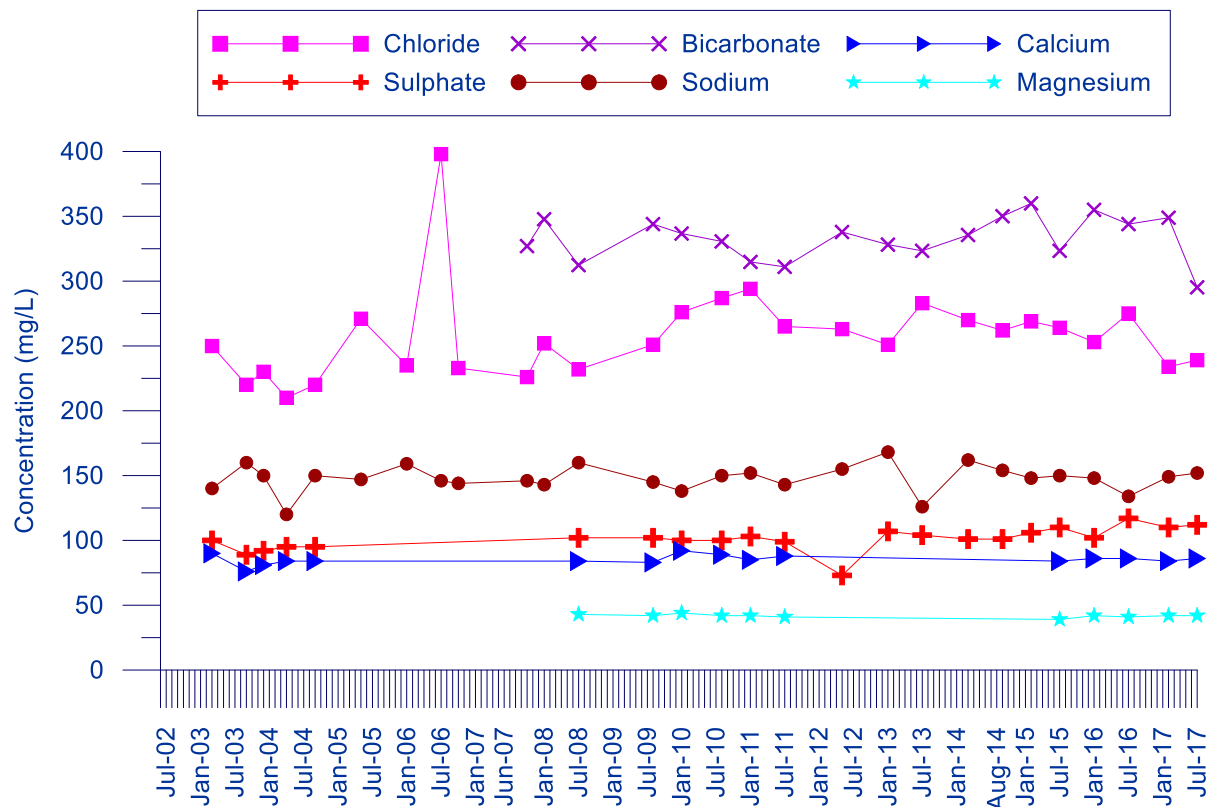
Western Aquifer System GSF Area Bore GSMB17



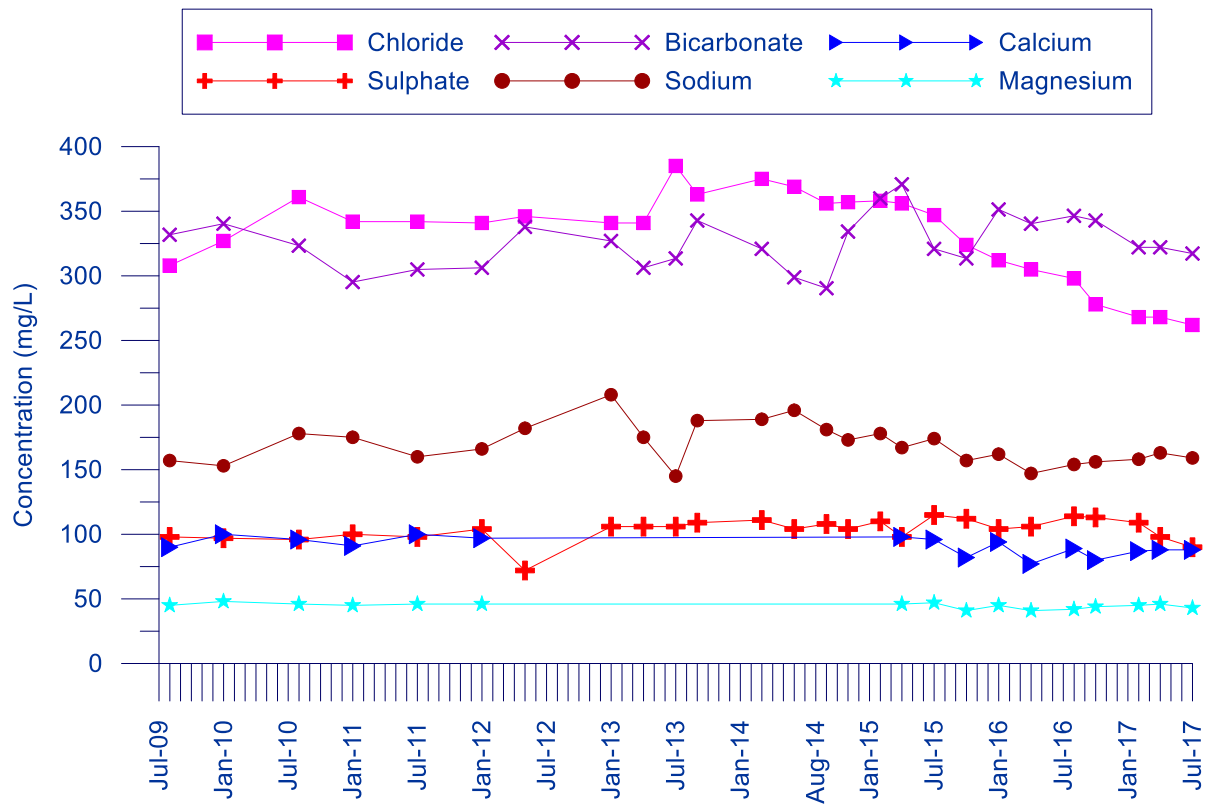
Western Aquifer System GSF Area Bore GSMB18



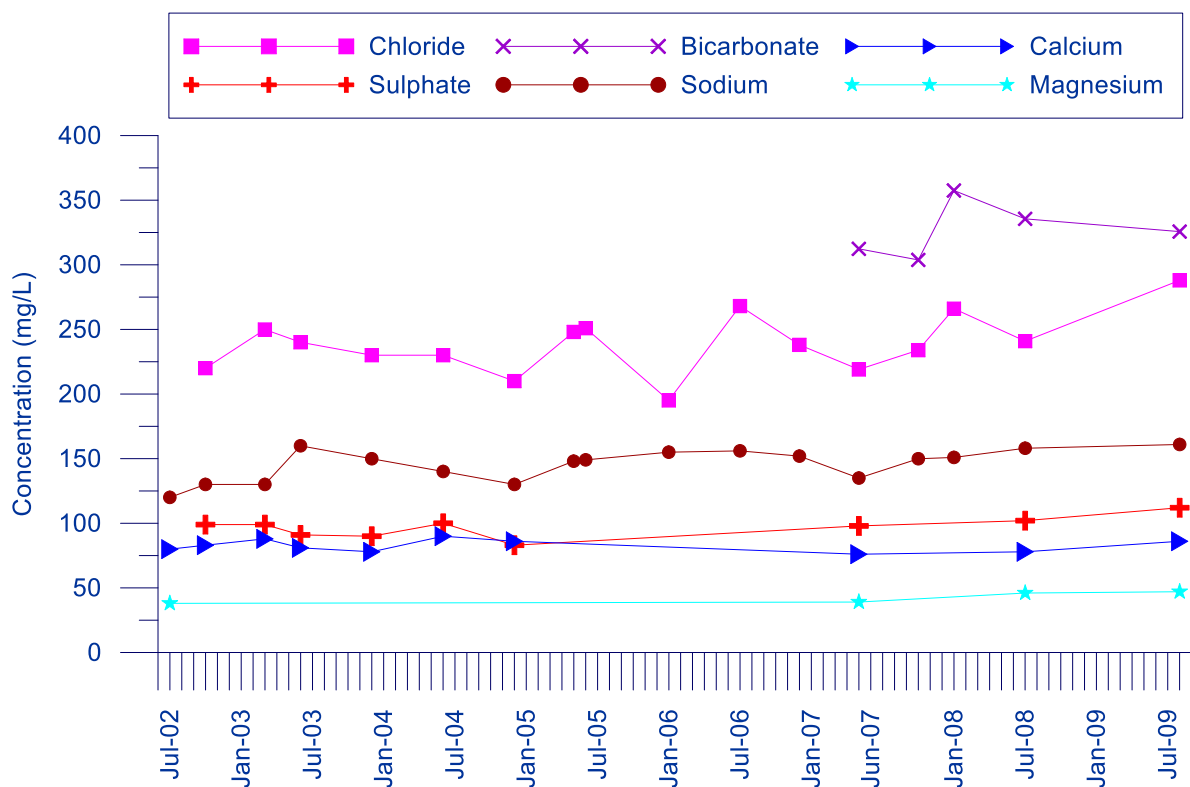
Western Aquifer System GSF Area Bore GSMB11



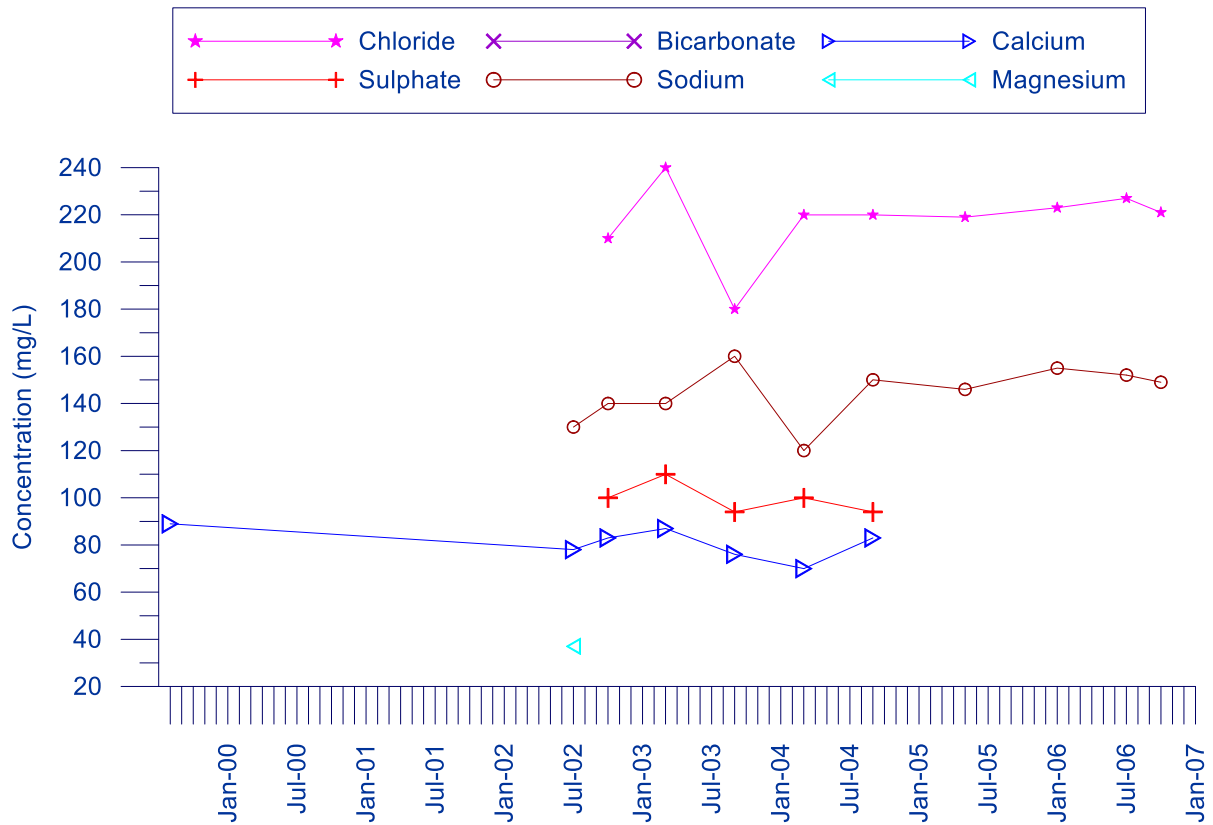
Western Aquifer System GSF Area Bore GSMB04B



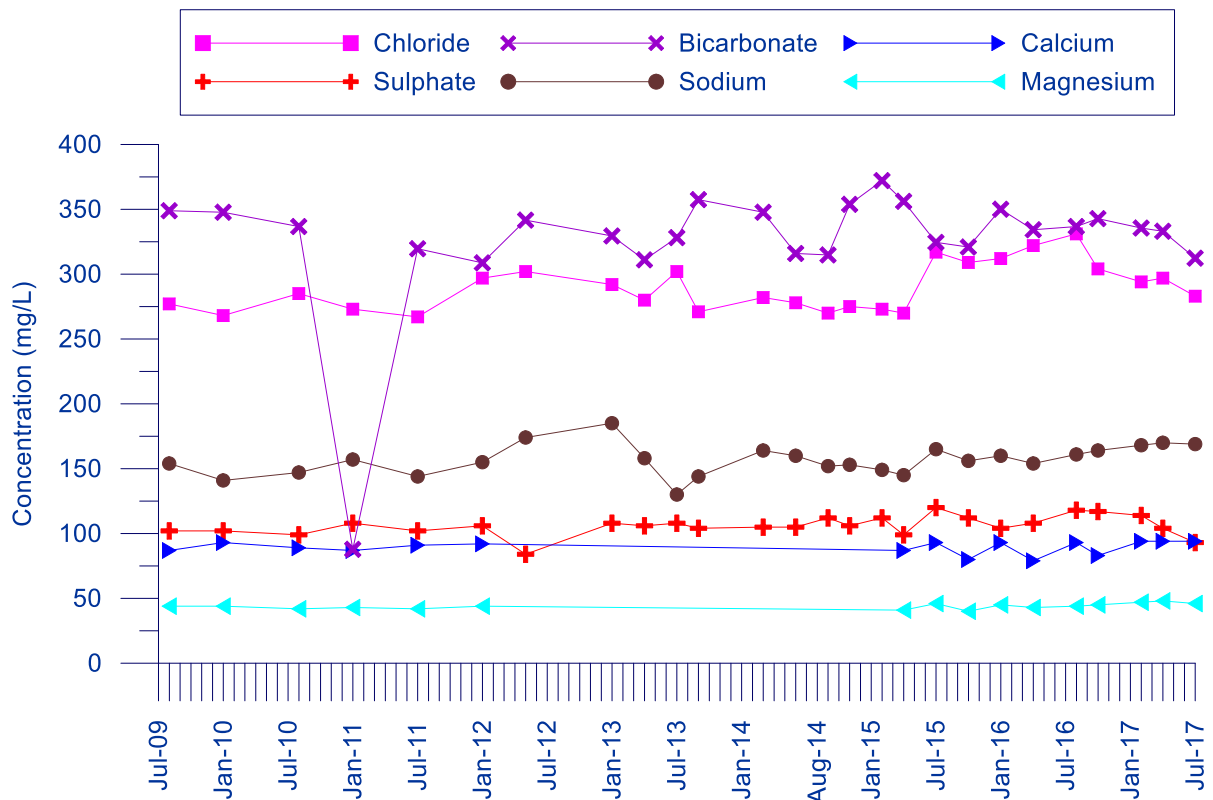
Western Aquifer System GSF Area Bore GSMB05



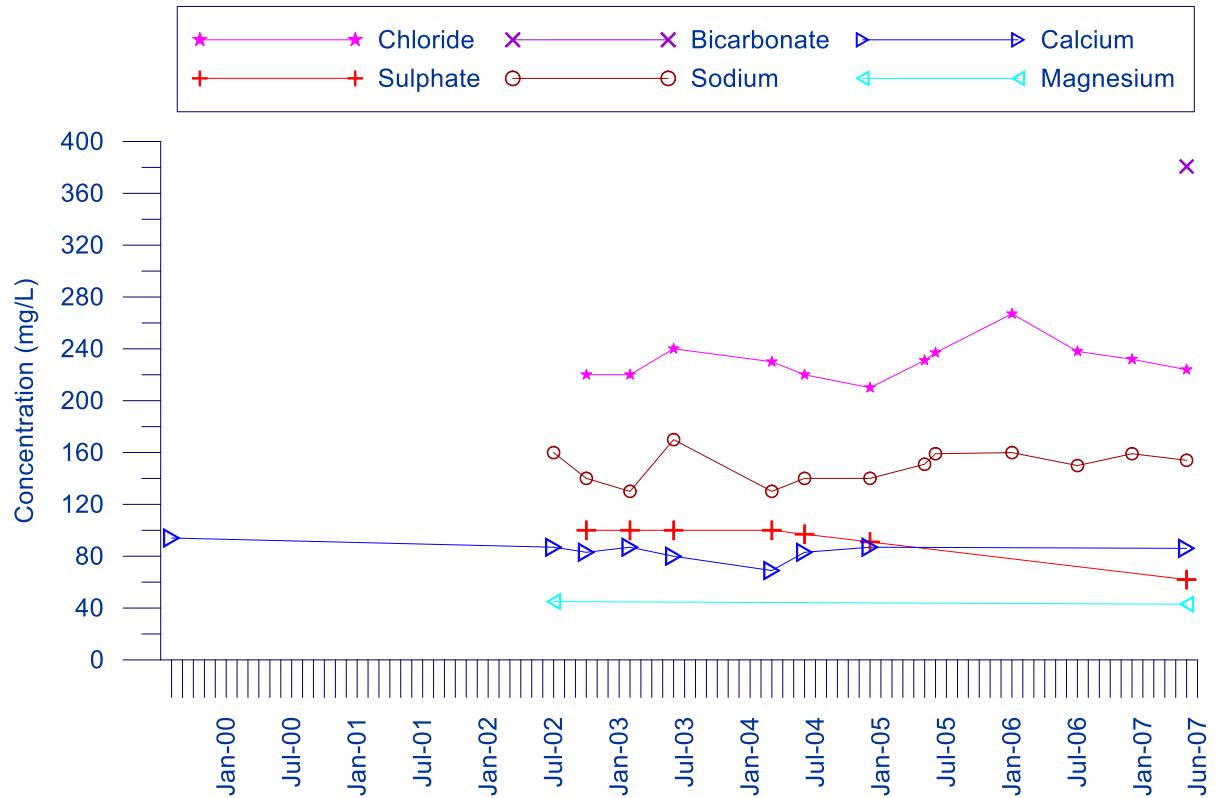
Western Aquifer System GSF Area Bore GSMB02



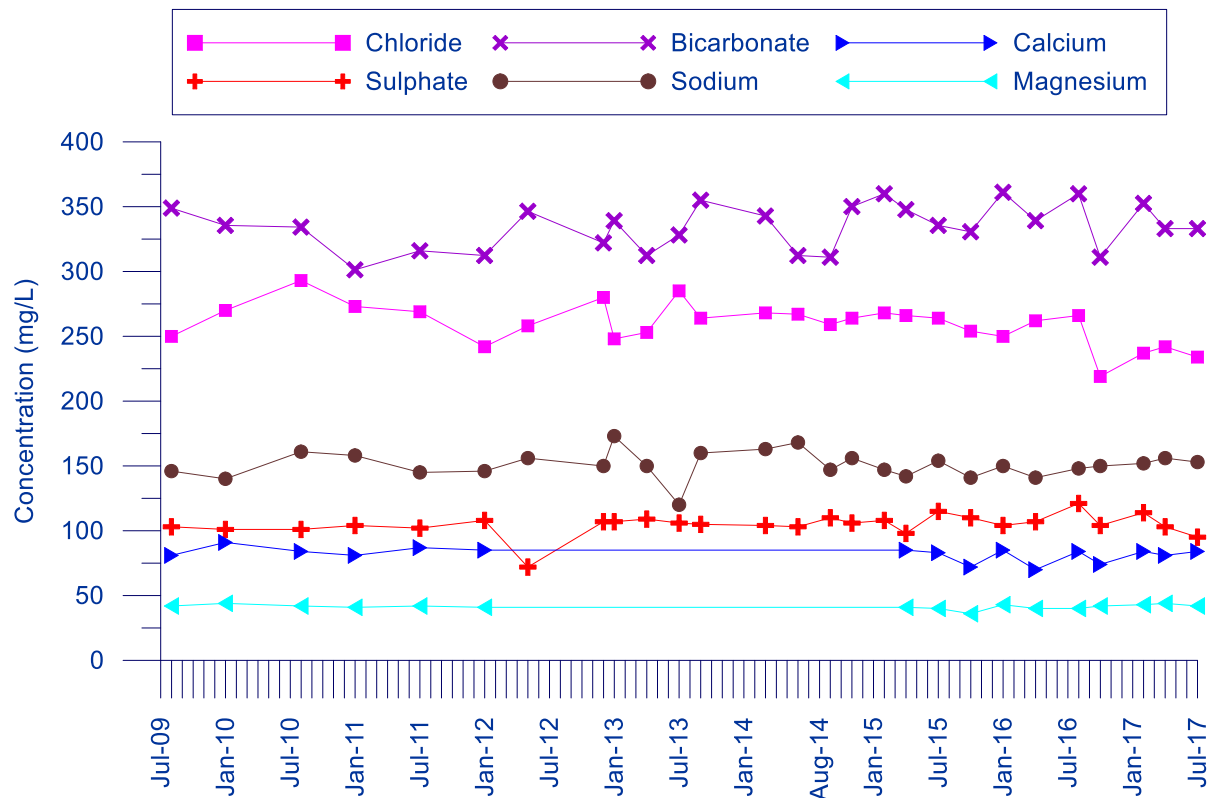
Western Aquifer System GSF Area Bore GSMB02A



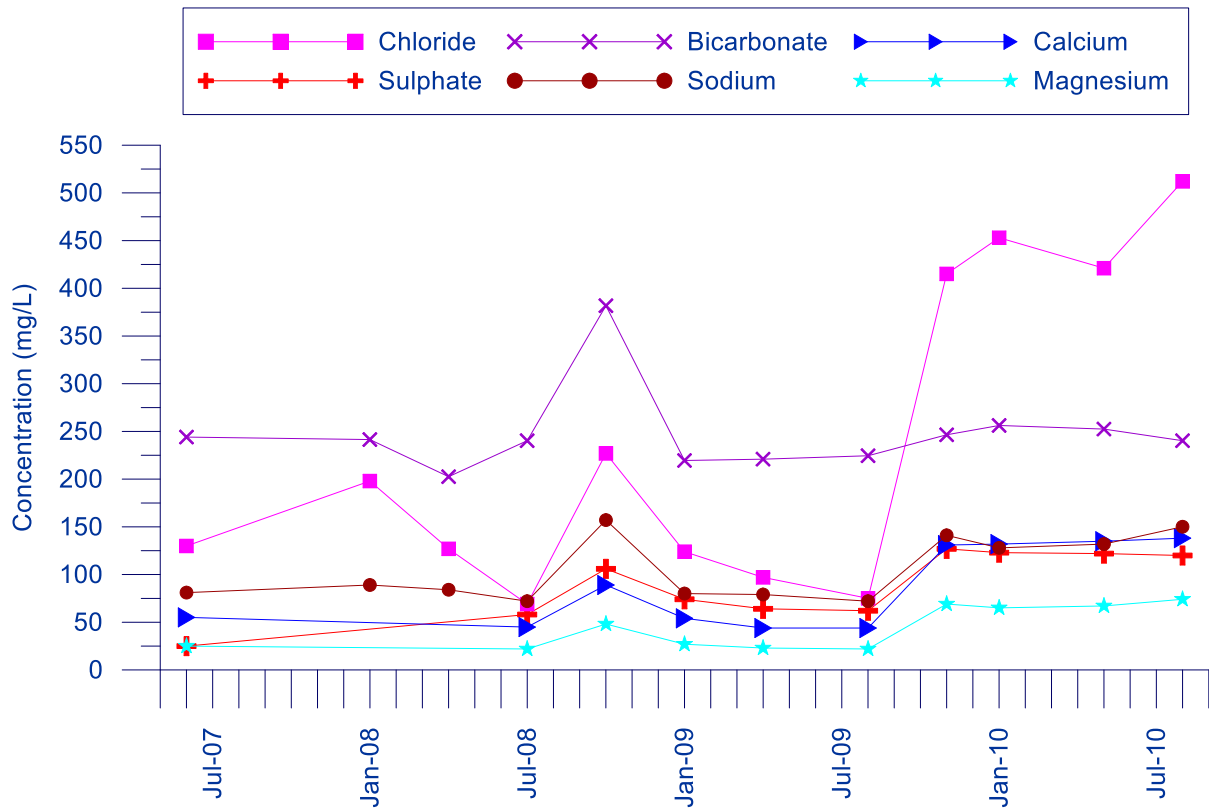
Western Aquifer System GSF Area Bore GSMB01



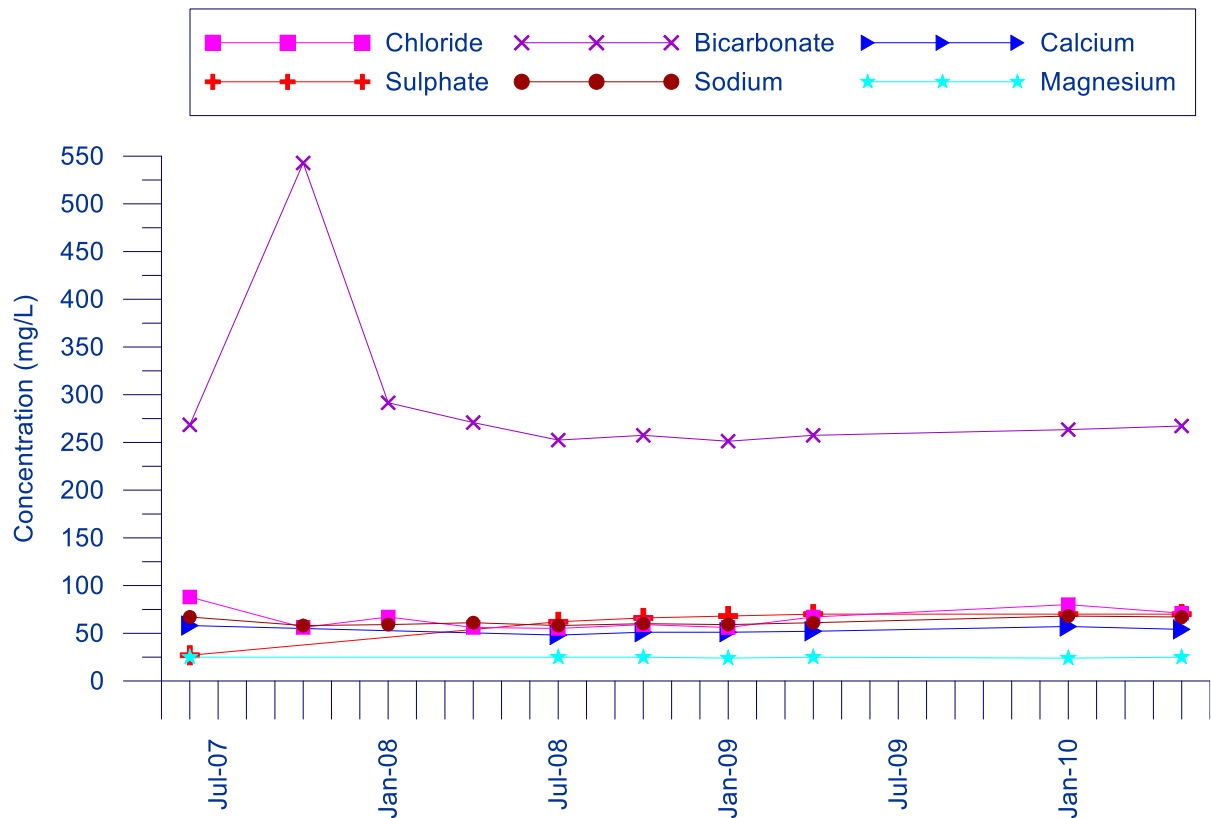
Western Aquifer System GSF Area Bore GSMB01A



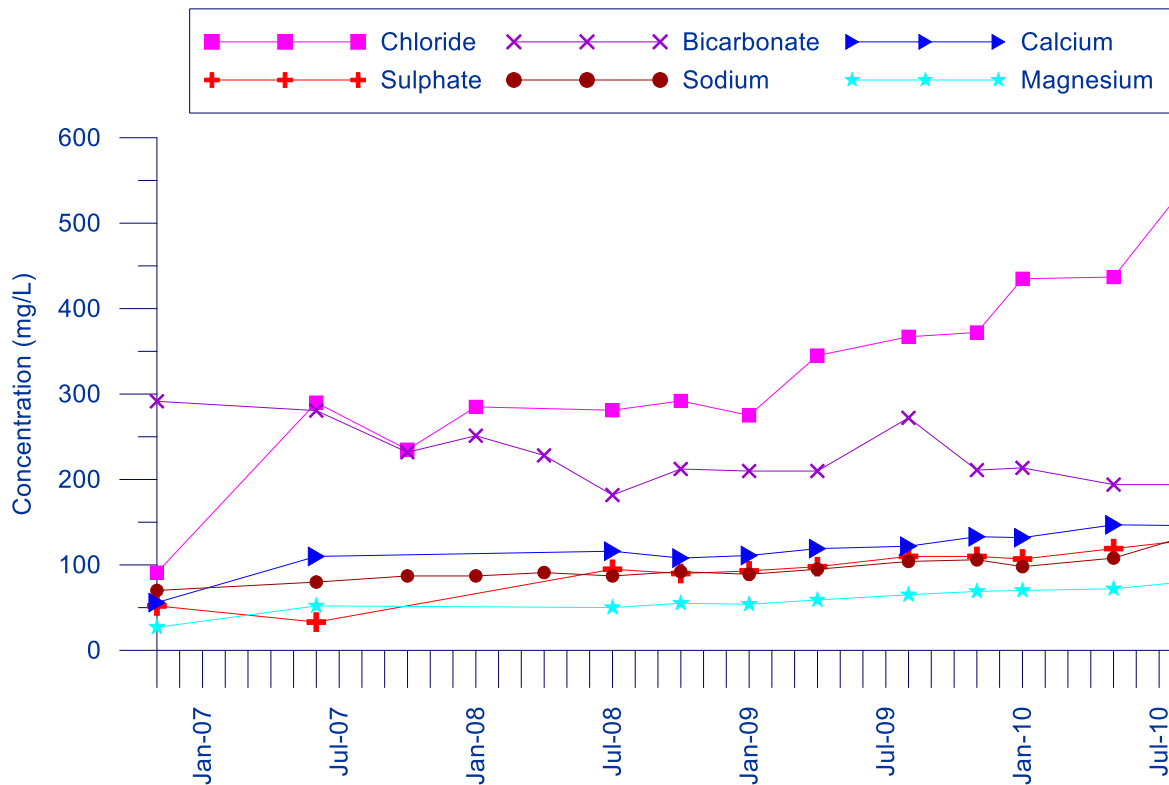
Western Aquifer System Slimes Dams Area Bore GW21



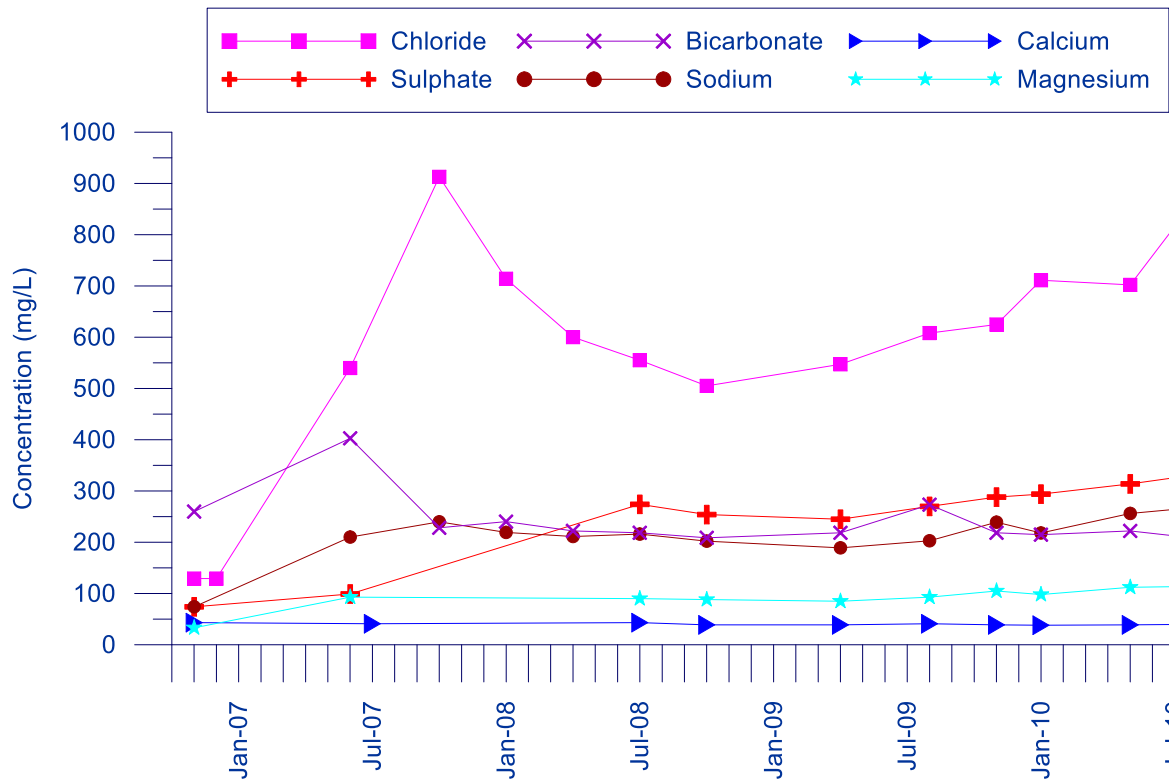
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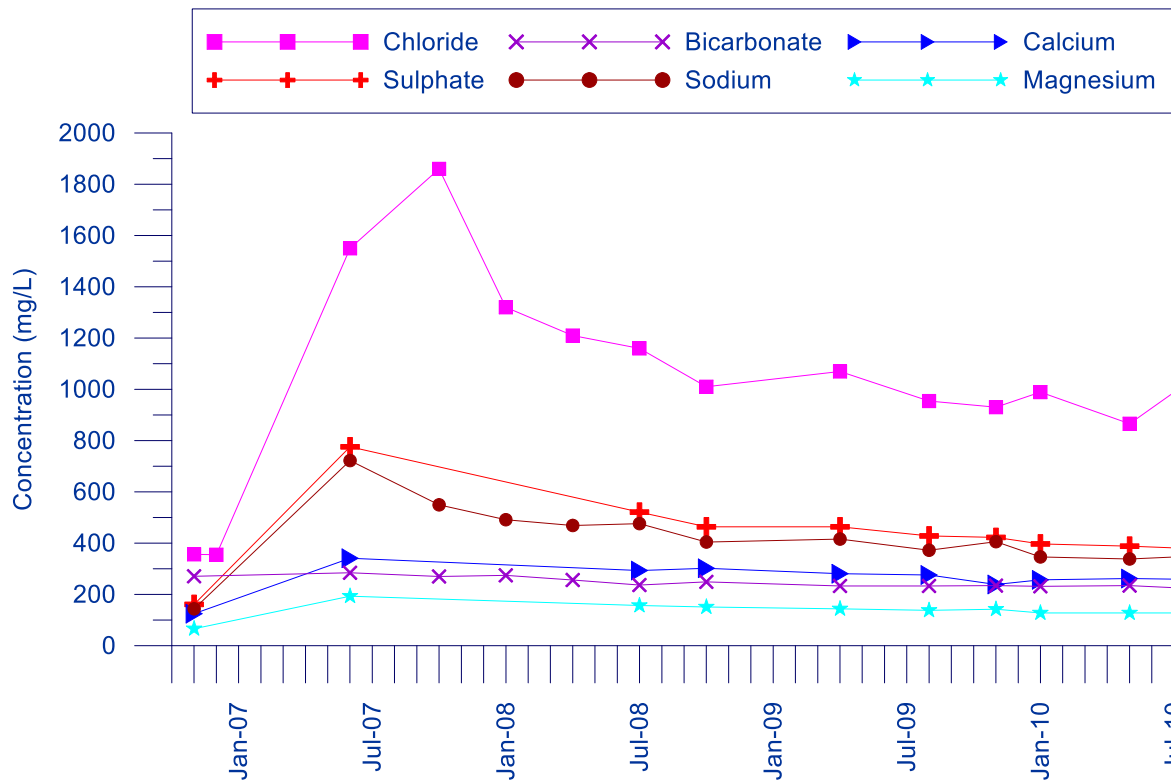
Western Aquifer System Slimes Dams Area Bore GW01



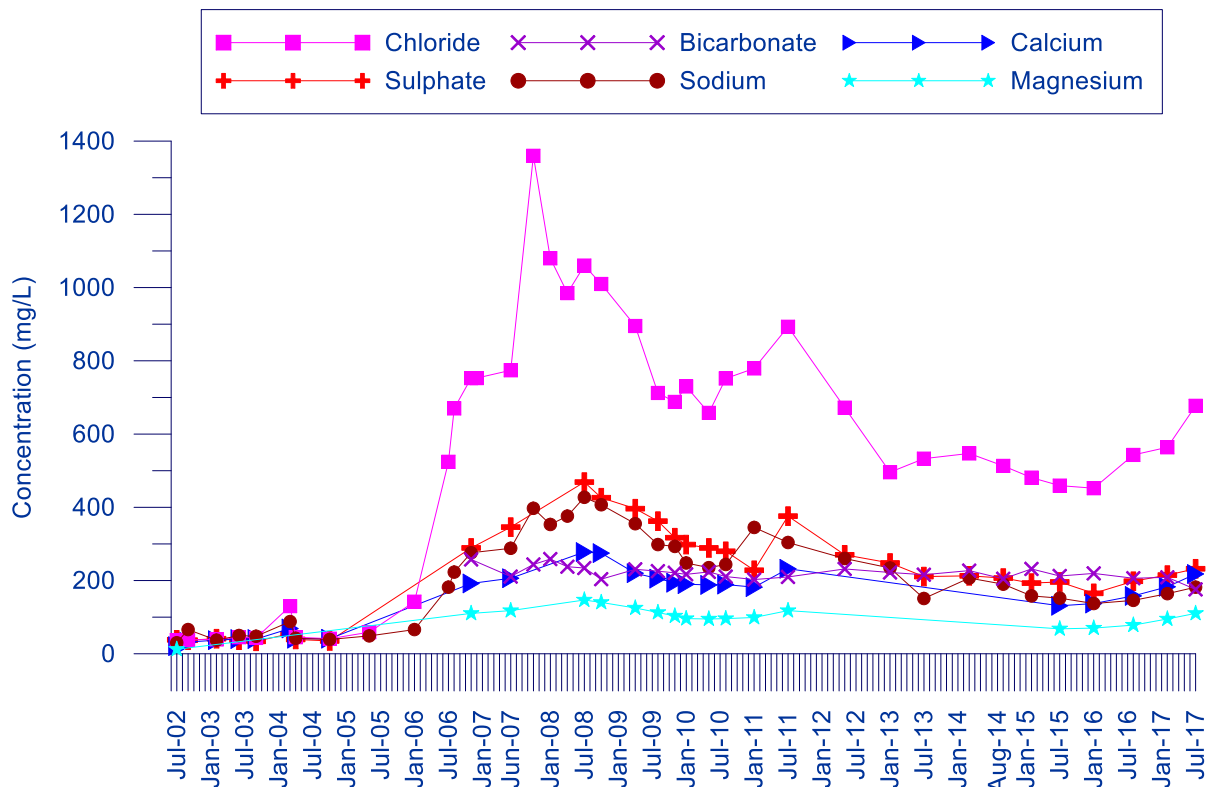
Western Aquifer System Slimes Dams Area Bore GW04



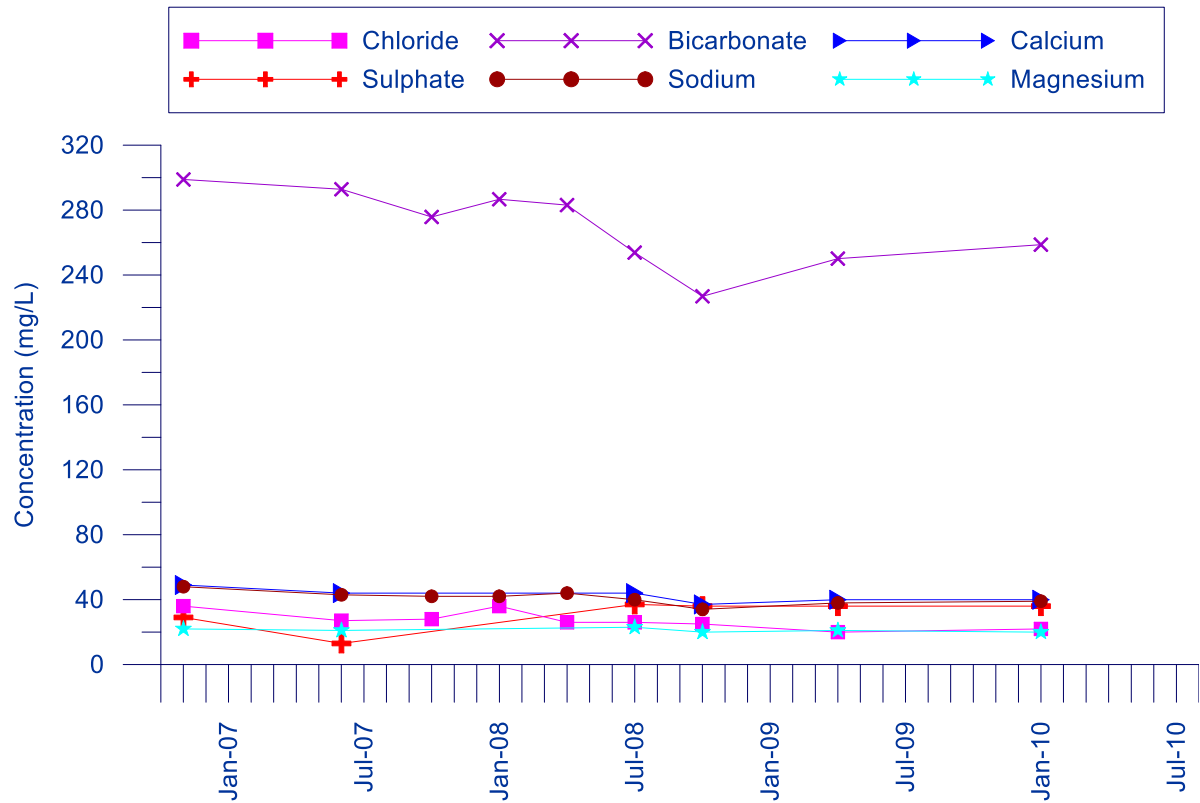
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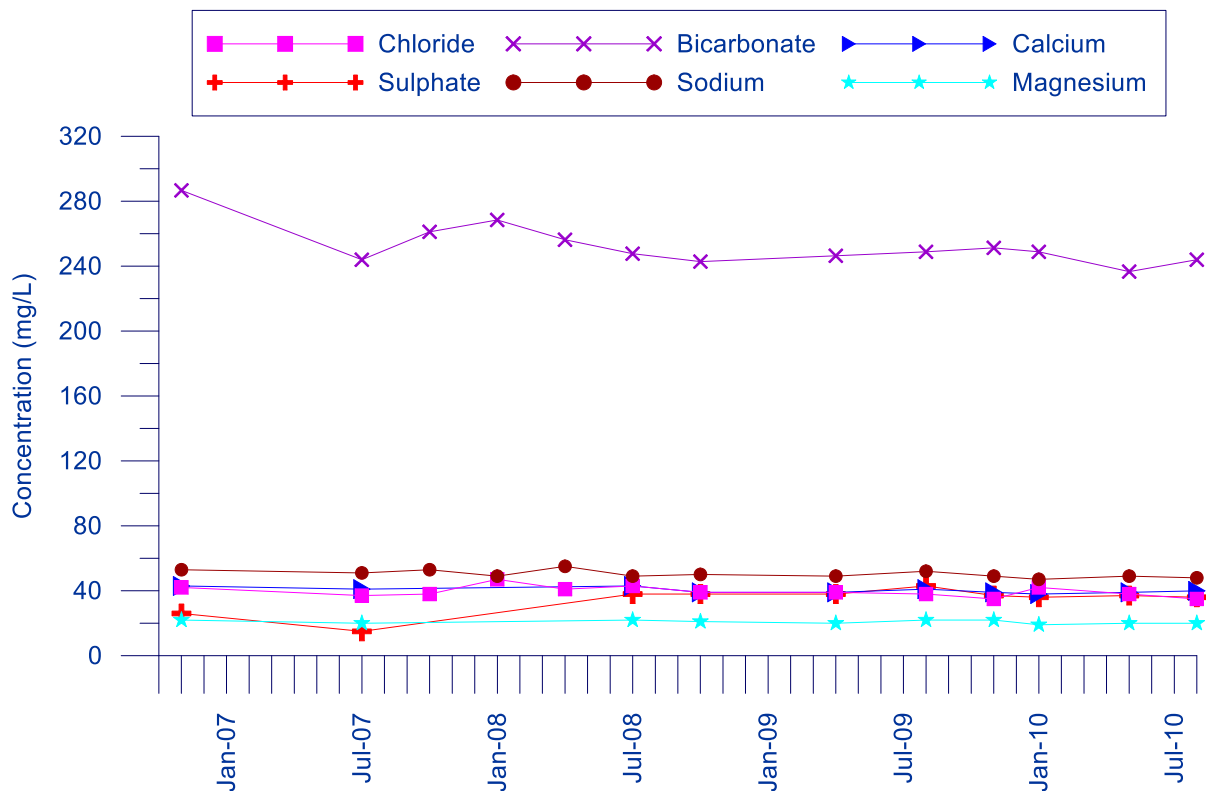
Western Aquifer System Slimes Dams Area Bore SDMB01



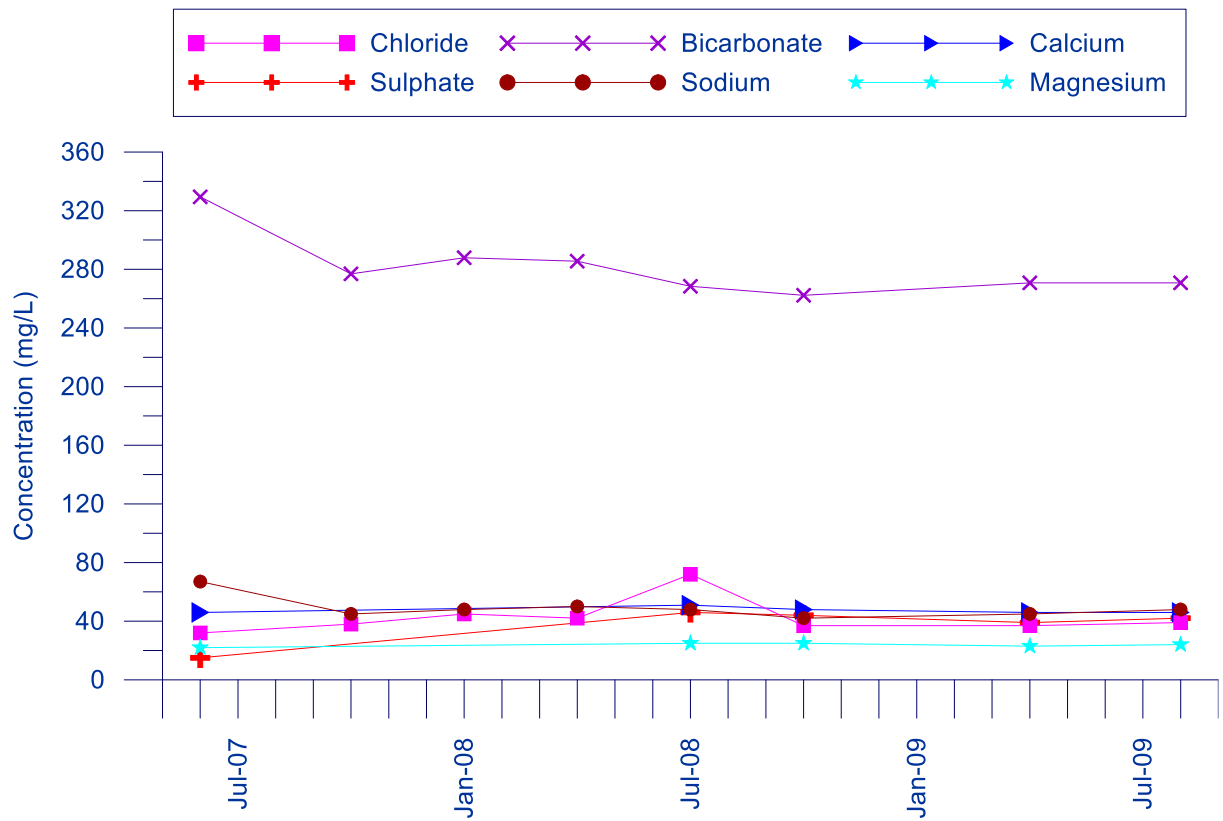
Western Aquifer System Slimes Dams Area Bore GW08



Western Aquifer System Slimes Dams Area Bore GW03



Western Aquifer System Slimes Dams Area Bore GW17



APPENDIX 8D

WAS Box-Whisker Plots

Salinity

Chloride

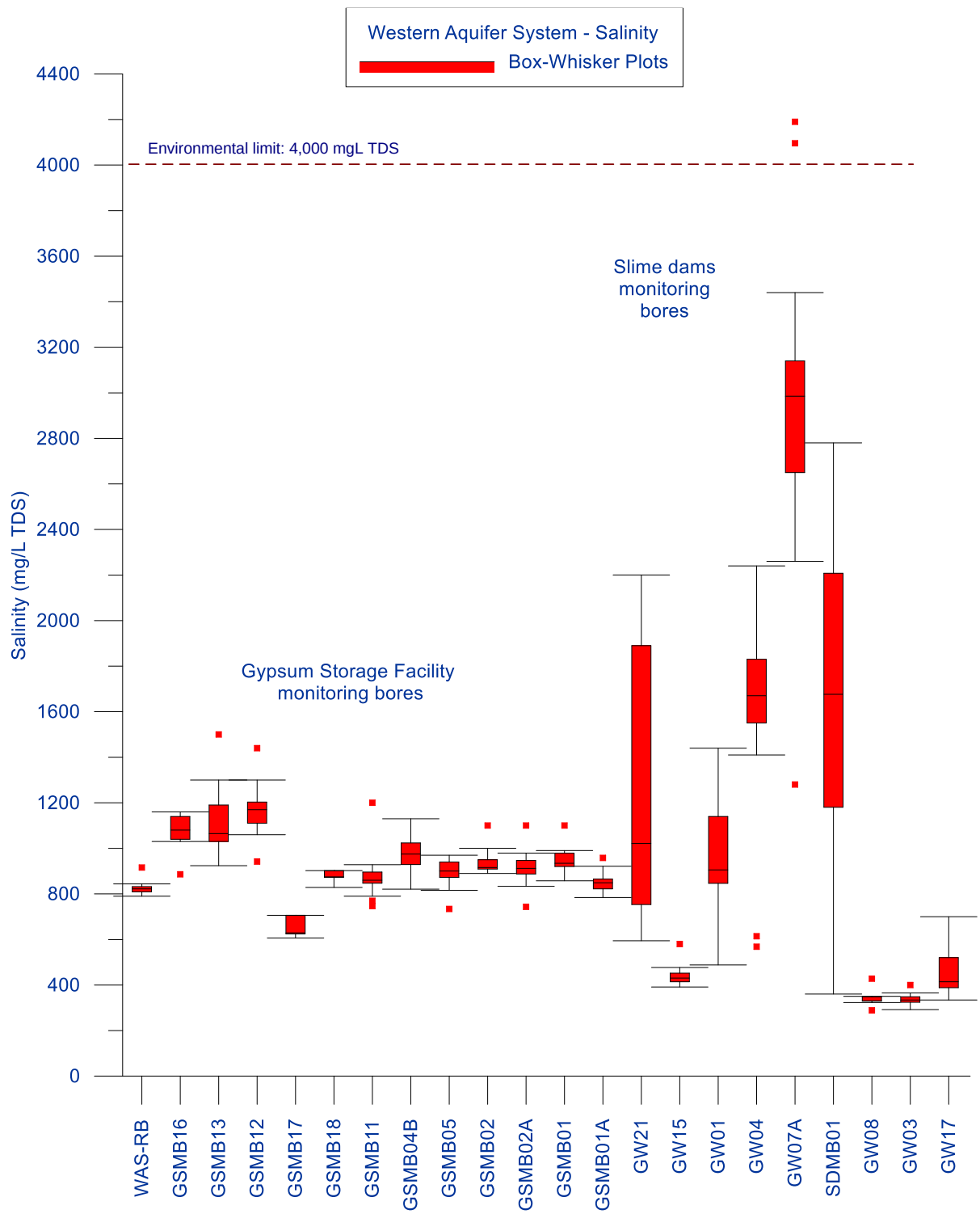
Sulphate

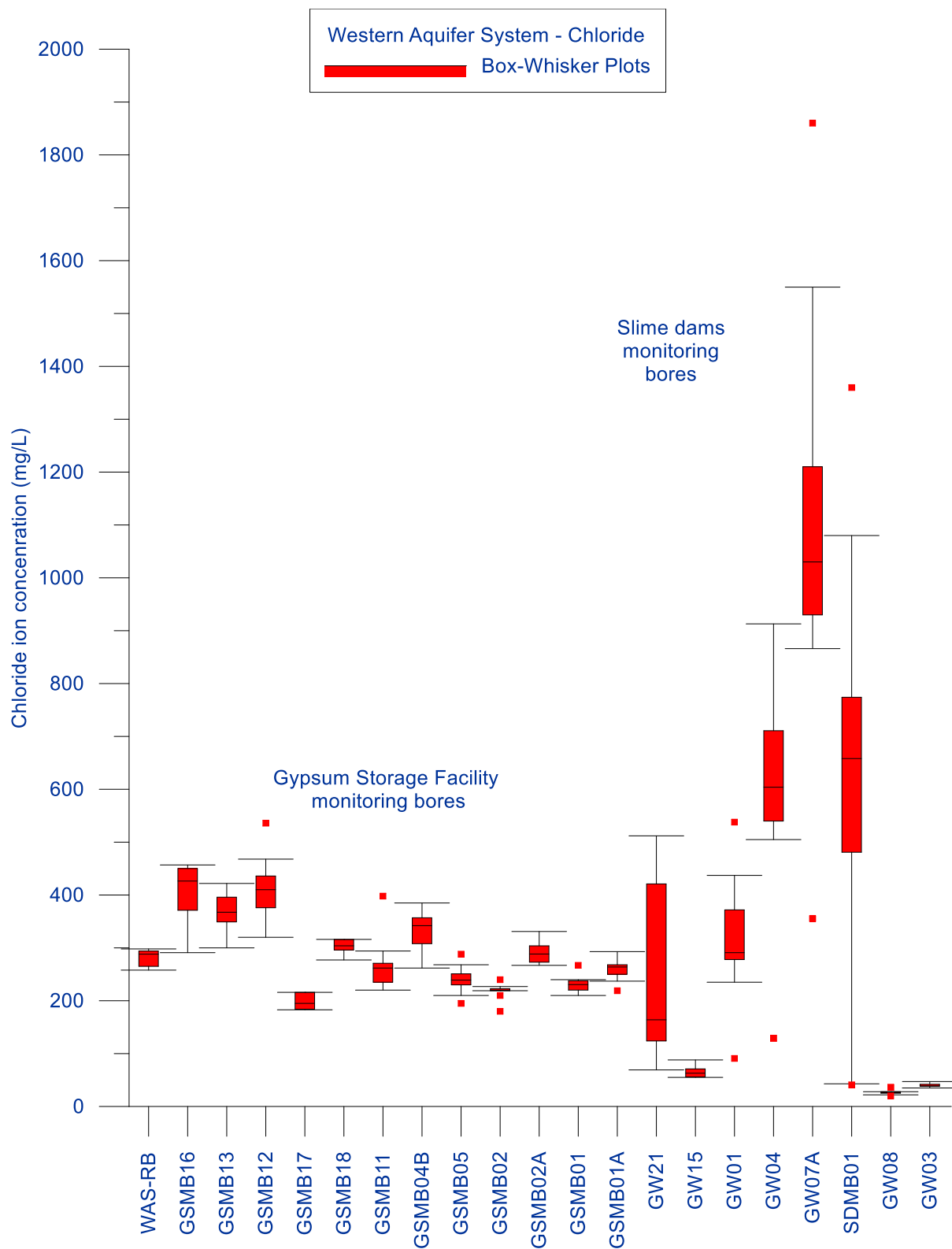
Fluoride

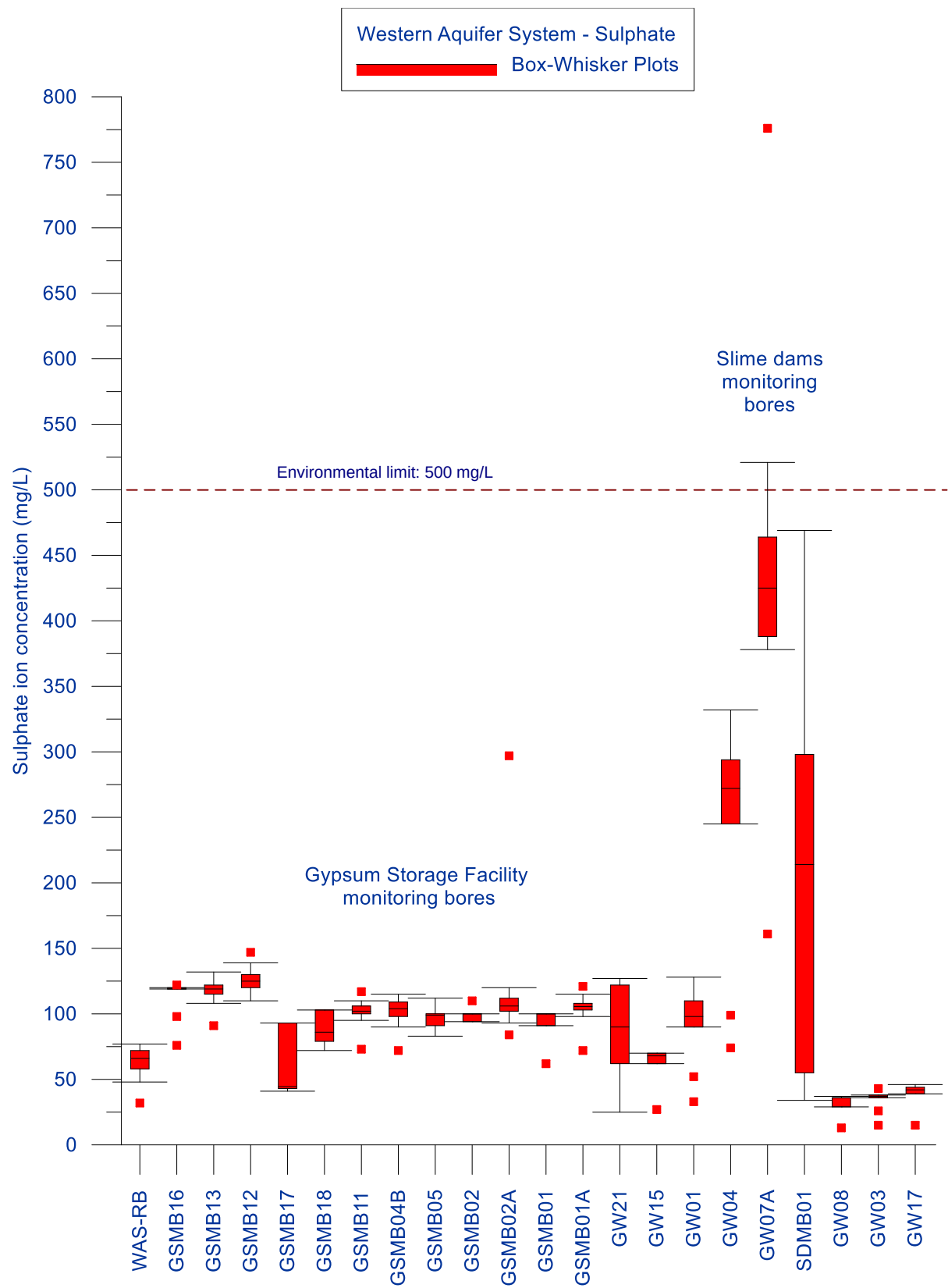
Acidity (laboratory measurements)

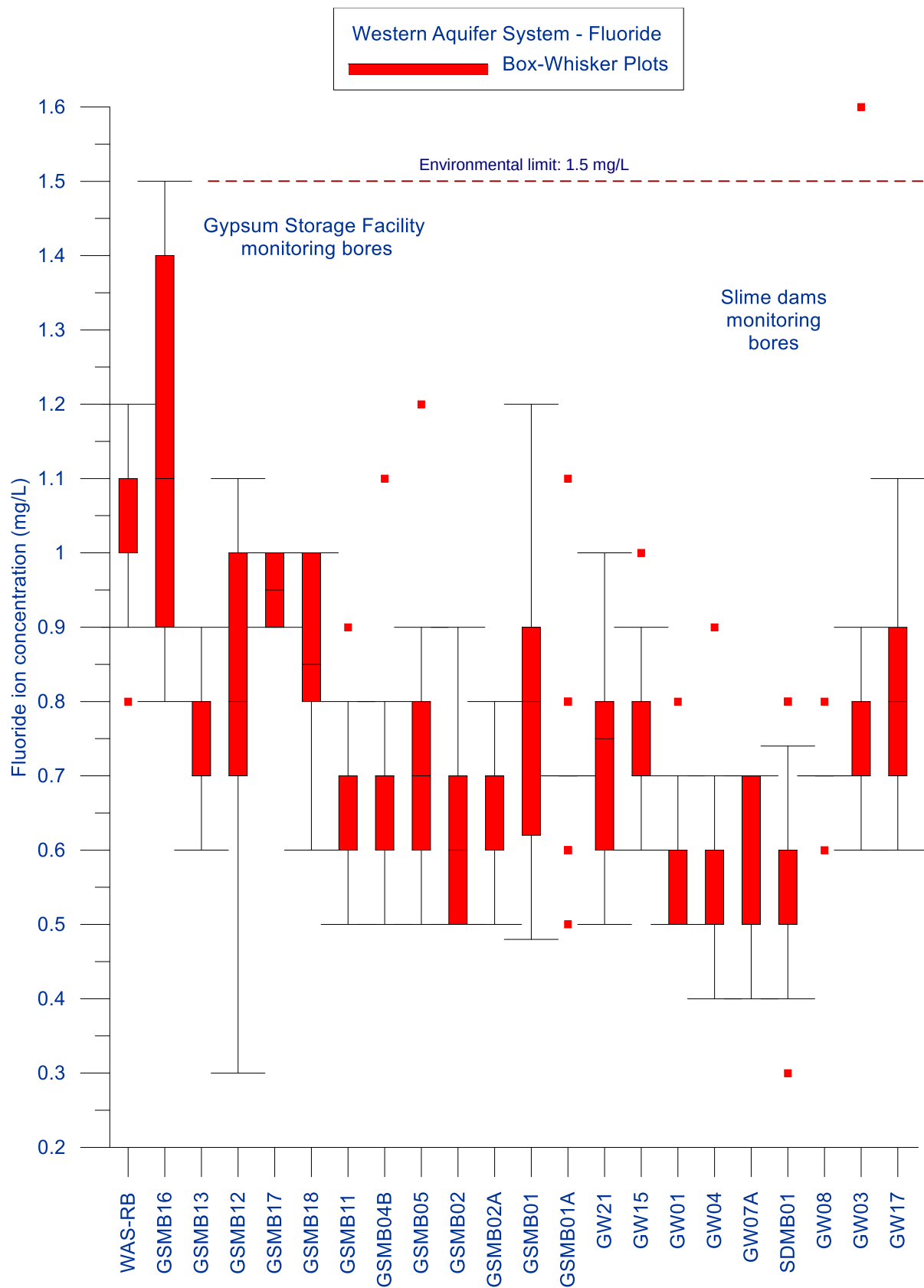
Total Nitrogen-N

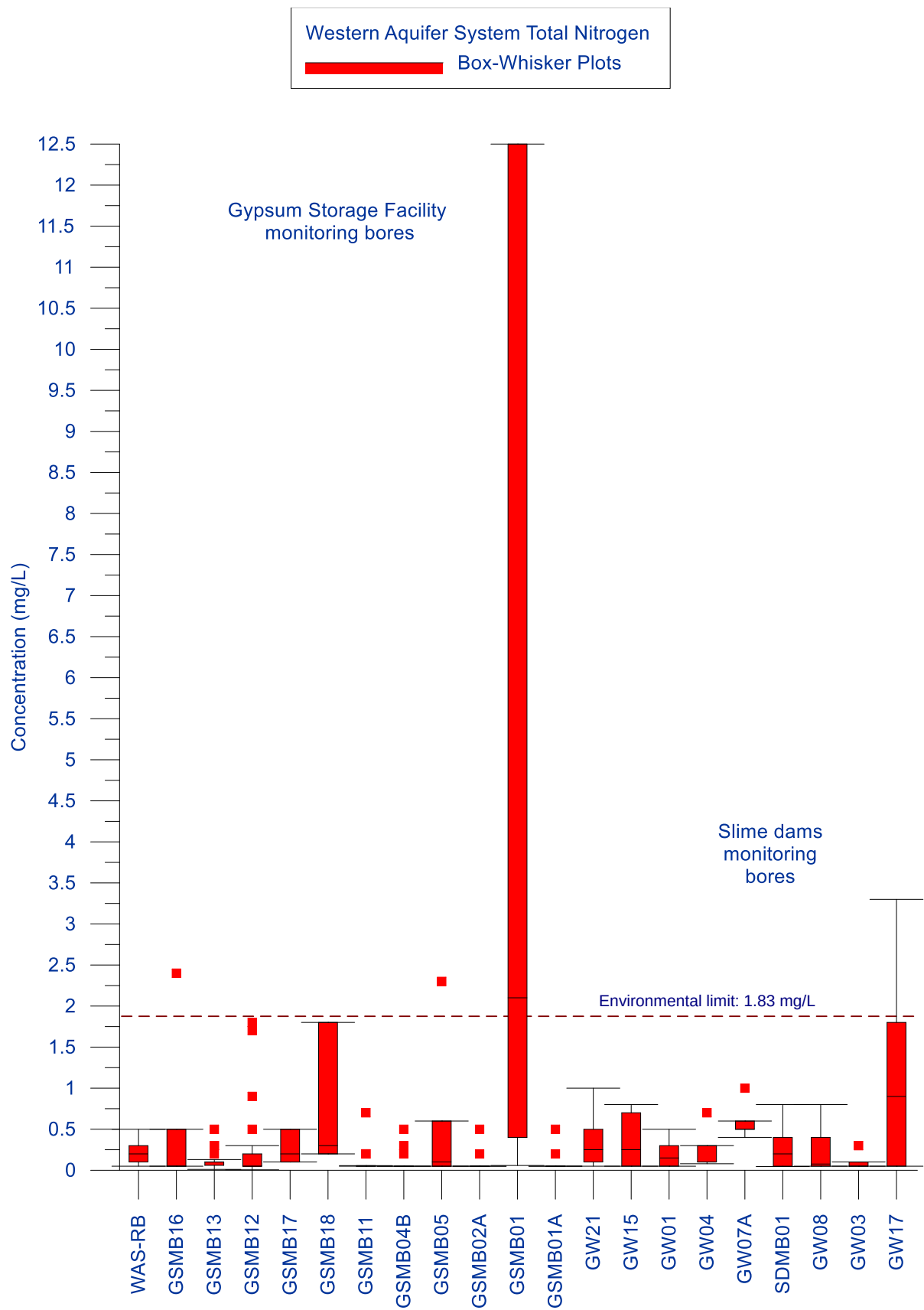
Total Phosphorous-P

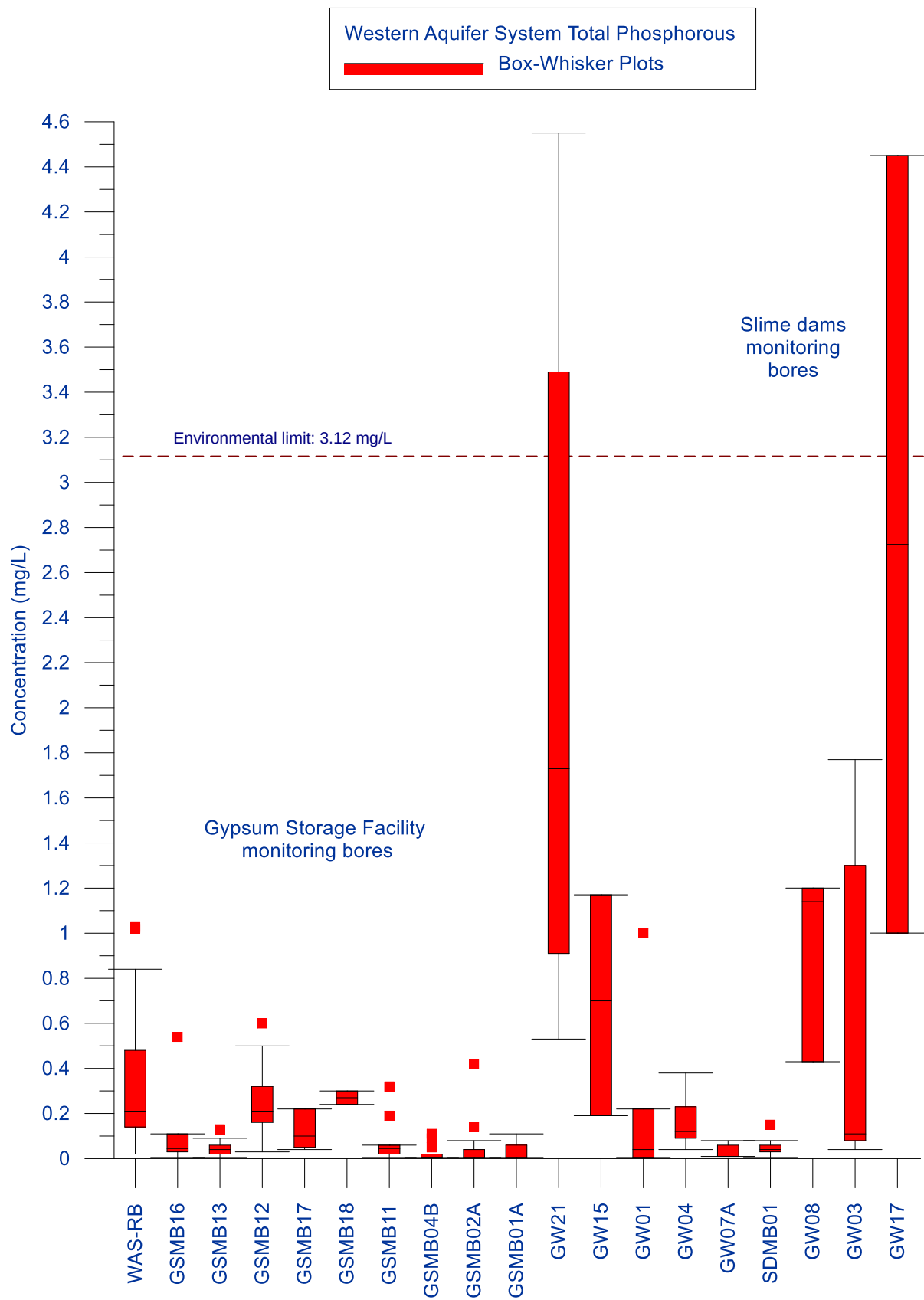












APPENDIX 9

GROUNDWATER CONTAMINATION MAPPING

Chloride ion January 2010

Sulphate ion January 2010

Chloride ion July 2017

Sulphate ion July 2017

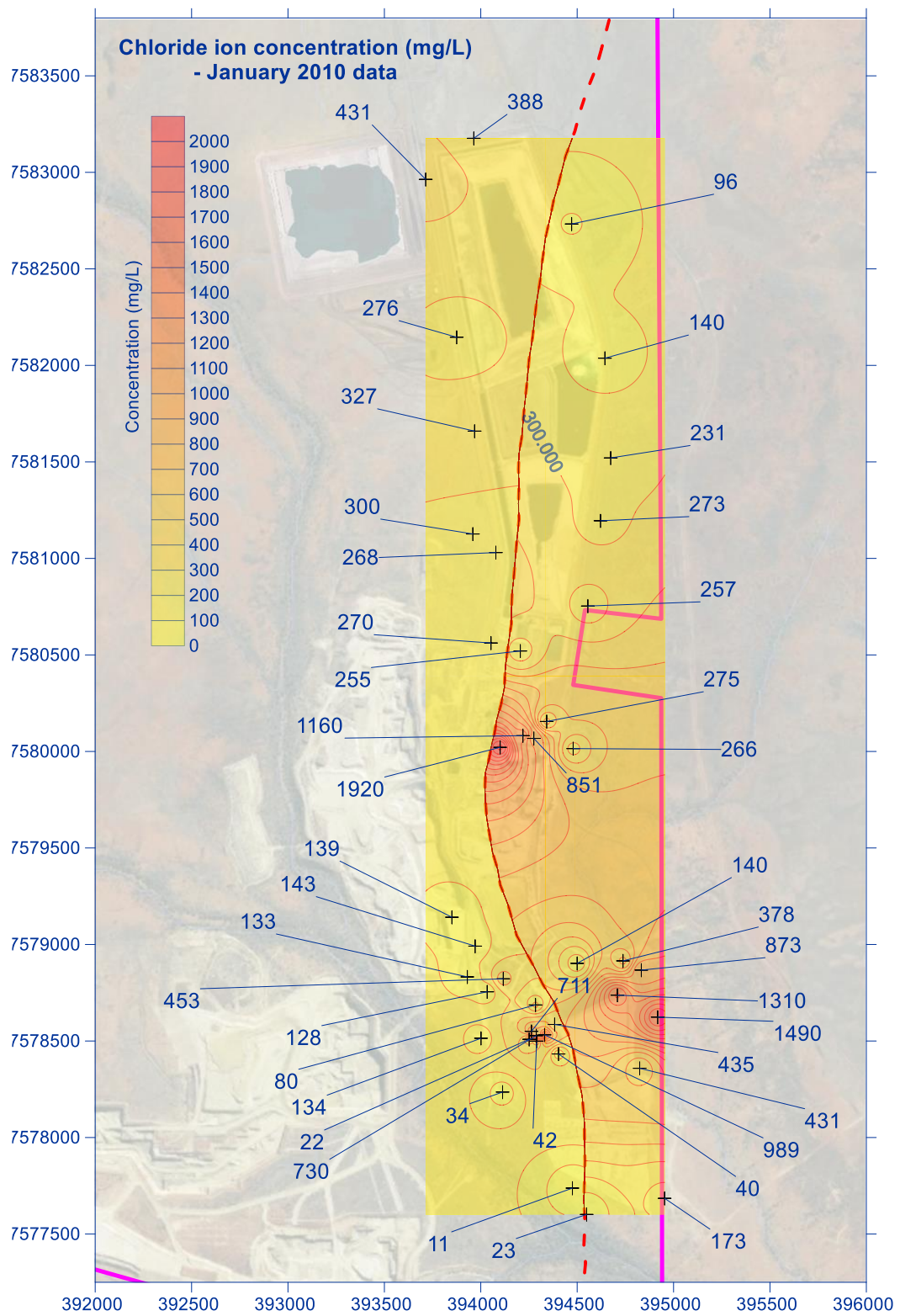
Fluoride ion July 2017

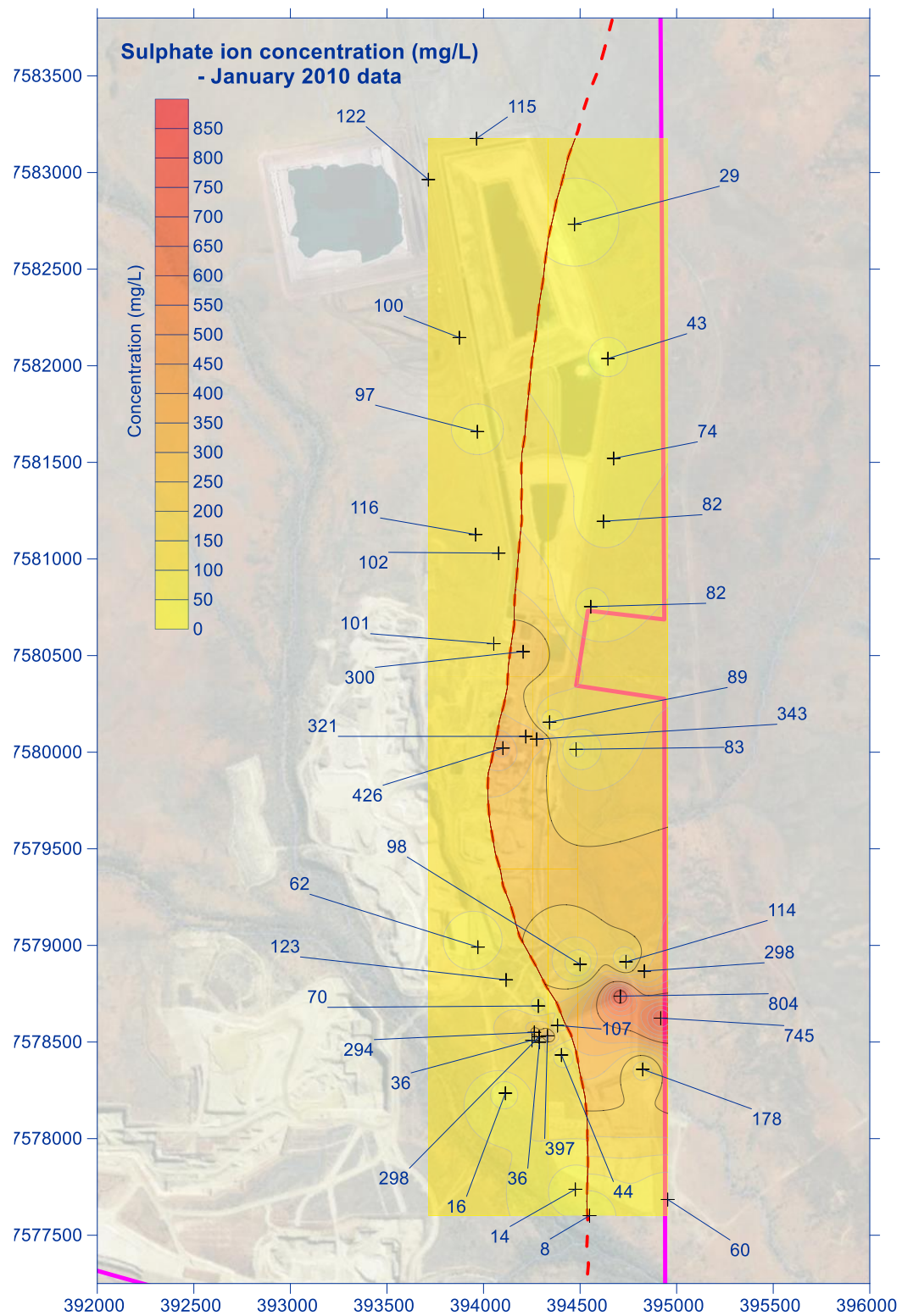
Acidity July 2017

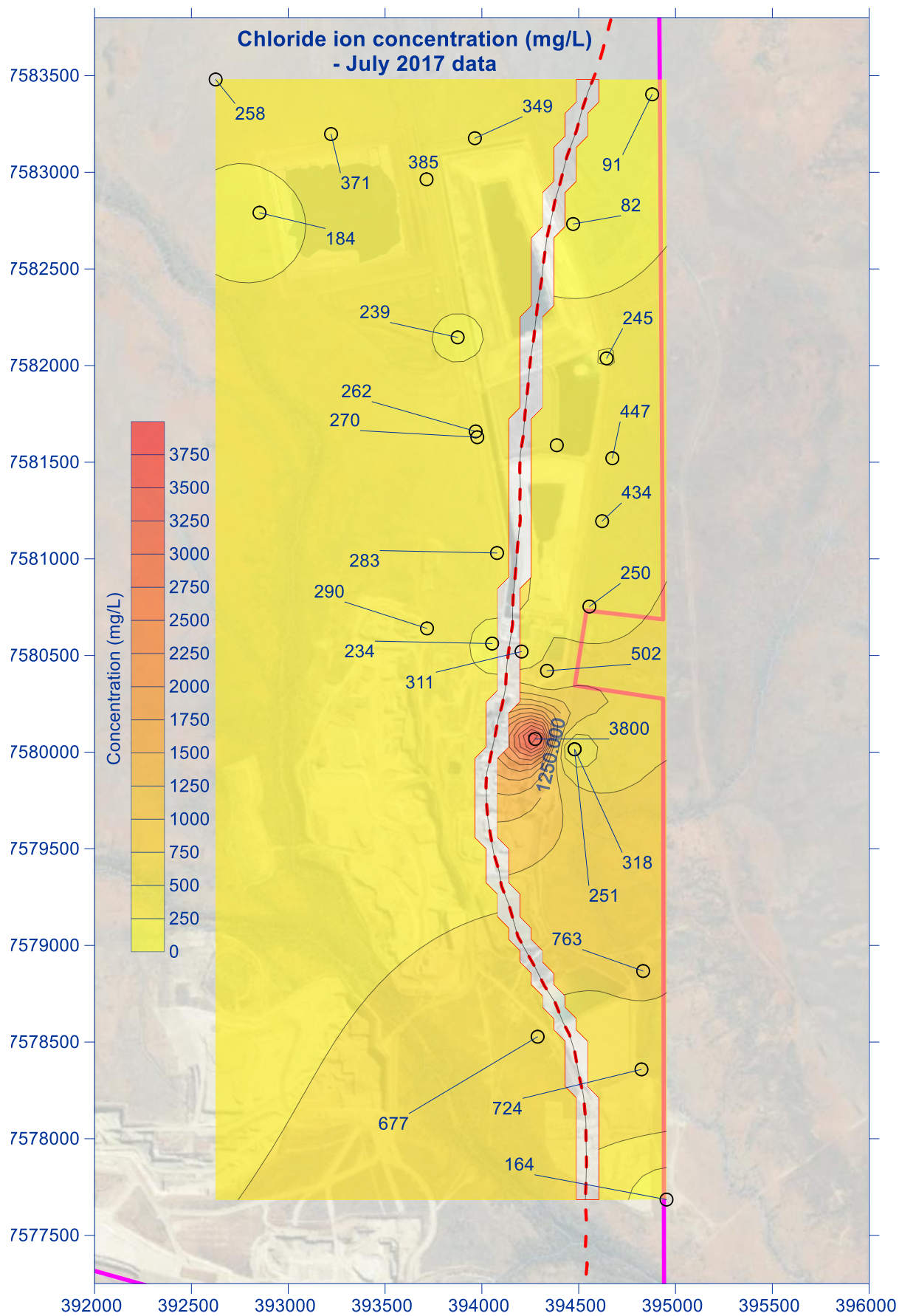
Dissolved Uranium July 2017

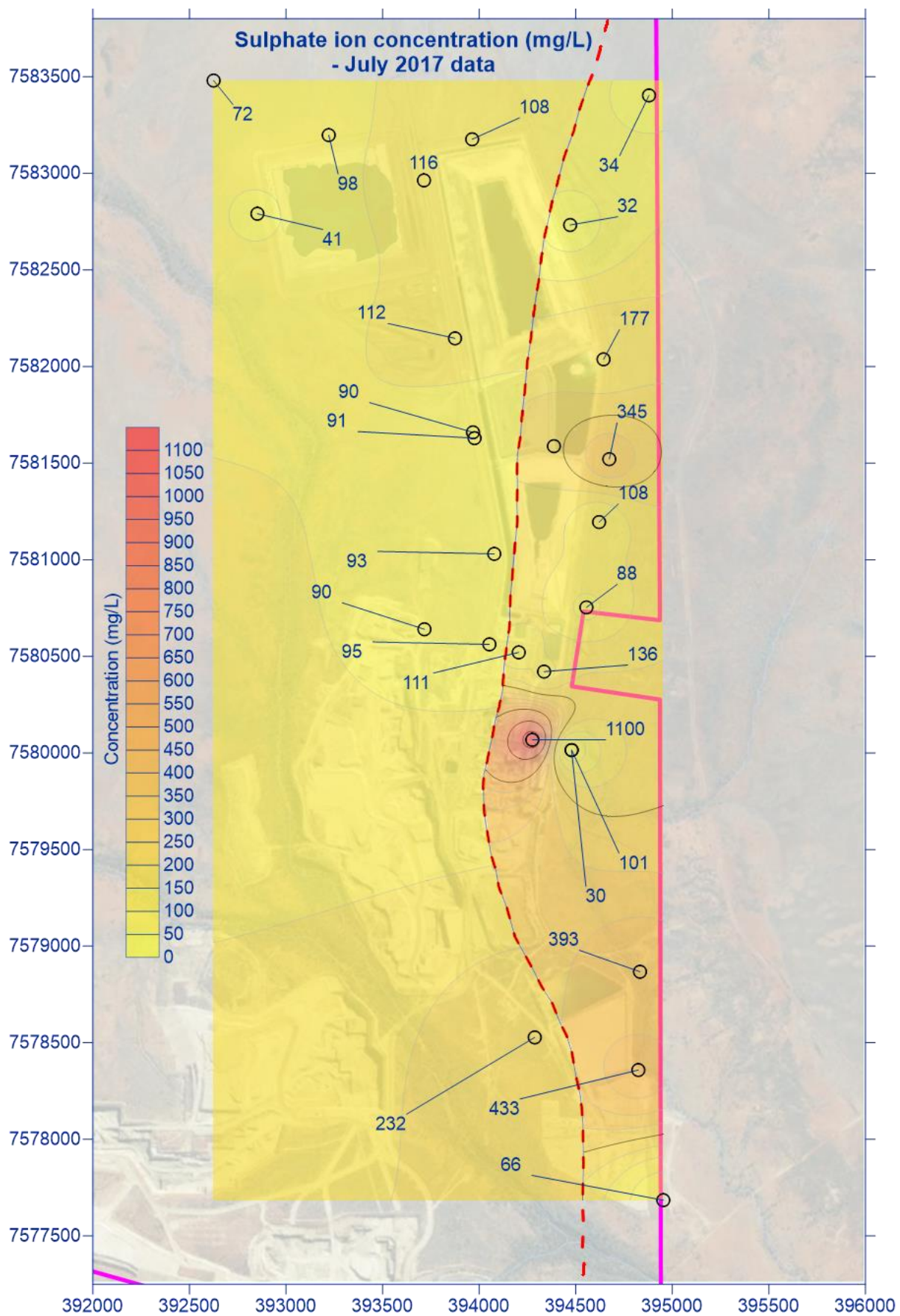
Total Nitrogen-N July 2017

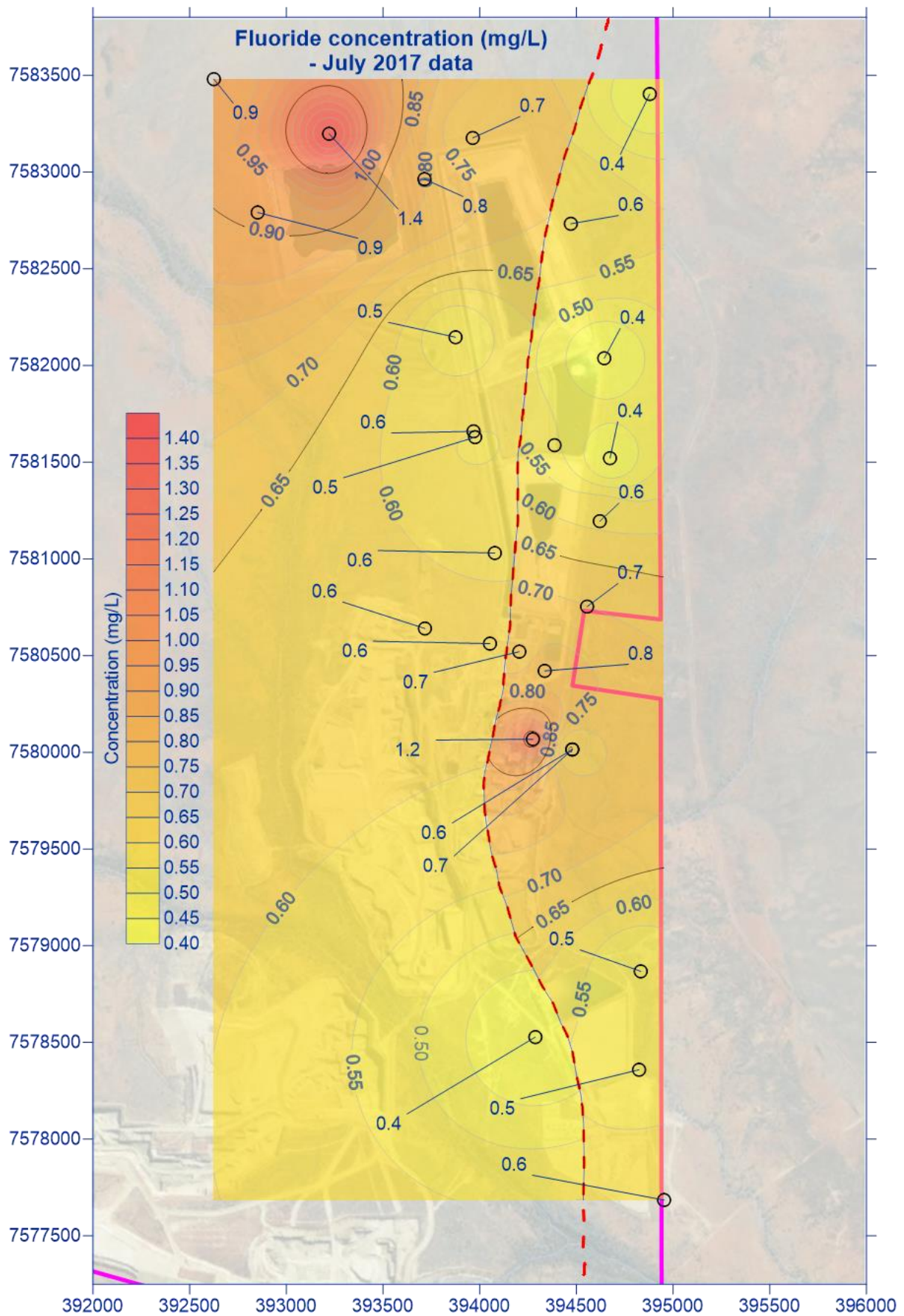
Total Phosphorous-P July 2017

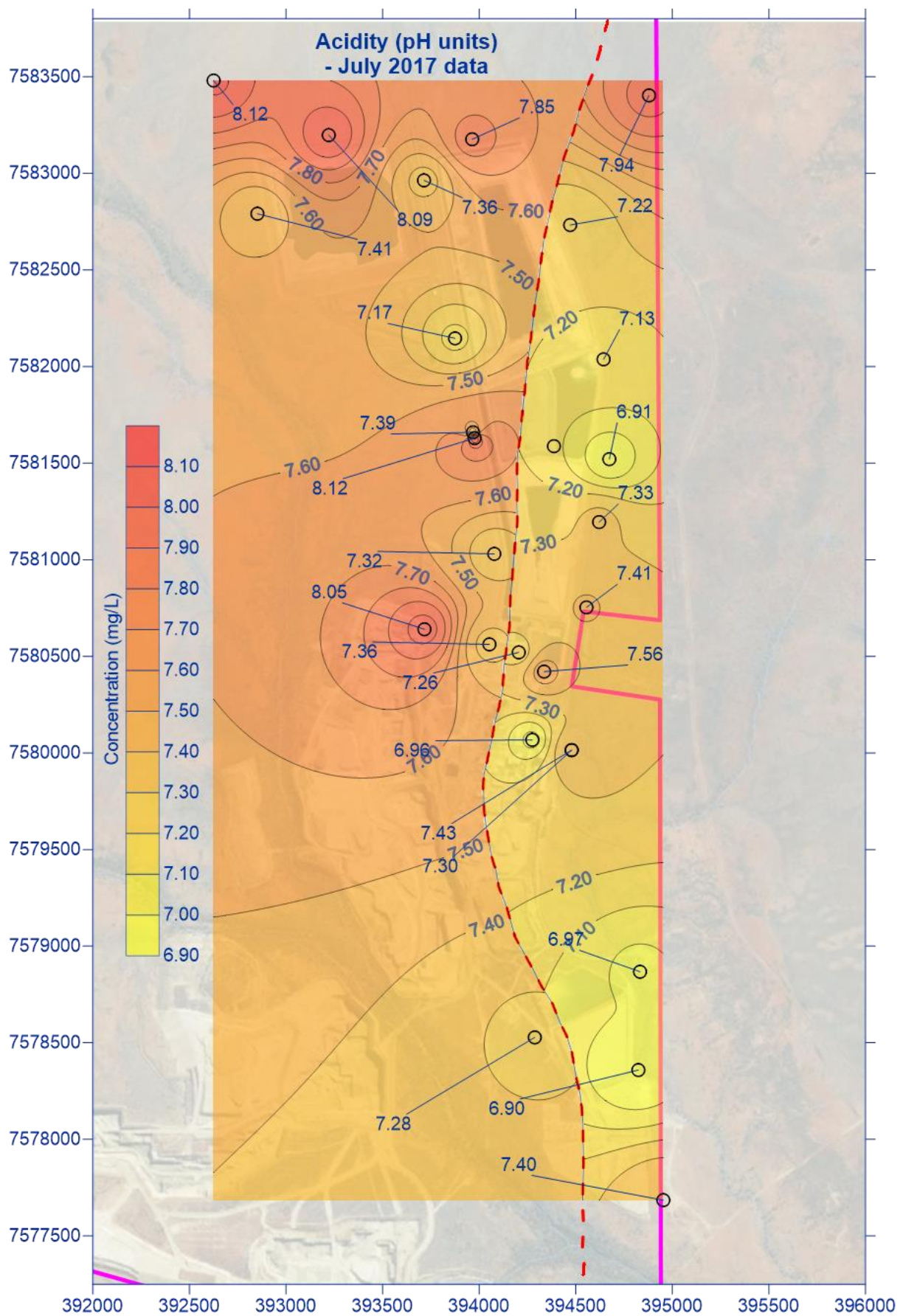


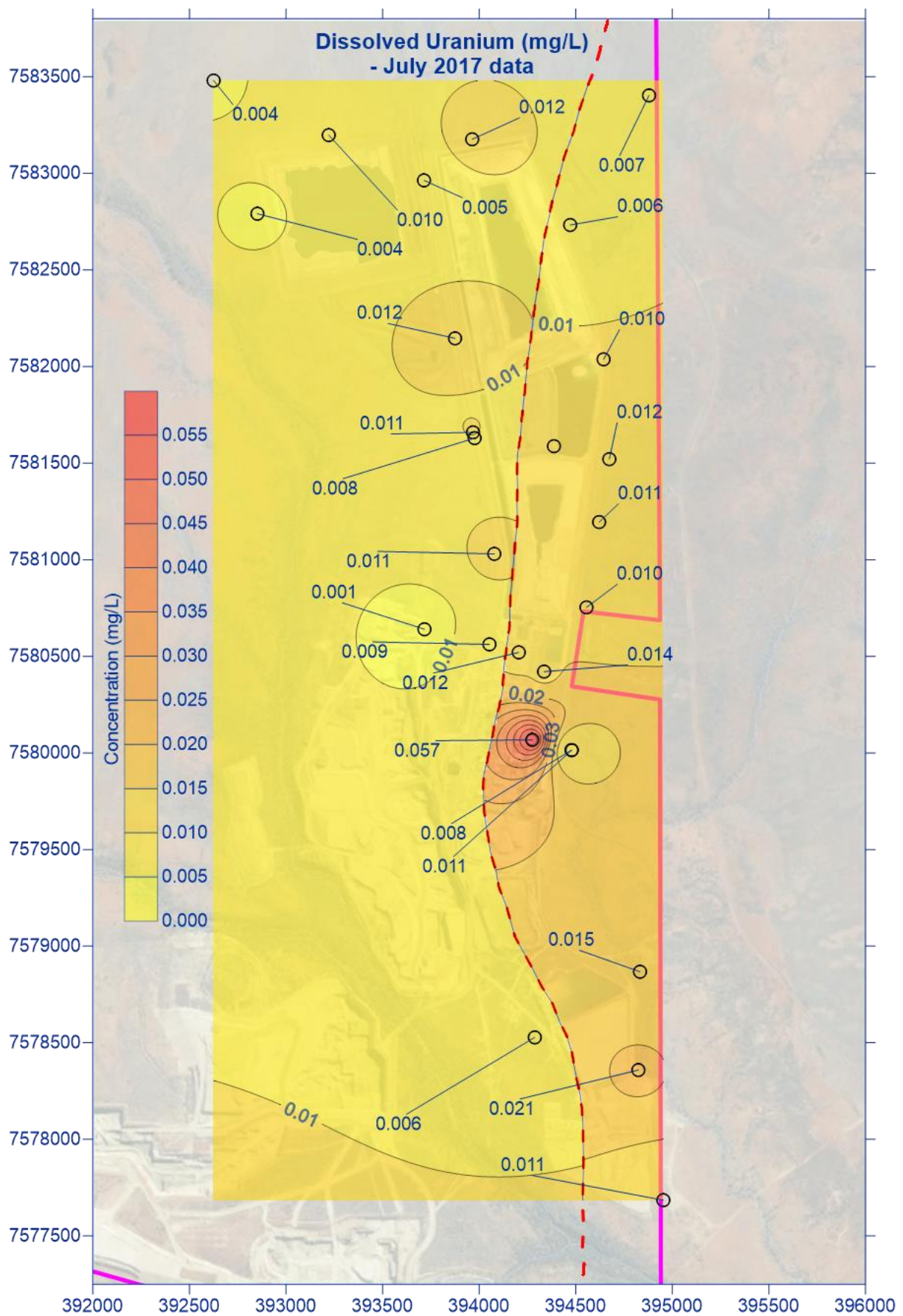


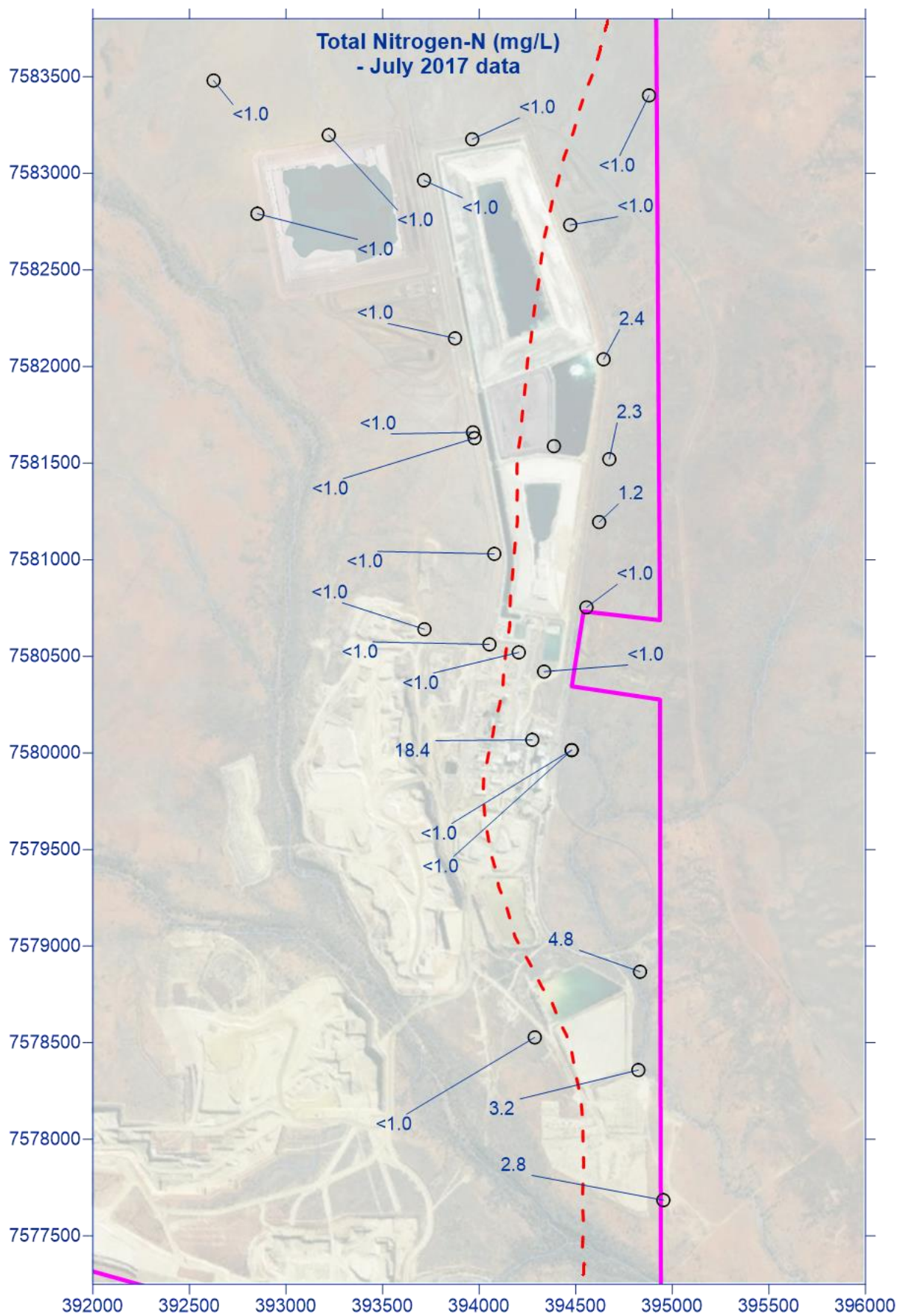


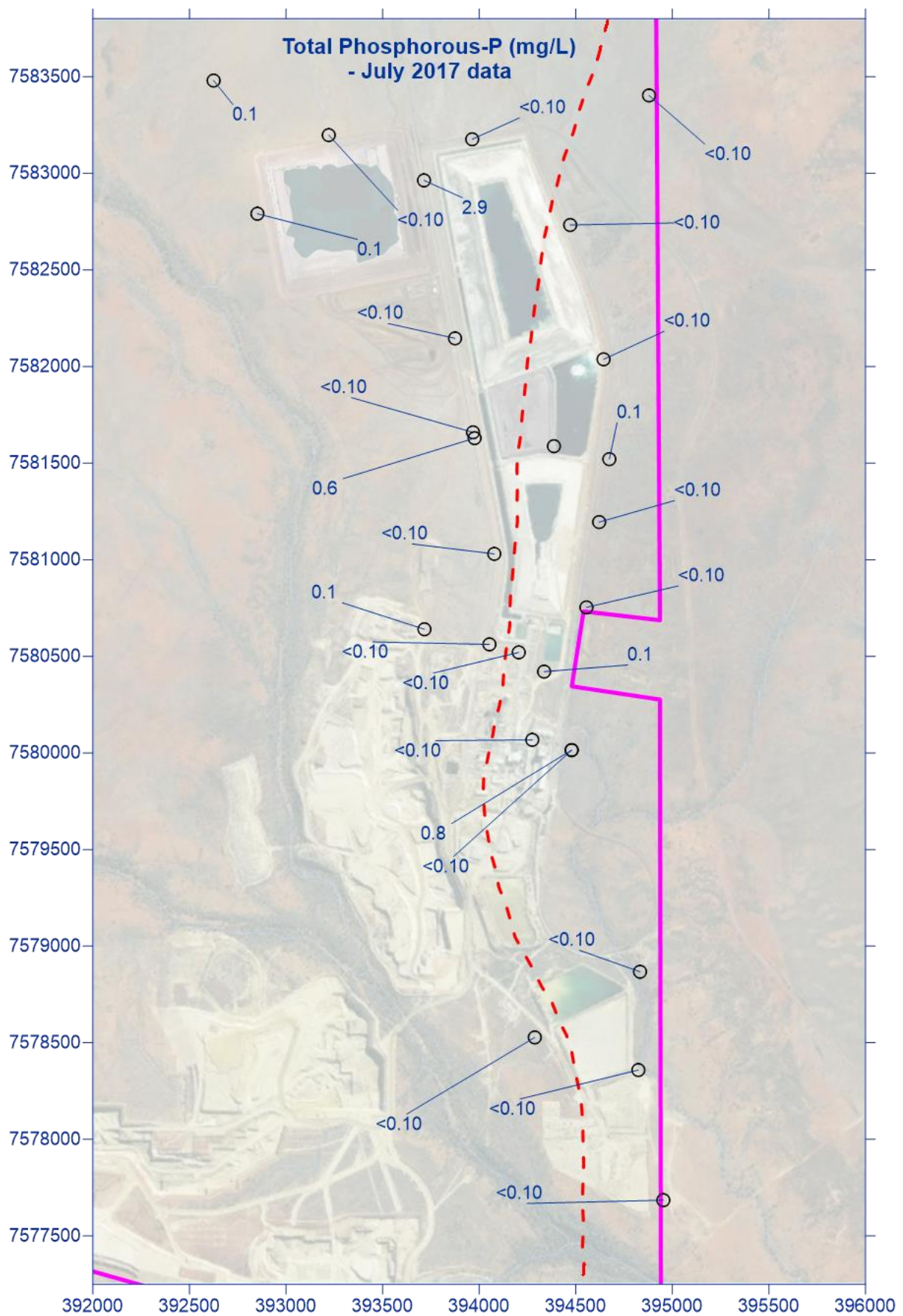












APPENDIX 10

GYPSUM STORAGE FACILITY GROUNDWATER CONTAMINATION RISK ASSESSMENT

GSF GROUNDWATER CONTAMINATION RISK ASSESSMENT

A groundwater contamination risk assessment (GCRA) for the Gypsum Storage Facility was undertaken to identify the risk of harm to groundwater users and/or the environment (JLCS, 2016). Although the GCRA was focused on the risk to receptors from potential contamination in the GSF area, much of the assessment is relevant to the PHM site. Consequently, the GCRA is reproduced in the following sections as background for assessing the entire PHM site. However, it needs to be stressed that the GCRA would need to be revised to include the other identified potential contamination sources in the plant and slimes dams areas.

The GSF GCRA (JLCS, 2016) included the risks to the important water resources in the Great Artesian Basin and the high conservation value groundwater dependent ecosystems (GDEs) in the Mount Merlin Area as well as receptor closer to the GSF.

METHODOLOGY

The methodology applied to assess the environmental and human health risks associated with failure of the GSF liners involved:

- Review of previous studies and other literature describing the regional and local geology, and hydrogeology of the Phosphate Hill area.
- Collation and review of bore and drillhole lithologic logs, groundwater level monitoring, aquifer permeability testing, and groundwater quality analysis.
- Development of regional and local/mine conceptual hydrogeological models.
- Review of literature on influence of faults on groundwater flow and aquifer compartmentalisation.
- Review of GSF construct details with emphasis on measures implemented to contain gypsum wastes and leachate within the various storage cells.
- Assessing observed impact of the GSF on local groundwater.
- Identification of values and assets that rely on groundwater in the Phosphate Hill area..
- Identification of groundwater beneficial uses, both actual and potential realistic uses down hydraulic gradient from the GSF potential contamination sources.
- Identification of groundwater pathways based on the conceptual hydrogeological model.
- Groundwater flow numerical modelling to verify groundwater flow pathways.
- Source-Pathways-Receptor-Consequence (S-R-P-C) modeling to quantify the identified risk.
- Ascertaining whether the risk consequences are acceptable or not, and whether remediation works are necessary to protect the identified receptors from harm.

SOURCE-PATHWAY-RECEPTOR CONSEQUENCE MODEL

The risk assessment was based on the Source-Pathway-Receptor-Consequence (S-P-R-C) model as illustrated in Figure 9.1.

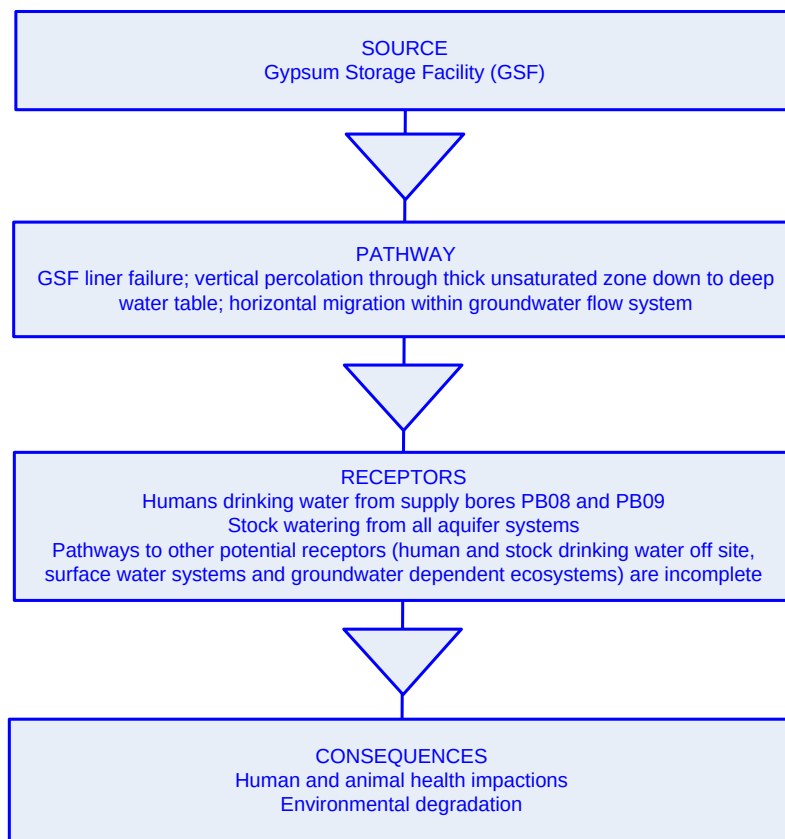


FIGURE 9.1 Phosphate Hill Groundwater Contamination S-P-R-C Model

Risk assessment involve determining the likelihood of a risk occurring and the consequence if it occurs. Risk assessments require identification of source (hazard), pathways and receptors. If contamination is to cause harm, it must reach a receptor. A pollutant linkage occurs when a source, pathway and receptor are all present. If no pathways are present the linkage is incomplete. Consequently, there is no risk of the source adversely affecting a receptor.

Source

The potential contamination source considered was restricted to the GSF.

Pathways

Complete pathways for process water leachate to reach potential receptors requires; 1) a failure (including ruptures) of the liners beneath the GSF cells, surge ditch or evaporation ponds; 2) vertical percolation of escaped leachate through a thick unsaturated zone to the deep water table; and 3) horizontal flow under the prevailing hydraulic gradient (natural or induced by groundwater pumping for mine supply bores) to a receptors.

Pathways between the source and possible receptors were assessed for the five “local” aquifer compartments identified in the conceptual hydrogeological model. The compartments, contained aquifer systems and main stratigraphic units considered are summarized in Table 9.1.

TABLE 9.1 GSF Risk Assessment Groundwater Flow Compartments

Compartment	Aquifer System	Main Stratigraphic Units	Aquifer type
Western	Western Aquifer System (WAS)	Inca Formation Beetle Creek Formation Thorntonia Limestone	Unconfined; multilayered
Eastern	Eastern Aquifer System (EAS)	Swift Formation Ninmaroo Formation	Unconfined; multilayered
Southern	Southern Aquifer System (SAS)	Beetle Creek Formation Thorntonia Limestone	Unconfined; multilayered
Mount Merlin	Mount Merlin Aquifer System (MMAS)	Ninmaroo Formation	Unconfined; multilayered ?
Great Artesian Basin	Great Artesian Basin (GAB)	Cadina-owie – Hooray Aquifer	Confined; multilayered

Receptors

Groundwater from bores in the WAS is used for drinking and other domestic uses at the PHM. Groundwater from the other local aquifer systems is not used as a source of human drinking water but could possibly be used depending on local groundwater quality and bore yield.

The land immediately south of the PHM (SAS) is subject to a mining lease held by Australia Venus Resources Pty Ltd (Venus). Venus has conducted test pit mining on the lease at Korella, and has completed exploratory drilling for water supplies for the mine presumably including water for drinking. However, anecdotal evidence indicated that no suitable supplies were identified apparently because bore yield were too low (D Burnes, pers. Comm., 2016). Nevertheless, drinking water from the SAS was considered in the risk assessment.

Groundwater is not used for stock watering within the PHM mining lease but it is a potential source of stock water both within and outside the lease boundary. Access to groundwater for stock within the PHM lease can be controlled by IPL who own the land. However, access to groundwater beyond IPL's mining lease is not controlled by IPL.

The streams in the Phosphate Hill area are ephemeral only flowing after significant rainfall events. The stream beds are above the water table. Consequently, groundwater does not discharge into the streams. On the contrary, the streams act as linear recharge sources during flooding events and are classified as "losing streams".

Significant GDEs in Queensland have been mapped by DEHP. No GDEs have been identified in the Phosphate Hill mine area. However, ecological significant GDEs with high conservation value have been mapped in the Mount Merlin area, 2-3 km east of the GSF

9.3 RISK ANALYSIS

The risk analysis involved considering the likelihood of an event occurring, and the severity of an event's consequence or impact. The likelihood of an event (Table 9.2) and the consequence/severity of the event (Table 3) were combined to derive a risk matrix (Table 9.4). The risk matrix was then used to ascertain the risk of harm to the identified receptors. The Risk of Harm under current conditions (controls) is summarized in Table 9.5. Residual risk after considering likely controls is summarized in Section 9.4.

TABLE 9.2 Event Likelihood

Descriptor	Rating	Frequency
Almost certain	5	Is expected to occur almost all the time.
Likely	4	Is expected to occur most of the time.
Possible	3	Might occur.
Unlikely	2	Might occur but is not expected to.
Rare	1	Only expected to occur under exceptional circumstances.
No likelihood	0	Cannot occur.

TABLE 9.3 Event Consequences/Severity

Indicator	Rating	Description
Severe	5	Death, substantial offsite impacts to broader environment, long-term environmental damage, extensive clean-up required and complete failure of environmental protection controls.
Significant	4	Hospitalisation, off-site impacts to a segment of the environment, medium-term environmental damage, offsite clean-up required, breach of environmental legislation.
Moderate	3	Medical attention, some offsite temporary impacts, and moderate onsite impacts.
Minor	2	First aid, minimal on-site impacts immediately contained, no discernible off-site impacts, no external complaints received.
Negligible	1	Very minor health impacts, very minor on-site impacts, no off-site impacts
None	0	No health impacts nor on-site or off-site environmental impacts.

The highest risk (medium) was determined for human health from drinking water at the PHM that is pumped from the WAS down hydraulic gradient from the GSF. The risk to human health was rated in the medium risk range even though contamination of the drinking water supply could have significant consequences. This “medium risk” rating was based on the monitoring data for the deep bores in the WAS which suggest no groundwater contamination impact, the considerable distance of the supply bores from the GSF, the attenuation potential within both the unsaturated and saturated zones, and dilution within the groundwater flow system. Groundwater induced into the pumped bores would be further diluted by the water drawn into the bores from surrounding uncontaminated groundwater.

TABLE 9.4 Risk Matrix

Consequence (Severity)	Likelihood					
	No likelihood (0)	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost certain (5)
Severe (5)	No risk (0 x 5 = 0)	Low (1 x 5 = 5)	High (2 x 5 = 10)	Very high (3 x 5 = 15)	Very high (4 x 5 = 20)	Very high (5 x 5 = 25)
Significant (4)	No risk (0 x 4 = 0)	Low (1 x 4 = 4)	Medium (2 x 4 = 8)	High (3 x 4 = 12)	Very high (4 x 4 = 16)	Very high (5 x 4 = 20)
Moderate (3)	No risk (0 x 3 = 0)	Low (1 x 3 = 3)	Medium (2 x 3 = 6)	High (3 x 3 = 9)	High (4 x 3 = 12)	Very high (5 x 3 = 15)
Minor (2)	No risk (0 x 2 = 0)	Very low (1 x 2 = 2)	Low (2 x 2 = 4)	Medium (3 x 2 = 6)	Medium (4 x 2 = 8)	High (5 x 2 = 10)
Negligible (1)	No risk (0 x 1 = 0)	Very low (1 x 1 = 1)	Very low (2 x 1 = 2)	Low (3 x 1 = 3)	Low (4 x 1 = 4)	Low (5 x 1 = 5)
None (0)	No risk (0 x 0 = 0)	No risk (1 x 0 = 0)	No risk (2 x 0 = 0)	No risk (3 x 0 = 0)	No risk (4 x 0 = 0)	No risk (5 x 0 = 0)

Notes: a) 0, No risk; b) 1-2; Very low risk; c) 3-5; Low risk; d) 6-8; Medium risk; e) 9-14, High risk; and f) 15-25 Very high risk

TABLE 9.5 Phosphate Hill GSF Risk of Harm Analysis Summary

Aquifer Compartment	Beneficial Use or Conservation Value	Current Use	Realistic Use Conservation Value	Contamination Likelihood	Consequence if contaminated	Risk Rank	Comments
Western	Drinking water	Y	During mining only	Unlikely	Significant	Medium (8)	Blended groundwater used for mine drinking water
	Stock water	N	Post mining	Rare	Minor	Very low (2)	Stock grazing most likely post mining land use
	Receiving water	N	Local losing streams	No likelihood	Moderate	No risk (0)	Local streams are "losing stream"
	GDEs	N	None mapped	No likelihood	Moderate	No risk (0)	GDEs have not been identified by DEHP
Eastern	Drinking water	N	During mining only	No likelihood	Moderate	No risk (0)	Drinking supply bores will not be constructed in the EAS
	Stock water	N	Y (post mining)	Rare	Minor	Very low (2)	Land use controlled by IPL
	Receiving water	N	Local losing streams	No likelihood	Moderate	No risk (0)	Groundwater does not discharge into local surface waters
	GDEs	N	None mapped	No likelihood	Moderate	No risk (0)	GDS have not been identified by DEHP
Southern	Drinking water	N	Possible but unlikely	Rare	Moderate	Very low (2)	Unlikely pathway; hydraulically separated by faults
	Stock water	Y	Possible	Rare	Minor	Very Low (1)	Low productivity aquifer
	Receiving water	N	None mapped	No likelihood	Moderate	No risk (0)	Local streams are "losing stream"
	GDEs	N	None mapped	No likelihood	Moderate	No risk (0)	GDEs have not been identified by DEHP
Mt Merlin	Drinking water	?	Y	No likelihood	Moderate	No risk (0)	>2.5 km across east of GSF
	Stock water	?	Y	No likelihood	Minor	No risk (0)	across hydraulic gradient
	Receiving water	?	Local losing streams	No likelihood	Moderate	No risk (0)	In different aquifer compartment
	GDEs	Y	Y	No likelihood	Moderate	No risk (0)	No pathway; hydraulically separated by faults
Great Artesian Basin	Drinking water	Y	Y ?	No likelihood	Significant	No risk (0)	> 30 km south of GSF
	Stock water	Y	Y	No likelihood	Minor	No risk (0)	In different aquifer compartment
	Receiving water	Y	Y	No likelihood	Moderate	No risk (0)	Most likely hydraulically separated by faults
	GDEs	Y	Y	No likelihood	Moderate	No risk (0)	Aquifers in GAB are confined

Notes: GDE, Groundwater Dependent Ecosystem

9.4 RISK MANAGEMENT

The finding of the Risk of Harm analysis indicated that the risks are acceptable with the possible exception for the risk to domestic drinking water at the PHM, i.e., a risk assessed as being in the medium risk category (Table 9.5).

The drinking water at PHM is chlorinated and currently tested every fortnight for pH, EC and Chloride ion concentration. However, the analyte testing program is considered to be insufficient. In order to manage and control the risks, it is recommended that the drinking water is tested for a broader analyte suite reflective of identified chemicals of concern including metals, sulphate, and reactive phosphorous.

If testing and chemical trend analyses indicates that the water quality is being impacted control measures to eliminate the risk to human health will be implemented. Any increase(s) in the concentration of parameters that could be harmful to human health is very unlikely to be abrupt which would provide time to implement controls on the use of the water and introduce an alternative drinking water source, if necessary.

Mitigation measures that could be implemented to reduce the risk of harm to an acceptable level include 1) further treating the drinking water (viability would depend on detected contaminants, likely effectiveness of treatment and cost benefit analysis), 2) isolating the contaminated groundwater source and replacing with groundwater from bores more distant from the GSF e.g., PB10 which is located about 220 m south of the current drinking water supply bores and significantly would be less likely to be contaminated by a source to the north as the three intervening bores would capture any contaminated groundwater migrating from further north, 3) installing new supply bores to the west of mine pits in area that is up-hydraulic gradient from the PHM, or 4), piping water from the mine camp at The Monument to the mine site.

The other identified risks are considered to be acceptable. However, the risk of stock drinking contaminated groundwater on IPL land post mining could be managed if ever required by isolating any bores and/or areas impacted by contamination.

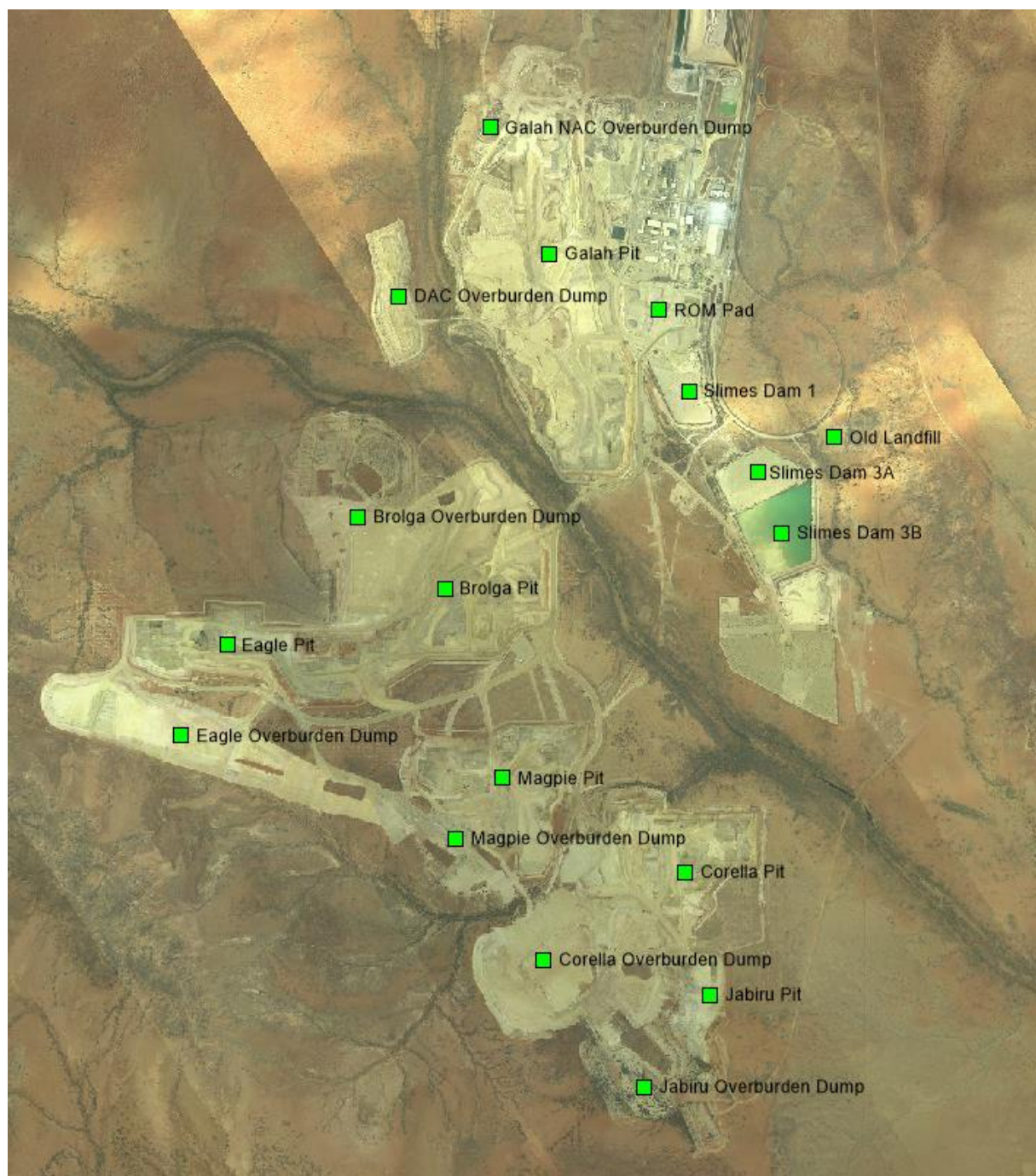
Risk to receptors to the south of the PHM are not expected to change post mining as the terminal pit lakes that will develop in the mined-out pits will function as groundwater sinks because of evaporation losses from the exposed water table in the pits.

APPENDIX 11

PHM SITE AREAS AND POTENTIAL CONTAMINATION SOURCES









IPL Phosphate Hill Mine –
Principal facilities and associated prominent chemicals and substances with the potential to represent a source of contamination should a pathway to the groundwater table exist

