TECHNICAL REPORT

FEASIBILITY STUDY & DESIGN FOR AN END-OF-CATCHMENT WETLAND TREATMENT SYSTEM – ELLEN BROOK

STAGE 2 REPORT – TECHNICAL & ENVIRONMENTAL PRE-FEASIBILITY

FINAL REPORT

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FOR

DEPARTMENT OF ENVIRONMENT AND CONSERVATION ON BEHALF OF THE SWAN RIVER TRUST

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EXECUTIVE SUMMARY

Syrinx Environmental PL (Syrinx) was engaged in July 2010 by the Department of Environment and Conservation (DEC) on behalf of the Swan River Trust (Trust) to determine the overall feasibility of installing an end-of-catchment treatment system at two sites within Ellen Brook. Both sites are located to the immediate north of West Swan Road Bridge in Belhus, upstream of the confluence with the Swan River.

Swan Canning Water Quality Improvement Plan

The purpose of the end-of-catchment treatment system is to provide nutrient load reductions prior to Ellen Brook discharging to the Swan River. The Swan Canning Water Quality Improvement Plan (SCWQIP) (Swan River Trust, 2009) identifies the Ellen Brook catchment as a key catchment of concern, whereby load reductions of 69% total nitrogen (TN) and 79% total phosphorus (TP) are required to reduce the annual nutrient discharge to the maximum acceptable levels. Modelling of a number of management measures within the Ellen Brook catchment has identified that no individual or combinations of management actions are able to achieve these TN or TP reduction targets (Department of Water, 2010). Additional or alternative management actions are therefore required.

Use of NUA as a nutrient and DOC removal media

Recent advances by the CSIRO into the use of mining by-products as environmental amendments has highlighted the potential to use neutralised used acid (NUA), either singularly or in combination with other amendments (NUA blend), as a nutrient and dissolved organic carbon (DOC) removal media. Preliminary column and turf farm field trials undertaken by CSIRO showed that NUA demonstrated high phosphorus retention capacity and good performance in terms of DOC and nutrient removal from influent water. Two subsequent pilot trials have since been undertaken, PTV1 (in 2010) and PTV2 (in 2011). Both trials utilised NUA blends as a filtration media in active, upward flow column-based “pump and treat” configurations. PTV2 also trialled passive vertical flow configurations.

Feasibility review and alternative scope

The original intention of the Syrinx Stage 2 document was to provide an overall feasibility assessment and conceptual designs incorporating the use of NUA blends within an end-of-catchment arrangement. Whilst all laboratory and pilot scale trials to date have shown that the NUA blend presents a promising nutrient removal media, albeit nutrient removal efficiencies were lower than expected in the pilot trial applications, there are still a number of issues and uncertainties which require resolution prior to the establishment of the overall feasibility for an end-of-catchment system for Ellen Brook. As a result, an alternative scope for Stage 2 was required to provide a pre-feasibility review. The purpose of this document is to therefore deliver the alternative scope and assess the technical and environmental pre-feasibility of an end-of-catchment treatment system within Ellen Brook utilising NUA blends as a focus, but also recommending other potential amendments that may be suitable for use in this context.

Key issues and uncertainties

Part 2 of this document provides a review of pilot trial (PTV1 and PTV2) outcomes and provides discussion of key issues. Part 3 provides a synthesis of key potential issues (technical/engineering and environmental) and uncertainties from all trials (laboratory, field and pilot) which still need to be addressed. Listed below are potential key issues and uncertainties identified as potentially compromising the effectiveness of an end-of-catchment wetland containing NUA or NUA blends. The following issues/uncertainties require further investigation:

Effects of Low Hydraulic Conductivity of Media

- The hydraulic conductivity of the NUA blend was well below that required to manage the expected flows and ensure optimal contact time.
- Clogging issues (and associated effects on Fe, Mn, Al, Ca and Si chemistry) will need to be carefully addressed in the overall design of any system.

Release of Contaminants

- Initial release (first flush) of major ions, nutrients and metals. This issue would need to be well controlled/managed in the context of an end-of-catchment treatment wetland and/or the development of well understood contingencies associated with direct release into a receiving environment.
- The passive and active systems in PTV2 behaved differently (hydro-dynamically and hydrogeochemically). There needs to be a more thorough understanding of why this is so, especially in the context of achieving steady state conditions, and the implications for long term metals release (especially Mn and Fe) and breakthrough of other elements.

Effects of High pH on Filter and Receiving Environment

- The pH levels of NUA blend effluent containing MgO is too high to support plant growth in the filter and therefore having a vegetated biofilter in order to improve the hydraulic properties of the system is not feasible. As such, interventions are required to reduce pH, most likely being the removal of MgO from the blend. Removal of MgO may mean that vegetating the system becomes feasible, subject to further investigation. Note the resultant ‘amended blend’ would need to be re-investigated to ensure it does not cause other issues.

- The pH levels of NUA blend effluent (including MgO) will impact on the receiving wetland during low flow periods, but are unlikely to have major impacts during high flow as a result of the dilution effect. Further investigations are needed to determine if this is an issue, and identify whether a dedicated polishing basin with an acid dosing facility is required.
- The pH is also a dominant control on metals stability. There needs to be a more thorough understanding pertaining to pH changes (over different time scales) and metals solubility in the context of environmental issues associated with a wetland catchment system or downstream receptor.
- The Sulfide (allied to Ca ion) content of the NUA blend effluent water is high, which can have implications for sulfide generation within the filter and downstream depending on pH and redox status. Therefore, a sulfide management plan may be required.

Uncertainties Due to Limitations of Trial

- The duration of the investigation did not appear long enough to fully observe issues associated with the interaction of metals and mineralisation processes, in particular there were significant differences in trial investigation periods between the passive and the active systems. This makes the comparison of data between the two systems difficult, and potentially misleading as investigation outcomes. Aligned trial times would be necessary to make meaningful commentary on the effectiveness of the systems relative to each other.
- The investigations did not provide an understanding of how the chemistry of the NUA blend filters will respond under seasonally variable conditions (e.g. wetting and drying cycles).
- The investigations did not provide an understanding of the NUA blend replacement requirements/replacement frequency (i.e. cessation of effective nutrient removal).

The above suite of technical and environmental issues need to be viewed in the context of environmental, economic and social risks and a balance needs to be sought based on agreed and appropriate nutrient removal efficiency for the Ellen Brook end-of-catchment treatment system.

Key recommendations

In response to the above issues, key recommendations that should be considered in future stages of the project include:

Effects of low hydraulic conductivity

- Extend duration of current and future pilot trials (and lab trials where applicable) to assess changes in hydraulic conductivity over time. Investigations should be carried out over a minimum duration of 12 months.
- Characterise typical/major causes of clogging (i.e. surface clogging, interstitial clogging, blend composition etc).
- Investigate potential methods to alleviate clogging issues (i.e. mechanical intervention, mechanical mixing, vegetation, pelletisation, fines screening, lower portions of NUA material).

Note that any changes to the NUA blend composition and configuration will require re-characterisation and re-assessment of nutrient and DOC removal efficiencies as well as potential issues.

Effects of High pH on Filter and Receiving Environment

- Resolve issues with hydraulic conductivity in the first instance. If high pH still remains as an issue the following could be undertaken:
    - Omit MgO from NUA blend; and/or
    - Implement additional treatment steps (i.e. HCl dosing) targeted at pH reduction.

Release of Contaminants

- Investigate potential management measures for the first flush issues, such as pre-treatment of NUA media.
- Re-characterise NUA blend and identify issues associated preferred arrangement (i.e. post resolution of hydraulic conductivity). Identify whether additional treatment steps or management measures are required within the treatment train (e.g. HCl dosing, humate pre-treatment for DOC).
- Establish trials to assess impacts of long term release of Mn, Fe and potentially Al which may impede on the overall effectiveness of an NUA blend utilised in a treatment train arrangement.

Other recommendations

- Review ANZECC guidelines and identify areas where site specific trigger values may be more appropriate in the context of an end-of-catchment wetland treatment train.

Ellen Brook end-of-catchment wetland

As part of the overall intent for this project, an end-of-catchment wetland is to be incorporated into the overall solution for improving the quality of Ellen Brook water and improving the biodiversity and landscape values of this part of the catchment. Part 4 of this document provides concept designs for an end-of-catchment wetland at the two sites in Belhus. The concept design has been configured in such a way that allows retrofitting at a later date with an amendment (NUA blend or other) filter component.

It is acknowledged that wetlands alone will provide limited nutrient removal function due to the large size of the Ellen Brook catchment (716.4 km^2), and the significant annual flows relative to the available wetland treatment area, hence why options for incorporating amendments or other engineering measures are also necessary.

The concepts utilise best practice river restoration principles and incorporate sequences of pools and riffles that would naturally occur along Ellen Brook. Wetlands provide an effluent polishing function for the amendment (i.e. NUA blend) filter to ensure that water is of acceptable quality prior to discharge to Ellen Brook and to provide opportunistic dissolved organic nitrogen removal. A number of other commercially available amendments may also be useful for application in place of, or combination with, the NUA blend filter, such as Phoslock (filterable reactive phosphorus reduction), Zeolite (ammonia and ammonium adsorption) and ViroBond (heavy metal adsorption).

Whilst the concepts can be applied to other sites along Ellen Brook to provide additional water quality improvements and importantly improved habitat and amenity values, it is important to recognise that an end-of-catchment approach should form part of a suite of management actions implemented throughout the Ellen Brook catchment. This will address catchment wide nutrient management issues rather than solely relying on an end-of-catchment solution. Other management actions may include: riparian revegetation, perennial pastures, fertiliser efficiency, land use change controls, fertiliser action plans and soil amendments.

PART 1 INTRODUCTION

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Syrinx Environmental PL (Syrinx) was engaged in July 2010 by the Department of Environment and Conservation (DEC) on behalf of the Swan River Trust (Trust) to determine the overall feasibility of installing an end-of-catchment treatment system at two sites within Ellen Brook. Both sites are located to the immediate north of West Swan Bridge Road in Belhus, upstream of the confluence with the Swan River.

The purpose of the end-of-catchment treatment system is to provide nutrient load reductions prior to Ellen Brook discharging to the Swan River. Syrinx was engaged to complete two stages of work. Stage 1 draft report was issued in January 2011 and included: literature and data review; site opportunities and constraints identification; and the development of three conceptual end-of-catchment treatment system designs. Inherent in the reviews and conceptual development was the use of a mining by-product, neutralised used acid (NUA) blended with other amendments, to provide a majority of the nutrient and dissolved organic carbon (DOC) removal function. Due to insufficient data available to draw accurate conclusions on the feasibility of utilising NUA blends within an end-of-catchment arrangement, this document provides an alternative to the original Stage 2 scope of works. The purpose and methodology of this alternative scope is outlined in section 1.3.

Project History

The Swan Canning Water Quality Improvement Plan (SCWQIP), released in December 2009, provides a roadmap for reducing nitrogen and phosphorus nutrient levels within the Swan Canning Catchment through Stream Quality Affecting Rivers and Estuaries (SQUARE) modelling and decision support tools. The SCWQIP identifies Ellen Brook, a 716.4 km^2 catchment, as a key catchment of concern. While Ellen Brook discharges only 14% (26,750 ML for the period 1997 to 2006) of the total flow from the Swan Canning coastal catchments, it is the greatest nutrient contributor of these catchments to the Swan Canning river system. To give some idea of the severity of the quality issues, modelling indicates that Ellen Brook delivers 71.4 tonnes (28%) of total nitrogen (TN) and 10.04 tonnes (39%) of total phosphorus (TP) to the Swan Canning river system. The SCWQIP identifies that load reductions of 69% TN and 79% TP are required to reduce the annual nutrient discharge to the maximum acceptable levels. SQUARE modelling for a number of management actions has since been undertaken. The modelling has identified that no individual or combinations of management actions are able to achieve the TN or TP reduction targets as required by the SCWQIP (DoW, 2010; Kelsey *et al*, 2010). Additional or alternative management actions are therefore required.

CSIRO Research

Recent advances by the CSIRO into the use of mining by-products as environmental amendments has highlighted the potential to use NUA, either singularly or in combination with other amendments, as a nutrient and DOC removal media. Extensive research has been undertaken by CSIRO characterising the NUA material and testing of NUA blends in field and pilot scale applications (Wendling *et al,* 2009a; Wendling *et al,* 2009b; Wendling *et al,* 2009c; Wendling *et al,* 2010; Douglas *et al,* 2008; Douglas *et al*, 2011). These trials identified that there was a significant opportunity to use an NUA-based filtration system to remove dissolved phosphorus, DOC and dissolved organic nitrogen (DON) from Ellen Brook waters prior to the confluence with the Swan River. Stage 1 report provides a review of NUA related CSIRO reports completed up to the year 2010.

Syrinx Stage 1 Outcomes

As part of Stage 1 scope Syrinx reviewed the CSIRO research, distilling key uncertainties relevant to the application of the NUA media to Ellen Brook. Briefly, uncertainties extended to: contaminant breakthrough; release of contaminants; increase in salinity; sulfide generation; and toxicological impacts. It was acknowledged that some of these uncertainties could potentially be addressed in the design of the treatment system.

In order to encapsulate potential design implications, a series of design criteria and responding design approaches were developed to inform the development of conceptual designs. Also informing the concepts were the site opportunities and constraints. The resulting concepts identify three potential approaches all of which utilised NUA blend media and wetlands to provide water quality improvement functions. Concept 1 utilised the NUA blend and wetlands in a passive (gravity) configuration, Concept 2 presented an active (pumping) configuration and Concept 3 presented a combined passive/active configuration.

Peer Review

The outcomes of the Syrinx Stage 1 review, and in particular uncertainties and concerns raised by Syrinx regarding the use of the NUA as a treatment media, were peer reviewed by Mike Grace (Director and Associate Professor at Water Studies Centre & School of Chemistry, Monash University, Victoria) who was commissioned by the Trust to provide independent advice. In short, the reviewer concluded that, while notwithstanding the major benefits of NUA as an amendment (primarily in terms of P and DOC removal), there are several issues associated with the use of NUA which may, to a different degree, cause various environmental and/or operational problems. In line with the Stage 1 findings, the reviewer noted that the major potential concerns for use of NUA amended soils include: the increase in EC/salinity, breakthrough of DOC and ammonia, potential ‘whole of effluent’ toxicity, pH and operational considerations (wetting/drying). The reviewer also suggested that further testing and modelling of the NUA (or NUA blend) should be undertaken to advance and refine understanding of the performance and behaviour of this amendment, particularly in regards to potential P and N breakthrough, effluent ecotoxicology, and structural changes caused by the operational variations such as wetting and drying.

Pilot Trials

Since completion of Stage 1, two pilot trials have been undertaken and completed. Details of these trials are covered in later sections. The first pilot trial (PTV1) was focussed on a column-based, “pump and treat” filter which could inform potential intervention structures implemented at Ellen Brook. The arrangement of PTV1 included a 12 m long column packed with a mixture of NUA, HIsmelt (HS), calcined magnesia (MgO) and coarse river sand. It was intended that this pipe was placed in a vertical position, however, due to site limitations and technical difficulties an inclination of only 15° was achieved. This resulted in significant slumping and limited interaction between the NUA blend and the Ellen Brook influent. As a consequence, only partial removal of nutrients and DOC occurred. This has emphasised that a range of practical design, operational and maintenance issues must be addressed in order to successfully implement an NUA blend end-of-catchment filtration device.

Upon conclusion of PTV1 it was identified that there was insufficient data to inform the completion of the Stage 2 feasibility study. As a result, a second field scale pilot trial (PTV2) was undertaken to address data gaps present in PTV1 and trial a passive system. The outcomes of PTV2 are discussed within this document in the context of identifying key issues and uncertainties and assessing the feasibility and strategic arrangement of an end-of-catchment treatment system. Generally, results from PTV2 are also inconclusive and determination of a preferred arrangement for an end-of-catchment treatment system cannot be progressed beyond the schematic/conceptual design stage until further investigations are undertaken. Recommendations for these investigations are provided in section 7.1.

1.2 PROJECT OBJECTIVES

The overall objective of this project is to ascertain the feasibility of an end-of-catchment treatment system for Ellen Brook.

Broad aims for the end-of-catchment treatment system encompass environmental, social and economic aspects. These aims were first identified in the Stage 1 Syrinx report and are listed below.

- Maximise water quality improvements within lower Ellen Brook and the Swan Canning river system;
- Minimise flood threat to infrastructure and existing land uses (agricultural and residential);
- Protection and enhancement of environmental values including environmental flows, hydrological cycles, biodiversity, ecosystems and habitats;
- Protection and enhancement of cultural and spiritual values: community education, community involvement, European heritage and Aboriginal heritage; and
- Maximise economic efficiency.

1.3 PURPOSE OF THIS DOCUMENT

The purpose of this document is to deliver the alternative Stage 2 scope and assess the technical and environmental pre-feasibility of an end-of-catchment treatment system for Ellen Brook. The main objectives of this document are:

1. Provide a clear and concise background into the project works completed to date.
2. Review field data in the context of an end-of-catchment solution, identifying key issues and uncertainties and their associated implications.
3. To recommend appropriate courses of actions for future project direction.

In addition, in order to allow progression of the wetland component of the treatment system, the latter part of this document includes a concept design for an end-of-catchment wetland which can be retrofitted at a later date with a filter component. Associated objectives include:

4. Assess feasibility of utilising an NUA blend within a best practice end-of-catchment treatment system for Ellen Brook.
5. Provide high level review of alternative management measures and amendments used in combination with or in lieu of an end-of-catchment NUA filter.

PART 2 PILOT TRIAL OUTCOMES

2.0 OVERVIEW

CSIRO have undertaken extensive laboratory assessment of NUA and NUA blends (Wendling *et al,* 2009a; Wendling *et al,* 2009b; Wendling *et al,* 2009c; Wendling *et al,* 2010; Douglas *et al,* 2008; Douglas *et al*, 2011) which provided a significant insight into the benefits, as well as challenges of using this by-product as a treatment media.

Since late 2010 two pilot trials utilising NUA blends (PTV1 and PTV2) have been undertaken. PTV1 was a joint collaboration between CSIRO and the Trust and was run between 9 September and 3 November 2010. PTV2 was a collaboration between the Trust (implementation and monitoring), Syrinx (conceptual and detailed design), ChemCentre (sample analysis and reporting), CSIRO (NUA blend specifications) and Iluka Resources (supply of NUA material). PTV2 ran between 19 September and 25 November 2011.

The pilot trials were intended to be an intermediate step between the laboratory scale and the full scale implementation. PTV1 outcomes are discussed by Douglas *et al* (2011) and summarised in section 3.0 below. PTV2 outcomes are reviewed in this document (section 4.0) in addition to documents developed by ChemCentre (2012) and CSIRO (Wendling, 2011).

Both PTV1 and PTV2 trials were located in Bullsbrook within Department of Defence owned land leased to livestock graziers (Douglas et al., 2011). Figure 1 (compiled at end of document) shows the site location. Water for both trials was sourced from a fenced off constructed wetland on Bingham Road Creek, a tributary of Ellen Brook.

3.0 PILOT TRIAL 1 (PTV1)

3.1 SYSTEM DESCRIPTION

PTV1 comprised of an upward flow column filter utilising a 12 m long by 0.6 m diameter HDPE pipe placed at a 15° angle. The column was filled with 5 m^3 of NUA blend, comprising of NUA (20%), HISmelt (20%), MgO (10%) and washed river sand (50%). Flow rates varied between 0 and 50,000 L/day.

3.2 OUTCOMES

Bromide tracer tests identified that slumping and subsequent formation of preferential flow paths had occurred in the column. This reduced the interaction and contact time between the influent water and NUA blend and as a consequence only partial removal of nutrients and DOC occurred when compared with CSIRO laboratory studies.

For example, CSIRO laboratory studies demonstrated very high and long lasting P retention capacity of NUA material resulting in >99% reduction in PO4-P and TP concentrations in influent waters (Wendling *et al,* 2010). In contrast, in PTV1 percentage of PO_4-P removal was much lower and importantly it rapidly declined over time (initial removal rate was 46% (5,000 L/day) declining to <1% at day 22 (50,000 L/day)).

Similarly, while NUA was shown to have good retention capacity for DOC and nitrogen in the laboratory study, only marginal removal for TN and DOC was achieved in PTV1 (~10% removal for TN and 10- 20% for DOC at (<20,000 L/day) and less than 10% at higher flows).

Like PTV2 (see section below for details), high levels of pH and EC were observed in the PTV1 effluent; the influent pH varied from 6.5 to 7.5 and the effluent pH attained a maximum value of 9.5 to 10, which was considered too high for discharge to aquatic receptors.

4.0 PILOT TRIAL 2 (PTV2)

Two arrangements were trialled in PTV2, including a passive system utilising a gravity fed vertical flow filter and an active system utilising an upward flow column filter. A brief description of each arrangement is provided below. ChemCentre (2012) have developed a comprehensive document outlining the PTV2 system description, sampling methodology and sample analysis. This document should be referred to for any further information.

4.1 PASSIVE SYSTEM

4.1.1 System Description

PTV2 trialled four vertical flow passive systems (PS1, PS2, PS3 and PS4). Figure 2 shows the configuration for all passive systems, comprising of a 1.2 m high by 1.83 m wide fibreglass tank filled, from bottom to top, with blue metal aggregate (150 mm), coarse river sand (100 mm) and NUA blend (400 mm). The key difference in the systems was variations in the NUA blend, whereby two replicates of each blend were trialled, including:

- PS1 and PS2: NUA (25%), coarse river sand (60%), granular activated carbon (10%) and calcined magnesia (5%).

- PS3 and PS4: NUA (40%), coarse river sand (45%), granular activated carbon (10%) and calcined magnesia (5%).

Water pumped from Bingham Wetland was equally distributed to each tank via slotted distribution pipes. The emergency outlet pipe maintained a 500 mm depth head across the NUA blend surface, allowing vertical flow of influent water (NFSIN) through the NUA blend. The treated water was collected via slotted subsoil drainage pipes located within the aggregate at the base of the tank.

Monitoring for physical, chemical and physiochemical parameters was undertaken by the Trust, with samples collected from the outlet point at each tank typically every two to five days from the 19th September to 25th November 2011 (69 days).

4.1.2 Physical Outcomes

Flow rates

Flow rate data provided by the Trust showed rapid flow rate decline from all passive systems throughout PTV2 trial period. Figure 3 shows that an initial flow rate above 1000 L/hr was sustained for the first three days of the trial. By day nine, outflows were reduced to just below 500 L/hr in PS2, PS3 and PS4, while flows in PS1 were reduced to 818 L/hr. Flow reduction continued rapidly in all passive systems until day 15 to approximately 200 L/hr, representing a flow reduction of 80% in 15 days of operation. After 50 days (7 weeks) of operation flows were reduced by more than 90% of the original rate, with a minimum flow rate of 10 L/hr observed. Flow rates and reduction patterns within this period appeared consistent across all NUA blends, except when mechanically disturbed.

In an attempt to re-establish original flow rates, PS1 and PS3 were mechanically disturbed to allow the creation of preferential flow paths. On days 53, 60 and 69 PS1 and PS3 were probed approximately 250 times on each occurrence with a 15 mm steel bar to create preferential flow paths. PS2 and PS4 remained unchanged.

Following the first mechanical intervention, flows rapidly recovered to near initial conditions (947 L/hr) in PS1 (25% NUA) and to approximately 50% of initial conditions (486 L/hr) in PS3 (40% NUA). The re-establishment of flows was short-lived and within a week flows were reduced to 62 L/hr and 108 L/hr in PS1 and PS3 respectively. The second mechanical intervention resulted in higher flows being achieved, but again flow recoveries were short-lived (four days). The higher initial flow rates may be attributed to preferential flow paths still present from the first intervention. Both interventions highlighted that PS1 had consistently higher flow rates than PS3. Considering that 57% of NUA is composed of particles < 63µm (Wendling, 2009b), this could be attributed to the lower portion of NUA material in PS1.

Insufficient data exists for the third intervention as the site was demobilised immediately following mechanical intervention.

Hydraulic conductivity

Based on the above flow rates, the hydraulic conductivity (k_s) for a range of flow rates experienced during PTV2 were calculated and are shown in Figure 3 on the secondary axis.

Figure 3 highlights that all passive systems had an initial k_s value of ~220 mm/hr, reflecting a sandy loam soil type (Engineers Australia, 2006). This initial k_s value is lower than expected when viewed in light of CSIRO data, which establishes the NUA (unblended) saturated hydraulic conductivity at 324 mm/hr (Wendling, 2009b). As the Stage 1 concepts assume the CSIRO k_s value the sizing of the NUA components within these concepts may no longer be applicable. The data indicates that assessment of hydraulic conductivity of any NUA blend should be undertaken over a longer period (i.e. 12 months at a minimum) to take into account physical and chemical changes in the system.

Nevertheless, the initial k_s shows amenable application to a passive filtration system if retained at a constant rate (i.e. 220 mm/hr). However, maintenance of the k_s at this rate was short-lived (three days) and over the duration of PTV2 the k_s value dropped rapidly over a fortnight to a rate of between 2 to 4 mm/hr, indicating systemic clogging. This latter rate reflects a heavy to medium clay and would not be suitable in a passive filtration application without intervention/s to address clogging issues (see section 4.1.4).

Similar trends of initial rapid decline in k_s have been observed in biofilter bench trials undertaken by the Monash University Facility for Advancing Water Biofiltration (FAWB). FAWB bench trials utilising a sandy loam vertical flow stormwater filter observed a rapid initial decline from an uncompacted rate of 300 mm/hr dropping to ~20 mm/hr. This decline occurred over a period of 4 to 6 months, after which the k_s steadily recovered over a 12 month period to 50 to 100% of the initial k_s value (Lewis *et al,* 2008; Hatt *et al,* 2009). The recovery was attributed to the establishment of vegetation which assisted in the maintenance of the k_s value through the creation of macropores due to root growth and senescence (Lewis *et al*, 2008). Furthermore, a survey of 37 in-situ biofilters situated in Melbourne, Sydney and Brisbane found that many of the biofilters were operating below the design k_s value. This survey established that 39% of biofilters have a k_s below 50 mm/hr, 44% between 50 and 200 mm/hr and 17% above 200 mm/hr (Le Coustumer, 2008). Note that the FAWB guidelines recommend a k_s value of between 100 to 300 mm/hr to ensure maintenance of the hydraulic performance of the system.

Contact time

The contact times within the NUA passive filters (25% NUA blend and 40% NUA blend) were determined using flow and hydraulic conductivity data presented in Figure 3. Table 1 shows that the design contact time of 1 hour was achieved in both NUA blend configurations at a flow rate of ~400-500 L/hr, however, this flow rate was not maintained throughout the trial period. Overall, contact times were similar for both configurations, with the 25% blend (PS1 and PS2) achieving slightly shorter contact times for a given flow rate. In line with the flow data, an initial contact time of 26 minutes achieved (k_s = 220 mm/hr), increasing rapidly over the duration of the trial to >45 hours.

Table 1 PTV2 passive system flow, hydraulic conductivity and contact time for 40% and 25% NUA blends

No. days observed above %	*Flow Rate, Q (L/hr)*	*System Hydraulic Conductivity, k_s (mm/hr)*	*Contact time 40% NUA blend (hours)*	*Contact time 25% NUA blend (hours)*
4.9%	1028.6	221	0.46	0.42
12.7%	1000	215	0.47	0.43
14.7%	900	193	0.52	0.48
16.7%	800	172	0.59	0.54
16.7%	700	150	0.67	0.62
16.7%	600	129	0.79	0.72
17.6%	500	107	0.94	0.87
23.5%	400	86	1.18	1.08
23.5%	300	64	1.57	1.44
29.4%	200	43	2.36	2.16
47.1%	100	21	4.72	4.33
64.7%	50	11	9.45	8.66
82.4%	20	4	23.62	21.65
100.0%	10	2	47.24	43.29

4.1.3 Chemical Outcomes

This section aims to provide a high-level overview of key components of the major ion, physio-chemical, nutrient and trace metal characteristics of PTV2 passive system, with emphasis on those variables that have been considered potentially problematic in past investigations. The data used in this section included water quality data, solid phase mineralogical data and wet chemistry NUA blend data taken from within cores of the passive system.

A complete analysis of all key analytes has been undertaken by the ChemCentre (2012). Furthermore, CSIRO (Wendling, 2011) have identified the key mechanisms via which nutrient attenuation is expected to be achieved with PTV2.

Major Ions

Assessment of major ion chemistry variability within the passive treatment systems is presented in Figure 4, Figure 5 and Figure 6. Assessment of major ion variability provides insight into the rate and duration via which the treatment system achieves equilibrium with respect to input water (NSFIN) and mineralisation - demineralisation processes within the treatment cell. Given the relatively limited temporal duration of the investigation, it was necessary to make the assumption that when an equilibrium, or steady state occurs, outputs from the treatment system will be dominated by inputs into the treatment system (as opposed to disequilibria reactions within the system). This assumption provides a guide to predictability of effluent quality (i.e. out-flowing water from the treatment cells) that without data obtained from a longer term investigation is necessary.

From Figure 4 (which includes two graphical representations of water chemistry; a Piper Diagram (above) and a Schoeller Diagram (below)) it is apparent that the major ion relationships in effluent water vary significantly over the duration experiment. Concentrations of major ions are present in the effluent water samples due to flushing of the NUA blend filters. Importantly the flushing of major ions is dominant in the initial period of the investigation (the first flush period) which lasts for approximately two weeks. Figure 4 shows that the major constituents of this first flush effluent are Ca and SO_4, with Mg also a less dominant contributor to effluent water chemistry. The extent of this period is seen in Figure 5, which shows concentrations of Ca and SO_4 in the effluent water over the duration of the investigation. Given the presence of gypsum in the NUA blend it is likely that Ca and SO_4 are derived from dissolution of this mineral (or minerals of similar chemistry e.g. bassinite and / or anhydrite). It is probable that Mg is derived from the calcined magnesia.

In alignment with the CSIRO investigations (referred to previously), it appeared that evolution of the NUA filter system was dominated by disequilibrium - equilibrium processes controlled by the initial dissolution of gypsum (which accounts for the high concentrations of Ca and SO_4 in the effluent water). This is highlighted in Figure 6, which shows the major ion constituents of water in samples from the beginning, middle and end of the investigation. In all of the passive system filters it appeared that a steady state occurred over the first month of the investigation, where, either:

- dissolution of gypsum diminishes after the first flush, or
- dissolution of gypsum during the first flush released major ions that sequentially became precipitated as diagenetic minerals elsewhere within the column.

Although understanding the specifics of this diagenetic process is important in understanding the long term fate of key analytes, for this investigation it was sufficient to assume that steady state conditions achieved by the passive systems are important for the attenuation of other analytes of interest in an end-of-catchment wetland design.

Given the dominance of sulphate in effluent waters it was important to note that sulfide was present in effluent waters in both the passive and the active systems (Figure 7). Sulfide can potentially form an ecotoxicological (and human health) issue in a gaseous state (as H_2S) and as a mineral where it can help facilitate the formation of acid volatile sulfides (AVS) in anaerobic conditions and acidic environments, which may then impact on other metals. Although AVS minerals are not an issue (per se) they represent a meta-stable mineral that becomes subject to environmental change. As such, sulfide is an important component of the end-of-catchment wetland mineral system, especially as it potentially represents a component of a temporary sink for metals (note release of metals is discussed later in this section) subject to changing seasonal conditions, and in the context of uncertain metals release characteristic of the NUA filters over time.

Physio-chemistry

Figure 8 shows that pH levels in all of the passive systems throughout the experiment were constantly higher than acceptable levels as supported by the ANZECC Freshwater Guidelines (which, although ANZECC guidelines are not being used as management criteria, are a good indicator of acceptable environmental health limits). Elevated pH levels were problematic as pH has significant toxicity related impacts upon aquatic and semi-aquatic biota, and is a major determinant on the speciation of key metals of potential concern.

In all passive system filters pH levels are extremely high (above 10.5 for PS3 and PS4 and above 11 for PS1 and PS2) though they progressively become lower as the passive system filters gradually attained a steady state. In all passive systems filters it appeared that the first flush effect was present and that after approximately two weeks there was a variable, though progressively decreasing trend of pH levels (note this conclusion is supported by a Mann-Kendall Statistic indicating a decreasing trend - Appendix 1). At the cessation of the experiment the pH levels appear (based on observation of the data) to have reached a stable state, with pH for all passive system effluent water ranging between circa 9.7 and 9.95.

From past CSIRO investigations, the use of NUA did not result in exaggerated pH levels in effluent water, whereas the use of calcined magnesia as part of the NUA blend did. It is therefore logical to assume that the calcined magnesia deleteriously impacts upon the effectiveness of the current NUA filter, in the context of the NUA filters forming a part of an end-of-catchment wetland. Even if the pH levels continued to progressively decrease, it would likely take considerable time (based on the decrease in pH in effluent observed during the trial investigation) for the pH of the effluent to stabilise at levels that are acceptable for discharge into aquatic receptors (note this conclusion would require further investigations to quantify).

As identified by previous investigations the relatively high electrical conductivity (EC) in effluent water was also considered potentially problematic in the context of an end-of-catchment wetland setting. Importantly in the passive system filters (as opposed to the active system filters, see section 4.2) the EC levels (which at the beginning of the experiment range from approximately 2,600 uS/cm to 2,900 uS/cm) appear to parallel Ca and SO_4 concentrations, and after the first flush the effluent EC achieved a steady state. As such, it appeared that the issue with EC was dominant during the first flush, after which it exhibited similar levels to the Ellen Brook water (NFSIN) used. Interestingly, at the cessation of the investigation, there was no apparent difference in the EC of effluent from the passive systems filters with different NUA content (nominally NUA content of 25% and 40%). As there was virtually no difference in EC at the end of the trial, it was not possible to conclude that the filters with the 25% NUA resulted in lower EC than those with 40% NUA. However, as we consider EC content to parallel gypsum dissolution, it is logical to conclude that lower gypsum content will result in lower EC in effluent water, potentially due to the dynamics of gypsum dissolution during the first flush of the system.

In general, dissolved oxygen (DO) was highly variable within the effluent water and to an extent followed the trend of DO within the Ellen Brook influent (NFSIN) water (although always lower). Given the presence of sulfide in the effluent water it can be assumed that generation of anaerobic conditions in the passive system occurs. However, as there were no clear relationships between sulfide and DO observed in the data there are no ways to use either parameter relative to the other to assess potential impacts on downstream receiving environments.

Nutrients

Nutrients assessed included total phosphorus (TP), soluble reactive phosphorus (PO_4), total nitrogen (TN), organic nitrogen (Org_N), nitrate (NO_3) and ammonia (NH_3). In the Ellen Brook system phosphorus is present due to up-stream agricultural land uses (and other anthropogenic runoff), whilst nitrogen is present (dominantly as dissolved organic nitrogen) due to agricultural land uses in addition to (anecdotally) past wetland draining activities that have resulted in release of organic nitrogen into the system. Both P and N represent potential issues (depending on concentration and speciation) in the context of an end-of-catchment wetland treatment system. Figure 9, Figure 10, Figure 11 and Figure 12 highlight key characteristics and trends exhibited by nutrients throughout the investigation in passive system effluent relative to Ellen Brook water.

Assessment of the effluent water has yielded the following key conclusions:

- Figure 9 shows that there were significant concentrations of nutrients in the Ellen Brook (NFSIN) water and effluent. In general, the Ellen Brook water contained higher concentrations of DOC, TN and N_org, whilst effluent water contained higher concentrations of NO_3 and NH_3 than the Ellen Brook water. Figure 9 shows that the concentrations of TN and Org_N are very similar in most samples, which is supported by statistical analysis that shows a strong correlation between the two variable (r^2=0.86).

- In particular, TP dominantly exhibited a lower concentration in effluent water than Ellen Brook water, whilst the concentrations of TN and Org_N were not universally lower in effluent water relative to Ellen Brook water. This suggests the NUA filters were more effective in attenuating phosphorus than nitrogen, which is subject to speciation changes (in particular the formation of NO_3 and to a lesser degree NH_3).
- Figure 10 and Figure 11 show that there was a very strong relationship between total organic carbon, DOC and N (organic nitrogen) which suggests that most N existed in conjunction with dissolved organic acids naturally present in the Ellen Brook water - a conclusion also revealed in Figure 9, where the concentrations of most TN and Org_N in water samples is very similar.
- Although there was a relatively strong correlation between TP and total organic carbon (Appendix 2) it was not clear whether P (which is known to speciate with some organic compounds) occurs solely in conjunction with an organic acid (as per N).
- P attenuation definitely occurred within the passive system (Figure 12), with Fe and Al potentially representing diagenetic sinks within the NUA filters (Figure 10). However, it was not apparent whether phosphorus became integrated into other, potentially more stable mineral species (such as hydroxyapatite), as has been suggested by past investigations (Wendling et al, 2010). Given the stability of trace metals within the filters (including, potentially Fe, Mn and Al that can form surface bound hydroxides) this may represent a long term issue for the attenuation of P, in particular if pH fluctuations result in Fe, Mn and/or Al speciation changes.

Based on the above it appears that the NUA material was effective for the removal of P, though not as effective as CSIRO laboratory trials which demonstrated >99% TP removal (Wendling *et al,* 2010). This may be due to differences in the diagenetic formation of gypsum and like minerals (and may be a result of prolonged contact time), though there is not enough pertinent data to draw more thorough conclusions than this. It was observed in PTV2 that the NUA blend was also less effective for the removal of N. Given the dominant speciation of N in the Ellen Brook system (i.e. dissolved organic form) it is possible that a substrate that targets removal of DOC (such as organic matter containing weak acids such as fulvic and humic acids) may be a more effective mechanism to also remove N from the water (due to the strong relationship between DOC and DON discussed earlier). As the effectiveness of this process will be constrained by the relationship between the type of organic acid and the type of organic substrate it may be worth undertaking further investigations characterising the nature of the organic acids present in the Ellen Brook water.

Metals

As a mining by-product, the NUA blend is characterised by metal contents that are significantly higher than naturally occurring non-mineralised geologic materials (Appendix 3 and 4).

Past investigations (laboratory and PTV1) have recognised that key metals (Ca, Co, Cu, Fe, Mg, Mn and Ni) in effluent samples potentially constitute issues with respect to:

- Ecotoxicological impacts on flora and fauna in wetland environments,
- Ecotoxicological issues on flora and fauna in downstream river / creek environments,

Analysis of PTV2 samples has revealed that other metals were also present as potential metals of concern. The full list assessed in this report includes the following:

- Aluminium (Al)
- Caesium (Cs),
- Chromium, in particular Hexavalent Chromium (Cr VI),
- Cobalt (Co),
- Copper (Cu),
- Iron (Fe),
- Lead (Pb),
- Manganese (Mn),
- Strontium (Sr),
- Uranium (U), and
- Zinc (Zn)

A detailed interpretation of each of the metals will be presented in a separate ChemCentre report (2012). This current section aims to identify those key characteristics, nominally concentrations of metals (Figure 13) and trends of metals in passive system effluent (Figure 14) that are relevant to the overall feasibility of an end-of-catchment wetland system. These identified issues are incorporated in later sections into an issues matrix (Table 3) that is intended to help inform steps required to manage these issues.

Figure 13 highlights the concentrations of all metals that have previously been noted as "of concern". In assessing concentrations in passive system effluent samples relative to Ellen Brook water it appeared that the metals that may pose a concern, and should be better understood in the context of the issues they may pose in an end-of-catchment wetland system, include:

- Co
- Cr VI

- Cu
- Sr
- Mn

The time series plots of these metals along with Fe, Al and U are shown in Figure 14.

In general the metals that attained a steady state in effluent samples included CrVI, Al, Sr and to an extent Fe. As such it will typically be within the first flush effluent (i.e. first two weeks of operation) that these metals may constitute an issue for receiving environments. In general, Fe, Mn and Al may also represent metals that are implicated in clogging processes and further understanding of the biogeochemistry of these metals should be acquired.

Metals which exhibited increasing concentration trends as the investigation continued included: Mn, Co, Cu, Pb and U (note Pb is not included in Figure 14). To ascertain the degree of release of these metals and potential impacts on receiving environments further investigations will be required. In particular understanding the long term fate of Mn (Mn oxides and oxyhydroxides are known as effective scavengers of other trace metals) in seasonally variable conditions (including redox variability as well as exaggerated pH conditions) will be important to address potential metals release characteristics to downstream receiving environments. This is highlighted in Figure 15 which shows the concentrations of Co, Cu, Mn, Pb and U in effluent water samples from PS3 and AS1OUT. It is clear that there was a relationship between Mn and the other metals, suggesting that the Mn (and the minerals that Mn was associated with) had a strong control on the solubility of the other metals.

4.1.4 Discussion of Passive System Trial

This section presents a broad discussion on key generic outcomes of the passive system trial and environmental and technical implications. A more detailed issues matrix, in the context of an end-of-catchment wetland is presented in Table 3 and discussed further in section 6.0.

Environmental implications

Review of PTV2 chemical and physiochemical outcomes identifies that NUA blends constitute a useful amendment for P removal though less efficient for N removal. For an end-of-catchment application a number of issues need to be addressed and further assessed, in particular initial release of *some* ions and high effluent pH. Implications/issues include:

- Significant concentration of analytes are present in effluent samples during the first flush (approximately two weeks after trial initiation) and techniques to address appropriate management of these analytes during the first flush will be necessary.

The first flush effluent is dominated by Ca and SO_4, which also constitutes the high electrical conductivity of the water samples.

- High pH is problematic as it potentially impacts upon the speciation of metals and key minerals, is toxic to a range of flora and fauna and is difficult to biologically neutralise in an end-of-catchment arrangement. To address this issue it will be necessary to either remove the factor that is resulting in the high pH (which is considered to be the calcined magnesia in the NUA blend) or dose the effluent with HCl (or another acid) post its exit from the NUA filters.
- Nutrient removal occurs for both P (for which the passive system appears efficient) and N (for which the passive system appears less efficient). However, effluent water samples in the passive system have higher concentrations of NO_3 and NH_4 than influent (NFSIN) water. Implications of this speciation change may need to be better understood in terms of an end-of-catchment wetland receiving environment (note - these higher concentrations are not necessarily a problem for wetland receiving environments, though excess nutrients can lead to enhanced eutrophic conditions).
- Electrical Conductivity, which is predominantly related to Ca and SO_4 ions, is high and may result in excessive stress to flora and fauna of downstream receiving environments. Excessive salts may also form diagenetic mineral crusts in wetlands, and excessive sulphate poses the risk of sulfide formation under anoxic conditions.
- Long term release of Mn (and potentially Fe) via diagenetic reactions impacting on oxides and oxyhydroxides is an issue that will require further investigation. It appears that the Mn (and potentially Fe) minerals present in the NUA blend have an impact upon the release of other metals (notably Co, Cu, Pb and U). Although these metals exhibit relatively low concentrations in the effluent water, and therefore may or may not pose an issue to downstream receiving environments, it is necessary to understand the magnitude of the metals release (which will require a longer investigation time) to appreciate the severity, or otherwise, of any downstream issue. The circumstances under which Mn may pose an ecotoxicological issue will also need to be assessed in the context of the downstream environment (in particular with respect to redox and pH variability). The issue of metals (and other rock forming minerals) forming a clogging problem is dealt with below.

Technical implications

Without mechanical intervention the passive system would, over time, treat only a small portion (i.e. <1%) of total influent for an extended contact time, with the majority of flows (99%) bypassing the system. This has implications on the treatment efficiency, scalability and ongoing management of the system. Furthermore, the prolonged contact time likely alters the chemical evolution of the passive system and potentially the efficiency via which nutrients are attenuated. In order to deliver a system which is scalable to an end-of-catchment application and provide meaningful P removal, ongoing maintenance of the required hydraulic conductivity is therefore essential.

Rapid declines in the flow rate and hydraulic conductivity indicate systemic clogging. Deductively, the likely cause of clogging is attributed to a combination of surface and interstitial clogging of the NUA blend filter. Clogging within the subsoil drainage system is considered unlikely based on two observations. Firstly, mechanical intervention saw the recovery of the flow rate to initial conditions. Secondly, subsoil pipe flushing did not result in sediment discharge from the subsoil drains or outlet pipes.

Surface clogging is likely to be a result of sediment deposition and TSS accumulation on the NUA blend filter surface. Although TSS concentrations in influent water (NSFIN) was low (~5 mg/L), the high inflow volume of >1000 l/hr equates to a potential TSS load of 120 g/day, or 45 g/m^2/day, for each passive system. Note that these values should be used as a preliminary guide as the volume of TSS discharged via the high flow bypass is unknown. Current recommendations for vertical flow sand subsurface flow wetlands suggest a maximum TSS loading of 5 g/m^2/day (Kadlec & Wallace, 2009). The NUA column trials conducted by Wendling *et al*. (2009) and Wendling *et al*. (2010) used flows of 0.2mL/min and 1.0mL/min, respectively. These flows are much lower than the ones trialled in this experiment.

Interstitial clogging is likely to result from changes in physical and chemical characteristics of the system. Generally, use of a silty/clay material in a filter arrangement can substantially reduce the hydraulic conductivity of the media via migration of fines into pore spaces and a subsequent decrease in the filters void ratio. FAWB guidelines for biofilters recommend a filter material containing less than 3% (W/W) silt/clay (<50µm). Considering that CSIRO (2012) particle size distribution analysis shows the total percentage of particles below this size is 7% (PS1 and PS2) and 9.5% (PS3 and 4), interstitial clogging could be attributed to the proportion of fines in the blend. Furthermore, biofilm accumulation throughout the filter media and the overall compaction of the media under a hydraulic loading (500 mm head) will result in a drop of the k_s value. It was observed that in all passive systems the filter had compressed by approximately 50 to 100 mm at the conclusion of the trial.

Precipitation of Fe, Al and Mn as oxide and hydroxide minerals may also contribute to interstitial clogging. Throughout PTV2 it was observed that dissolved Fe was consistently reduced from an average of 0.96 mg/L (NFSIN) to ~0.25 mg/L (PS1, PS2, PS3 and PS4). This suggests precipitation of more than 70% (~0.71 mg/L) of the influent (NFSIN) Fe. This is supported by CSIRO (Douglas *et al*. 2008) XRD analysis during the turf trials that shows Fe oxides/hydroxides forming a coating around quartz grains. Considering that low concentrations of Fe (<0.2 mg/L) is known to cause clogging in other water related infrastructure (i.e. scheme, groundwater and irrigation), the potential influent concentration of 0.7 mg/L has the potential to be a contributor to interstitial clogging. Diagenetic alterations affecting Si, Ca, Fe, Mn and potentially Al may also contribute to mineralisation and precipitation issues within the NUA filter.

Improvements in hydraulic conductivity and prevention of clogging are therefore key in the long term success of the passive system. Several interventions could be applied to deliver improvements:

- Pre-treatment. Removal of fine to coarse sediment from influent water prior to conveyance to passive NUA blend filtration system.
- Decreasing NUA content and increasing coarse sand content. This may reduce P removal efficiencies, require ongoing mechanical intervention and could result in more frequent replacement of NUA blend filter.
- Pelletisation of NUA. Increases the void ratio, however lifespan of pellet form is unknown. Requires additional processing either by Iluka or an alternative party which may be difficult to execute.
- Vegetation with rushes, sedges, shrubs and trees to create macropores. As the vegetation is sensitive to high pH, the MgO material will need to be omitted from the blend. Additional longer term research (>12 months) is required to ascertain plant establishment within an NUA blend media under stabilised hydraulic conditions.
- Regular mechanical intervention occurring fortnightly or monthly.

Resolution of clogging issues and maintenance of an appropriate hydraulic conductivity will likely present a technically feasible NUA blend based arrangement that can be applied to an end-of-catchment treatment system, subject to more detailed hydraulic modelling.

4.2 ACTIVE SYSTEM

4.2.1 System Description

The active system comprised two replicates (AS1 and AS2) of a three column pressurised upward flow filtration system (refer Figure 16 for drawings). The columns were fabricated from HDPE PN16 pipe, with each column measuring 2 m long by 0.5 m internal diameter and placed in an upright vertical position. Blue metal aggregate (10 to 20 mm) was placed within the base of each column to cover the inlet (~200 mm depth) and prevent blockages. A 40% NUA blend consistent with PS3 and PS4 above was packed on top of the aggregate to the height of the column (~1.7 m).

Three columns were paced in series to increase contact time with the NUA blend. The position of the column in the series is named in ascending alphabetical order, AS1A refers to the first column, AS1B the second and AS1C the third. An inlet near the base of each of the first columns (AS1A and AS2A) receives influent water (NFSIN) pumped water from Bingham

Wetland. This water flows in an upward direction through the NUA blend and is discharged via an outlet at the top of the columns, moving under pressure to successive columns via a 50 mm HDPE pipe. A manifold/high flow bypass allowed the isolation of columns should maintenance be required. The pump comprised of a 5.5 kW Regent Pump operating at 45 m of head and 3 L/s volumetric flow.

Monitoring for physical, chemical and physiochemical parameters was undertaken by the Trust, with samples collected from the outlet for each system (AS1 and AS2) typically every two to five days and from the outlets AS1A, AS1B, AS2A and AS2B every seven to ten days. Delays in the system operation meant that the trial ran for a shorter duration than the passive system, commencing on 13th October and operating until 25th November 2011 (45 days).

In order to prevent total suspended solids (TSS) and fines from moving through and discharging from the system, a filter device was placed between the column and each outlet. Originally, the filter comprised a 90 micron geotextile clamped between the flange with the aid of two gaskets. On the 10th November, 28 days after the commencement of the trial, this was changed to metal mesh filters due to blockage issues. The latter comprised a 100 micron mesh sandwiched between supporting coarse mesh. These filters were installed on all AS1 columns and AS2B and AS2C. AS2A had only coarse mesh, then a 50µm inline sock filter.

4.2.2 Physical Outcomes

Flow rates

Based on the concept drawings provided in Figure 16, the design flow rate for the active system was set at 0.16 L/s or 576 L/hr to achieve a contact time of 1 hour. Figure 17 shows the observed flow rates throughout PTV2. The data highlights that the design flow rate was not achieved nor maintained throughout the trial period.

Variable outflows in AS1 were observed, with flows maintained below 50 L/hr in the first week of operation and increasing to 272 L/hr in a single event approximately 10 days after monitoring commenced. For the remainder of the trial (31 days), AS1 outflows continued to fluctuate, ranging between 20 L/hr and 122 L/hr. Outflows from AS2 were less variable and ranged between 10 L/hr to 80 L/hr for the duration of the trial. When reviewing individual columns it is evident that flows are being constricted in AS1B and AS2B, with higher flow rates consistently observed from AS1A and AS2A sampling points.

Flow impedances are likely the result of the NUA blend porosity and/or the capacity of the pump. Neither the engagement of the high flow bypass shortly after the commencement of the trial or alteration of the geofabric (90 µm) to the metal mesh screens (100 µm) appeared to alter the flow rates from AS1OUT and AS2OUT.

Contact time

Table 2 shows the NUA blend contact time within the active system for a range of flow rates. Note that the contact time shown is the total contact time of all three columns in series (i.e. outflows from AS1 and AS2) and differs from the design contact due to design variations upon implementation (e.g. volume and compaction of NUA). From the flow (Figure 17) and contact data it is evident that AS1 contact time varied between 2 and 23 hrs and averaged 7.2 hrs at 64 L/hr. AS2 contact time varied between 46.3 hrs and 5.8 hrs and averaged 10 hrs at 46 L/hr. The design contact time was therefore exceeded, on average, by 7 to 10 hours.

Table 2 PTV2 Active system contact time for active system 1 (AS1) and active system 2 (AS2)

No. days observed above %	*Flow Rate, Q (L/hr)*	*Contact time, (mins)*	*Contact time, (hours)*
0.0%	500	56	0.9
0.0%	400	69	1.2
0.0%	300	93	1.5
3.3%	200	139	2.3
10.0%	100	278	4.6
13.3%	80	347	5.8
30.0%	60	463	7.7
56.7%	40	694	11.6
90.0%	20	1389	23.1
100.0%	10	2777	46.3
100.0%	5	5554	92.6

4.2.3 Chemical Outcomes

This section aims to provide a high-level overview of key components of the major ion, physio-chemical, nutrient and trace metal characteristics of the active system trials (using the same broad methodology as the appreciation of the passive system effluent data) within PTV2, with emphasis on those variables that have been considered potentially problematic in past investigations.

Major Ions

From Figure 18 (which is layed out in the same format as Figure 4 with the Piper on top and the Schoeller on the bottom), it was apparent that the major ion relationships in effluent water did not vary as significantly over time as in the passive system effluent. The degree of this variability (as concentrations of major ions) is also seen in Figure 18, which, like the passive system, shows significant concentrations of major ions in the effluent water that were not originally present in Ellen Brook water.

As per the passive system the dominant major ions within the active system effluent were Ca and SO_4. However, unlike the passive system it was apparent that the concentrations of key major ions (in particular Ca and SO_4) did not decrease as much over time when the system was subjected to Ellen Brook water (Figure 19). This was observed diagrammatically in specific water samples taken during the start, middle and end of the evaluation (Figure 20), which suggests that the active system did not attain the same steady state (relative to the Ellen Brook water) over the duration of the investigation.

Physio-chemistry

From Figure 21 it is evident that the pH of the active system effluent remains high throughout the investigation period. This is similar to the passive system, suggesting a similar generation mechanism (namely the calcined magnesia).

The pH levels observed within the effluent of the active system are more variable (Figure 21) than the pH levels observed in the effluent of the passive system. This suggests that there may be other factors which affect pH levels (such as the mineral dissolution / precipitation of Ca dominated minerals) than solely the presence of calcined magnesia.

Unlike the passive system, EC levels do not approximate Ellen Brook EC levels after a few weeks. As per the dominant major ions (in particular Ca and SO_4), EC levels do not attain a steady state relative to the low levels observed in the Ellen Brook water.

Figure 21 reveals that the concentrations of DO were variable and that there were no clear relationships between DO content of the Ellen Brook water and DO content of the effluent. However, this may be an artefact caused by the sampling methodology, such as the introduction of oxygen into effluent samples during the sampling process (i.e. at the sample outlet the pressure head within the active systems may have forced water to run through the sample tap which may have introduced oxygen into the sample *pers. comm.* A. Hams).

Nutrients

Using a similar rationale for interpreting the nutrient data from the passive system, the following key conclusions (typically highlighted in Figure 22) can be drawn from assessment of the effluent data from the active system:

- The active systems are efficient at removal of phosphorus in both measured forms though there was less data compared with the passive system trial due to the length of the respective trials.

- TP and PO4 were efficiently attenuated by the active system, and were apparently constrained (to some degree - see Figure 23) by the same relationships that controlled nutrients in the passive systems. Like the passive system the same uncertainties exist for the long term fate of phosphorus attenuation. For example, given the long term stability of trace metals within the filters (including, potentially Mn, Fe and Al that typically form as surface bound hydroxides) this may represent a long term concern for the attenuation of phosphorus, in particular if pH fluctuations occur.
- There were significant concentrations of nutrients in the Ellen Brook influent (NSFIN) water, and with the exception of NO_3 and NH_3 all other species (with minor exceptions pertaining to TN) had equal or lower concentrations than the Ellen Brook water.
- The active system effluent samples had a greater variance with respect to dissolved organic carbon, TN and Org_N content (Figure 24), and may be (given the uncertainties in interpretation generated through having less data than the passive system) considered more effective at attenuating these analytes. This may be due (anecdotally) to different flow mechanisms within the two trial systems, though such an interpretation cannot be verified with the data available.
- The active system effluent contains substantially greater concentrations of NO_3 than the passive system effluent, and typically the NO_3 occured in higher concentrations than in the Ellen Brook water.

Metals

Using a similar rationale for interpreting metals data from the passive system, the following key conclusions can be drawn from assessment of the metals data (Figure 25 and Figure 26) from the effluent of the active system (note the ChemCentre (2012) report will provide a more thorough review of observed trends):

- Concentrations of Al, Fe and Mn were initially very low in effluent samples at the beginning of the investigation, yet concentrations rose on day 30 (approximately) of the trial, which suggests a perturbation (and potentially release of TSS) of the system of some sort.
- Cr, U and Sr concentrations were higher in effluent water or equal to concentrations in Ellen Brook water throughout the duration of the investigation.
- Mn and Co concentrations were higher in effluent water than Ellen Brook water as a result of rising concentrations, though this only occurred in two samples towards the end of the trial period in AS1A and AS2A.
- Sr and Cr(VI) and to an extent U had concentrations in effluent that were higher than the metals concentrations in Ellen Brook water due to a first flush release.

Interpretation of the data shows that in general metals attenuation by the active systems was relatively efficient. However, key issues that limit the ability to thoroughly interpret the data (especially in relation to the passive system trials data) include:

- the shorter duration of the investigation, and the lack of observable trend data, and
- the implications on metals mobility associated with not achieving steady state conditions (as occurred in the passive system).

4.2.4 Discussion

Environmental implications

The active system didn't achieve a steady state (with respect to major ions, pH, EC and some metals) which suggests that the first flush management period will be prolonged relative to the passive system first flush management period. Importantly, Cr(VI) is one of the metals that was present in effluent water during a prolonged first flush period.

Whilst the active system showed good removal efficiency for TP and TN and was amenable to act as an amendment, the increased release of NO_3 when compared to the passive system was considered an issue that would need further investigation in the context of an end-of-catchment wetland system.

Technical implications

PTV2 highlighted the technical difficulties in utilising NUA in an active arrangement. Technical difficulties which need to be overcome include: hydraulic conductivity (filter media specification and proportion of fines), contact time, high head conditions, low pump rates, capacity to retain filter media in columns and outlet filter specifications.

The low flow rates observed in the active systems have implications on the systems scalability and treatment efficiency. Scaling up the system to an end-of-catchment application would present serious economic implications, particularly the capital and operating expenditure associated with high head pumps (see section 8.3). Furthermore, the active system would require additional end of line treatment steps to prevent NUA blend particulates exiting the system and discharging directly to Ellen Brook. Considering the composition of NUA used in PTV2 (89% is < 50µm), such end of column/outlet filtration systems would need to target very fine particulates.

Whilst reconfiguration of the active system would likely result in a technically feasible approach, the economic practicalities of operating such a system bring into question the long term treatment effectiveness of the system (i.e. $/kg TP removed).

PART 3 END-OF-CATCHMENT TREATMENT SYSTEM PRE-FEASIBILITY ASSESSMENT

5.0 PURPOSE OF PRE-FEASIBILITY ASSESSMENT

This section presents a technical and environmental pre-feasibility assessment. Note that due to insufficient information it is not the intention to provide a full feasibility at this stage. Rather, the purpose of this section is to identify issues and define areas which require resolution before a full feasibility can be progressed.

6.0 ISSUES & UNCERTAINTIES

This section aims to summarise all key issues and/or uncertainties identified in the Stage 1 Syrinx report in light of the peer review conducted by Associate Professor Mike Grace and outcomes from PTV1 and PTV2. Table 3 synthesises the relevant issues and uncertainties which still need to be addressed <u>in the context of the use of an NUA blend within an end-of-catchment treatment system in Ellen Brook.</u>

The argument that a majority of these issues can be managed through dilution requires further investigation, particularly considering the hydraulic efficiency of an end-of-catchment treatment system. Section 8.5 provides discussion on water quantity modelling, identifying that treatment of Ellen Brook flows will occur during both low and high flow periods. Furthermore, during some low flow periods, a large proportion of Ellen Brook flow (i.e. up to 100%) could be diverted to the treatment system.

Ultimately, addressing the identified issues will require additional laboratory and field scale trials as the current data is inconclusive. Section 7.1 presents a range of recommendations for additional trials.

Table 3 NUA issues matrix

	Issue Identified		Implications	Potential future investigations/Suggested actions
Environmental (Water Quality)	Manganese	▪ Soluble Mn release observed in CSIRO column trials (4 mg/L). ▪ Particulate release in PTV2 (active system) likely related to TSS release from the columns.	▪ Potential long term release may cause a range of unacceptable environmental impacts. ▪ Potential particulate Mn release from the passive system arrangement if periodically flooded and active system if fines filter is omitted. ▪ Potential -speciation changes of Mn downstream depending on temperature, pH and redox conditions.	▪ Further research to investigate long term release of Mn.
	Sulphate	▪ Sulphate release observed CSIRO column trials and PTV2. ▪ PTV2 – initial release from passive system, ongoing release from active system.	▪ Increase in EC which could be detrimental to a fresh water system and may result in microbial and plant decline or deaths. ▪ Potential sulfide generation where oxygen levels are low. Can cause toxicity to plant roots and aquatic organisms.	▪ Ensure that receiving system, post NUA filter is kept aerobic.
	Sulfide	▪ Sulfide release in PTV2 active system and to a lesser extent in passive system.	▪ Possible gas release may cause health issues to human receptors. ▪ Potential to help the formation of acid volatile sulfide in anoxic conditions.	
	Calcium	▪ High soluble and total calcium concentrations in the PTV2 active system	▪ Potential $CaCO_3$ precipitation with decreasing pH, possible smothering of downstream benthic and littoral habitats and potential to cause clogging of filter media.	
	pH	▪ High pH (>9) observed throughout PTV1 and PTV2 ▪ Likely relationship between pH and MgO.	▪ High pH can: ▪ affect aquatic life (flora and fauna) downstream of the NUA filter both in current and ecologically restored (i.e. end-of-catchment wetland) ecosystem. ▪ potentially impact metal speciation in receiving environments. ▪ potentially impact upon integrity of steel and concrete infrastructure.	▪ Investigate if the pH issue is solved by the removal of MgO from the filter blend. ▪ If MgO is retained investigate cost effective options (e.g. chemical dosing) for lowering pH to acceptable levels in a dedicated polishing unit.
	Electrical Conductivity (EC)	▪ High EC levels in PTV1 and PTV2 ▪ PTV2 – high levels initially in the passive system and maintained throughout in the active system.	▪ EC can significantly impact health of aquatic receiving environments.	▪ Investigate lower proportion of NUA in the filter blend. ▪ Better assess relationship between gypsum dissolution and concomitant EC in effluent.
	Copper	▪ PTV2 passive system – although in very low concentrations (Max = 0.005mg/L), an increasing concentration trend was observed.	▪ Potential to cause a range of unacceptable environmental impacts.	▪ Further research to investigate long term release of copper from NUA. ▪ Investigate lower proportion of NUA in the filter blend.
	Cobalt	▪ PTV2 passive and active system - although in very low concentrations (Max = 0.0006mg/L in active system and 0.0021mg/L in passive), an increasing concentration trend was observed.	▪ Potential to cause a range of unacceptable environmental impacts. Impacts have not yet been determined due to lack of data.	▪ Further research to investigate long term release of cobalt from NUA. ▪ Investigate lower proportion of NUA in the filter blend.
	Chromium VI	▪ Initial release of chromium VI in PTV2 passive system and active systems	▪ Cr VI is potentially toxic to aquatic organisms and human receptors.	▪ Confirm if recirculation of initial “flush” of effluent allows for released chromium to be retained in the filter. ▪ Investigate lower proportion of NUA in the filter blend.

	Issue Identified		Implications	Potential future investigations/Suggested actions
	Caesium	▪ Soluble and total caesium release in the PTV2 active system upon first flush and typically throughout.	▪ Possible environmental impacts have not yet been determined. ▪ Potential to cause a range of unacceptable environmental impacts.	▪ Further research to investigate long term release of caesium from NUA.
	Strontium	▪ High in active system throughout and especially in first flush. Initial release of strontium in passive system.	▪ Potential to cause a range of unacceptable environmental impacts. Impacts have not yet been determined due to lack of data. ▪ Require management of first flush conditions over a longer period in the active system.	▪ Further research to investigate long term release of strontium from NUA.
	DOC removal	▪ Lower than anticipated DOC attenuation throughout PTV2 in the passive system, with the exception of first flush (average of 19% removal in both 25% and 40% NUA blend) but high (average of 60% removal) in the active system.	▪ Implies that DON will not be attenuated as efficiently in the Active system due to the less efficient attenuation of DOC.	▪ Further research to investigate long term DOC removal at higher flow rates and limited contact time. ▪ Further research into most effective organic substrate type to attenuate DOC in the treatment train
	DON removal	▪ During the PTV2, DON attenuation was low in the Passive system but high in the active system.	▪ Low DON removal not expected. DON breakthrough occurring earlier than initially thought.	▪ Further research to investigate DON (and related DOC) removal at higher flow rates.
	Ecotoxicology	▪ Swan-Canning species (freshwater copepod, *Macrocyclops albidus*, and western pygmy perch *Edelia vittata*) have not been tested.	▪ Potential ecotoxicology to Swan-Canning species that were not tested.	▪ Further research to investigate chronic toxicity to local species.
Engineering (Technological)	Surface clogging	▪ TSS accumulation on the NUA filter surface creating a layer of fines at the filter surface. Although TSS concentrations are low, loads are high because of the high flows applied.	▪ Decrease in hydraulic conductivity value (k_s) at the surface, resulting in: o Bypassing of NUA filter (i.e. small percentage of flows treated) o High contact time o Requirement for intervention to maintain appropriate k_s value	▪ Further lab scale research to verify relationship between flows, influent TSS, surface clogging and assess cost effectiveness of maintenance frequency. ▪ Pre-treatment to remove TSS.
	Interstitial clogging	▪ High percentage of fines in NUA (57% of particles <63µm and 72% of particles <125µm) ▪ Biofilm accumulation ▪ Filter compaction/settling. Filter media compaction/settling in the order of 50-100mm was observed in the passive system. ▪ Iron precipitation as $FeOH_3$ in the filter medium. High removal of Fe (76% removal of soluble Fe in the passive system and higher in the Active system during PTV2). ▪ Aluminium precipitation as AlOOH in the filter medium. High removal of Al (86% removal of soluble Al in the passive system during PTV2). ▪ Interstitial clogging due to mineralisation through hydroxyapatite ± other mineral phases	▪ Compaction leads to reduced hydraulic conductivity. ▪ Iron and aluminium precipitation is one likely cause of interstitial clogging.	▪ Lab scale assessment of hydraulic conductivity should be undertaken over a significant duration of time (i.e. 12 months minimum) and measured post initial filter settling/compaction/clogging to reflect normal operating conditions. ▪ Pre-treatment of iron, aluminium prior to NUA filter ▪ Investigate ways to increase K in NUA blend: o Reduce quantity of NUA added. o NUA pelletisation. o Screening and removal of particles <125µm prior to installation. o In-situ mechanical intervention. o In-situ biological intervention (vegetation).

	Issue Identified	Implications		Potential future investigations/Suggested actions
	Filter media Specifications	▪ Quantity of fines due to NUA is high (25% NUA blend contains 7% of fines. 40% NUA blend contains 9.5% of fines). This is much higher than a range of guidelines for similar applications (e.g exceeds FAWB biofilter guidelines -3% particles <50µm; exceeds the Danish wastewater vertical flow wetland filter media guidelines for (Max allowed is 0.5% particles <125µm). (Danish guidelines for vertical flow wetlands treating wastewater, Brix and Arias, 2005).	▪ System clogging – the composition of NUA blend is potentially a cause of system clogging. To comply with FAWB guidelines, the maximum permissible proportion of NUA in any filter blend, assuming that other materials (e.g. sand, activated carbon, etc) are free of fines, is 5.2%. To comply with the Danish guidelines for vertical flow wetlands, the maximum permissible proportion of NUA in any filter blend is 0.7%. Note that although VF wetlands are designed to treat continuous flows, intermittent dosing is usually recommended to allow resting of the bed and prevent clogging. It is important to note that bioretention systems are designed to treat stormwater, ie. stochastic events, not continuous flows. A continuous flow system is likely to clog even when FAWB Guidelines are met.	▪ Investigate if incorporating lower percentages of NUA and higher percentages of coarse sand in the blend together with regular intervention/vegetation help minimise (postpone) clogging. Trials are needed to assess what is an acceptable NUA content and/or how to aggregate NUA to avoid clogging.
	NUA loss	▪ Fine particles of NUA were flushed from the filter medium in the active system during PTV2.	▪ TSS and turbidity impact in receiving waters. ▪ Uncontrolled release on NUA material directly into Ellen Brook and receiving environment – unknown consequences.	▪ Investigate alternative filter arrangement which considers: ▪ Containment of NUA within a passive system during flooding ▪ Fine particulate filtration post active system ▪ Disregard active system.

6.1 POTENTIAL ISSUES & RISKS

Listed below are potential key issues and risks identified as potentially compromising the effectiveness of an end-of-catchment wetland containing NUA/NUA blends as part of the treatment train. The following requires further investigation:

Effects of Low Hydraulic Conductivity of Media

- The hydraulic conductivity of the NUA blend was well below that required to manage the expected flows and ensure optimal contact time.
- Clogging issues (and associated effects on Fe, Mn, Al, Ca and Si chemistry) will need to be carefully addressed in the overall design of any system.

Release of Potential Contaminants

- Initial release (first flush) of major ions, nutrients (in particular NO_3 and NH_4) and metals. This issue would need to be well controlled/managed in the context of an end-of-catchment wetland and/or the development of well understood contingencies associated with direct release into a receiving environment.
- The passive and active systems in PTV2 behaved differently (hydro-dynamically and hydrogeochemically). There needs to be a more thorough understanding of why this is so, especially in the context of achieving steady state conditions, and the implications for long term metals release (especially Mn and Fe and potentially Al) and breakthrough of other elements.

Effects of High pH on Filter and Receiving Environment

- The pH levels of NUA blend effluent containing MgO is too high to support plant growth in the filter and therefore having a vegetated biofilter in order to improve the hydraulic properties of the system is not feasible. As such, interventions are required to reduce pH, most likely being the removal of MgO from the blend. Removal of MgO may mean that vegetating the system becomes feasible, subject to further investigation. Note the resultant 'amended blend' would need to be re-investigated to ensure it does not cause other issues.
- The pH levels of NUA blend effluent (including MgO) will impact on the receiving wetland during low flow periods, but are unlikely to have major impacts during high flow as a result of the dilution effect. Further investigations are needed to determine if this is an issue, and identify whether a dedicated polishing basin with an acid dosing facility is required.
- The pH is also a dominant control on metals stability. There needs to be a more thorough understanding pertaining to pH changes (over different time scales) and

metals solubility in the context of environmental issues associated with a wetland catchment system or downstream receptor.

- The sulphate (allied to Ca ion) content of the NUA blend effluent water is high, which can have implications for sulfide generation within the filter and downstream depending on pH and redox status. Therefore, a sulfide management plan may be required.

Uncertainties Due to Limitations of Trial

- The duration of the investigation did not appear long enough to fully observe issues associated with the interaction of metals and mineralisation processes, in particular there were differences in trial investigation periods/durations between the passive and the active systems. This makes the comparison of data between the two systems difficult, and potentially misleading as investigation outcomes. Aligned trial times would be necessary to make meaningful commentary on the effectiveness of the systems relative to each other.
- The investigations did not provide an understanding of how the chemistry of the NUA blend filters will respond under seasonally variable conditions (e.g. wetting and drying cycles).
- The investigations did not provide an understanding of the NUA blend replacement requirements/replacement frequency (i.e. cessation of effective nutrient removal).

The above suite of technical and environmental issues need to be viewed in the context of environmental, economic and social risks and a balance needs to be sought based on agreed and appropriate nutrient removal efficiency for the Ellen Brook end-of-catchment treatment system.

7.0 IMPLICATIONS FOR DESIGN OF AN END-OF-CATCHMENT TREATMENT SYSTEM

Generally, there are still too many uncertainties to ascertain a preferred arrangement of NUA blend in an end-of-catchment treatment train. Further trials need to be conducted to investigate hydraulic conductivity, NUA volume in blend, contact time, pH changes over time (including implications of removal of MgO), the attainment of steady state conditions and first flush management strategies.

Notwithstanding these knowledge gaps, certain design criteria can now be set to allow progression of a conceptual level system design, in particular, the wetland component of the treatment system. This is addressed in section 8.0.

7.1 KEY RECOMMENDATIONS

Effects of low hydraulic conductivity

- Extend duration of current and future pilot trials (and lab trials where applicable) to assess changes in hydraulic conductivity over time. Investigations should be carried out over a minimum duration of 12 months.
- Characterise typical/major causes of clogging (i.e. surface clogging, interstitial clogging, blend composition etc).
- Investigate potential methods to alleviate clogging issues (i.e. mechanical intervention, mechanical mixing, vegetation, pelletisation, fines screening, lower portions of NUA material).

Note that any changes to the NUA blend composition and configuration will require re-characterisation and re-assessment of nutrient and DOC removal efficiencies as well as potential issues.

Effects of High pH on Filter and Receiving Environment

- Resolve issues with hydraulic conductivity in the first instance. If high pH still remains as an issue the following could be undertaken:
    - Omit MgO from NUA blend; and/or
    - Implement additional treatment steps (i.e. HCl dosing) targeted at pH reduction.

Release of Contaminants

- Investigate potential management measures for the first flush issues, such as pre-treatment of NUA media.
- Re-characterise NUA blend and identify issues associated preferred arrangement (i.e. post resolution of hydraulic conductivity). Identify whether additional treatment steps or management measures are required within the treatment train (e.g. HCl dosing, humate pre-treatment for DOC).
- Establish trials to assess impacts of long term release of Mn, Fe and potentially Al which may impede on the overall effectiveness of an NUA blend utilised in a treatment train arrangement.

Other recommendations

- Review ANZECC guidelines and identify areas where site specific trigger values may be more appropriate in the context of an end-of-catchment wetland treatment train.

PART 4 CONCEPT DESIGN

8.0 END-OF-CATCHMENT WETLAND TREATMENT SYSTEM

As part of the overall intent for this project, an end-of-catchment wetland treatment system is to be incorporated into the overall solution for improving the quality of Ellen Brook water and improving the biodiversity and landscape values of this part of the catchment. It is acknowledged that wetlands alone will provide limited nutrient removal function due to the large size of the Ellen Brook catchment (716.4 km²), and the significant annual flows relative to the available wetland treatment area, hence why options for incorporating amendments or other engineering measures are also necessary. Given that the progress with nutrient filter blends/amendments is still at the trial stage, this section addresses a wetland concept design that can be built and then effectively ‘retrofitted’ with additional off-line components when the integration of amendments have been better resolved.

This section aims to present a best practice approach to river restoration which incorporates off-line wetlands and can be retrofitted with an NUA blend filtration system or other nutrient amendment product to provide enhanced nutrient removal. Best practice principles as applied to this project incorporate the following:

1. Replicating nature in the location and arrangement of constructed measures.
2. Flow velocity reduction.
3. Stream bank and bed protection and repair.
4. Surface erosion and sediment transport reduction.
5. Replacing, protecting and rehabilitating fringing vegetation.

This approach will provide an improvement to the existing site conditions. Flora surveys for Site 1 and 2 and identify that no Threatened Ecological Communities are present within the sites and that generally the native vegetation is in poor – very poor condition (Connell, 2010). Similarly, fauna surveys recorded a depauperate fauna and this was reflected in its degraded habitats, low quantity and quality of complexes and small size of the fragmented remnants (Prefumo, 2011).

Concepts presented in this section have been developed for both Site 1 and 2 (see Figure 27 for site location and Figure 29 for conceptual drawings). Ultimately these concepts can be applied to other sites along Ellen Brook to provide additional water quality improvements and importantly improved habitat and amenity values. This will act as an extension of broader rehabilitation projects currently being undertaken within Ellen Brook.

8.1 DESIGN CRITERIA

In light of the pilot trial outcomes several amendments have been made to the existing design criteria identified in Stage 1 of this project. Criteria review and resulting modifications were co-ordinated with the Project Working Group (PWG) at a meeting held at the Trust on the 21 December 2011. Appendix 5 presents the revised Design Criteria and Design Approach framework. Generally, the revisions extend to:

- Recognising that site specific water quality guidelines may be more appropriate and should be used in addition to/in place of ANZECC criteria. Appropriate site specific trigger values require review within the PWG and development in future stages of work.
- Utilising wetlands to provide enhanced TN reductions for the ‘treatable’ flows to reduce reliance on an NUA blend based system. PTV2 data highlighted that, in a passive configuration, TN reductions are three fold lower than expected, whereby 20% TN reduction was achieved rather than the 60% identified in Stage 1. It was therefore identified that wetlands, rather than NUA, are required to provide enhanced nitrogen reductions.
- Allowing for the abstraction of water from within the channel to divert to a separate NUA or similar treatment module, and no in-channel use of NUA.
- Maintenance of hydraulic capacity and conveyance of the existing site to a level that protects existing infrastructure and land uses rather than to predevelopment conditions. The maintenance of predevelopment conditions is not possible in the likely instance where on-site storage (i.e. weirs) is required.
- Aboriginal heritage site identification shall take place following conceptual design works, rather than prior to the commencement of such works, at the request of the Aboriginal consultants.

8.2 SYSTEM DESCRIPTION

Figure 28 and Figure 29 presents conceptual arrangements for best practice river restoration within Sites 1 and 2. Three distinct components are identified within each concept: riffles, pools and floodplain depressions (in effect, surface flow off-line wetlands). These components are arranged to form a treatment train for treatment efficiency. Sequences of riffles and pools mimicking natural streams make up the first steps of the treatment train and deliver important habitat creation, oxygenation, sedimentation and storage function. Retrofit of the aforementioned pools with an off-take allows the conveyance of Ellen Brook water to an off-line NUA blend filtration system for enhanced P removal. Unvegetated and vegetated off-line wetlands form the final step of the treatment train, polishing NUA effluent and enabling opportunistic N removal prior to discharge to Ellen Brook.

8.2.1 Riffles

Reinstatement of riffles within Ellen Brook provides important ecological functions (aquatic fauna habitat, oxygenation) in addition to opportunities for flow control and resultant sedimentation and sets the water depth in the pools. In this case, shallow rock riffles are proposed in strategic locations along straight reaches/meander inflection points. The distance between riffles has been calculated using the rule of thumb principal that the length of the pool riffle sequence is on average six times the bankfull width of the stream (Penn, 1999).

In order to maintain the water level in the pools, the core of the riffle will comprise of a 2 meter high clay bund which will act as a water level control structure. The bund will have an upstream batter no more than 1 in 4 m, a downstream batter of 1 in 20 m configured to allow fish passage. Geotextile and gravel/sand bedding will extend over the bund to bankfull levels to allow the keying in of well graded angular rocks and minimise disturbance and potential erosion of existing Bassendean Sand site soil.

Modifications to the existing channel batters will be required in some areas to allow the placement of riffles and implementation of stable banks. As the existing bank is an inherently unstable incised channel within Site 1, and some portions of Site 2, re-grading at a 1 in 6 slope and revegetation is considered appropriate. Areas vulnerable to erosion may require additional soft engineering works such as large woody debris and/or jutematting/brushmattressing.

8.2.2 Ephemeral Pools

The pools perform two important functions. Firstly, they slow down the water velocity and allow the coarse to medium sized sediments to drop out of suspension and settle. Secondly, they provide an important storage function, allowing abstraction points for an NUA blend filter system.

The location of the pools is focused in areas where they would likely naturally occur, mainly in areas of existing meander bends. The depth and surface area of the pool is controlled by the elevation of the downstream riffle and clay bund combination. In this case, the depth of the pool will range from 0 m (upstream) to 2 m (downstream) high. The surface area of the pool will generally extend upstream to the next riffle and, with bank re-grading, extend across to the existing floodplain in some areas.

As shown in Table 4, assuming an average water depth of 1 m and total surface area of 3.44 ha, the total storage capacity provided within pools in Site 1 and 2 is approximately 34.4 ML. This capacity provides storage for approximately 19% (5.07 GL) of average annual (1997) Ellen Brook flows assuming water is turned over/treated in a 24-hour period. Provision of this storage volume provides ample opportunity to treat a significant portion of Ellen Brook flows through an NUA blend should the site be retrofitted in the future. For example, the pools could be connected to a passive filter arrangement via a passive (channel) or pumped conveyance system or to an active system via a pipe and pump arrangement.

Table 4 Site 1 and Site 2 pool surface area and volume

	Surface area (m^2)	Ave. depth (m)	Volume (m^3)
Site 1	17,676	1.0	17,676
Site 2	16,679	1.0	16,679
Total	**34,355**	**-**	**34,355**

All pools will be ephemeral, impounding water during low flow periods, becoming dry for parts of the year and overtopping the riffle bund during high flows. This represents an improvement of existing conditions particularly for habitat creation when combined with revegetation. Revegetation provides enhanced habitat amenity, particularly for the western swamp tortoise, addresses potential erosion issues and provides shade. Shade, together with the tannin water are important considerations in reducing algal bloom occurrences.

Considering that clogging presents real issues which may compromise the long term treatment effectiveness of any end-of-catchment filter (passive or active), settling out of sediments prior to any off-line filter is essential. Section 8.6.1 provides an assessment on the sedimentation capability. Additional structural measures may be required within the pools to assist with enhanced sedimentation and precipitation of some metals (for instance Fe and Mn).

8.2.3 Surface Flow Wetlands

Surface flow wetlands are intended to mimic natural floodplain depression, and are to be located at the terminal end of the NUA blend filter (see section below). They are intended to receive and polish effluent and provide opportunistic nutrient removal, (primarily N), prior to discharge to Ellen Brook.

Similar to the pools, the wetlands are positioned in the floodway. The shape and extent of each wetland is confined by the site constraints, particularly the topography, hydrology and infrastructure protection. Wetlands are to be located such that the required grade ensures that a free flowing system can be achieved. Whilst this provides a best practice approach and efficient hydraulic design, it is not an ideal arrangement as it means that the wetlands will be subject to periodic flooding. Bunding will therefore be required around the wetland perimeter to prevent interaction with Ellen Brook water during an average year. As a result, during a critical storm event greater than 1 year ARI, the bunds and performance of the wetland may be compromised. Further investigations are therefore be required once the preferred NUA blend is determine to assess the effect of wetland flooding and implications of precipitate mobilisation.

Within Site 1 and 2 two types of wetlands will be present:

1. Unvegetated open water bodies- located immediately after the NUA blend filter to polish effluent and precipitate metals prior to discharging to a vegetated wetland. If the present blend of media (i.e with MgO) is used in the final design, then the effluent from the NUA blend filter will be highly alkaline, and above the threshold level for the majority of wetland plant species. Consequently there will be minimal vegetation establishment in this wetland. Dependant on the pH buffering capacity of the wetlands, additional measures may be required to lower the pH such as the removal of MgO from the blend or chemical (HCl) dosing.
2. Vegetated surface flow wetlands - the vegetated surface flow wetlands are to be densely planted, variable in depth (average 0.4 m) and comprise of aerobic and anaerobic zones.

Table 5 shows the surface area and volume for wetlands identified in the concepts. Assuming a nominal water depth of 0.4 m and a total surface area of 6.07 ha, the total storage capacity provided by the wetlands in both sites is approximately 24.3 ML. All wetland areas are to be lined with clay to avoid interaction with the groundwater and maximise detention.

Table 5 Site 1 and Site 2 wetlands surface area and volume

	Surface area (m^2)	Ave. depth (m)	Volume (m^3)
Site 1	35443	0.4	14,177
Site 2	25242	0.4	10,097
Total	**60,685**	**-**	**24,274**

Because the wetlands are arranged in series, discharge of water to each downstream pool will duplicate treatment (i.e. treated water could be abstracted from the downstream pool and treated multiple times). A high flow bypass is therefore required within each wetland to bypass treated water around the downstream treatment systems, discharging to Ellen Brook. Technical resolution of wetland hydraulics will be required in the future stages of work.

8.3 INTEGRATION OF NUA BLEND FILTER

As there needs to be resolution of the issues and uncertainties outlined in section 6.0, the integration of the NUA blend within an end-of-catchment treatment system can only be described conceptually.

Integration of the NUA filter blend within a best practice river restoration would preferably comprise of a passive arrangement due to technical and environmental issues in addition to economic issues. Preliminary scaling assessment shows that when scaling up the PTV2 active system in an end-of-catchment application, 580 active systems in a three column series arrangement are required. This assumes a 1 hour contact time, 500 L/hr flow rate (Table 2), and a sustainable diversion rate of 7 ML/day (refer water quantity section 8.5). The capital purchase of the column systems, together with the capital and operational costs associated with the pumps would likely present an economic constraint for the use of the active system. Comparatively, scaling up of the passive system assuming a conservative long term hydraulic conductivity of 50 mm/hr (assumes intervention) would require an NUA blend surface area of ~5,900 m^2.

As per Stage 1, Concept 2, the passive arrangement could comprise a vertical flow filter, with a set filter depth and head. Modifications to the original concepts developed in Stage 1 are required to address clogging issues and maintain an appropriate hydraulic conductivity. Implementation of clogging interventions (section 4.1.3) would likely deliver a more cost effective approach when compared to the active system, particularly for ongoing operational costs.

8.4 DOMINANT PROCESSES

Dominant physical, chemical and biological processes for the conceptual arrangements are synthesised in Table 6 below. Generally, the system operates in a treatment train configuration whereby riffles and pools slow the water down and allow settling out of sediments prior to influent conveyance to an NUA blend filter. The NUA blend filter provides enhanced P removal and some degree of N removal but the effluent requires post treatment to neutralise pH and remove metals, which can occur in a dedicated polishing unit. Once pH has been adjusted (if required), polished flows receive further biological treatment and opportunistic N removal is provided within the wetlands prior to discharging to Ellen Brook. Potential operational issues and serviceability requirements are also indicated in Table 7.

Table 6 Best practice river restoration and end-of-catchment treatment system dominant processes

	1 River	2 Ephemeral pools and riffles	3 NUA filter	4 Unvegetated wetland	5 Vegetated wetland	6 River
Purpose	▪ Intake of high nutrient (DON, DOC) water to be treated	▪ Detention (24 hours) for eventual distribution to NUA filter ▪ Removal of sediments prior to NUA filter to reduce surface clogging ▪ Removal of contaminants associated with sediments ▪ Precipitation of Fe (aerators) to reduce interstitial clogging	▪ Phosphorus removal ▪ Some DON removal ▪ Some DOC removal	▪ Neutralisation of pH ▪ Removal of metals	▪ Ammonification, nitrification and denitrificiation processes ▪ Nitrogen removal organic and inorganic nitrogen ▪ DOC removal ▪ Habitat creation ▪ Environmental restoration	▪ Discharge of treated effluent to Ellen Brook
Dominant physical processes	▪ Conveyance of Ellen Brook water to Swan River. ▪ Seasonal flows. ▪ 26.75 GL/yr average annual flow volume.	▪ Settling of coarse to medium-sized sediments (>125 µm).	▪ Conveyance of water across NUA filter ▪ Formation of 500 mm depth head ▪ Vertical flow of water through NUA blend ▪ Conveyance of effluent via subsoil drains to a polishing system (4) ▪ P adsorption	▪ Dosing required to adjust pH rapidly (e.g HCl dosing) ▪ Flocculation of metals likely to occur	▪ Filtration through organic substrate and macrophytes. ▪ Settling of fines ▪ Evapotranspiration ▪ Accretion	▪ Discharge of treated effluent to Ellen Brook flows. ▪ Dilution of effluent via mixing (in high flow conditions)
Dominant chemical processes	▪ Ion-exchange (??) ▪ Oxidation and reduction reactions	▪ Potential removal of contaminants (metals) associated with settling of fine to coarse sediment ▪ Potential precipitation of Fe	▪ P precipitation ▪ Metal precipitation ▪ Metal solubilisation	▪ Reduction of pH ▪ Precipitation of metals	▪ Reduction of pH ▪ Precipitation of metals ▪ Sulphate reduction ▪ Elemental cycling	▪ Oxidation and reduction reactions
Dominant biological processes	▪ Respiration ▪ Photosynthesis	▪ Respiration ▪ Photosynthesis	▪ Microbially mediated oxidation and reduction reactions	▪ Microbially mediated oxidation and reduction reactions (minor, due to short retention time)	▪ Microbial and plant growth and chemical uptake ▪ Microbial Nutrient transformation: Ammonification, Nitrification, Denitrification ▪ Respiration and photosynthesis	▪ Respiration ▪ Photosynthesis
Potential issues	▪ Flooding	▪ Re-suspension of fines during high flows ▪ Fauna passage ▪ Infrastructure protection ▪ Algae proliferation	▪ Hydraulic constraints: surface and interstitial clogging. ▪ Initial release of metals and long term release of metals ▪ High pH ▪ High EC	▪ Flows may be too high for full pH adjustment to occur (inc. flocculation process) ▪ Over or under dosing of acid if dosing system becomes faulty.	▪ Potential smothering via precipitation of metals (Fe and Mn) on wetland surface ▪ High or low pH entering the wetland in case of a faulty dosing system	▪ Concentrated effluent at discharge point. ▪ No mixing at low flow conditions

	1 **River**	2 **Ephemeral pools and riffles**	3 **NUA filter**	4 **Unvegetated wetland**	5 **Vegetated wetland**	6 **River**
			▪ Note that the high pH and EC may not be an issue with the removal of MgO from the NUA blend			
Serviceability	▪ N/A	▪ Moderate. ▪ Removal of accumulated sediment (> 10% pool volume)	▪ Poor if vegetated (i.e. will not be able to remove/scrape accumulated sediments from surface)	▪ High degree of serviceability necessary. Can be controlled through constructed dosing unit. ▪ High degree of control to ensure proper dosing.	▪ Moderate. Weeding, erosion control, scour protection. ▪ Weeding and supplementary planting required	▪ N/A - monitoring of effluent required

8.5 WATER QUANTITY

Water quantity modelling presented in Stage 1 was revisited based on the new, best practice river restoration concepts presented in this document. Assuming that the pools have 34.4 ML total storage, modelling shows that approximately 19% of all Ellen Brook average annual flows (1997) can be diverted to an NUA blend filter assuming the water is turned over/treated in a 24-hour period. This sets the flow rate to approximately 400 L/s, with higher flow rates achievable during high flow periods.

Figure 31 shows the diversion of 19% of the flows, highlighting that for most months of the year, excluding August and September, a large proportion of average daily Ellen Brook flow can be diverted to the NUA blend filter. Reliance on a dilution factor is therefore inappropriate and wetlands become essential for effluent polishing to an acceptable standard for discharge. As a result, the diversion rate to an NUA blend filter is inherently controlled by the treatment capability and volumetric capacity of the wetlands and not the storage capacity of the pools.

Assuming a total vegetated and unvegetated wetland surface area of 6 ha and a standard 72-hour detention time, the maximum diversion rate to the wetlands is set at 7 ML/day or 81 L/s. Optimisation is therefore required to achieve meaningful TP reductions and adequate wetland polishing/retention time. Note that a 72 hour retention time cannot reduce pH from 11 to background levels and MgO will either need to be omitted from the blend or a dosing system (e.g. HCl) will need to be integrated within the treatment train prior to effluent entering the wetland.

8.6 TREATMENT EFFICIENCY

8.6.1 Total Suspended Solids

TSS reduction is achieved within the pools through processes of temporary detention and reduction of flow velocities. Assessment of sediment capture efficiency was undertaken using the Fair and Geyer (1954) expression (Equation 1) to determine if the pools were adequately sized to target medium and coarse sediments.

$$R = 1 - \left(1 + \frac{1}{n}\frac{v_s}{Q/A}\right)^{-n}$$

Equation 1

Where R represents the fraction of target sediment removed;
v_s = settling velocity of target sediment (m/s);
Q / A = rate of applied flow (m3/s) divided by pool surface area (m2);
n = turbulence or short-circuiting parameter.

Assumptions included a target sediment size of >125 µm (i.e. medium to coarse sediment) with a settling velocity of 11 mm/s operating at the 1 year ARI peak discharge of 14 m3/s. Calculations indicated that the pools are generally oversized and provide excellent sedimentation function, typically removing target sediment at 85% efficiency in the smallest pool (~4000 m^2) and 93% in the largest (~7000 m^2). Further calculations indicate a minimum removal rate of 50% for fine silt. Considering contaminant association with particulates, there is expected to be some particulate contaminant removal achieved within the pools. However, as a majority of N and P is in dissolved form significant nutrient reductions are unlikely.

8.6.2 Nutrients

As the preferred blend and contact time have not been ascertained, nutrient reduction modelling provided in this section is intended as a preliminary estimate only.

Based on the outcomes of water quantity modelling, TP and TN removal modelling was undertaken for a range of diversion rates between 7 ML/day to 35 ML/day. PTV2 nutrient removal efficiencies for a passive NUA blend arrangement were assumed, delivering maximum removal efficiencies of 86% for TP and 20% for TN (and DON). Note that the removal efficiencies for TN are significantly lower than those used Stage 1, and the long term N removal capacity of the passive system is currently unknown and requires further assessment.

Wetland nutrient removal efficiencies were calculated using Kadlec and Knight (1996) first order decay modelling assuming a K value of 18 m/year. Further assumptions included a maximum 6 ha wetland surface area and no groundwater interaction.

Table 7 shows the achievable TP reductions. With a sustainable diversion rate of 7 ML/day (i.e. 72-hour wetland retention time) a total TP reduction of 4.7% is achieved. Enhanced TP removal is achieved if the wetland detention time is compromised (i.e. < 72-hours). For example, a 35 ML/day diversion rate provides a 17.1% TP reduction. Additional investigations are required to optimise detention time and ensure sufficient polishing.

Table 7 Total phosphorus removal rates for passive NUA blend filter and end-of-catchment wetland

			TP removal					
			NUA		Wetland		Total	
Diversion Rate (ML/day)	**GL/yr treated**	**%total flow (26.76 GL)**	**Tonnes**	**% reduction**	**Tonnes**	**% reduction**	**Tonnes**	**% reduction**
7	**1.28**	**4.78%**	0.41	4.1%	0.06	0.6%	0.47	4.7%
10	**1.77**	**6.61%**	0.57	5.7%	0.06	0.6%	0.63	6.3%
15	**2.53**	**9.45%**	0.82	8.1%	0.06	0.6%	0.88	8.7%
20	**3.24**	**12.11%**	1.05	10.4%	0.06	0.6%	1.11	11.0%
25	**3.91**	**14.61%**	1.26	12.6%	0.06	0.6%	1.32	13.2%
30	**4.54**	**16.97%**	1.46	14.6%	0.06	0.6%	1.52	15.2%
35	**5.14**	**19.21%**	1.66	16.5%	0.06	0.6%	1.72	17.1%

Table 8 shows the achievable TN reductions. A 2.6% reduction was achieved for the 7 ML/day diversion increasing to 5.4% for 35 ML/day diversion. Note that diversion rates greater than 15 ML/day will compromise the ability for the wetland to reduce TN as a function of the reduced detention time. Optimising the detention time in the wetland will deliver limited benefits for TN removal and if enhanced TN removal is sought additional treatment train components will be required.

Table 8 Total nitrogen removal rates for passive NUA blend filter and end-of-catchment wetland

			TN removal					
			NUA		Wetland		Total	
Diversion Rate (ML/day)	**GL/yr treated**	**%total flow (26.76 GL)**	**Tonnes**	**% reduction**	**Tonnes**	**% reduction**	**Tonnes**	**% reduction**
7	**1.28**	**4.78%**	0.68	1.0%	1.15	1.6%	1.8	2.6%
10	**1.77**	**6.61%**	0.94	1.3%	1.22	1.7%	2.2	3.0%
15	**2.53**	**9.45%**	1.35	1.9%	1.22	1.7%	2.6	3.6%
20	**3.24**	**12.11%**	1.73	2.4%	1.20	1.7%	2.9	4.1%
25	**3.91**	**14.61%**	2.09	2.9%	1.18	1.7%	3.3	4.6%
30	**4.54**	**16.97%**	2.42	3.4%	1.15	1.6%	3.6	5.0%
35	**5.14**	**19.21%**	2.74	3.8%	1.12	1.6%	3.9	5.4%

8.7 OTHER NUTRIENT MANAGEMENT MEASURES

A number of other commercially available amendments may also be useful for application in place of, or combination with, the NUA blend filter. For example, Phoslock™ could be integrated with the end-of-catchment treatment train to deliver enhanced P removal. Local studies have shown >90% filterable reactive phosphorus reductions as a result of Phoslock™ application (Douglas *et al*, 1999). Similarly, Zeolite (ammonium adsorption) and ViroBond (heavy metal adsorption) could be integrated at particular stages of the treatment train where appropriate. A brief literature review was conducted on the above amendments to identify the dominant processes (Table 9).

Table 9 Alternative commercially available amendments dominant processes

	Phoslock™	**Zeolite**	**ViroBond**
Purpose	▪ Dissolved P removal ▪ Sediment derived P removal (prevents P release)	▪ Ammonia (NH3) and ammonium (NH4+) removal	▪ Copper removal ▪ Chromium removal
Possible location/ application	▪ Slurry/ dripper application within sedimentation pools	▪ Filtration through granules/powder within wetlands.	▪ Downstream of NUA filter in polishing basin.
Dominant chemical processes	▪ P adsorption	▪ NH3 and NH4+ adsorption	▪ Heavy metal adsorption
Potential issues	▪ Loss of Phoslock via flushing downstream during high flow events. ▪ Wetting/drying cycles – affect on P adsorption ▪ Reduction of pool storage capacity due to sediment accumulation	▪ Low removal efficiencies in high flows/low contact time. ▪ Blanket application over wetlands may modify benthic environment and biological N and P removal.	▪ Loss of ViroBond downstream during high flow events could modify benthic environment and biological N and P removal in wetlands.
Serviceability	▪ Low to moderate depending on dripper/spray application and sediment removal from pools.	▪ Low to moderate depending on replacement frequency.	▪ Low to moderate depending on replacement frequency.

CSIRO (Wendling *et al*, 2009a) research into a range of mining and industrial by-products for reuse as environmental amendments highlights potential use of other, non-commercially available amendments. It should be noted that the CSIRO research identified NUA as a preferred amendment and additional research would need to be undertaken for other non-commercial amendments.

Ultimately, as stipulated within the design criteria (Appendix 5), the end-of-catchment treatment system should form part of a suite of management actions implemented throughout the Ellen Brook catchment to address catchment wide nutrient management issues rather than solely relying on an end-of-catchment solution. Other management actions may include:

riparian revegetation, perennial pastures, fertiliser efficiency, landuse change controls, fertiliser action plans and soil amendments.

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FIGURES

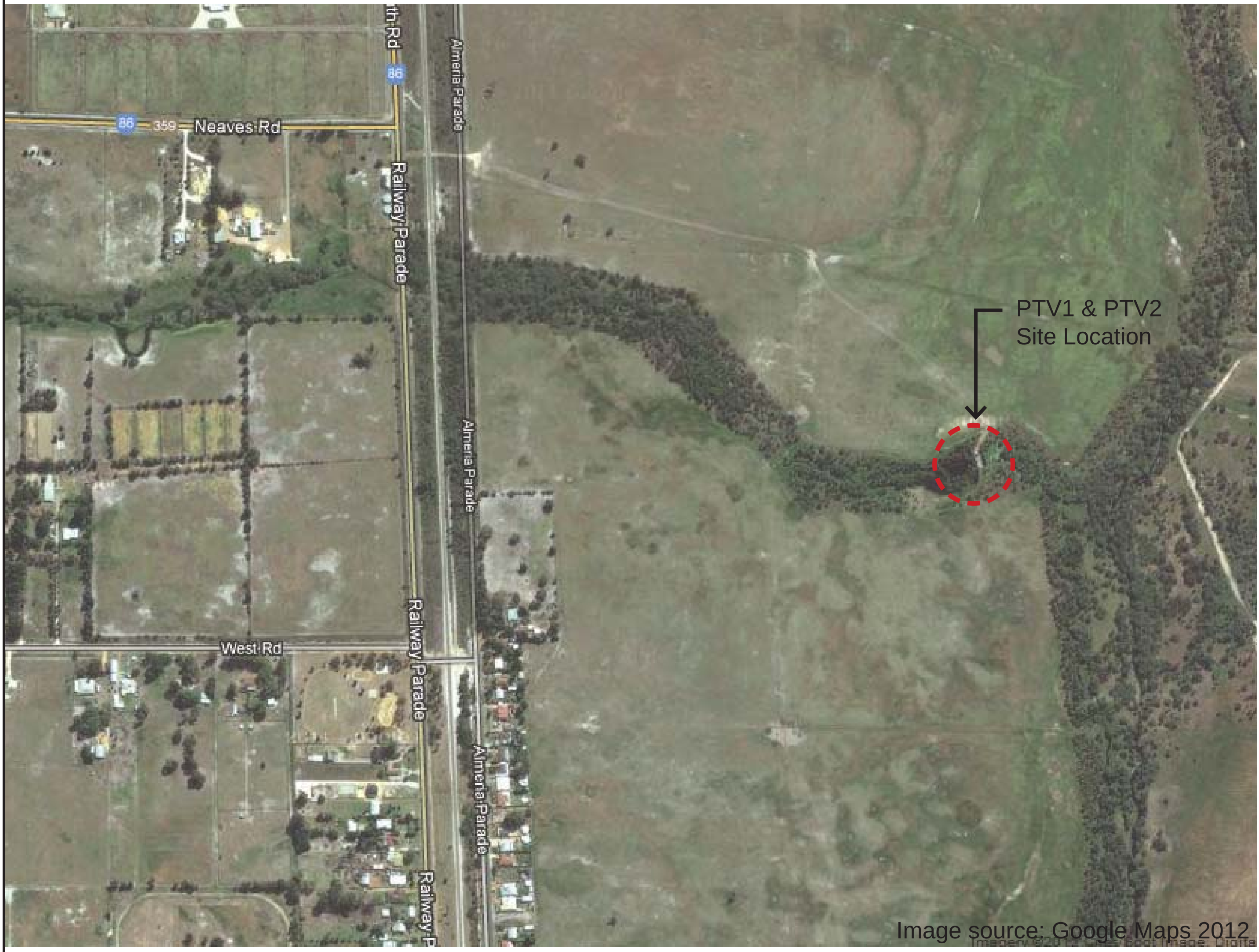

Image source: Google Maps 2012

DESCRIPTION: PTV1 & PTV2 Site Location

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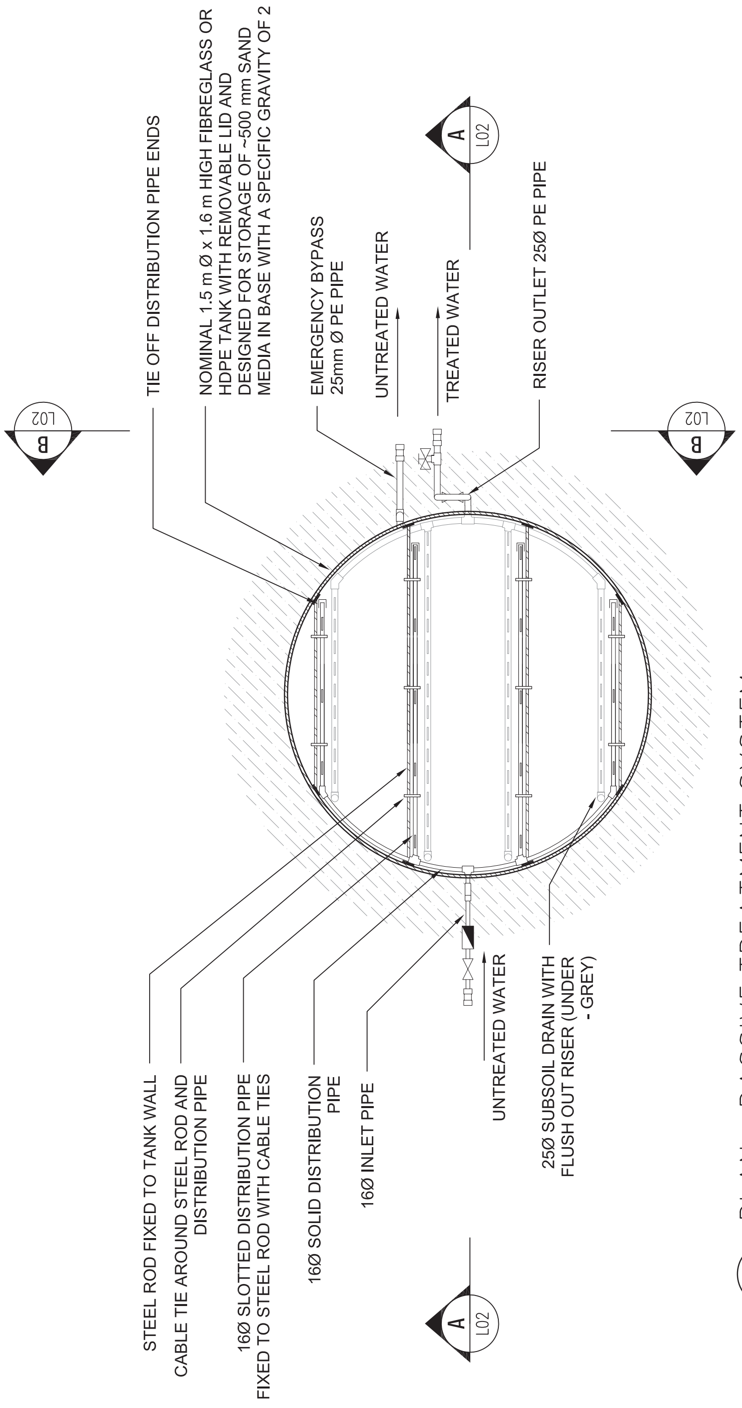
	CLIENT: Swan River Trust	DATE: 23/01/12



01
L01

PLAN - PASSIVE TREATMENT SYSTEM

SCALE: 1:20 @ A3

DESCRIPTION: Passive system drawings (1 of 2)

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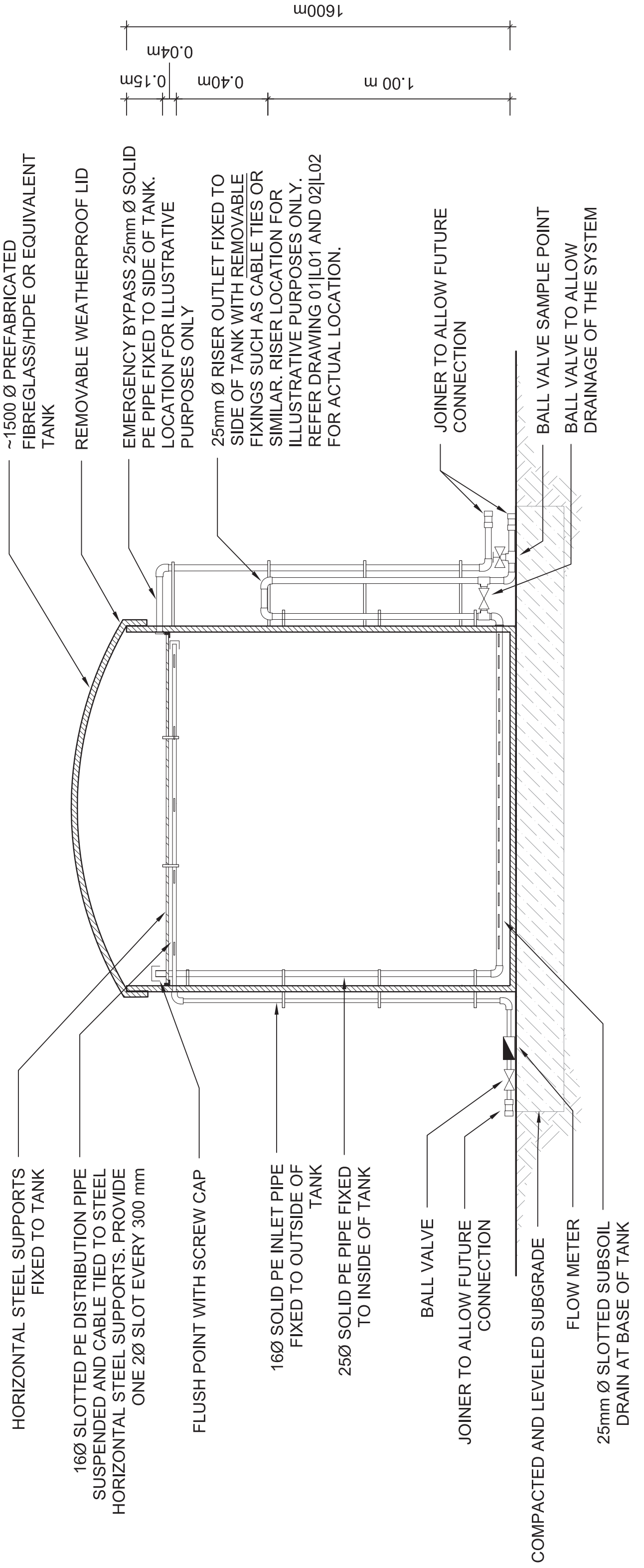
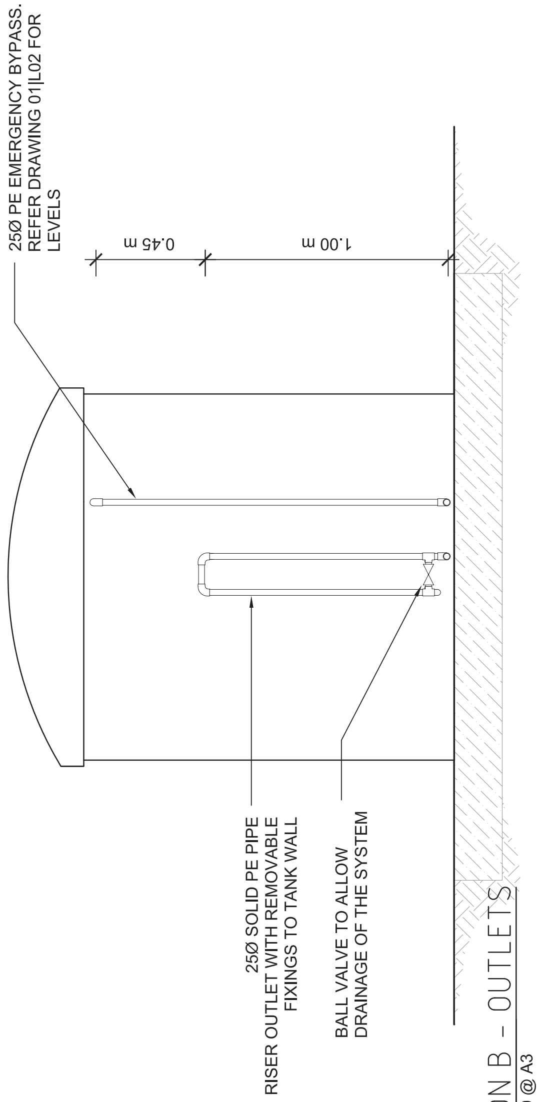
	CLIENT: Swan River Trust	DATE: 23/01/12



01 L02 SECTION A - PASSIVE TREATMENT SYSTEM HYDRAULICS

SCALE: 1:20 @ A3



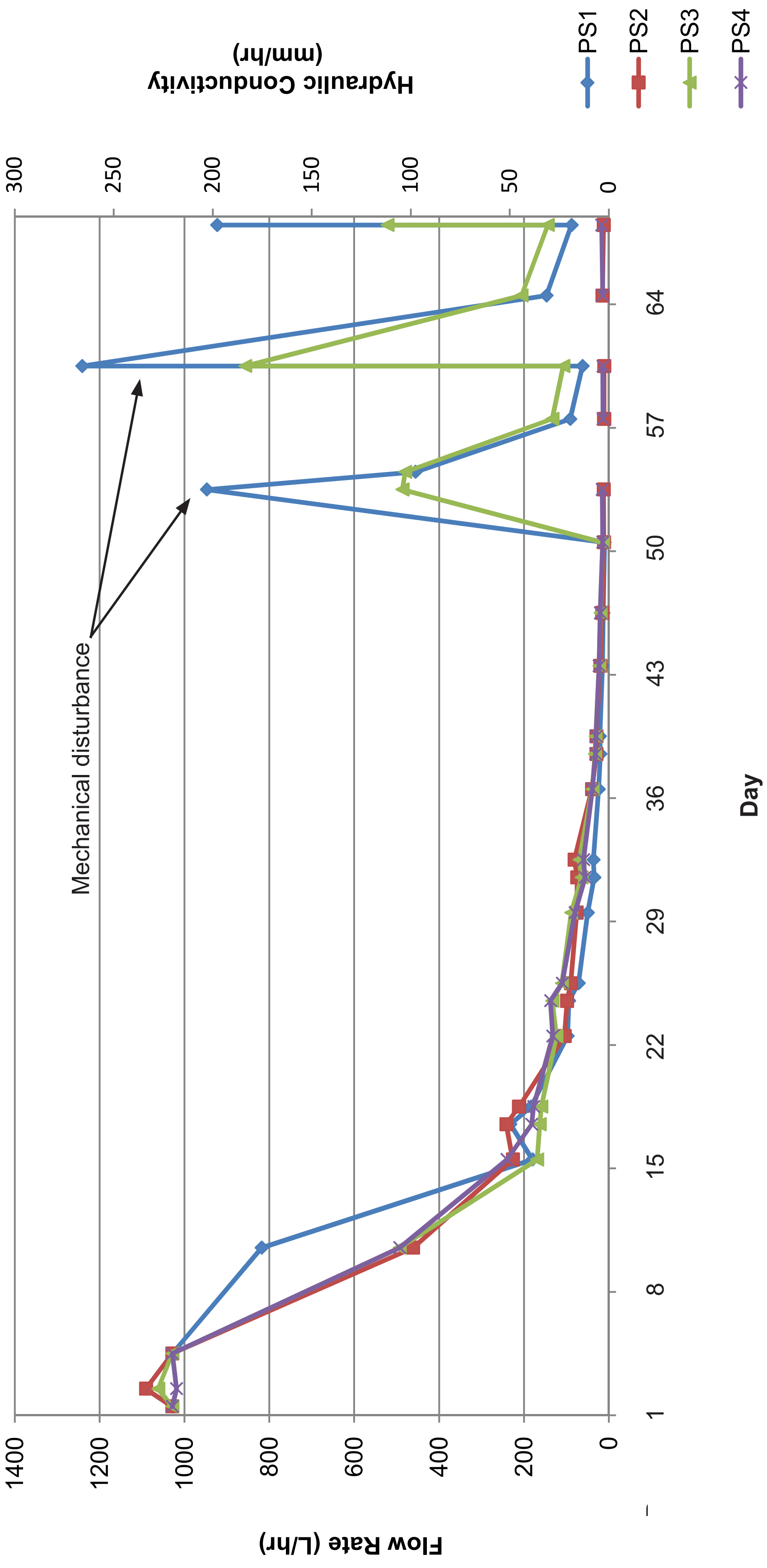
02 L02 SECTION B - OUTLETS

SCALE: 1:20 @ A3

DESCRIPTION: Passive system drawings (2 of 2)

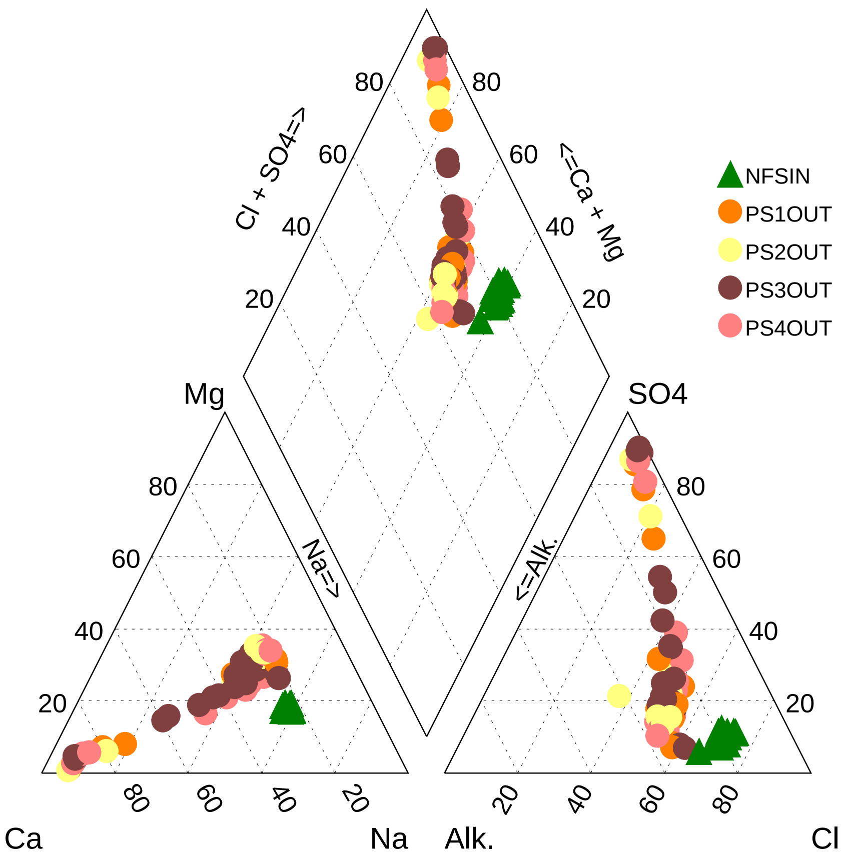
SYRINX environmental pl

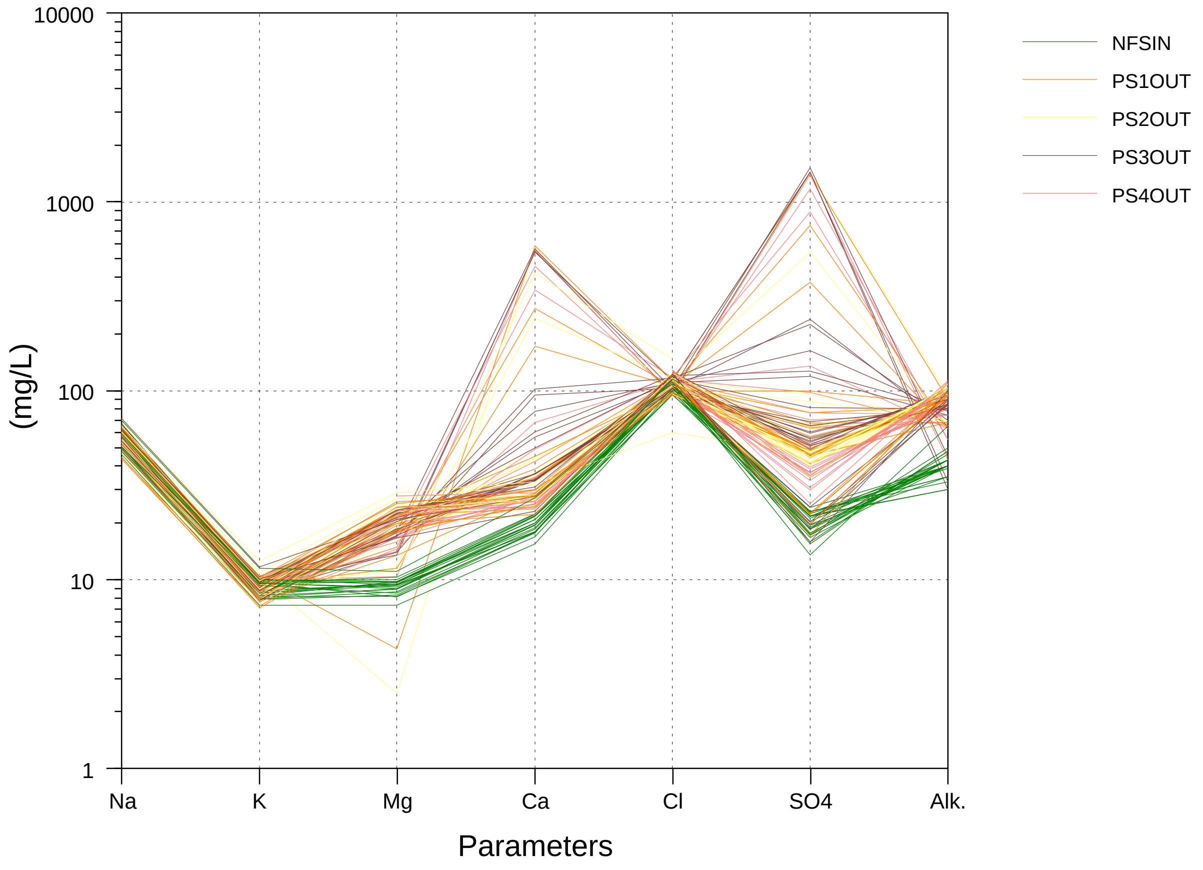
PROJECT: Ellen Brook 1012	FIGURE #: 02b
CLIENT: Swan River Trust	DATE: 23/01/12



DESCRIPTION: PTV2 passive system flow rate and hydraulic conductivity

	PROJECT: Ellen Brook 1012	FIGURE #: 3
	CLIENT: Swan River Trust	DATE: 23/01/12





DESCRIPTION: Major Ion Trends in All Passive System Effluent Samples and Ellen Brook Water

SYRINX environmental pl	PROJECT: Ellen Brook 1012	FIGURE #: 04
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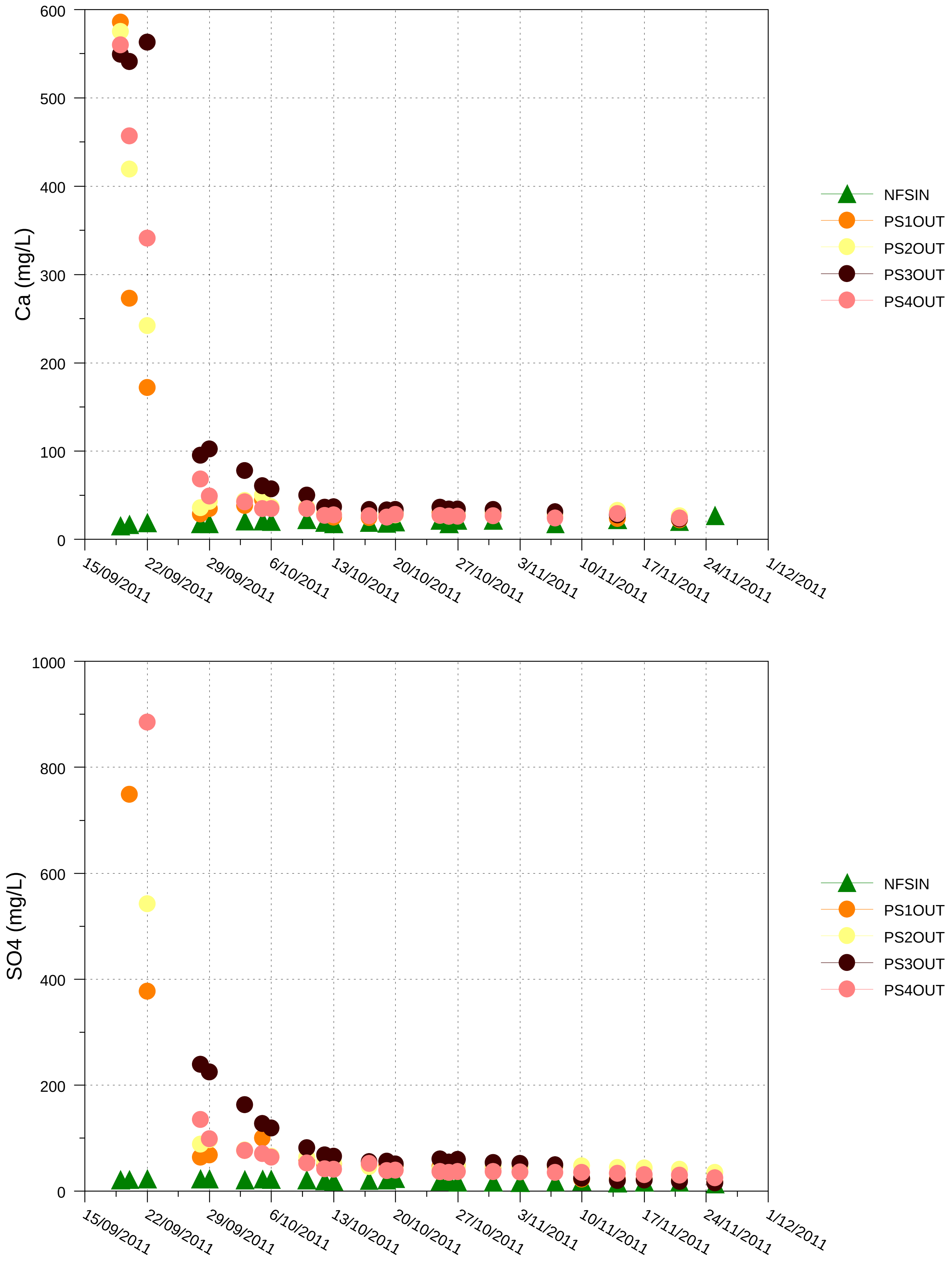

DESCRIPTION: Ca and SO4 Trends in All Passive System Effluent Samples and Ellen Brook Water

SYRINX environmental pl	PROJECT: Ellen Brook 1012	FIGURE #: 05
	CLIENT: Swan River Trust	DATE: 23/01/12

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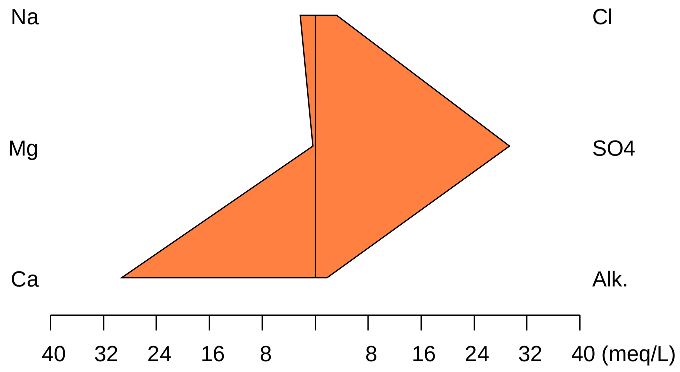

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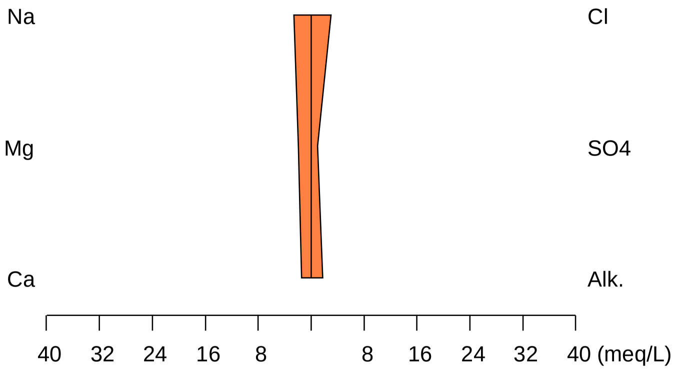

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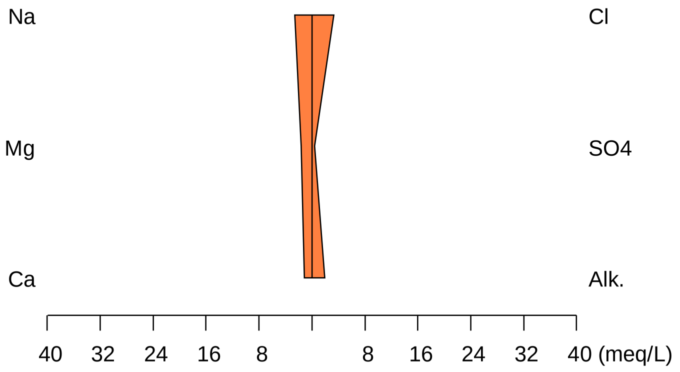

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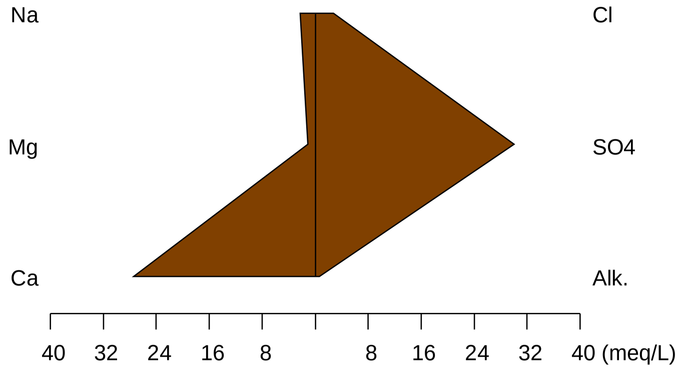

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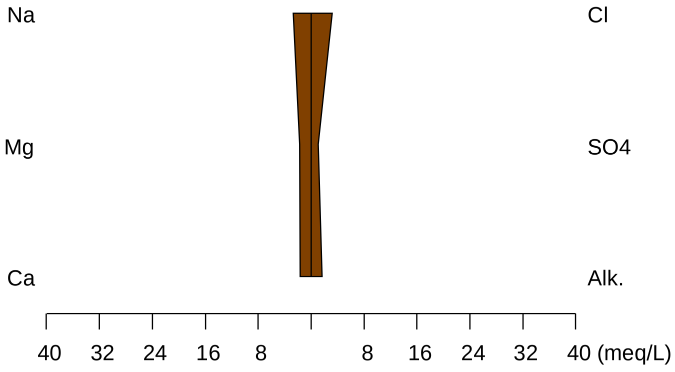

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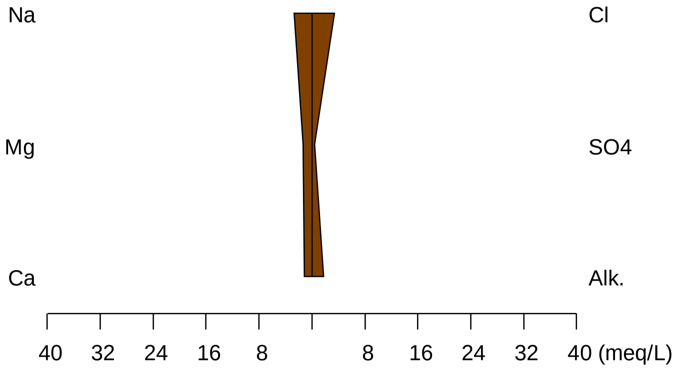


DESCRIPTION: Major Ion Chemistry of Selected Passive System Effluent Samples Taken from the Beginning, Middle and End of the Trial

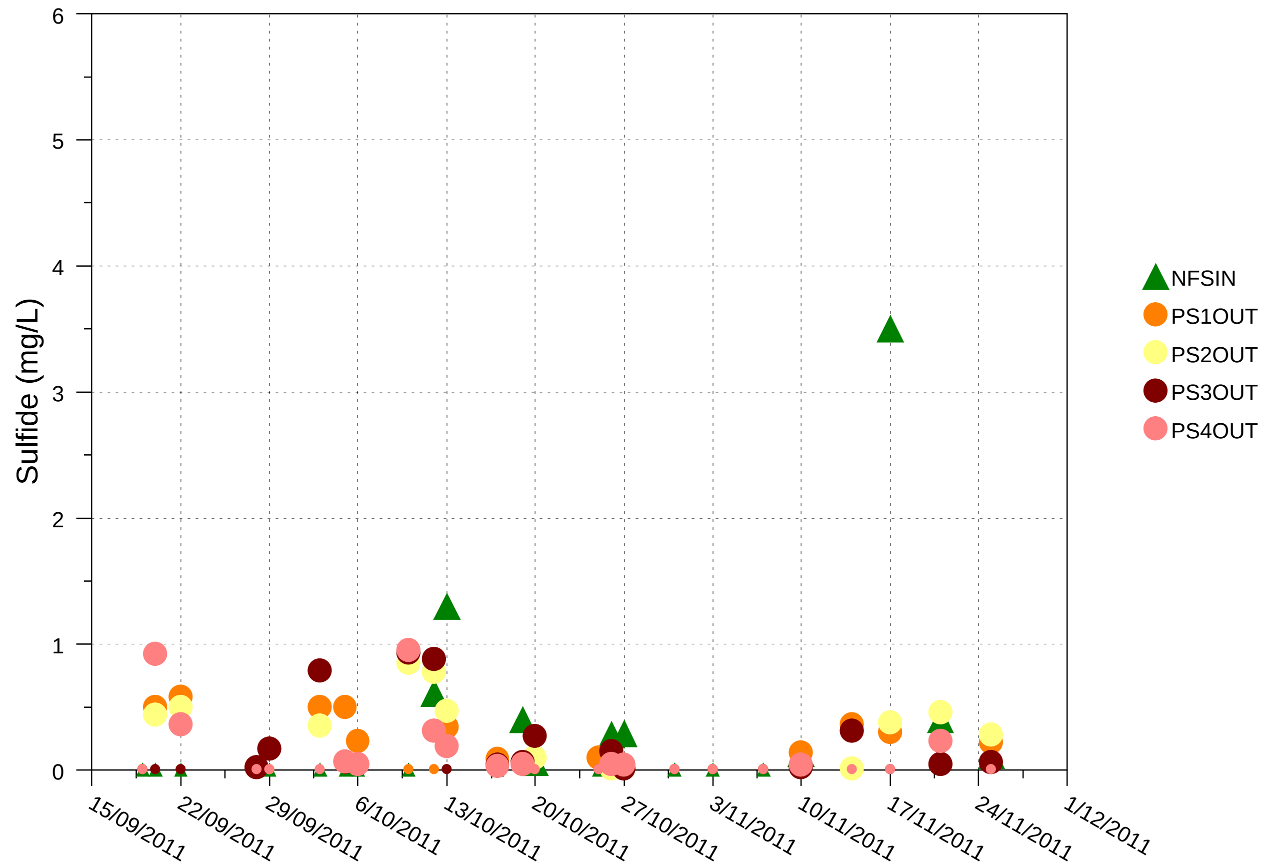
SYRINX environmental pl

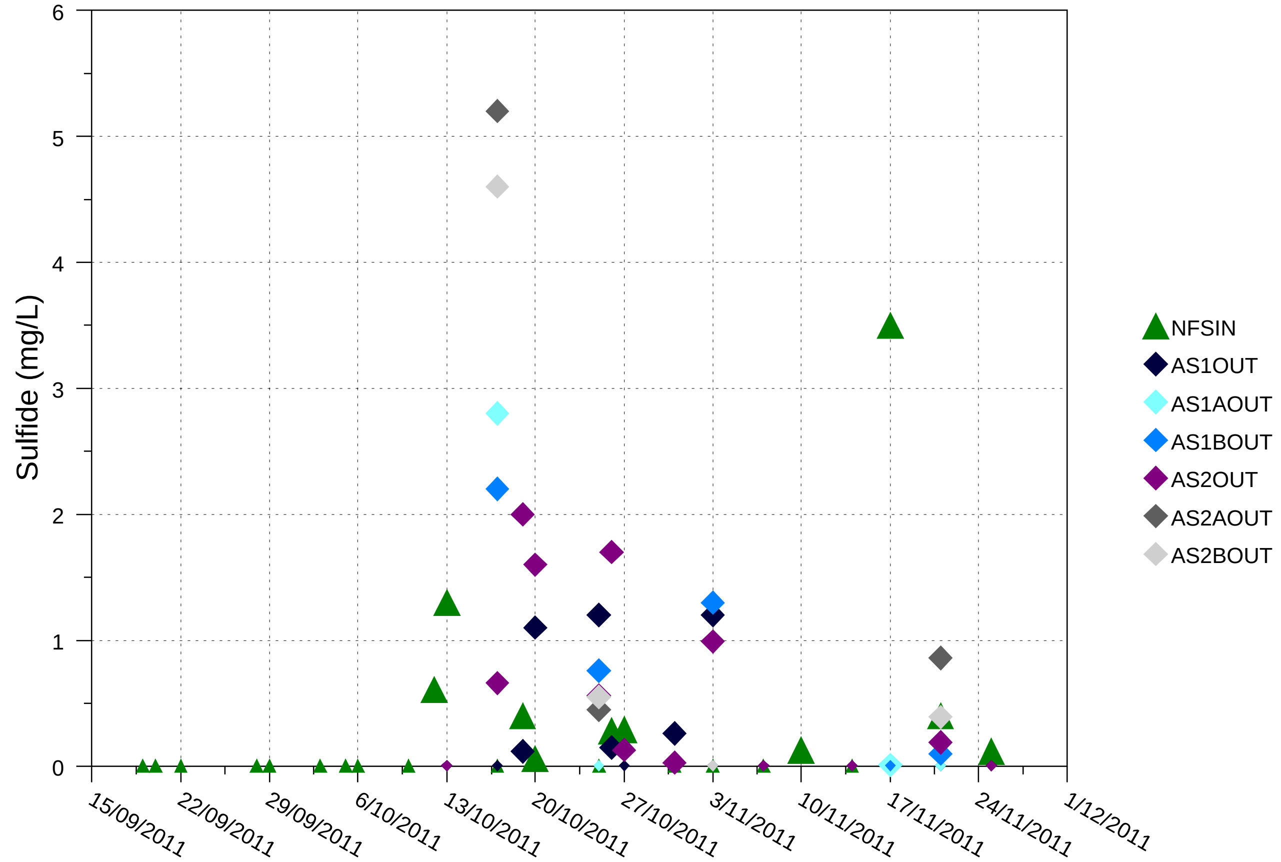
PROJECT: Ellen Brook 1012

FIGURE #: 06

CLIENT: Swan River Trust

DATE: 23/01/12



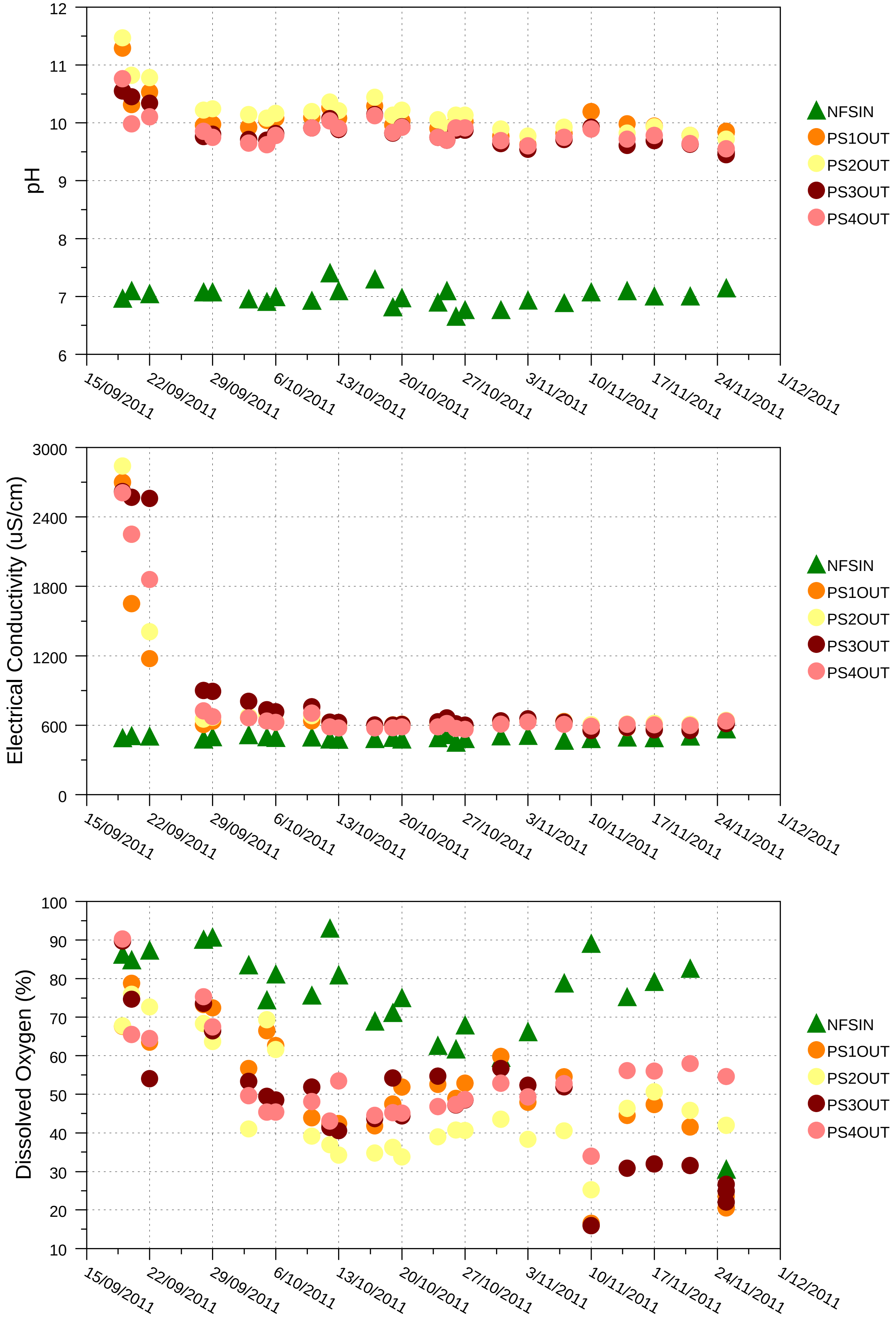


DESCRIPTION: Sulfide Trends in All Passive and Active System Effluent Samples and Ellen Brook Water

SYRINX
environmental pl

PROJECT: Ellen Brook 1012
CLIENT: Swan River Trust

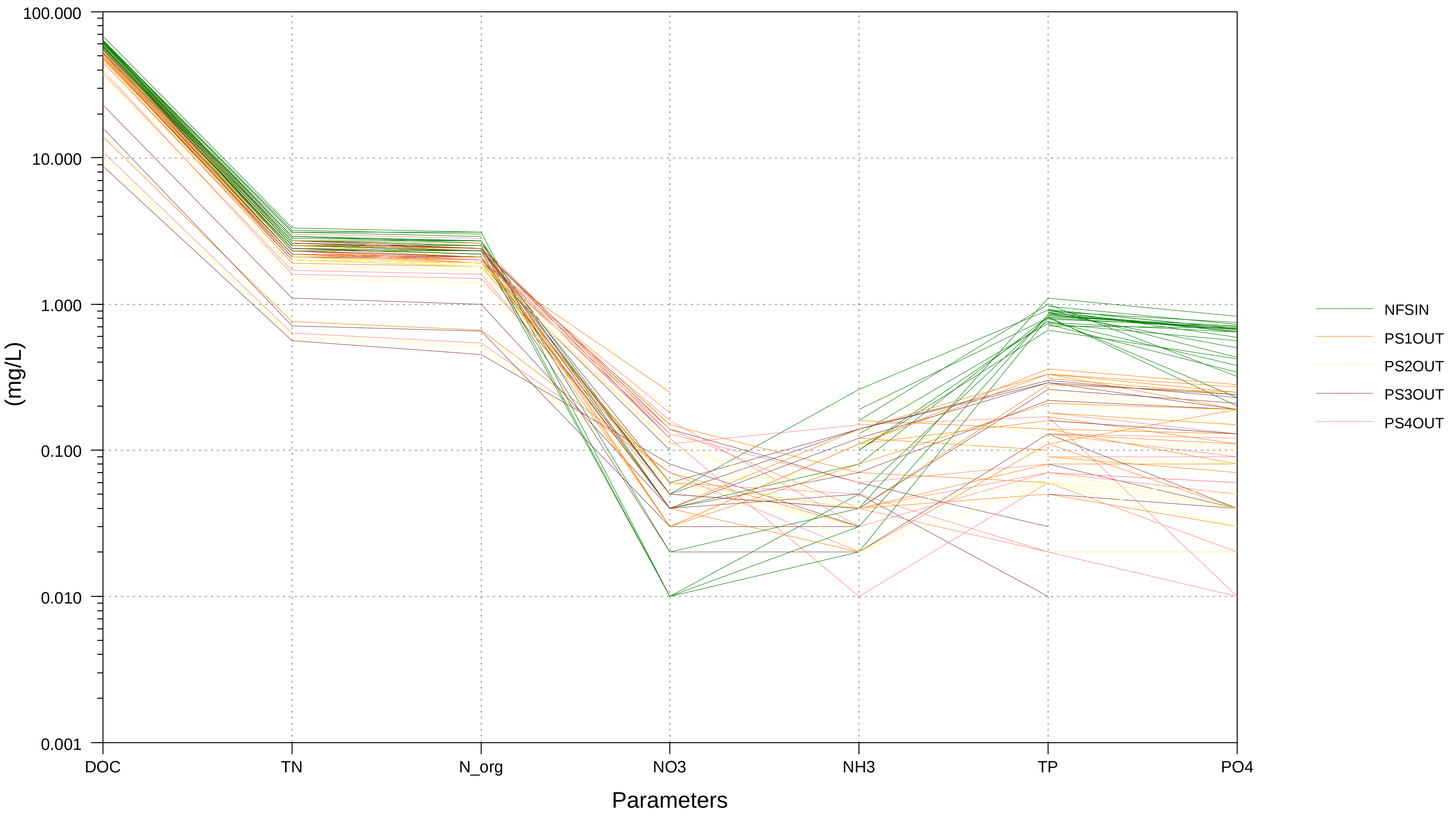
FIGURE #: 07
DATE: 23/01/12



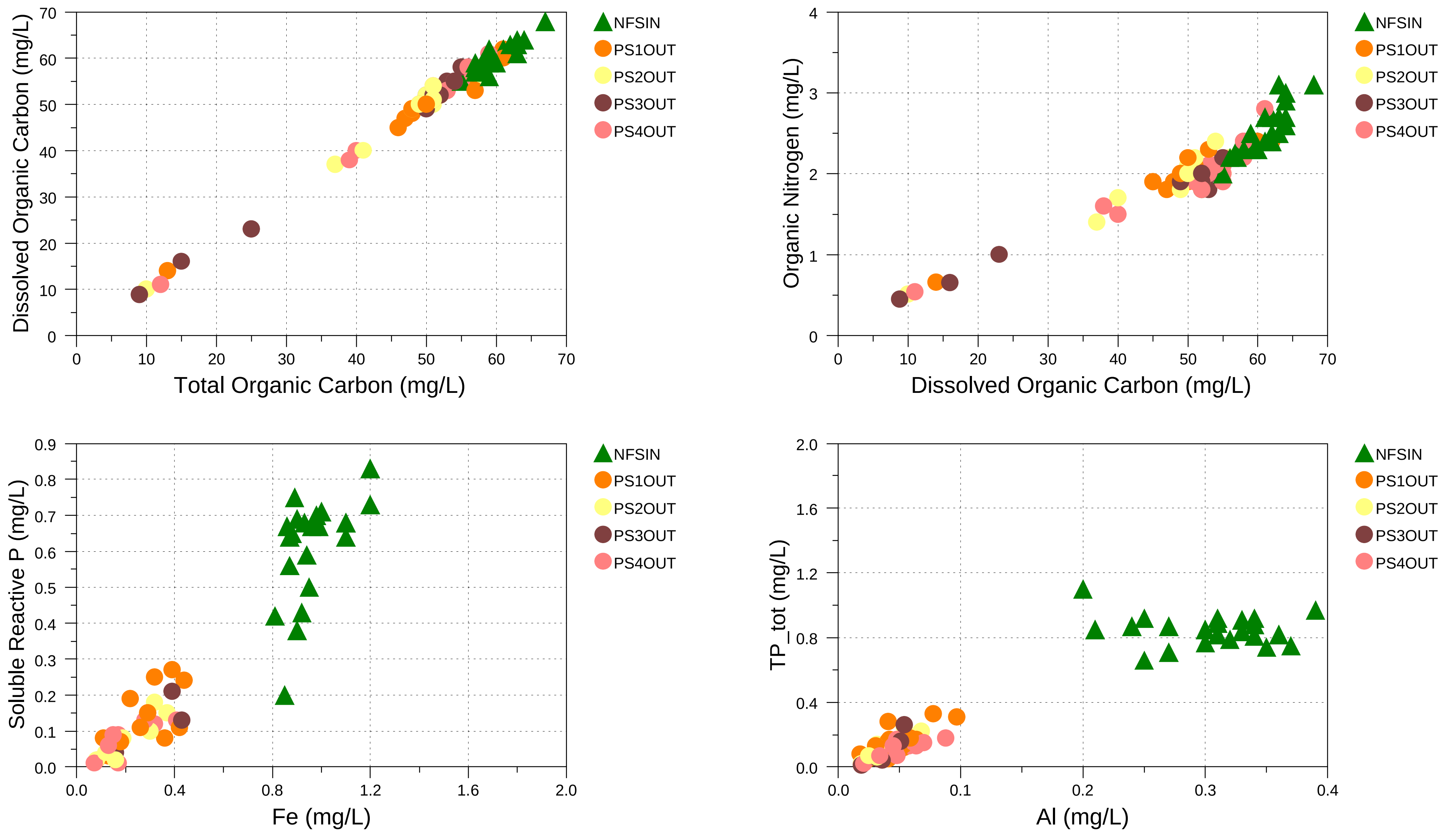
DESCRIPTION: pH, EC and DO Trends in All Passive System Effluent Samples and Ellen Brook Water

SYRINX environmental pl

PROJECT:	Ellen Brook 1012	FIGURE #:	08
CLIENT:	Swan River Trust	DATE:	23/01/12



DESCRIPTION:	Nutrient Concentrations from All Passive Effluent Samples and Ellen Brook Water		
PROJECT:	Ellen Brook 1012	FIGURE #:	09
CLIENT:	Swan River Trust	DATE:	23/01/12



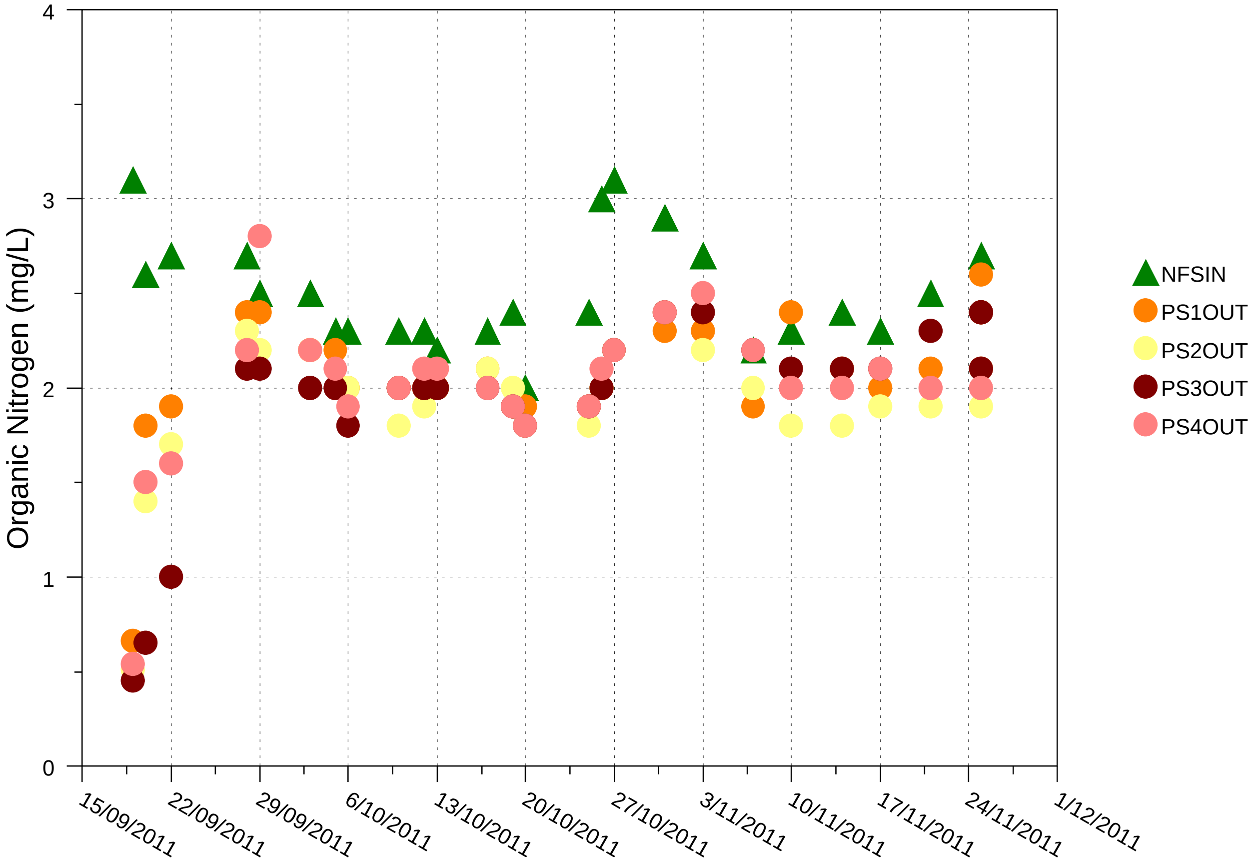
DESCRIPTION: Dominant Relationships Impacting Nutrient Concentrations in All Passive Effluent Samples and Ellen Brook Water

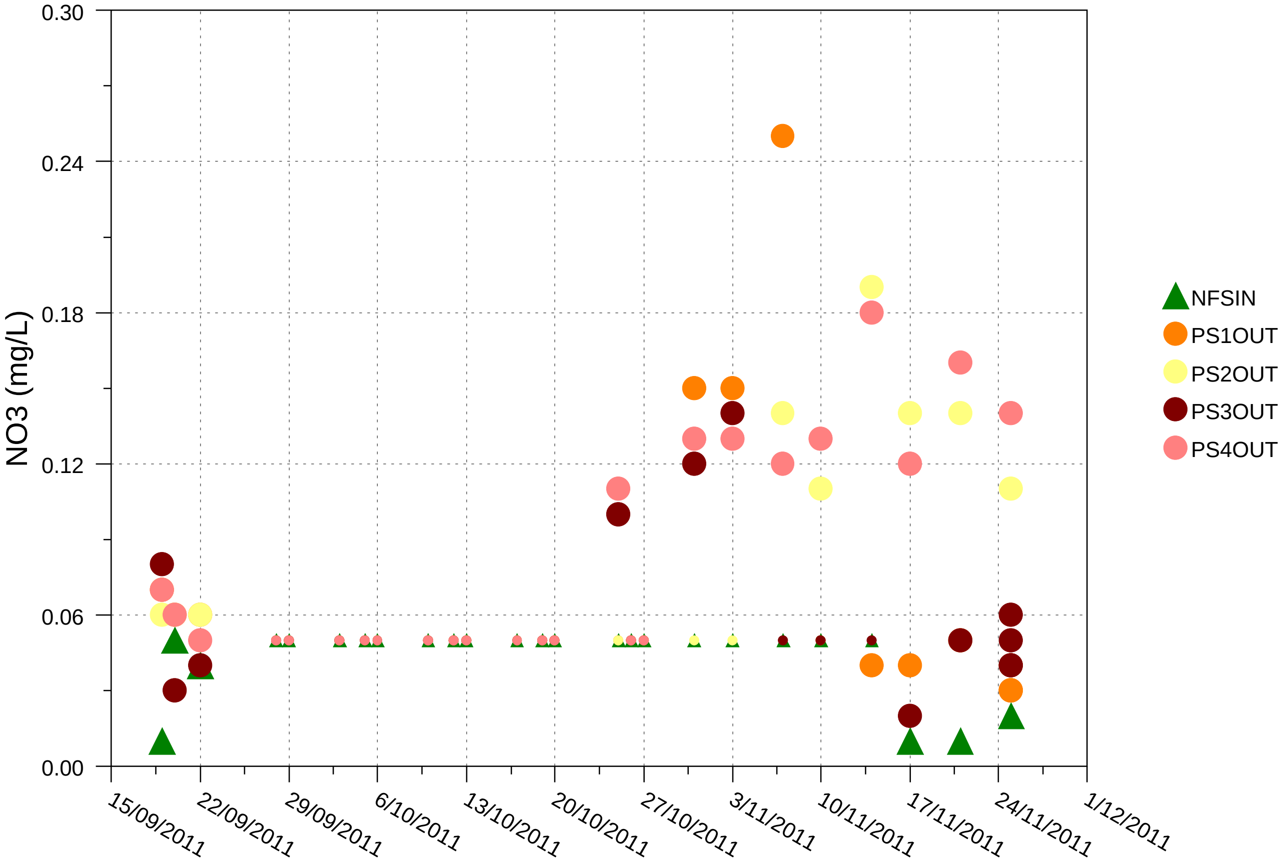
PROJECT: Ellen Brook 1012

FIGURE #: 10

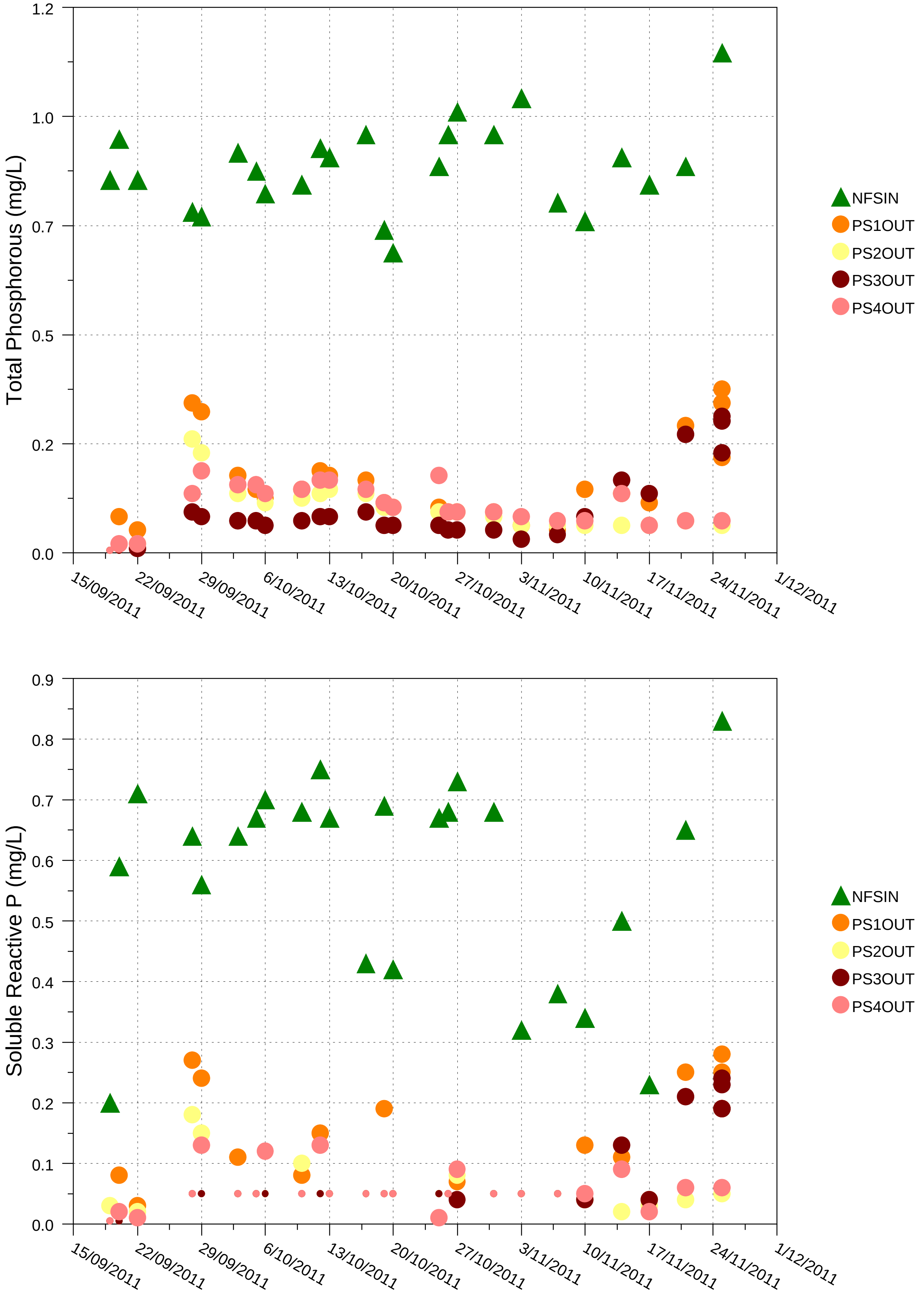
CLIENT: Swan River Trust

DATE: 23/01/12





DESCRIPTION: Trends of Key Nitrogen Species in All Passive System Effluent Samples and Ellen Brook Water			
SYRINX environmental pl	PROJECT: Ellen Brook 1012 CLIENT: Swan River Trust	FIGURE #: 11 DATE: 23/01/12	



DESCRIPTION: Trends of Key Phosphorous Species in All Passive System Effluent Samples and Ellen Brook Water

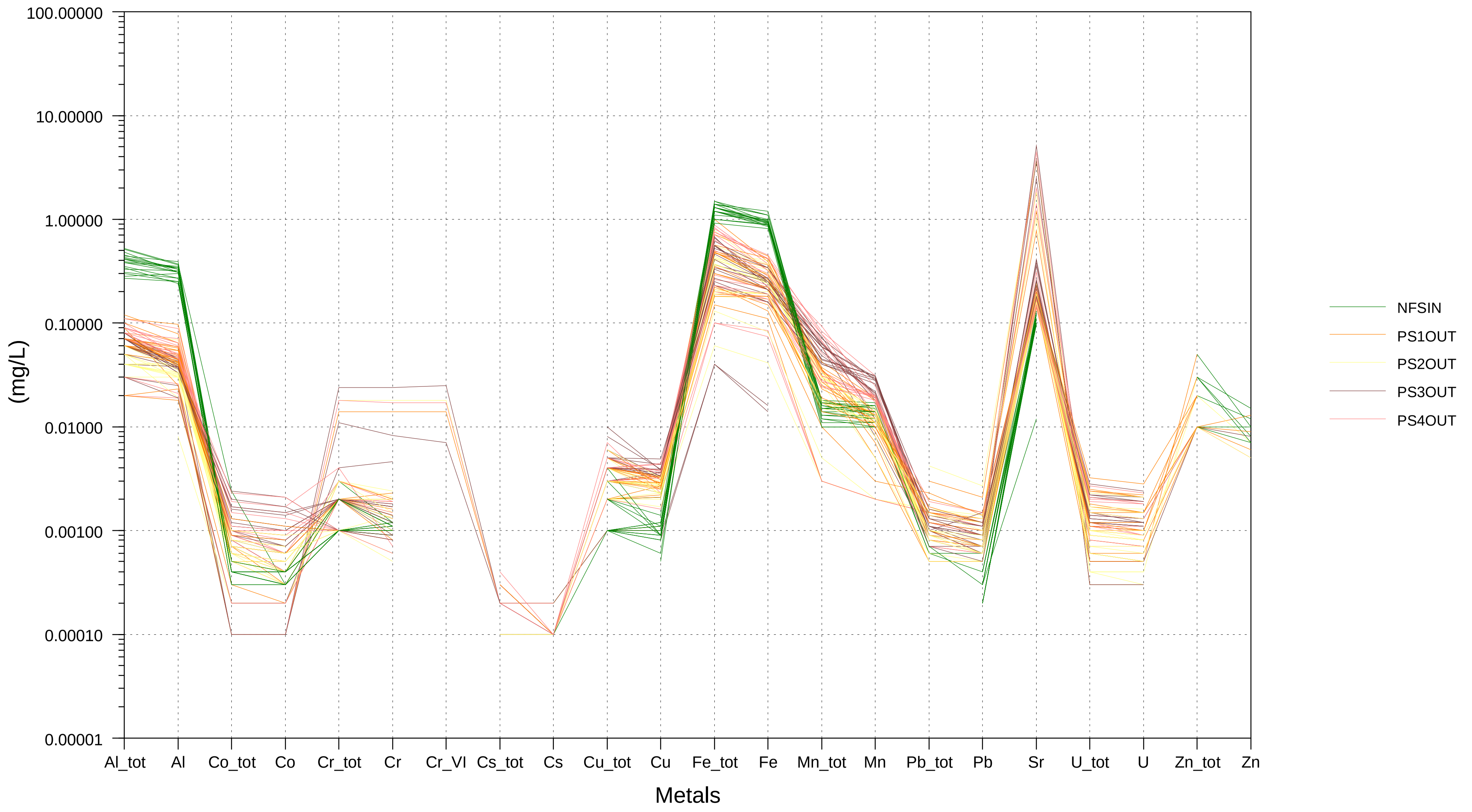
SYRINX environmental pl

PROJECT: Ellen Brook 1012

CLIENT: Swan River Trust

FIGURE #: 12

DATE: 23/01/12



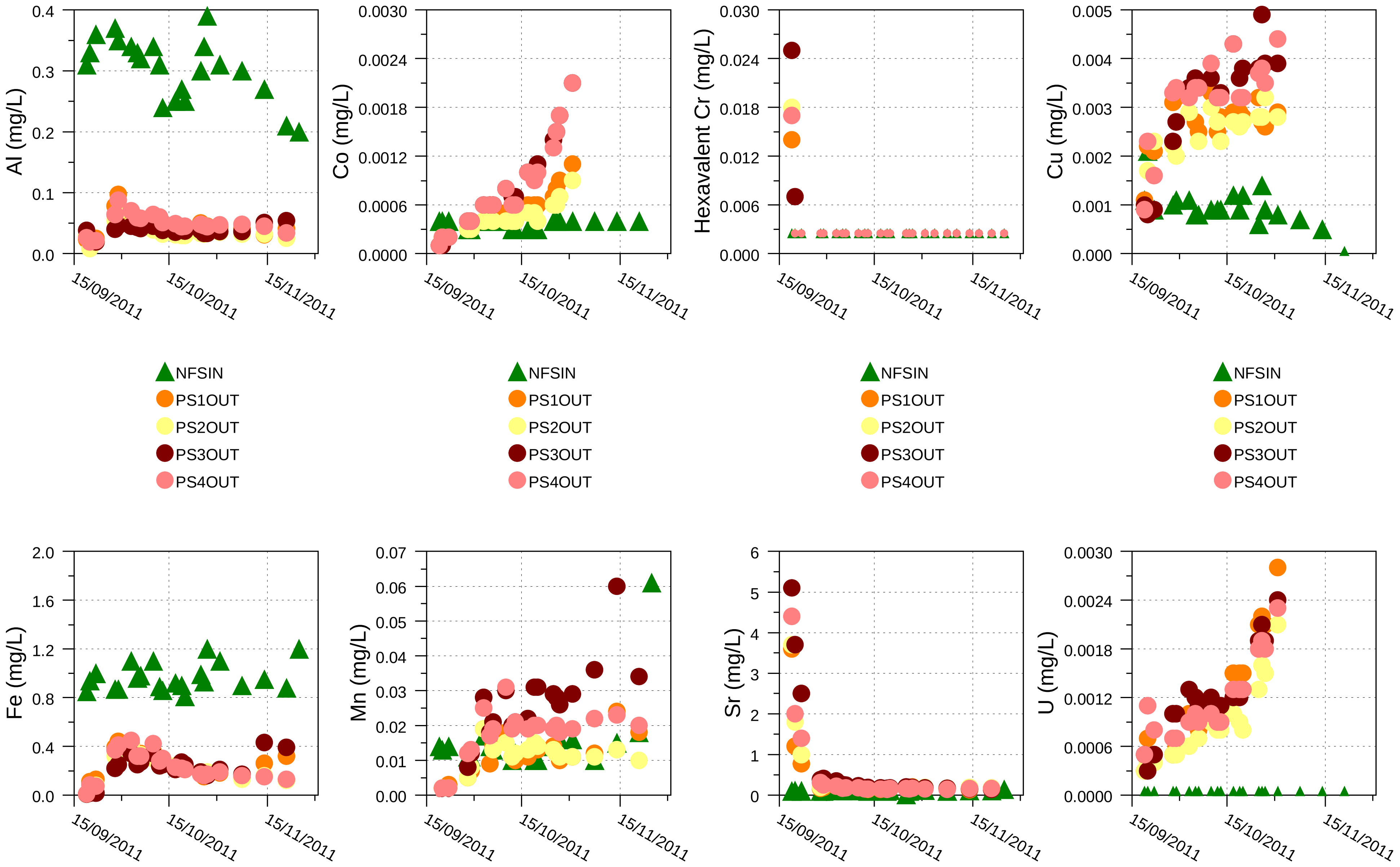
DESCRIPTION: Concentrations of Metals in All Passive System Effluent Samples and Ellen Brook Water

PROJECT: Ellen Brook 1012

FIGURE #: 13

CLIENT: Swan River Trust

DATE: 23/01/12



DESCRIPTION: Concentration Trends of Key Metals in All Passive System Effluent Samples and Ellen Brook Water

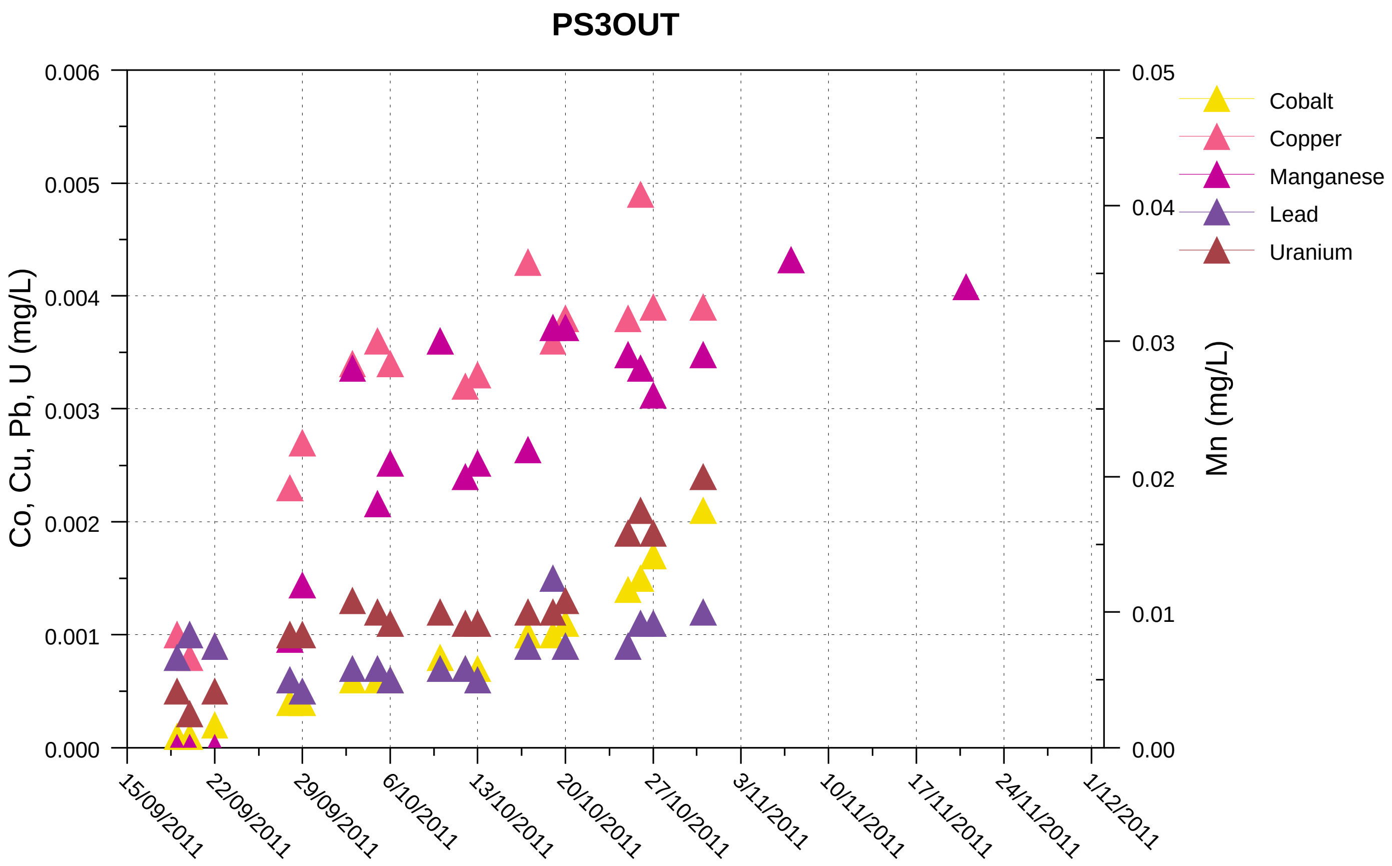
SYRINX environmental pl

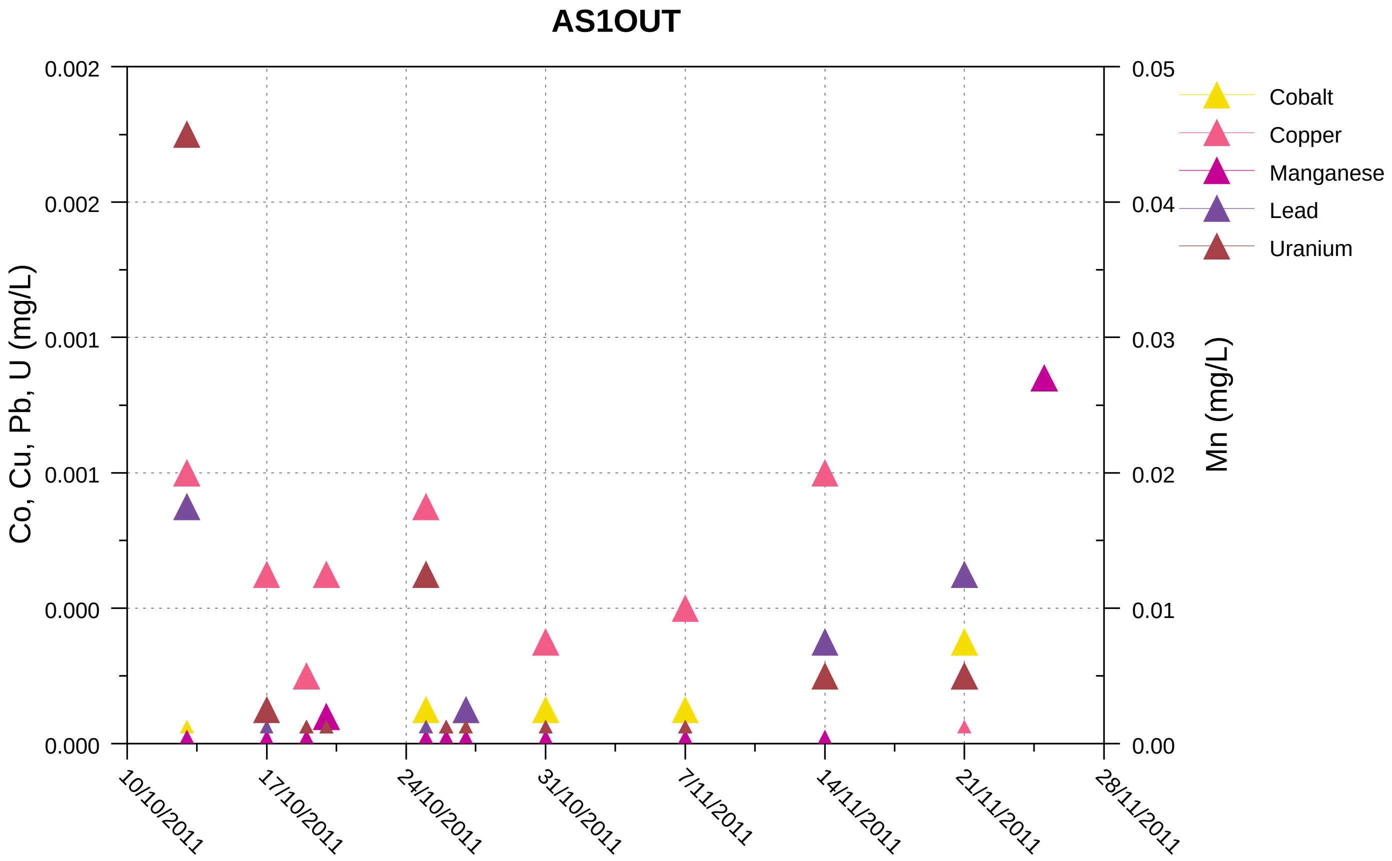
PROJECT: Ellen Brook 1012

FIGURE #: 14

CLIENT: Swan River Trust

DATE: 23/01/12





DESCRIPTION: Key Metal Trends in Effluent Water Samples from PS3OUT and AS1OUT

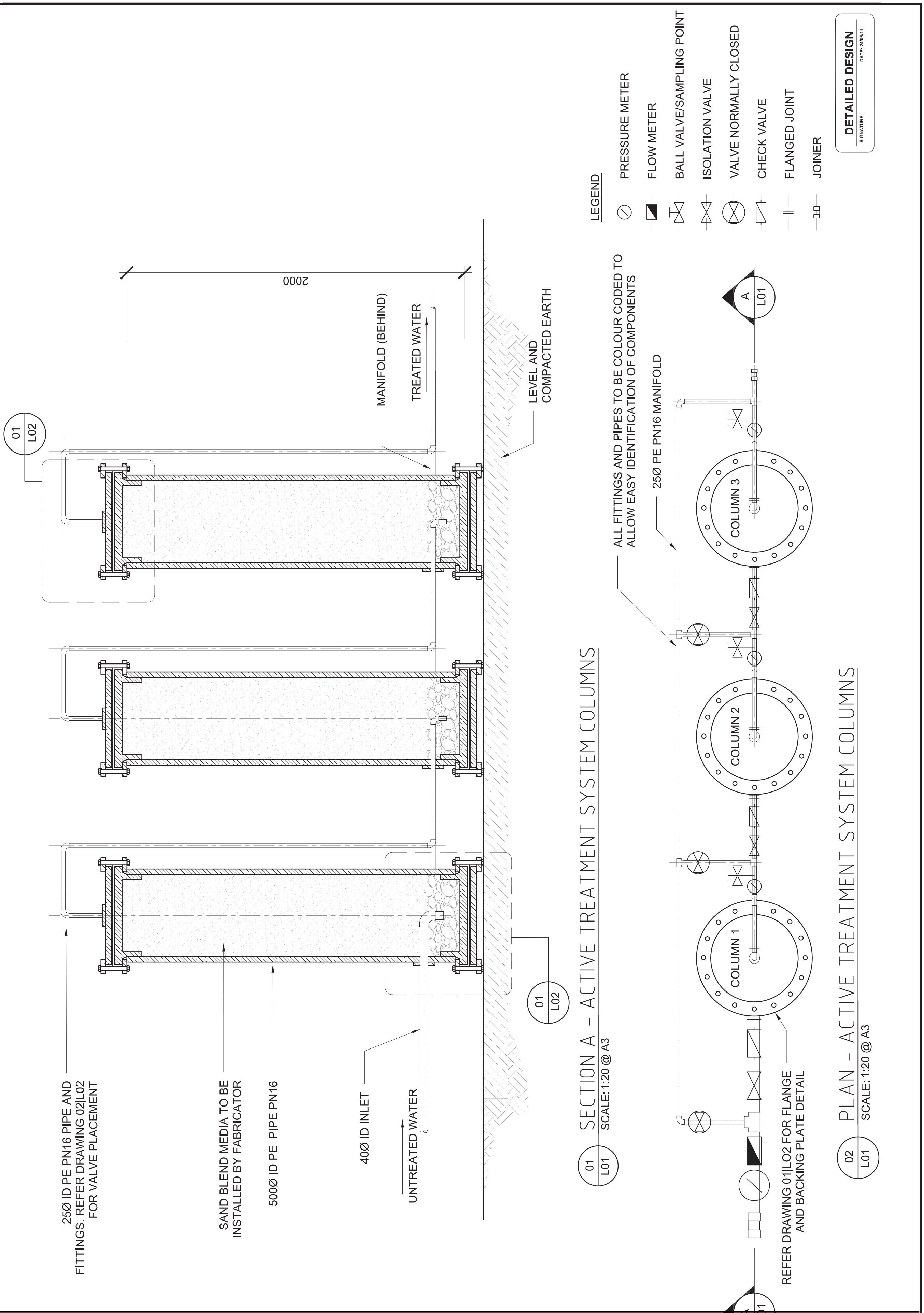
SYRINX environmental pl

PROJECT: Ellen Brook 1012

FIGURE #: 15

CLIENT: Swan River Trust

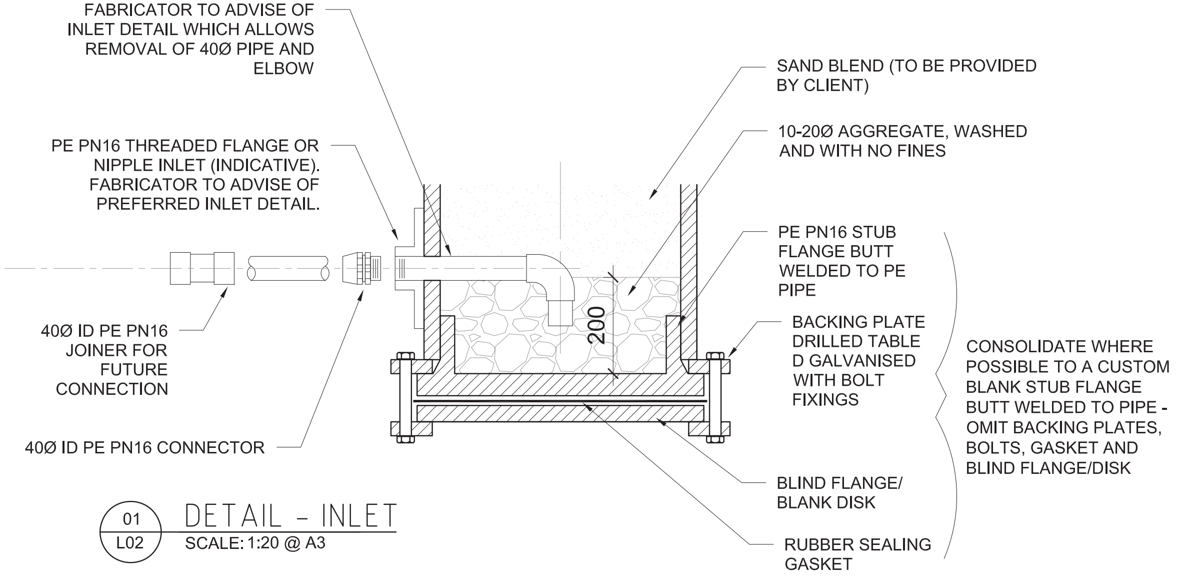
DATE: 23/01/12



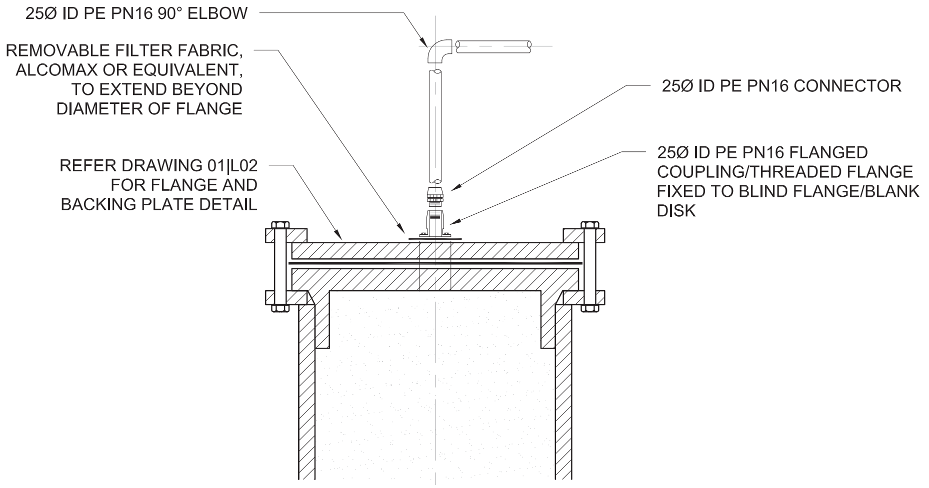
DESCRIPTION: Active system drawings (1 of 2)

SYRINX environmental pl	PROJECT: Ellen Brook 1012	FIGURE #: 16a
	CLIENT: Swan River Trust	DATE: 23/01/12

DESCRIPTION: Active system drawings (2 of 2)



01
L02
DETAIL - INLET
SCALE: 1:20 @ A3



02
L02
DETAIL - OUTLET
SCALE: 1:20 @ A3

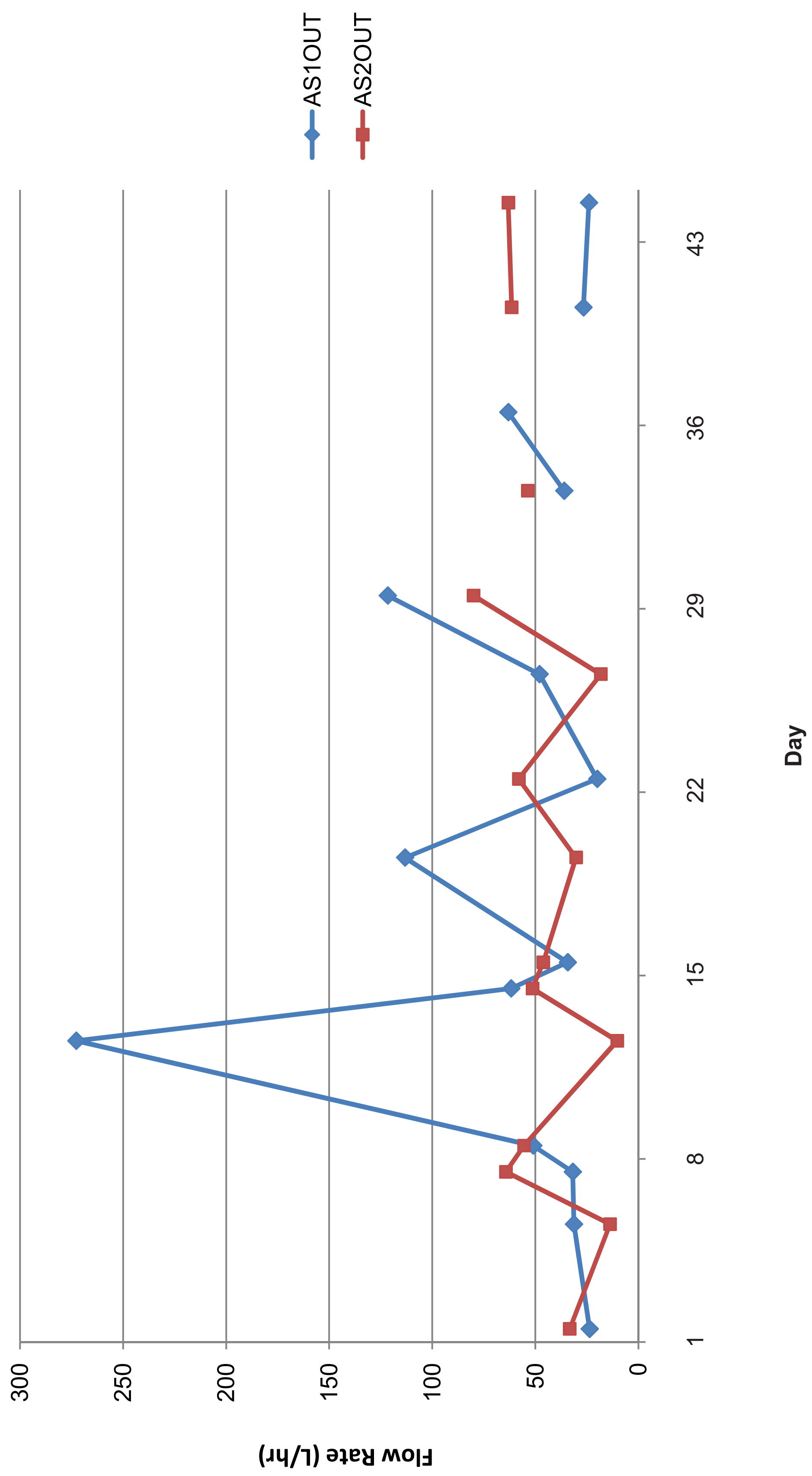
SYRINX environmental pl

PROJECT: Ellen Brook 1012

CLIENT: Swan River Trust

FIGURE #: 16b

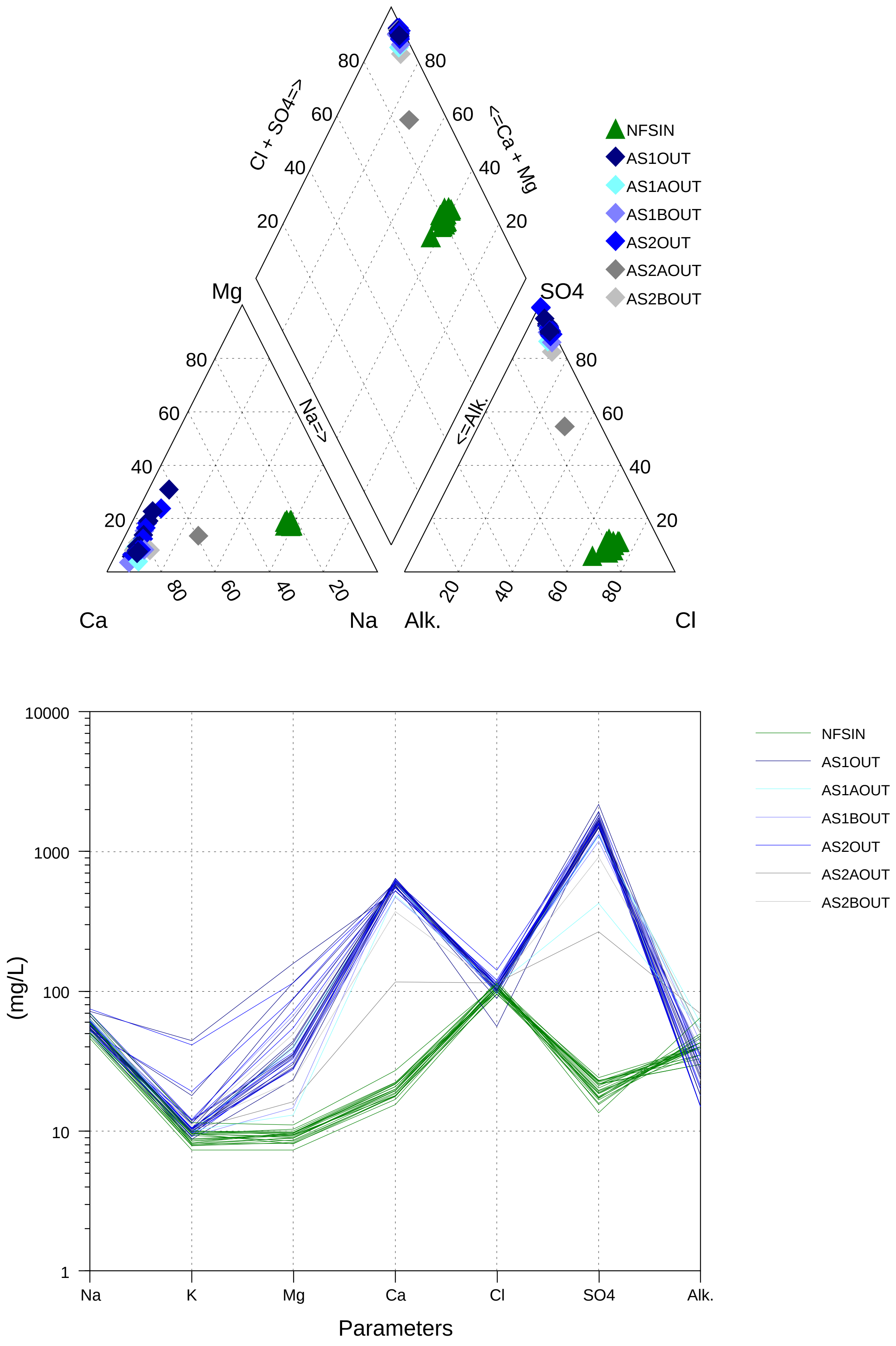
DATE: 23/01/12



DESCRIPTION: PTV2 Active system flow rates

SYRINX environmental pl

PROJECT: Ellen Brook 1012	FIGURE #: 17
CLIENT: Swan River Trust	DATE: 23/01/12



DESCRIPTION: Major Ion Trends in All Active System Effluent Samples and Ellen Brook Water

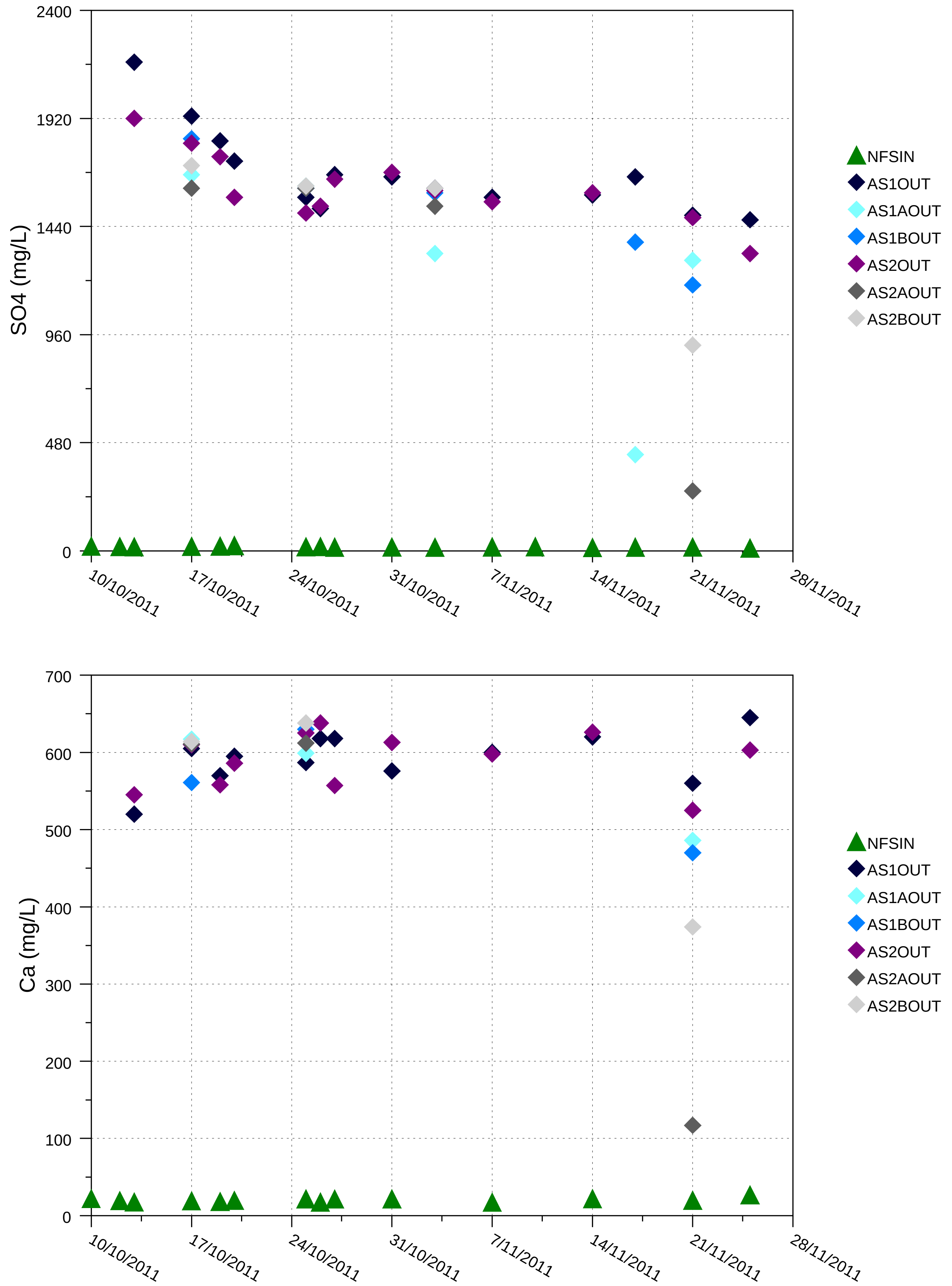
SYRINX environmental pl

PROJECT: Ellen Brook 1012

CLIENT: Swan River Trust

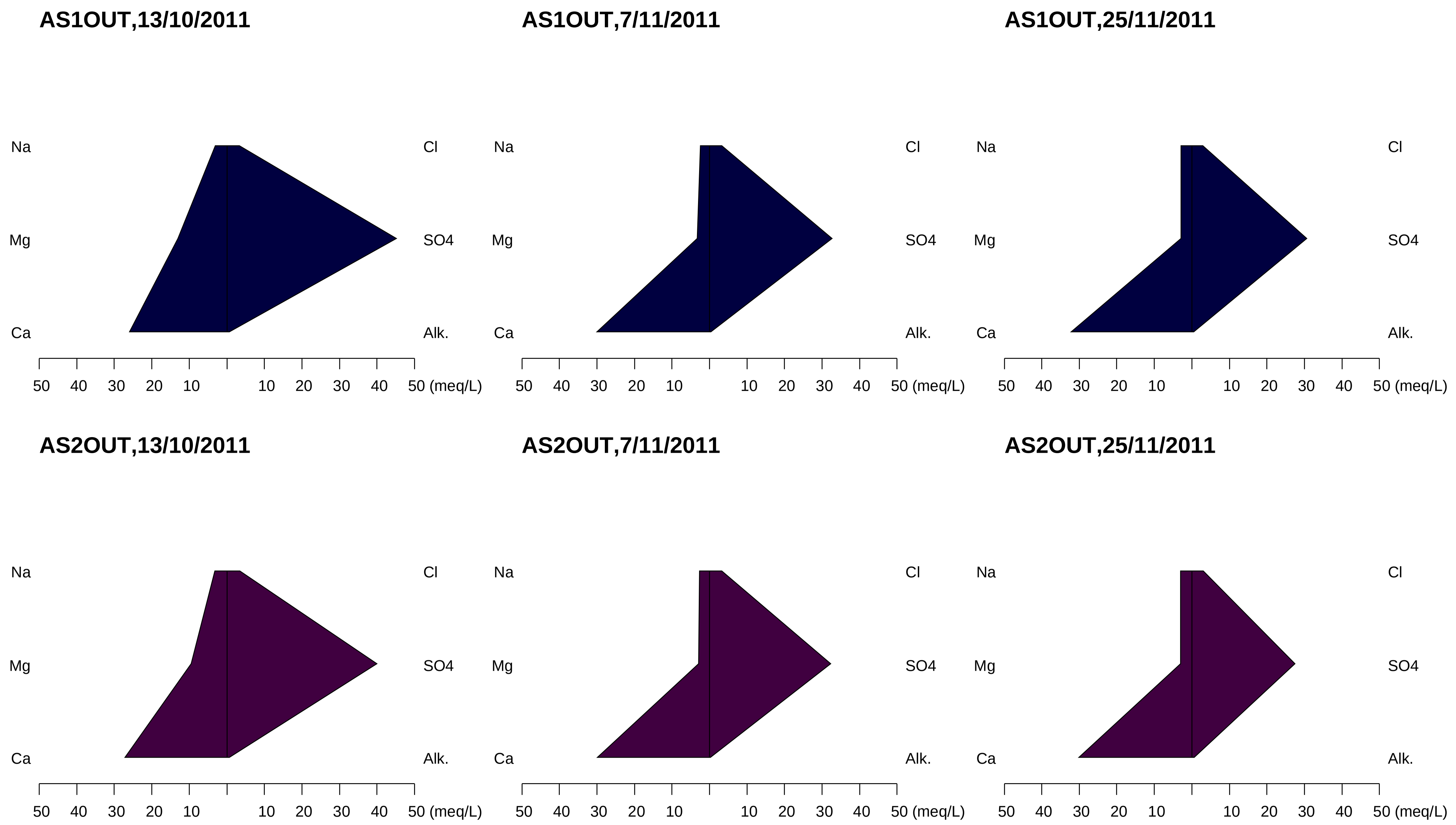
FIGURE #: 18

DATE: 23/01/12



DESCRIPTION: Ca and SO4 Trends in All Active System Effluent Samples and Ellen Brook Water

SYRINX environmental pl	PROJECT: Ellen Brook 1012	FIGURE #: 19
	CLIENT: Swan River Trust	DATE: 23/01/12



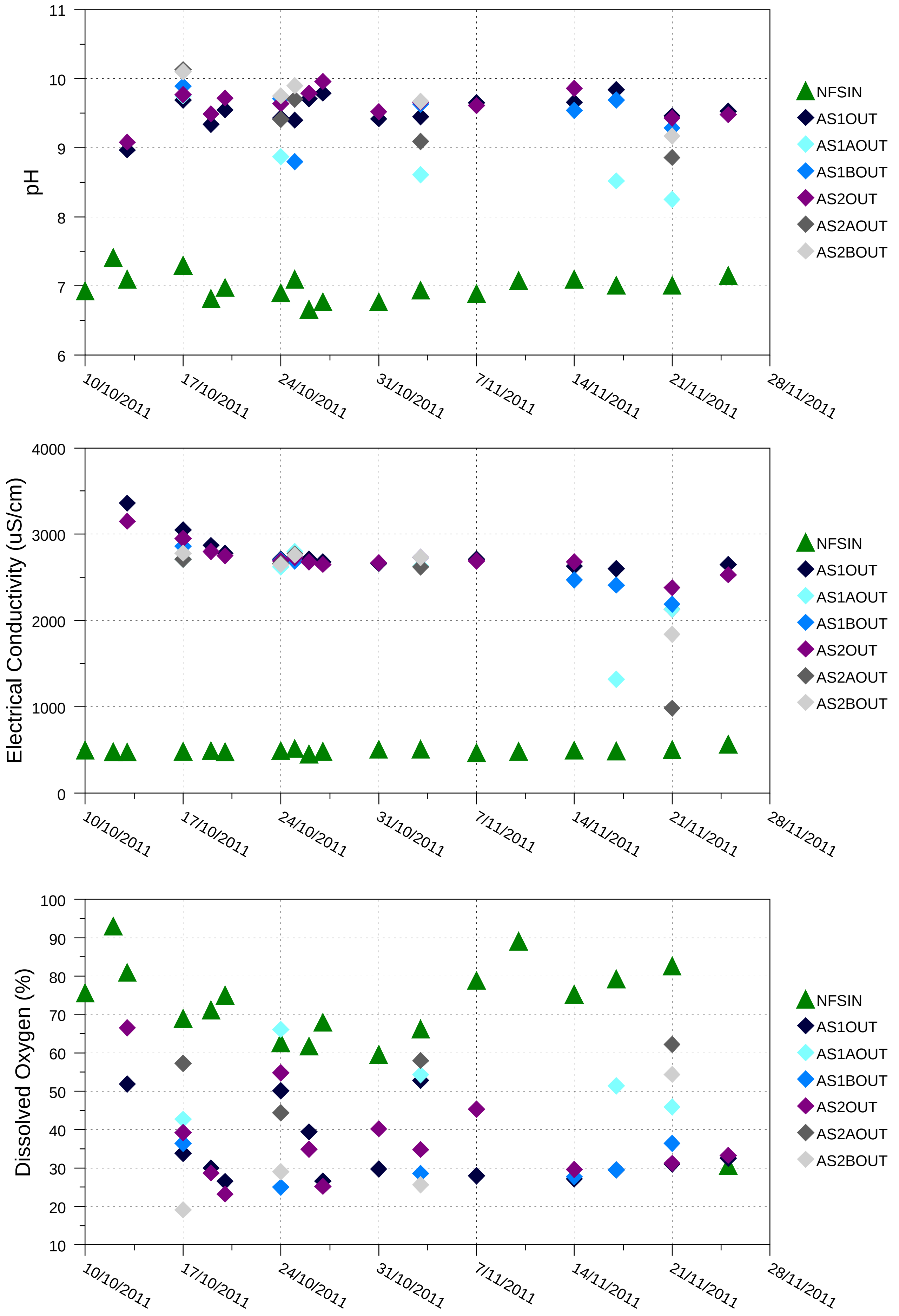
DESCRIPTION: Major Ion Chemistry of Selected Active System Effluent Samples Taken from the Beginning, Middle and End of the Trial

PROJECT: Ellen Brook 1012

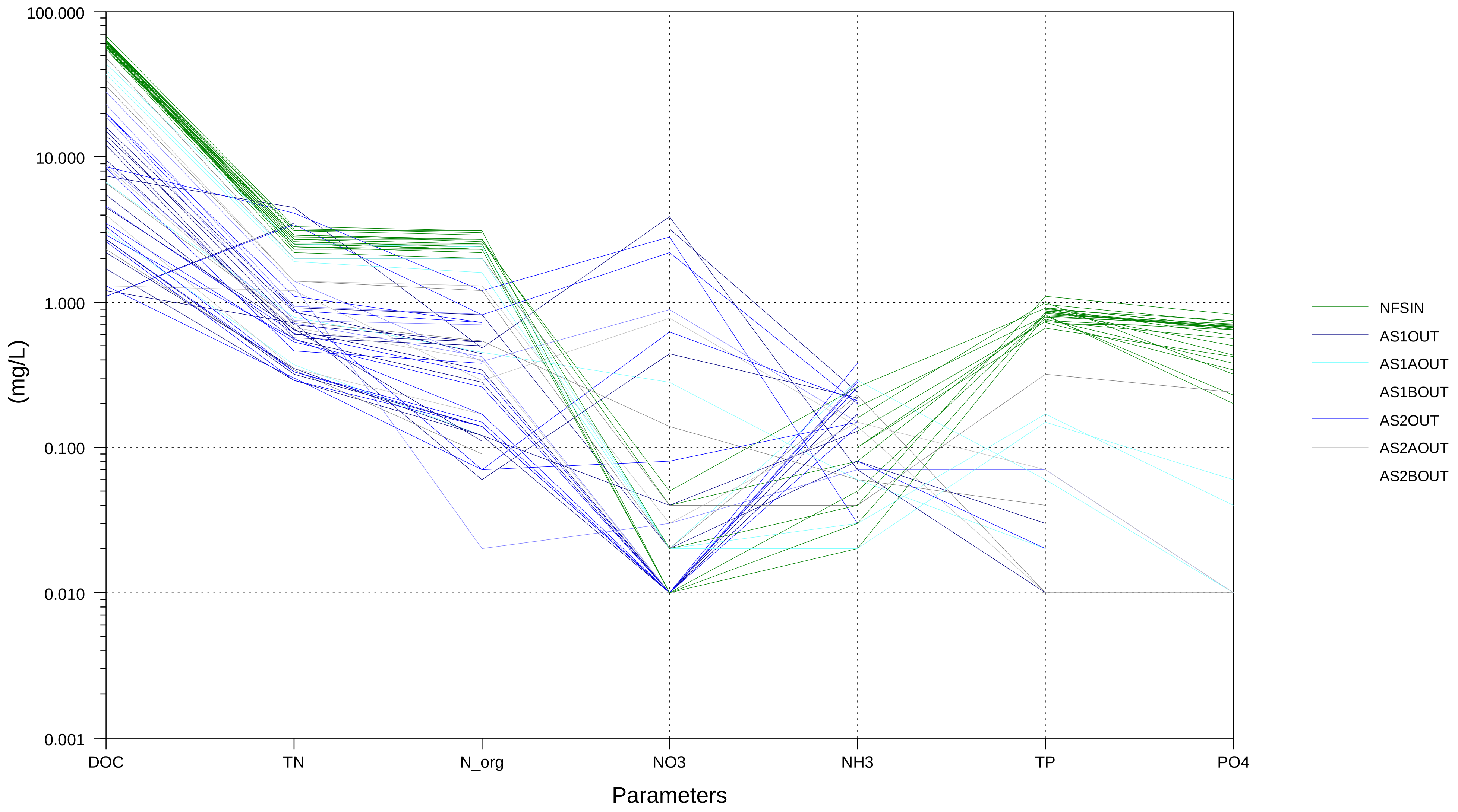
CLIENT: Swan River Trust

FIGURE #: 20

DATE: 23/01/12



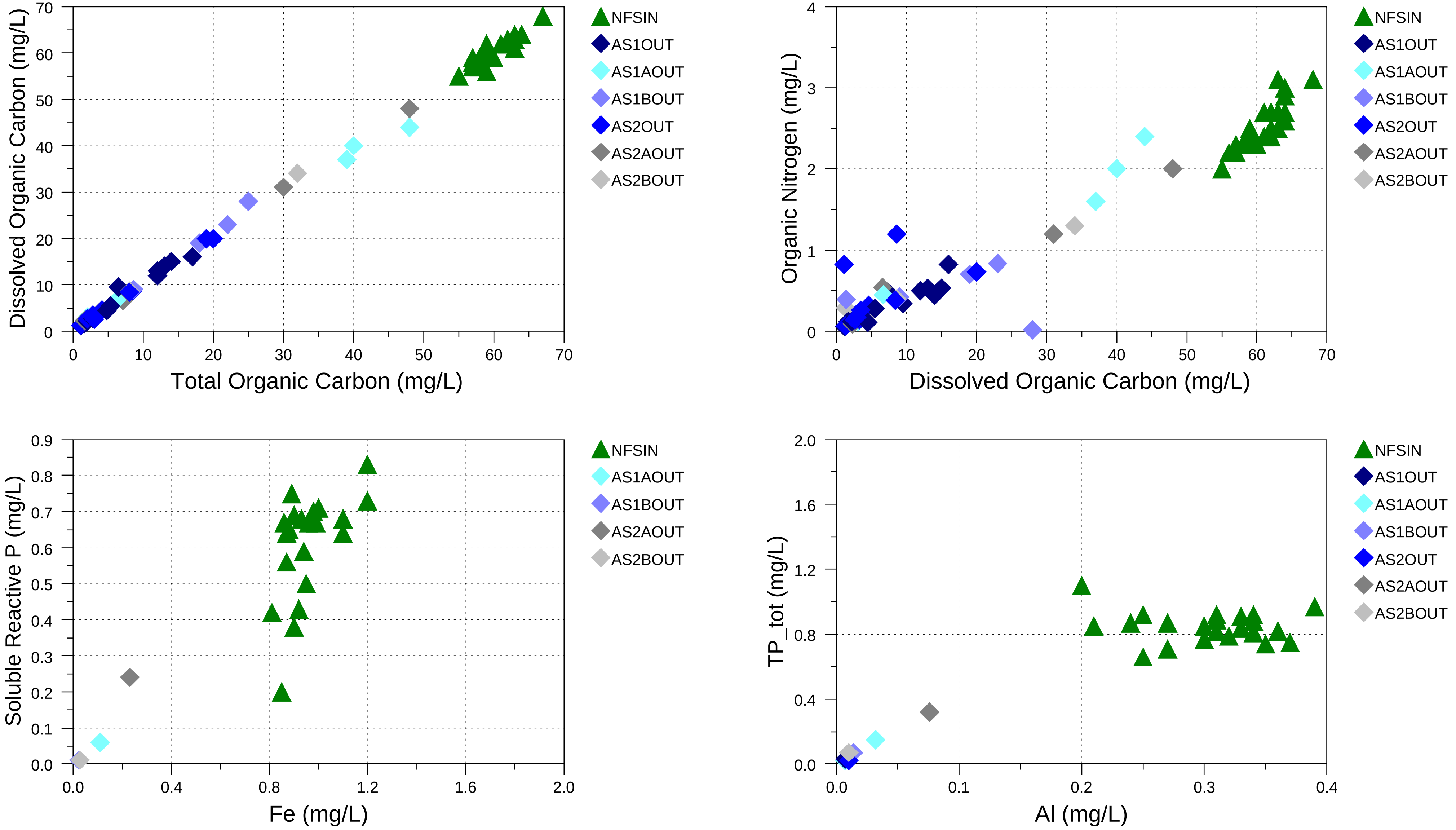
DESCRIPTION:	pH, EC and DO Trends in All Active System Effluent Samples and Ellen Brook Water	
SYRINX environmental pl	PROJECT: Ellen Brook 1012	FIGURE #: 21
	CLIENT: Swan River Trust	DATE: 23/01/12



DESCRIPTION:	Nutrient Concentrations from All Active Effluent Samples and Ellen Brook Water

PROJECT:	Ellen Brook 1012	FIGURE #:	22
CLIENT:	Swan River Trust	DATE:	23/01/12

SYRINX environmental pl



DESCRIPTION: Dominant Relationships Impacting Nutrient Concentrations in All Active Effluent Samples and Ellen Brook Water

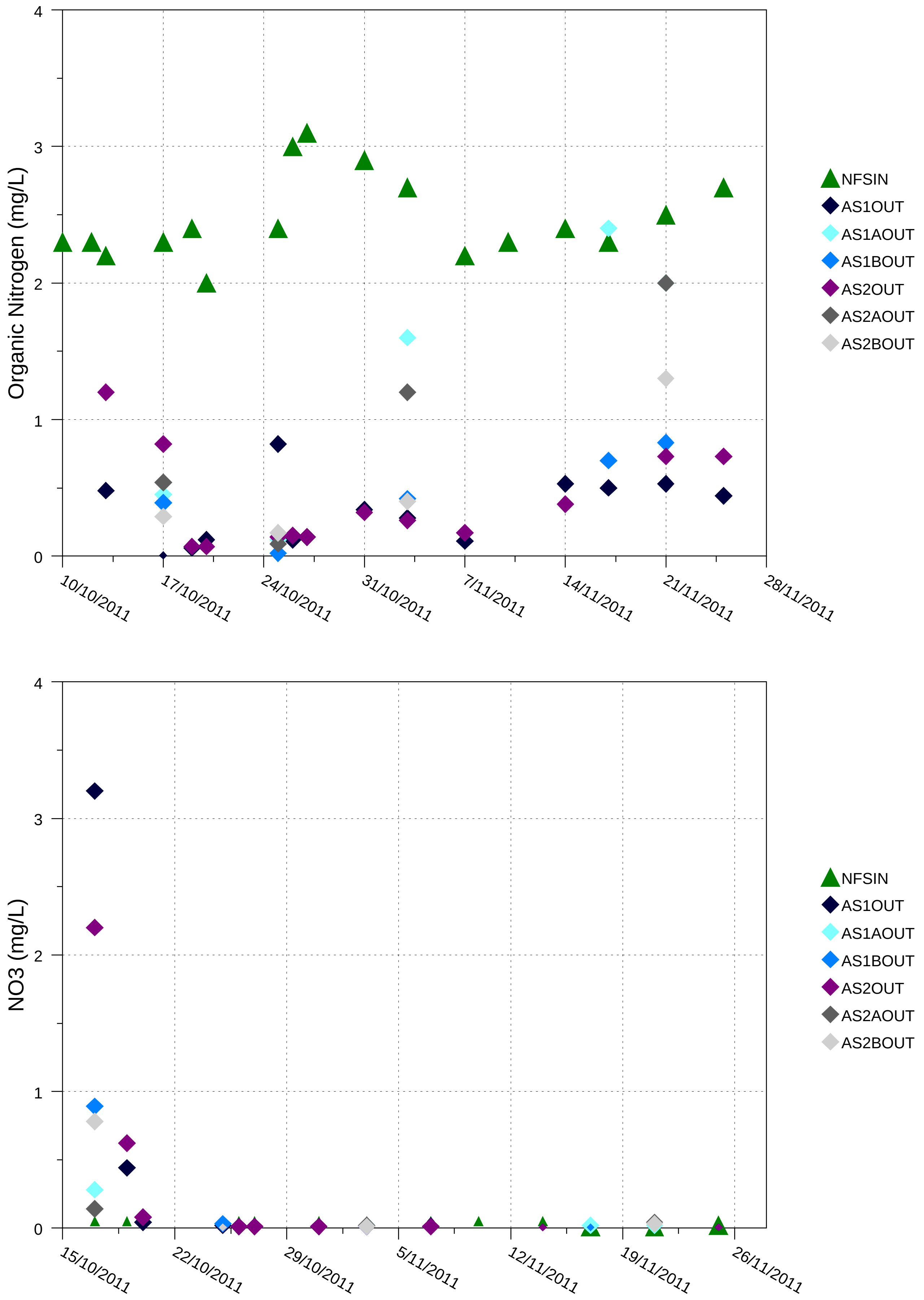
SYRINX environmental pl

PROJECT: Ellen Brook 1012

FIGURE #: 23

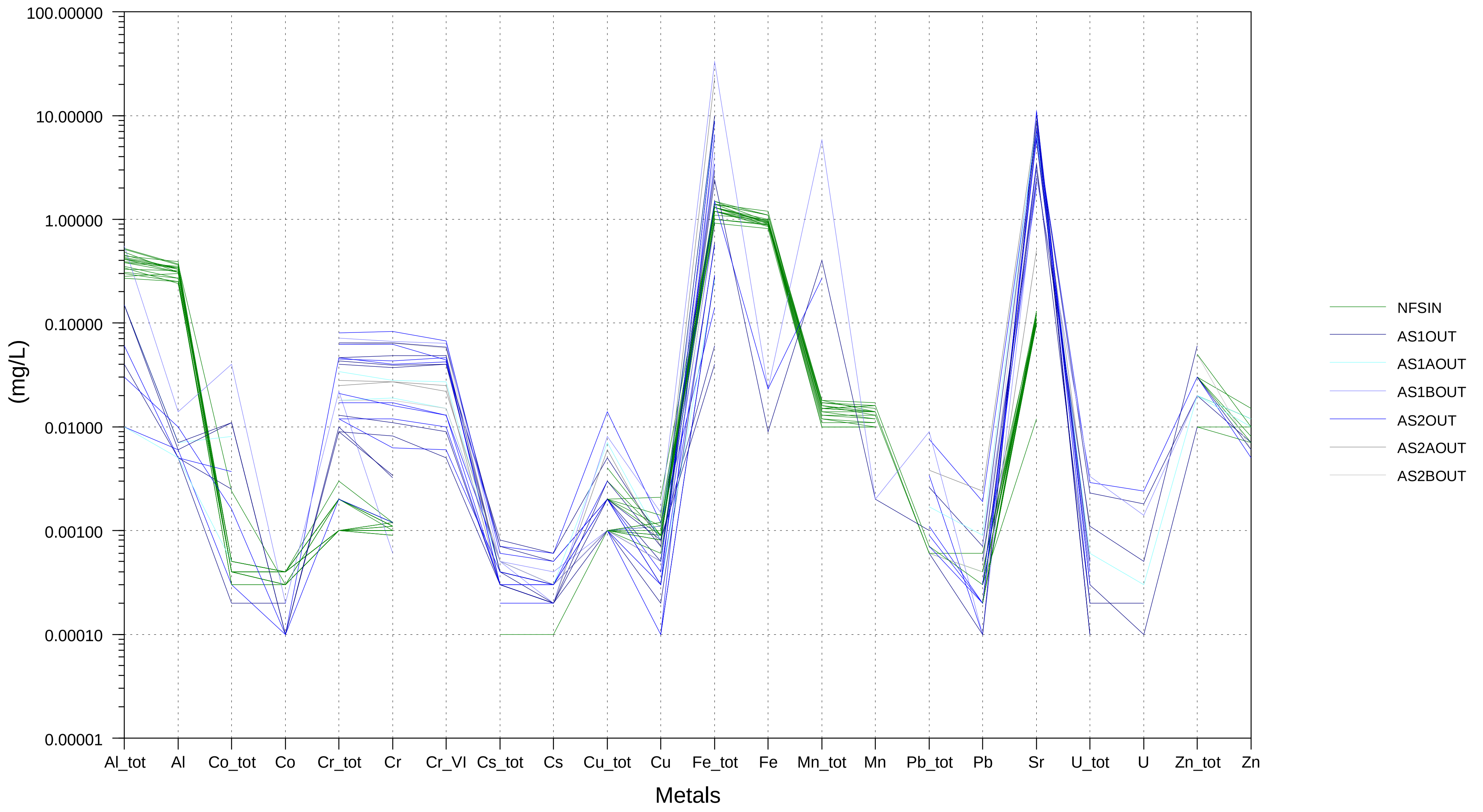
CLIENT: Swan River Trust

DATE: 23/01/12



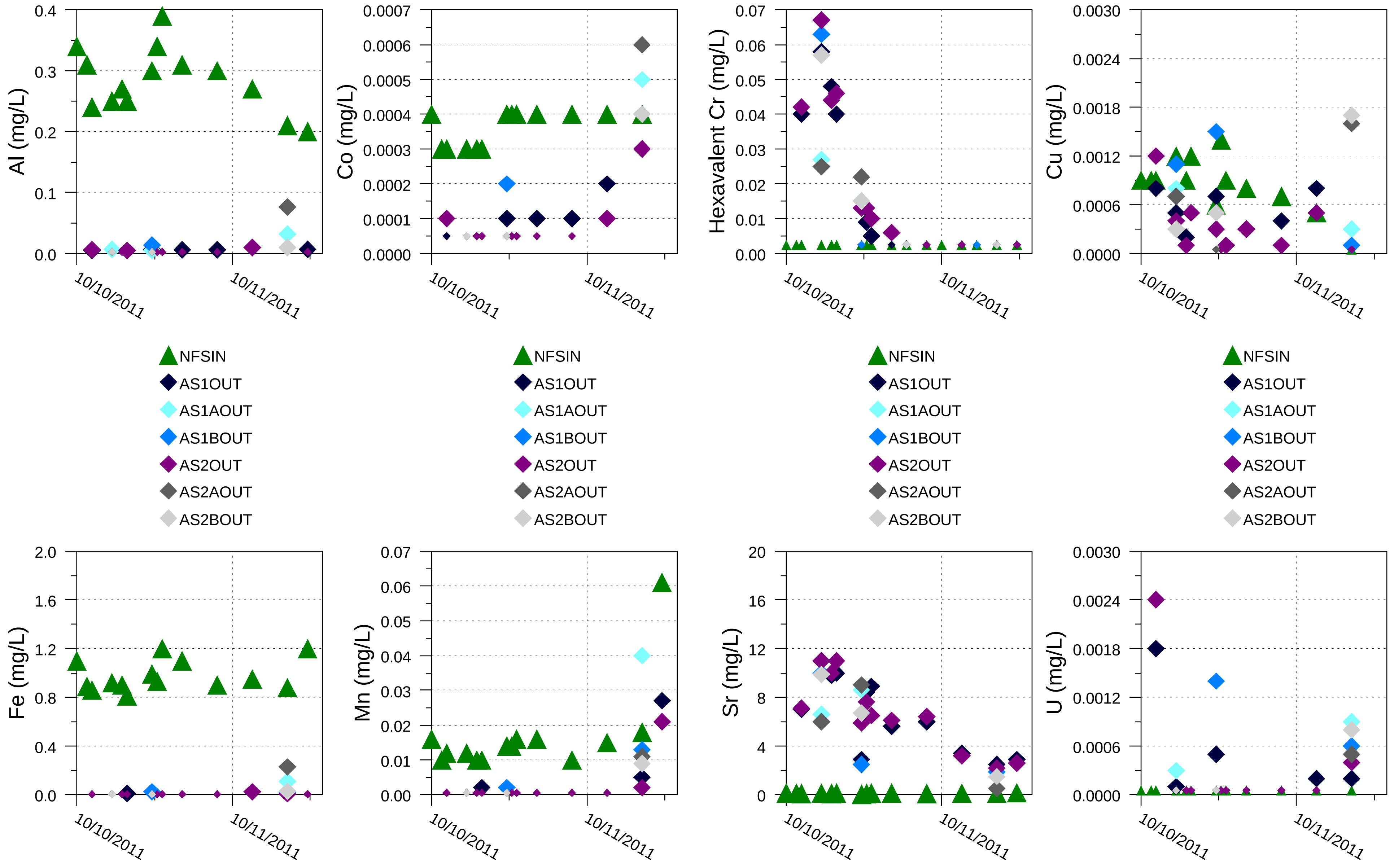
DESCRIPTION: Trends of Key Nitrogen Species in All Active System Effluent Samples and Ellen Brook Water

SYRINX environmental pl	PROJECT: Ellen Brook 1012	FIGURE #: 24
	CLIENT: Swan River Trust	DATE: 23/01/12



DESCRIPTION: Concentrations of Metals in All Active System Effluent Samples and Ellen Brook Water

SYRINX environmental pl	PROJECT: Ellen Brook 1012	FIGURE #: 25
	CLIENT: Swan River Trust	DATE: 23/01/12



DESCRIPTION: Concentration Trends of Key Metals in All Active System Effluent Samples and Ellen Brook Water

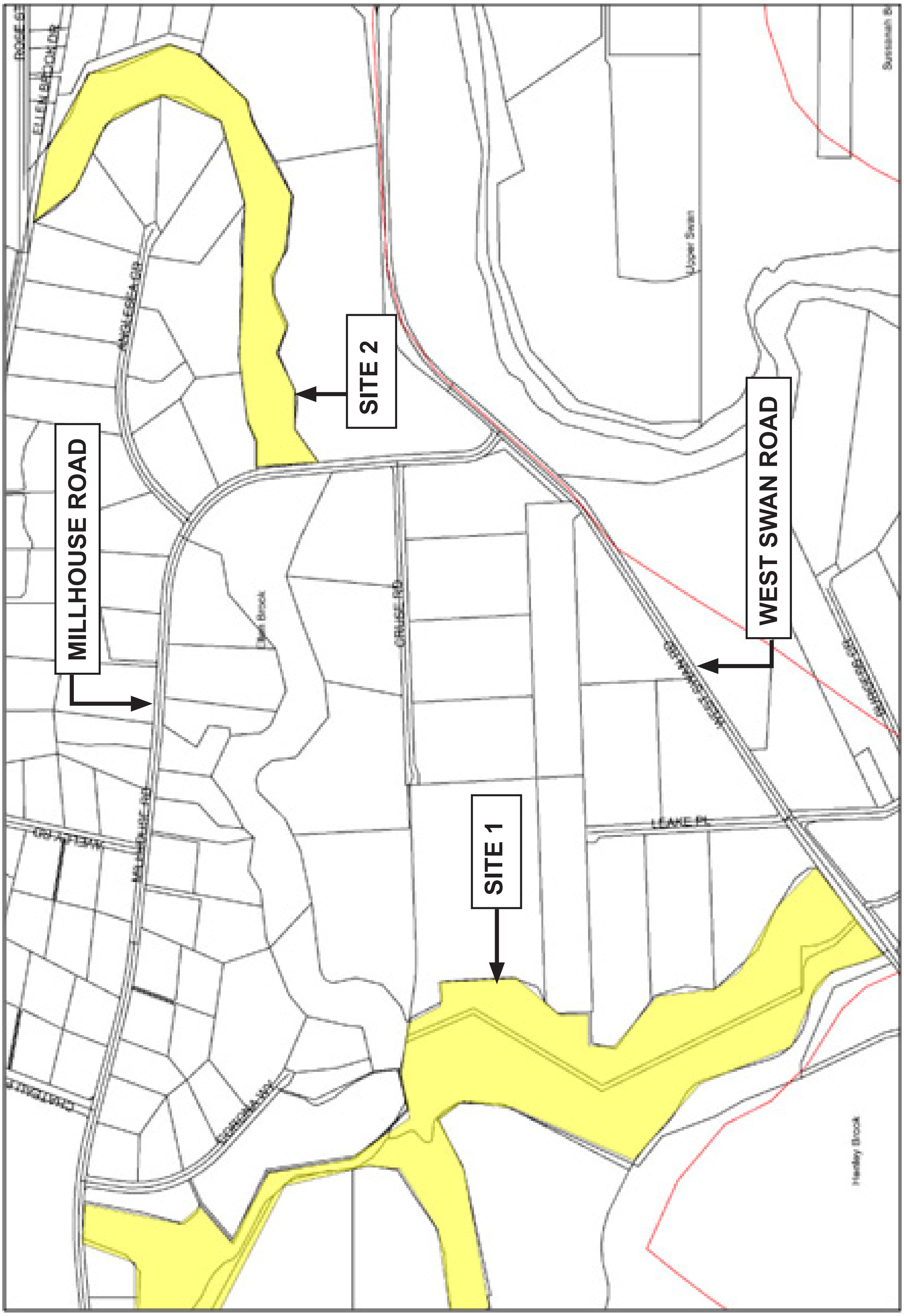
SYRINX environmental pl

PROJECT: Ellen Brook 1012

FIGURE #: 26

CLIENT: Swan River Trust

DATE: 23/01/12



DESCRIPTION: Site location - Site 1 & 2

SYRINX environmental pl

PROJECT: Ellen Brook 1012

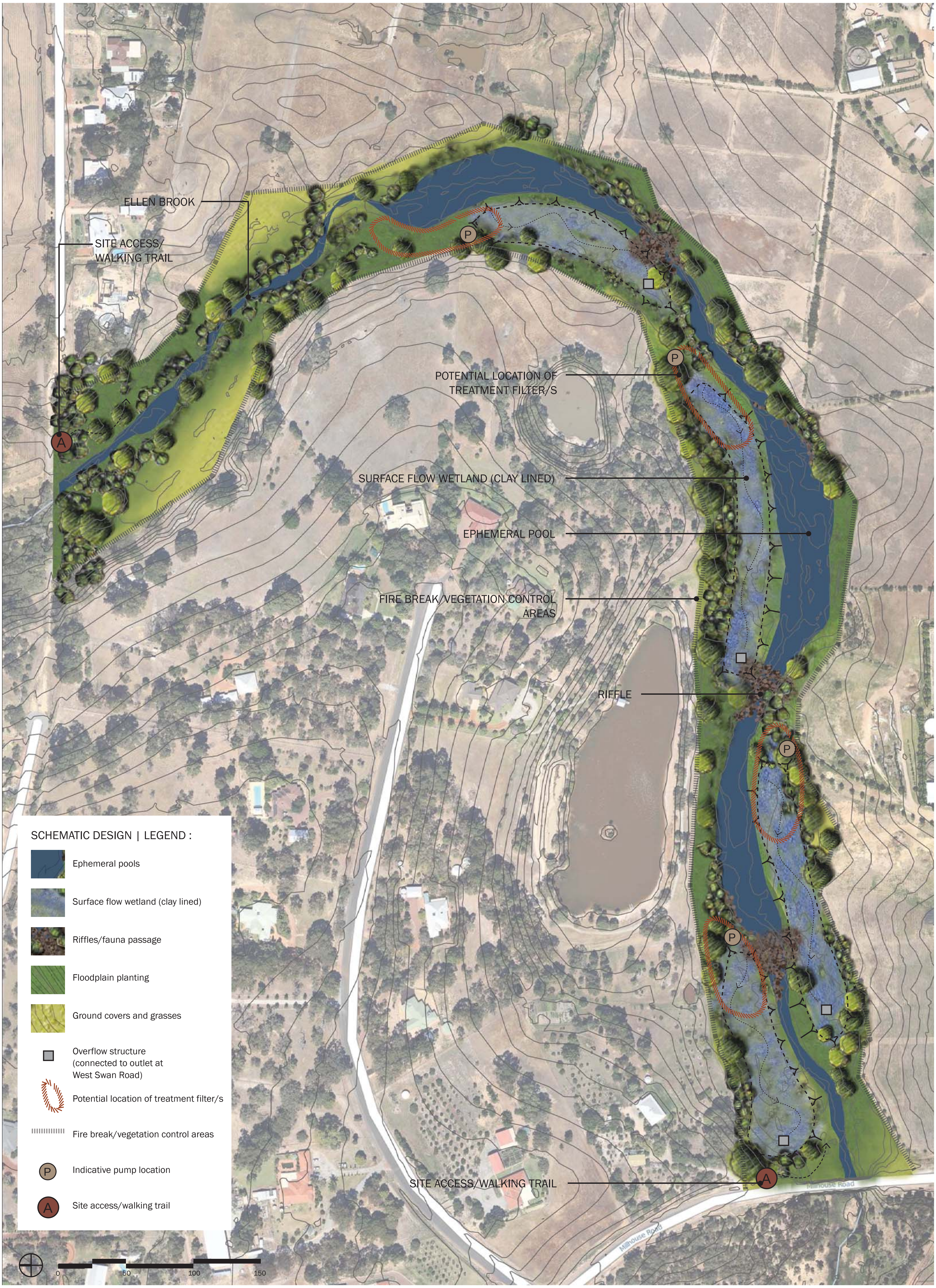
FIGURE #: 27

CLIENT: Swan River Trust

DATE: 23/01/12

CLIENT :	SWAN RIVER TRUST	**DRAWING :**	SCHEMATIC DESIGN	**DATE :**	18.01.2012
PROJECT :	FEASIBILITY STUDY & DESIGN FOR AN END OF CATCHMENT WETLAND TREATMENT SYSTEM - ELLEN BROOK	**DRAWING NUMBER :**	FIGURE 28	**SCALE :**	1:3,000 @ A2
PROJECT NUMBER :	1012	**DRAWING REFERENCE :**	C10	**DRAWN BY :**	KG

SYRINX
environmental pl

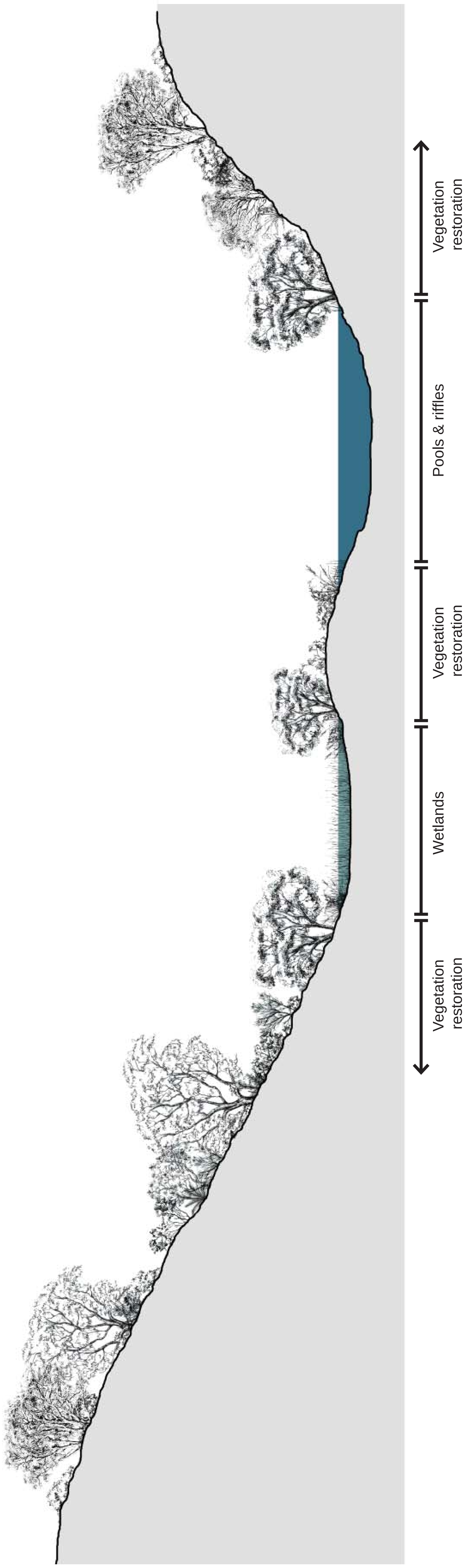


CLIENT : SWAN RIVER TRUST
PROJECT : FEASIBILITY STUDY & DESIGN FOR AN END OF CATCHMENT WETLAND TREATMENT SYSTEM - ELLEN BROOK
PROJECT NUMBER : 1012

DRAWING : SCHEMATIC DESIGN
DRAWING NUMBER : FIGURE 29
DRAWING REFERENCE : C10

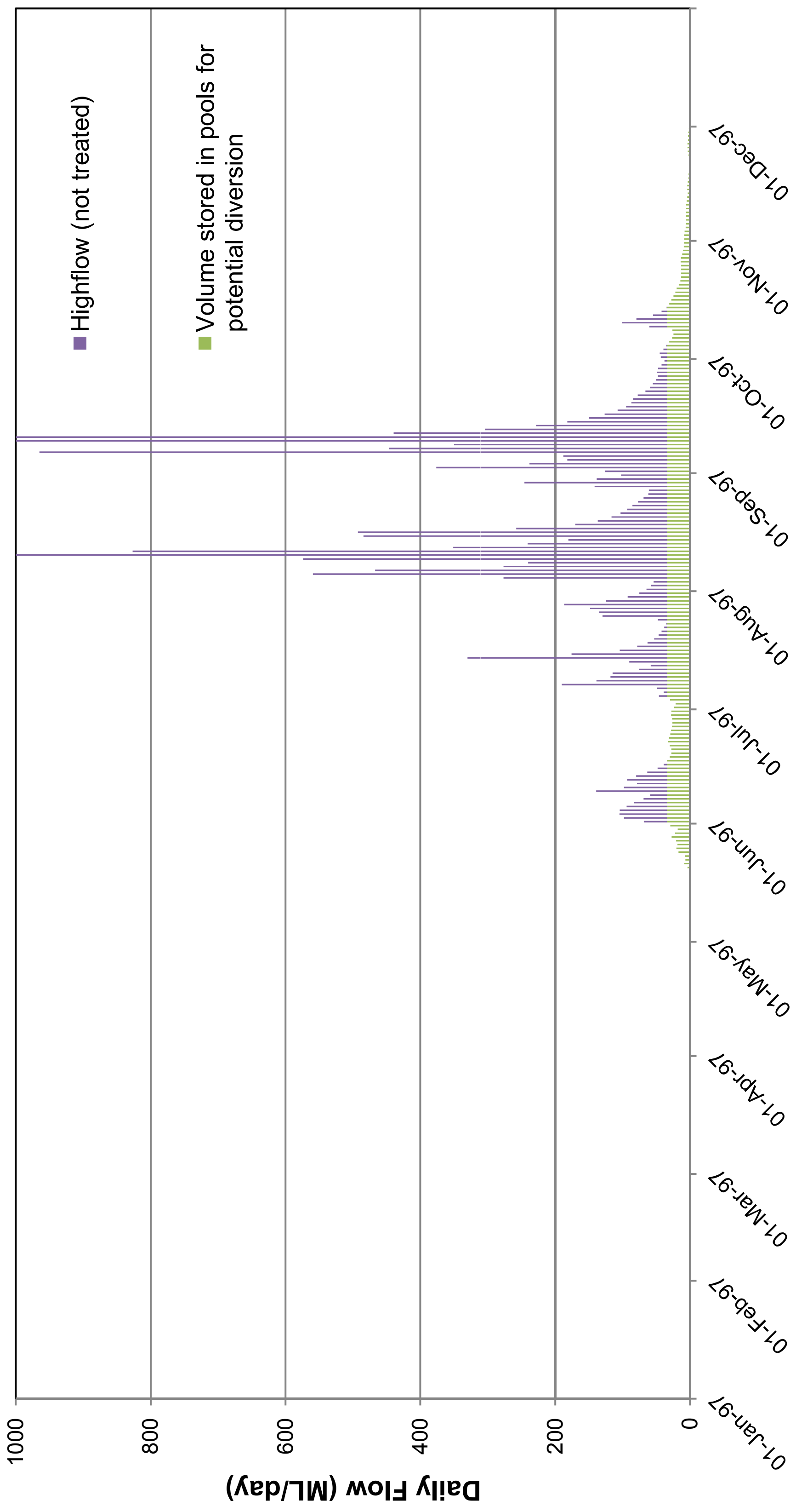
DATE : 18.01.2012
SCALE : 1:2,500 @ A2
DRAWN BY : EB

SYRINX
environmental pl



CLIENT : SWAN RIVER TRUST
PROJECT : FEASIBILITY STUDY & DESIGN FOR AN END OF CATCHMENT WETLAND TREATMENT SYSTEM - ELLEN BROOK
PROJECT NUMBER : 1012
DRAWING : SCHEMATIC DESIGN
DRAWING NUMBER : FIGURE 30
DRAWING REFERENCE : C10
DATE : 18.01.2012
SCALE : NTS
DRAWN BY : KG

SYRINX environmental pl



DESCRIPTION: 19th percentile Ellen Brook flows diverted (shown for year 1997)

SYRINX environmental pl

PROJECT: Ellen Brook 1012

FIGURE #: 31

CLIENT: Swan River Trust

DATE: 23/01/12

APPENDICES

APPENDIX 1 SUMMARY STATISTICS OF KEY ANALYTES FOR EACH TRIAL STATION

STATION NFSIN

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	N D#	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	14.33	29.27	14.94	4.99	25	19.8	3.496	6.992	12.22	17.66	0.008	0	0	164
pH (field)		6.66	7.41	0.75	0.18	26	7	0.1597	0.3194	0.0255	2.28	0.00754	0	0	-20
DO	mg/L	30.6	93.1	62.5	15.9	25	75.9	13.4	26.8	179.8	17.66	0.008	0	0	-112
TOC	mg/L	55	67	12	5	24	60.5	2.99	5.98	8.95	4.95	0.0085	0	0	-66
TSS	mg/L	1	8	7	2	24	4.65	1.75	3.5	3.06	36.24	0.00907	4	1	16
El. Cond.	uS/cm	455	569	114	22.75	26	497.4	20.94	41.88	438.7	4.21	0.00754	0	0	-7
Ca	mg/L	15.5	27.2	11.7	3.5	22	19.86	2.48	4.96	6.14	12.48	0.0097	0	0	80
Mg	mg/L	7.3	11.1	3.8	1.1	22	9.22	0.839	1.678	0.703	9.1	0.0097	0	0	50
Na	mg/L	46.1	69.5	23.4	9.33	22	56.2	6.4	12.8	40.95	11.38	0.0097	0	0	47
K	mg/L	7.3	11.5	4.2	1.405	22	9.04	0.99	1.98	0.98	10.95	0.0097	0	0	98
Cl	mg/L	95	119	24	6	25	106	5.99	11.98	35.8	5.65	0.008	0	0	103
Measured Alkalinity	mg/L	30	65	35	4	25	41.2	7.15	14.3	51.1	17.36	0.008	0	0	189
SO4	mg/L	13.6	24.2	10.6	4.5	25	19.7	2.81	5.62	7.9	14.26	0.008	0	0	-186
F	mg/L	0.05	0.24	0.19	0.03	25	0.0862	0.0546	0.1092	0.002976	49.6	0.0131	28	7	-26
SiO2	mg/L	3.7	13	9.3	4.4	25	7.95	2.74	5.48	7.5	34.46	0.008	0	0	-1
Sr	mg/L	0.012	0.14	0.128	0.0175	22	0.1062	0.0241	0.0482	0.000581	22.7	0.0097	0	0	45
Sulfide	mg/L	0.06	3.5	3.44	0.39	25	0.2866	1.044	2.088	1.09	147.2	0.0316	60	15	-10
DOC	mg/L	55	68	13	4.25	24	60.8	3.14	6.28	9.85	5.17	0.0085	0	0	-45
TN_tot	mg/L	2.2	3.3	1.1	0.4	25	2.67	0.29	0.58	0.084	10.86	0.008	0	0	-56
N_org	mg/L	2	3.1	1.1	0.4	25	2.51	0.2914	0.5828	0.085	11.62	0.008	0	0	-31
NH3	mg/L	0.02	0.26	0.24	0.1	25	0.0726	0.0746	0.1492	0.00557	70.8	0.0274	56	14	-18
NO3	mg/L	0.01	0.05	0.04	0.025	25	0.0436	0.0175	0.035	0.0003067	75.1	0.068	76	19	-2
TP_tot	mg/L	0.66	1.1	0.44	0.12	25	0.848	0.0975	0.195	0.0095	11.5	0.008	0	0	51
TP	mg/L	0.2	0.83	0.63	0.25	25	0.574	0.172	0.344	0.0296	29.94	0.008	0	0	-11
Cr_VI	mg/L	N/A	N/A	N/A	0	25	<0.0050	N/A	#VALUE!	N/A	N/A	N/A	100	25	0
Cesium	mg/L	0.0001	0.0001	0	0	21	5.24E-05	0	0	N/A	N/A	1	95	20	0
Aluminum	mg/L	0.2	0.39	0.19	0.07	22	0.304	0.051	0.102	0.002597	16.76	0.0097	0	0	-97
Cobalt	mg/L	0.0003	0.0004	0.0001	0.0001	21	0.000367	4.83E-05	9.66E-05	0	13.17	0.0104	0	0	16
Chromium	mg/L	0.0009	0.0012	0.0003	0.0001	22	0.001077	9.22E-05	0.000184	8.5E-09	8.56	0.0097	0	0	-33
Copper	mg/L	0.0005	0.0021	0.0016	0.0003	21	0.000945	0.000337	0.000674	1.136E-07	34.04	0.01118	5	1	-60
Iron	mg/L	0.81	1.2	0.39	0.115	22	0.964	0.111	0.222	0.01233	11.52	0.0097	0	0	37
Manganese	mg/L	0.01	0.061	0.051	0.0045	22	0.0155	0.01044	0.02088	0.000109	67.4	0.0097	0	0	43
Molibdenum	mg/L	N/A	N/A	N/A	0	21	<0.0010	N/A	#VALUE!	N/A	N/A	N/A	100	21	0
Nickel	mg/L	0.001	0.001	0	0	21	0.000571	0	0	0	N/A	0.1925	86	18	0
Lead	mg/L	0.0002	0.0006	0.0004	0.0001	21	0.000295	0.000102	0.000205	1.048E-08	34.7	0.0104	0	0	-48
Tin	mg/L	0.0001	0.0007	0.0006	0.0003	21	0.000233	0.000186	0.000371	3.44E-08	67.1	0.01427	19	4	8
Thorium	mg/L	0.0002	0.0003	0.0001	0.0001	21	0.000243	5.07E-05	0.000101	0	20.9	0.0104	0	0	22
Uranium	mg/L	N/A	N/A	N/A	0	21	<0.00010	N/A	#VALUE!	N/A	N/A	N/A	100	21	0
Vanadium	mg/L	0.0016	0.0023	0.0007	0.0003	21	0.001952	0.000199	0.000398	3.96E-08	10.2	0.0104	0	0	-102
Zinc	mg/L	0.005	0.015	0.01	0.002	22	0.00877	0.002202	0.004404	4.85E-06	25.1	0.0097	0	0	-22

STATION AS1AOUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	22	27.5	5.51	0.21	5	24.05	2.055	4.11	4.225	8.55	0.0894	0	0	0
pH (field)		8.25	9.75	1.5	0.95	6	8.95	0.632	1.264	0.4	7.07	0.068	0	0	-13
DO	mg/L	42.7	66.1	23.4	8.4	5	52.1	9.06	18.12	82	17.4	0.0894	0	0	-2
TOC	mg/L	2.1	48	45.9	33.8	5	27.06	21.25	42.5	451.7	78.5	0.0894	0	0	6
TSS	mg/L	1	500	499	193	4	182.5	221.5	443	49045.7	121.3	0.125	0	0	4
El. Cond.	uS/cm	1320	2800	1480	437.5	6	2368.3	564	1128	318136.7	23.8	0.068	0	0	-7
Ca	mg/L	486	617	131	65.5	3	567.3	71	142	5042.3	12.52	0.1925	0	0	-3
Mg	mg/L	13	40.7	27.7	13.85	3	30.7	15.37	30.74	236.3	50.1	0.1925	0	0	-1
Na	mg/L	49.1	62.6	13.5	6.75	3	54	7.45	14.9	55.5	13.78	0.1925	0	0	1
K	mg/L	9.95	10.2	0.25	0.125	3	10.08	0.1258	0.2516	0.01583	1.248	0.1925	0	0	-1
Cl	mg/L	97	116	19	10	5	106.2	7.7	15.4	59.2	7.24	0.0894	0	0	2
Measured Alkalinity	mg/L	15	59	44	36	5	39.2	21	42	440.7	53.6	0.0894	0	0	8
SO4	mg/L	427	1670	1243	330	5	1265.4	499	998	248985.8	39.4	0.0894	0	0	-8
F	mg/L	0.15	0.47	0.32	0.26	5	0.3	0.1528	0.3056	0.02335	50.9	0.0894	0	0	-6
SiO2	mg/L	1.1	7.5	6.4	5.3	5	4.38	3	6	8.99	68.4	0.0894	0	0	6
Sr	mg/L	1.8	8.6	6.8	3.4	3	5.67	3.495	6.99	12.21	61.7	0.1925	0	0	-1
Sulfide	mg/L	0.01	2.8	2.79	1.395	5	0.565	1.973	3.946	3.89	140.4	0.3536	60	3	-1
DOC	mg/L	3.1	44	40.9	33.3	5	26.16	19.6	39.2	384.4	75	0.0894	0	0	6
TN_tot	mg/L	0.37	2.5	2.13	1.21	5	1.512	0.893	1.786	0.798	59.1	0.0894	0	0	6
N_org	mg/L	0.12	2.4	2.28	1.55	5	1.314	0.988	1.976	0.976	75.2	0.0894	0	0	6
NH3	mg/L	0.02	0.29	0.27	0.22	5	0.13	0.1294	0.2588	0.01675	99.6	0.0894	0	0	-4
NO3	mg/L	0.02	0.28	0.26	0.065	5	0.069	0.13	0.26	0.0169	152.9	0.125	20	1	-3
TP_tot	mg/L	0.02	0.17	0.15	0.105	5	0.081	0.0716	0.1432	0.00513	71.6	0.125	20	1	4
TP	mg/L	0.01	0.06	0.05	0.025	5	0.024	0.02517	0.05034	0.000633	68.6	0.1925	40	2	3
Cr_VI	mg/L	0.015	0.027	0.012	0.006	5	0.0099	0.00849	0.01698	0.000072	40.4	0.3536	60	3	-1
Cesium	mg/L	0.0001	0.0003	0.0002	0.0001	3	0.000233	0.000116	0.000231	1.333E-08	49.5	0.1925	0	0	-2
Aluminum	mg/L	0.005	0.032	0.027	0.0135	3	0.01467	0.01504	0.03008	0.0002263	102.6	0.1925	0	0	1
Cobalt	mg/L	0.0005	0.0005	0	0	3	0.0002	0	0	N/A	N/A	1	67	2	0
Chromium	mg/L	0.0005	0.028	0.0275	0.01375	3	0.01583	0.01402	0.02804	0.0001966	88.6	0.1925	0	0	-3
Copper	mg/L	0.0003	0.0008	0.0005	0.00025	3	0.000467	0.000289	0.000577	8.33E-08	61.9	0.1925	0	0	-2
Iron	mg/L	0.11	0.11	0	0	3	0.0383	0	0	N/A	N/A	1	67	2	0
Manganese	mg/L	0.04	0.04	0	0	3	0.01367	0	0	N/A	N/A	1	67	2	0
Molibdenum	mg/L	0.003	0.005	0.002	0.001	3	0.002833	0.001414	0.002828	0.000002	35.36	0.3536	33	1	1
Nickel	mg/L	0.001	0.001	0	0	3	0.000667	0	0	N/A	N/A	1	67	2	0
Lead	mg/L	0.0009	0.0009	0	0	3	0.000333	0	0	N/A	N/A	1	67	2	0
Tin	mg/L	0.0001	0.0005	0.0004	0.0002	3	0.000217	0.000283	0.000566	8E-08	94.3	0.3536	33	1	-1
Thorium	mg/L	N/A	N/A	N/A	0	3	<0.00010	N/A	#VALUE!	N/A	N/A	N/A	100	3	0
Uranium	mg/L	0.0003	0.0009	0.0006	0.0003	3	0.000417	0.000424	0.000848	0	70.7	0.3536	33	1	1
Vanadium	mg/L	0.0008	0.0008	0	0	3	0.0003	0	0	N/A	N/A	1	67	2	0
Zinc	mg/L	0.01	0.012	0.002	0.001	3	0.011	0.001	0.002	0.000001	9.1	0.1925	0	0	-1

STATION AS1BOUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	22.34	30.8	8.46	1.595	6	25.2	2.95	5.9	8.72	11.72	0.068	0	0	5
pH (field)		8.8	9.89	1.09	0.285	7	9.5	0.3616	0.7232	0.1308	3.8	0.054	0	0	-9
DO	mg/L	25	36.4	11.4	6.75	6	30.6	4.74	9.48	22.45	15.5	0.068	0	0	4
TOC	mg/L	1.2	25	23.8	13.4	5	14.96	9.87	19.74	97.3	66	0.0894	0	0	4
TSS	mg/L	7	180	173	86.5	4	48.9	99.6	199.2	9919	153.2	0.1925	25	1	-1
El. Cond.	uS/cm	2190	2860	670	275	7	2578.6	231.1	462.2	53414.3	8.96	0.054	0	0	-17
Ca	mg/L	470	630	160	80	3	553.7	80.3	160.6	6440.3	14.5	0.1925	0	0	-1
Mg	mg/L	14.7	67.3	52.6	26.3	3	36.9	27.24	54.48	742.1	73.8	0.1925	0	0	-1
Na	mg/L	50.4	63.8	13.4	6.7	3	55.2	7.46	14.92	55.7	13.52	0.1925	0	0	3
K	mg/L	9.21	12.3	3.09	1.545	3	10.54	1.59	3.18	2.53	15.1	0.1925	0	0	-1
Cl	mg/L	100	116	16	8	5	108	6.44	12.88	41.5	5.96	0.0894	0	0	6
Measured Alkalinity	mg/L	15	43	28	15	5	30.4	11.35	22.7	128.8	37.3	0.0894	0	0	4
SO4	mg/L	1180	1830	650	240	5	1516	248.6	497.2	61780	16.4	0.0894	0	0	-10
F	mg/L	0.23	0.62	0.39	0.1	5	0.336	0.1647	0.3294	0.02713	49	0.0894	0	0	-6
SiO2	mg/L	1	4.1	3.1	1	5	2.46	1.16	2.32	1.348	47.2	0.0894	0	0	4
Sr	mg/L	1.9	10	8.1	4.05	3	4.8	4.51	9.02	20.37	94	0.1925	0	0	-3
Sulfide	mg/L	0.1	2.2	2.1	0.93	5	0.873	0.888	1.776	0.788	81.5	0.125	20	1	-4
DOC	mg/L	1.4	28	26.6	14	5	16.08	10.77	21.54	116	67	0.0894	0	0	4
TN_tot	mg/L	0.72	1.4	0.68	0.55	5	1.022	0.313	0.626	0.098	30.63	0.0894	0	0	-4
N_org	mg/L	0.02	0.83	0.81	0.31	5	0.472	0.314	0.628	0.0985	66.5	0.0894	0	0	8
NH3	mg/L	0.05	0.29	0.24	0.08	5	0.134	0.0953	0.1906	0.00908	71.1	0.0894	0	0	-2
NO3	mg/L	0.01	0.89	0.88	0.44	5	0.188	0.502	1.004	0.2524	162.1	0.1925	40	2	-3
TP_tot	mg/L	0.07	0.07	0	0	5	0.018	0	0	N/A	N/A	1	80	4	0
TP	mg/L	0.01	0.01	0	0	5	0.006	0	0	N/A	N/A	1	80	4	0
Cr_VI	mg/L	0.063	0.063	0	0	5	0.0146	0	0	N/A	N/A	1	80	4	0
Cesium	mg/L	0.0001	0.0004	0.0003	0.00015	3	0.0002333	0.0001528	0.0003056	2.333E-08	65.5	0.1925	0	0	-3
Aluminum	mg/L	0.014	0.014	0	0	3	0.00633	0	0	N/A	N/A	1	67	2	0
Cobalt	mg/L	0.0002	0.0004	0.0002	0.0001	3	0.0002167	0.0001414	0.0002828	0.00000002	47.1	0.3536	33	1	1
Chromium	mg/L	0.0006	0.066	0.0654	0.0327	3	0.0223	0.0462	0.0924	0.00214	138.9	0.3536	33	1	-1
Copper	mg/L	0.0001	0.0015	0.0014	0.0007	3	0.0009	0.000721	0.001442	0	80.1	0.1925	0	0	-1
Iron	mg/L	0.02	0.023	0.003	0.0015	3	0.01517	0.00212	0.00424	0.0000045	9.87	0.3536	33	1	-1
Manganese	mg/L	0.002	0.013	0.011	0.0055	3	0.00517	0.00778	0.01556	0.0000605	103.7	0.3536	33	1	1
Molibdenum	mg/L	0.002	0.005	0.003	0.0015	3	0.0025	0.00212	0.00424	0.0000045	60.6	0.3536	33	1	-1
Nickel	mg/L	0.002	0.002	0	0	3	0.001	0	0	N/A	N/A	1	67	2	0
Lead	mg/L	0.0001	0.0007	0.0006	0.0003	3	0.0002833	0.000424	0.000848	0	106.1	0.3536	33	1	1
Tin	mg/L	0.002	0.002	0	0	3	0.0007	0	0	N/A	N/A	1	67	2	0
Thorium	mg/L	N/A	N/A	N/A	0	3	<0.00010	N/A	#VALUE!	N/A	N/A	N/A	100	3	0
Uranium	mg/L	0.0006	0.0014	0.0008	0.0004	3	0.000683	0.000566	0.001132	0.00000032	56.6	0.3536	33	1	-1
Vanadium	mg/L	0.0005	0.0005	0	0	3	0.00035	0	0	0	N/A	0.3536	33	1	0
Zinc	mg/L	0.008	0.008	0	0	3	0.00433	0	0	N/A	N/A	1	67	2	0

STATION AS1OUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	N D#	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	20.55	32.3	11.77	1.297	14	25.1	3.28	6.56	10.74	13.06	0.0191	0	0	25
pH (field)		8.97	9.84	0.87	0.25	15	9.53	0.216	0.432	0.0467	2.267	0.0172	0	0	33
DO	mg/L	26.5	52.8	26.3	9.63	14	34.9	9.65	19.3	93.2	27.64	0.0191	0	0	-11
TOC	mg/L	1.1	17	15.9	9.2	14	7.13	5.36	10.72	28.7	70.1	0.02133	7	1	37
TSS	mg/L	1	40	39	13	13	10.15	12.08	24.16	145.9	101.4	0.0274	15	2	3
El. Cond.	uS/cm	2130	3360	1230	100	15	2732.7	256.8	513.6	65949.5	9.4	0.0172	0	0	-80
Ca	mg/L	520	645	125	43.5	12	592.8	33.24	66.48	1104.7	5.61	0.02406	0	0	23
Mg	mg/L	23.5	158	134.5	36.4	12	58.5	41.6	83.2	1727.8	71.1	0.02406	0	0	-42
Na	mg/L	48.9	71.9	23	4.225	12	57.5	6.6	13.2	43.55	11.47	0.02406	0	0	23
K	mg/L	8.76	44.4	35.64	1.513	12	13.72	9.95	19.9	99	72.5	0.02406	0	0	-19
Cl	mg/L	56	116	60	8.75	14	102.6	15.3	30.6	234.6	14.92	0.0191	0	0	0
Measured Alkalinity	mg/L	15	35	20	11.5	14	21.43	6.7	13.4	44.9	31.26	0.0191	0	0	22
SO4	mg/L	1470	2170	700	145	14	1675	190.2	380.4	36165.4	11.35	0.0191	0	0	-59
F	mg/L	0.25	0.69	0.44	0.205	14	0.374	0.1484	0.2968	0.02203	39.65	0.0191	0	0	-67
SiO2	mg/L	0.9	2.2	1.3	0.775	14	1.507	0.48	0.96	0.23	31.8	0.0191	0	0	43
Sr	mg/L	2.5	11	8.5	5.85	12	6.53	3.1	6.2	9.6	47.4	0.02406	0	0	-37
Sulfide	mg/L	0.12	1.2	1.08	0.998	14	0.291	0.545	1.09	0.2975	81.2	0.068	57	8	6
DOC	mg/L	1.1	16	14.9	10.43	14	7.56	5.57	11.14	31.05	73.7	0.0191	0	0	49
TN_tot	mg/L	0.29	4.5	4.21	0.27	14	1.084	1.264	2.528	1.6	116.7	0.0191	0	0	-9
N_org	mg/L	0.06	0.82	0.76	0.38	14	0.3196	0.229	0.458	0.0524	66.6	0.02133	7	1	22
NH3	mg/L	0.07	0.44	0.37	0.1625	14	0.2036	0.1214	0.2428	0.01475	59.7	0.0191	0	0	14
NO3	mg/L	0.01	3.9	3.89	0.43	14	0.551	1.548	3.096	2.395	182.3	0.037	36	5	-30
TP_tot	mg/L	0.01	0.03	0.02	0.01	14	0.00714	0.01414	0.02828	0.0002	70.7	0.3536	86	12	-1
TP	mg/L	N/A	N/A	N/A	0	14	0.00821	N/A	#VALUE!	N/A	N/A	N/A	100	14	0
Cr_VI	mg/L	0.005	0.058	0.053	0.02925	14	0.0157	0.0215	0.043	0.0004615	64.4	0.068	57	8	-10
Cesium	mg/L	0.0002	0.0006	0.0004	0.0001	11	0.0003	0.0001342	0.0002684	0	44.7	0.0274	0	0	-27
Aluminum	mg/L	0.005	0.007	0.002	0.0015	12	0.00425	0.000894	0.001788	0.0000008	14.9	0.068	50	6	8
Cobalt	mg/L	0.0001	0.0003	0.0002	0.0001	11	0.0001	0.0000894	0.0001788	0.000000008	55.9	0.0894	55	6	7
Chromium	mg/L	0.0032	0.064	0.0608	0.0343	12	0.0179	0.02327	0.04654	0.000541	87.1	0.0442	33	4	-20
Copper	mg/L	0.0001	0.0008	0.0007	0.0004	11	0.0004	0.000254	0.000508	6.44E-08	53.1	0.037	18	2	-2
Iron	mg/L	0.009	0.009	0	0	12	0.00304	0	0	N/A	N/A	1	92	11	0
Manganese	mg/L	0.002	0.027	0.025	0.0125	12	0.00321	0.01365	0.0273	0.0001863	120.4	0.1925	75	9	3
Molibdenum	mg/L	0.002	0.005	0.003	0.0015	11	0.00373	0.00101	0.00202	0.000001018	27.07	0.0274	0	0	-15
Nickel	mg/L	0.001	0.001	0	0	11	0.000545	0	0	N/A	N/A	1	91	10	0
Lead	mg/L	0.0001	0.0007	0.0006	0.0003	11	0.0001773	0.000258	0.000516	6.67E-08	64.5	0.125	64	7	0
Tin	mg/L	0.0001	0.0005	0.0004	0.00025	11	0.0001682	0.0001633	0.0003266	2.667E-08	61.2	0.068	45	5	-10
Thorium	mg/L	0.0001	0.0001	0	0	11	0.0000591	0	0	0	N/A	0.3536	82	9	0
Uranium	mg/L	0.0001	0.0018	0.0017	0.0003	11	0.000282	0.000709	0.001418	0	126.6	0.0894	55	6	-3
Vanadium	mg/L	0.0002	0.0004	0.0002	0.000125	11	0.00015	0.0000957	0.0001914	9.17E-09	29.46	0.125	64	7	5
Zinc	mg/L	0.006	0.022	0.016	0.0015	12	0.00592	0.00625	0.0125	0.0000391	67	0.068	50	6	7

STATION AS2AOUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	22.57	29.16	6.59	1.723	4	24.6	3.06	6.12	9.36	12.44	0.125	0	0	2
pH (field)		8.86	10.13	1.27	0.61	5	9.44	0.501	1.002	0.251	5.31	0.0894	0	0	-8
DO	mg/L	44.4	62.2	17.8	4.975	4	55.5	7.7	15.4	59.2	13.87	0.125	0	0	4
TOC	mg/L	1.6	48	46.4	28.8	4	21.68	21.43	42.86	459.2	98.9	0.125	0	0	4
TSS	mg/L	1	49	48	24	3	27	24.25	48.5	588	89.8	0.1925	0	0	1
El. Cond.	uS/cm	984	2770	1786	90	5	2348.8	765	1530	585237.2	32.6	0.0894	0	0	-6
Ca	mg/L	117	612	495	247.5	3	446.7	285.5	571	81510.3	63.9	0.1925	0	0	-1
Mg	mg/L	16.2	35.2	19	9.5	3	26.8	9.69	19.38	93.9	36.15	0.1925	0	0	-1
Na	mg/L	49.7	61.5	11.8	5.9	3	53.7	6.76	13.52	45.6	12.58	0.1925	0	0	1
K	mg/L	9.89	10.2	0.31	0.155	3	10.02	0.1626	0.3252	0.02643	1.623	0.1925	0	0	1
Cl	mg/L	99	115	16	13	4	106.5	8.19	16.38	67	7.69	0.125	0	0	4
Measured Alkalinity	mg/L	15	69	54	37.5	4	38	26.04	52.08	678	68.5	0.125	0	0	4
SO4	mg/L	266	1610	1344	396	4	1254	659.7	1319.4	435264	52.6	0.125	0	0	-5
F	mg/L	0.14	0.44	0.3	0.135	4	0.275	0.128	0.256	0.01637	46.5	0.125	0	0	-4
SiO2	mg/L	1.1	5.9	4.8	3.825	4	3.325	2.434	4.868	5.92	73.2	0.125	0	0	4
Sr	mg/L	0.5	9	8.5	4.25	3	5.17	4.31	8.62	18.6	83.4	0.1925	0	0	-1
Sulfide	mg/L	0.45	5.2	4.75	2.375	4	1.63	2.63	5.26	6.93	121.3	0.1925	25	1	-1
DOC	mg/L	2.3	48	45.7	29.7	4	21.98	21.47	42.94	460.7	97.7	0.125	0	0	4
TN_tot	mg/L	0.34	2	1.66	0.91	4	1.12	0.732	1.464	0.535	65.3	0.125	0	0	4
N_org	mg/L	0.09	2	1.91	0.973	4	0.958	0.831	1.662	0.691	86.8	0.125	0	0	4
NH3	mg/L	0.04	0.25	0.21	0.18	4	0.145	0.1103	0.2206	0.01217	76.1	0.125	0	0	-2
NO3	mg/L	0.02	0.14	0.12	0.06	4	0.0513	0.0643	0.1286	0.00413	96.4	0.1925	25	1	-1
TP_tot	mg/L	0.01	0.32	0.31	0.155	4	0.0938	0.171	0.342	0.02923	138.6	0.1925	25	1	1
TP	mg/L	0.01	0.24	0.23	0.115	4	0.065	0.1626	0.3252	0.02645	130.1	0.3536	50	2	1
Cr_VI	mg/L	0.022	0.025	0.003	0.0015	4	0.013	0.00212	0.00424	0.0000045	9.03	0.3536	50	2	-1
Cesium	mg/L	0.0001	0.0003	0.0002	0.0001	3	0.0002	0.0001	0.0002	0.00000001	50	0.1925	0	0	-1
Aluminum	mg/L	0.076	0.076	0	0	3	0.027	0	0	N/A	N/A	1	67	2	0
Cobalt	mg/L	0.0006	0.0006	0	0	3	0.000233	0	0	N/A	N/A	1	67	2	0
Chromium	mg/L	0.0009	0.027	0.0261	0.01305	3	0.0183	0.01507	0.03014	0.000227	82.3	0.1925	0	0	-2
Copper	mg/L	0.0007	0.0016	0.0009	0.00045	3	0.000783	0.000636	0.001272	0	55.3	0.3536	33	1	1
Iron	mg/L	0.23	0.23	0	0	3	0.0783	0	0	N/A	N/A	1	67	2	0
Manganese	mg/L	0.011	0.011	0	0	3	0.004	0	0	N/A	N/A	1	67	2	0
Molibdenum	mg/L	0.003	0.005	0.002	0.001	3	0.002833	0.001414	0.002828	0.000002	35.36	0.3536	33	1	1
Nickel	mg/L	0.002	0.002	0	0	3	0.001	0	0	N/A	N/A	1	67	2	0
Lead	mg/L	0.0002	0.0024	0.0022	0.0011	3	0.000883	0.001556	0.003112	0	119.7	0.3536	33	1	-1
Tin	mg/L	0.0002	0.0002	0	0	3	0.0001	0	0	N/A	N/A	1	67	2	0
Thorium	mg/L	0.0001	0.0001	0	0	3	6.67E-05	0	0	N/A	N/A	1	67	2	0
Uranium	mg/L	0.0005	0.0005	0	0	3	0.0002	0	0	N/A	N/A	1	67	2	0
Vanadium	mg/L	0.0011	0.0011	0	0	3	0.0004	0	0	N/A	N/A	1	67	2	0
Zinc	mg/L	0.046	0.046	0	0	3	0.017	0	0	N/A	N/A	1	67	2	0

STATION AS2BOUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	24	29	5.02	1.998	4	25.5	2.374	4.748	5.64	9.3	0.125	0	0	2
pH (field)		9.17	10.1	0.93	0.23	5	9.72	0.3474	0.6948	0.1207	3.575	0.0894	0	0	-8
DO	mg/L	19.1	54.4	35.3	11.38	4	32	15.47	30.94	239.4	48.3	0.125	0	0	4
TOC	mg/L	3.6	32	28.4	14.2	4	11.05	15.26	30.52	233	104.8	0.1925	25	1	3
TSS	mg/L	5	24	19	9.5	3	13	9.85	19.7	97	75.8	0.1925	0	0	-1
El. Cond.	uS/cm	1840	2780	940	110	5	2552	401.1	802.2	160870	15.72	0.0894	0	0	-6
Ca	mg/L	374	638	264	132	3	542	146	292	21312	26.93	0.1925	0	0	-1
Mg	mg/L	23.1	49.4	26.3	13.15	3	36	13.16	26.32	173.1	36.5	0.1925	0	0	-3
Na	mg/L	50.8	62.7	11.9	5.95	3	55	6.68	13.36	44.6	12.14	0.1925	0	0	3
K	mg/L	9.77	11.2	1.43	0.715	3	10.62	0.754	1.508	0.569	7.1	0.1925	0	0	-1
Cl	mg/L	100	113	13	8.5	4	106	6.06	12.12	36.7	5.71	0.125	0	0	4
Measured Alkalinity	mg/L	15	50	35	12.5	4	26.5	16	32	256.3	60.4	0.125	0	0	6
SO4	mg/L	913	1710	797	206.8	4	1463.3	369.6	739.2	136588.9	25.26	0.125	0	0	-6
F	mg/L	0.21	0.45	0.24	0.18	4	0.345	0.119	0.238	0.01417	34.5	0.125	0	0	-6
SiO2	mg/L	1	3.6	2.6	1.1	4	1.85	1.207	2.414	1.457	65.2	0.125	0	0	6
Sr	mg/L	1.5	9.9	8.4	4.2	3	6.03	4.24	8.48	17.97	70.3	0.1925	0	0	-3
Sulfide	mg/L	0.39	4.6	4.21	2.105	4	1.386	2.386	4.772	5.69	129.2	0.1925	25	1	-3
DOC	mg/L	1.3	34	32.7	11.63	4	11.98	15	30	224.7	125.2	0.125	0	0	6
TN_tot	mg/L	0.35	1.4	1.05	0.66	4	0.905	0.481	0.962	0.2318	53.2	0.125	0	0	2
N_org	mg/L	0.17	1.3	1.13	0.365	4	0.54	0.515	1.03	0.2655	95.4	0.125	0	0	4
NH3	mg/L	0.14	0.26	0.12	0.0525	4	0.1825	0.0544	0.1088	0.00296	29.8	0.125	0	0	2
NO3	mg/L	0.01	0.78	0.77	0.385	4	0.2063	0.439	0.878	0.1926	160.6	0.1925	25	1	-1
TP_tot	mg/L	0.01	0.07	0.06	0.03	4	0.0225	0.0424	0.0848	0.0018	106.1	0.3536	50	2	1
TP	mg/L	0.01	0.01	0	0	4	0.00625	0	0	N/A	N/A	1	75	3	0
Cr_VI	mg/L	0.015	0.057	0.042	0.021	4	0.01925	0.0297	0.0594	0.000882	82.5	0.3536	50	2	-1
Cesium	mg/L	0.0001	0.0003	0.0002	0.0001	3	0.000233	0.000116	0.000231	1.333E-08	49.5	0.1925	0	0	-2
Aluminum	mg/L	0.01	0.01	0	0	3	0.005	0	0	N/A	N/A	1	67	2	0
Cobalt	mg/L	0.0004	0.0004	0	0	3	0.000167	0	0	N/A	N/A	1	67	2	0
Chromium	mg/L	0.0006	0.063	0.0624	0.0312	3	0.0272	0.0322	0.0644	0.001037	118.4	0.1925	0	0	-3
Copper	mg/L	0.0003	0.0017	0.0014	0.0007	3	0.000833	0.000757	0.001514	5.73E-07	90.9	0.1925	0	0	3
Iron	mg/L	0.028	0.028	0	0	3	0.011	0	0	N/A	N/A	1	67	2	0
Manganese	mg/L	0.009	0.009	0	0	3	0.00333	0	0	N/A	N/A	1	67	2	0
Molibdenum	mg/L	0.001	0.005	0.004	0.002	3	0.003333	0.00208	0.00416	0.00000433	62.4	0.1925	0	0	-3
Nickel	mg/L	0.002	0.002	0	0	3	0.001	0	0	N/A	N/A	1	67	2	0
Lead	mg/L	0.0004	0.0004	0	0	3	0.000167	0	0	N/A	N/A	1	67	2	0
Tin	mg/L	0.0001	0.0003	0.0002	0.0001	3	0.00015	0.000141	0.000283	0.00000002	70.7	0.3536	33	1	1
Thorium	mg/L	N/A	N/A	N/A	0	3	<0.00010	N/A	#VALUE!	N/A	N/A	N/A	100	3	0
Uranium	mg/L	0.0008	0.0008	0	0	3	0.0003	0	0	N/A	N/A	1	67	2	0
Vanadium	mg/L	0.0005	0.0005	0	0	3	0.0002	0	0	N/A	N/A	1	67	2	0
Zinc	mg/L	0.006	0.011	0.005	0.0025	3	0.0065	0.003536	0.007072	0.0000125	41.6	0.3536	33	1	1

STATION AS2OUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	20.13	30.6	10.5	2.28	13	24.8	2.833	5.666	8.03	11.41	0.02133	0	0	30
pH (field)		9.08	9.96	0.88	0.26	14	9.62	0.218	0.436	0.0475	2.265	0.0191	0	0	-3
DO	mg/L	23.2	66.5	43.3	10.6	13	37.45	12.17	24.34	148.2	32.5	0.02133	0	0	-12
TOC	mg/L	1.1	20	18.9	5.35	13	5.78	6.71	13.42	45.1	99.5	0.0274	15	2	26
TSS	mg/L	1	39	38	26	12	15.38	15.3	30.6	234.2	91.5	0.0274	8	1	9
El. Cond.	uS/cm	2380	3150	770	72.5	14	2720	177.5	355	31492.3	6.52	0.0191	0	0	-64
Ca	mg/L	525	638	113	58.3	12	590.3	36.14	72.28	1305.9	6.12	0.02406	0	0	8
Mg	mg/L	27.6	115	87.4	28.6	12	48.8	28.55	57.1	815.1	58.5	0.02406	0	0	-37
Na	mg/L	50.6	74.9	24.3	8.3	12	59.2	7.54	15.08	56.8	12.73	0.02406	0	0	17
K	mg/L	9.14	41.4	32.26	1.865	12	13.87	9.06	18.12	82.1	65.3	0.02406	0	0	-23
Cl	mg/L	97	142	45	15	13	109.8	12.44	24.88	154.8	11.33	0.02133	0	0	13
Measured Alkalinity	mg/L	15	34	19	6	13	20.08	6.8	13.6	46.2	33.9	0.02133	0	0	19
SO4	mg/L	1320	1920	600	150	13	1611.5	154.7	309.4	23947.4	9.6	0.02133	0	0	-44
F	mg/L	0.2	0.81	0.61	0.23	13	0.366	0.1817	0.3634	0.033	49.6	0.02133	0	0	-44
SiO2	mg/L	0.8	2.7	1.9	0.5	13	1.446	0.588	1.176	0.346	40.7	0.02133	0	0	44
Sr	mg/L	2.2	11	8.8	2.975	12	6.63	3.003	6.006	9.02	45.3	0.02406	0	0	-43
Sulfide	mg/L	0.03	2	1.97	1.41	13	0.606	0.739	1.478	0.546	84.6	0.037	31	4	-14
DOC	mg/L	1.1	20	18.9	5.78	13	6.12	6.7	13.4	44.9	101.8	0.02406	8	1	33
TN_tot	mg/L	0.29	4.1	3.81	0.57	13	1.06	1.228	2.456	1.51	115.8	0.02133	0	0	-3
N_org	mg/L	0.07	1.2	1.13	0.59	13	0.3985	0.357	0.714	0.1274	89.6	0.02133	0	0	21
NH3	mg/L	0.03	0.38	0.35	0.11	13	0.1985	0.0979	0.1958	0.00958	49.3	0.02133	0	0	17
NO3	mg/L	0.01	2.8	2.79	0.61	13	0.444	1.084	2.168	1.175	169.6	0.037	31	4	-26
TP_tot	mg/L	0.02	0.02	0	0	13	0.00615	0	0	N/A	N/A	1	92	12	0
TP	mg/L	N/A	N/A	N/A	0	13	0.00846	N/A	#VALUE!	N/A	N/A	N/A	100	13	0
Cr_VI	mg/L	0.006	0.067	0.061	0.03225	13	0.0195	0.0224	0.0448	0.000503	74.4	0.0442	38	5	-19
Cesium	mg/L	0.0002	0.0006	0.0004	0.00005	11	0.000318	0.000125	0.00025	1.564E-08	39.3	0.0274	0	0	-33
Aluminum	mg/L	0.005	0.01	0.005	0.0025	12	0.003625	0.002646	0.005292	0.000007	37.8	0.1925	75	9	1
Cobalt	mg/L	0.0001	0.0003	0.0002	0.0001	11	8.18E-05	0.000116	0.000231	1.333E-08	69.3	0.1925	73	8	2
Chromium	mg/L	0.0012	0.082	0.0808	0.0346	12	0.02344	0.0276	0.0552	0.000763	98.3	0.0316	17	2	-39
Copper	mg/L	0.0001	0.0012	0.0011	0.0004	11	0.000327	0.000344	0.000689	1.186E-07	88.6	0.037	18	2	-9
Iron	mg/L	0.006	0.023	0.017	0.0085	12	0.0045	0.01202	0.02404	0.0001445	82.9	0.3536	83	10	-1
Manganese	mg/L	0.002	0.021	0.019	0.0095	12	0.002333	0.01344	0.02688	0.0001805	116.8	0.3536	83	10	1
Molibdenum	mg/L	0.002	0.006	0.004	0.0015	11	0.00382	0.00125	0.0025	1.564E-06	32.75	0.0274	0	0	-28
Nickel	mg/L	0.001	0.001	0	0	11	0.000545	0	0	N/A	N/A	1	91	10	0
Lead	mg/L	0.0001	0.0019	0.0018	0.000075	11	0.000286	0.000697	0.001394	4.86E-07	144.2	0.068	45	5	2
Tin	mg/L	0.0001	0.0007	0.0006	0.0003	11	0.000173	0.000249	0.000498	0	77.8	0.0894	55	6	-5
Thorium	mg/L	N/A	N/A	N/A	0	11	<0.00010	N/A	#VALUE!	N/A	N/A	N/A	100	11	0
Uranium	mg/L	0.0004	0.0024	0.002	0.001	11	0.000296	0.001414	0.002828	0.000002	101	0.3536	82	9	-1
Vanadium	mg/L	0.0002	0.0005	0.0003	0.00015	11	0.000127	0.000153	0.000306	2.333E-08	45.8	0.1925	73	8	3
Zinc	mg/L	0.005	0.006	0.001	0.00025	12	0.00358	0.0005	0.001	0.00000025	8.7	0.125	67	8	3

STATION PS1OUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	15.85	25.9	10.05	3	27	20.34	2.585	5.17	6.68	12.7	0.00713	0	0	247
pH (field)		9.62	11.3	1.67	0.235	28	10.04	0.312	0.624	0.0974	3.11	0.00675	0	0	-173
DO	mg/L	16.5	78.8	62.3	18.8	27	49.7	16.25	32.5	264	32.7	0.00713	0	0	-198
TOC	mg/L	13	61	48	8	18	50.3	10.37	20.74	107.5	20.62	0.0131	0	0	-17
TSS	mg/L	1	73	72	2	27	4.56	15.5	31	240.4	271.3	0.0104	22	6	58
El. Cond.	uS/cm	563	2700	2137	36.75	28	745.4	442.1	884.2	195475.1	59.3	0.00675	0	0	-138
Ca	mg/L	22.2	586	563.8	8.5	21	74.9	131.6	263.2	17324.3	175.6	0.0104	0	0	-136
Mg	mg/L	4.3	25.9	21.6	5.4	21	19.67	5.2	10.4	27.04	26.43	0.0104	0	0	122
Na	mg/L	43.8	65	21.2	9.4	21	55.7	6.42	12.84	41.2	11.52	0.0104	0	0	55
K	mg/L	7.12	10.6	3.48	1.61	21	8.89	1.005	2.01	1.01	11.3	0.0104	0	0	43
Cl	mg/L	95	125	30	13	25	107.7	8.23	16.46	67.8	7.65	0.008	0	0	56
Measured Alkalinity	mg/L	63	110	47	12	25	86.5	12.36	24.72	152.8	14.3	0.008	0	0	213
SO4	mg/L	17.1	1410	1392.9	19.5	25	143.7	305.1	610.2	93095.4	212.4	0.008	0	0	-262
F	mg/L	0.05	0.32	0.27	0.09	25	0.0872	0.0964	0.1928	0.0093	74.9	0.0172	40	10	-12
SiO2	mg/L	2.7	7.9	5.2	1.4	25	4.12	1.42	2.84	2.02	34.5	0.008	0	0	-44
Sr	mg/L	0.13	3.6	3.47	0.04	21	0.413	0.773	1.546	0.598	187.1	0.0104	0	0	-99
Sulfide	mg/L	0.03	0.58	0.55	0.36	25	0.158	0.182	0.364	0.0331	60.8	0.02133	48	12	-33
DOC	mg/L	14	62	48	5.5	18	50.1	10	20	99.9	19.94	0.0131	0	0	-29
TN_tot	mg/L	0.76	2.7	1.94	0.4	28	2.25	0.3655	0.731	0.1336	16.23	0.00675	0	0	97
N_org	mg/L	0.66	2.6	1.94	0.325	28	2.077	0.345	0.69	0.1192	16.62	0.00675	0	0	109
NH3	mg/L	0.02	0.16	0.14	0.07	28	0.0634	0.04585	0.0917	0.002103	55.7	0.02133	54	15	22
NO3	mg/L	0.03	0.25	0.22	0.03	28	0.0625	0.0663	0.1326	0.00439	86.1	0.02133	54	15	-38
TP_tot	mg/L	0.05	0.36	0.31	0.1	28	0.1584	0.0956	0.1912	0.00913	58.2	0.00713	4	1	26
TP	mg/L	0.03	0.28	0.25	0.16	28	0.113	0.0828	0.1656	0.00686	52.9	0.01427	39	11	34
Cr_VI	mg/L	0.014	0.014	0	0	25	0.00296	0	0	N/A	N/A	1	96	24	0
Cesium	mg/L	0.0001	0.0002	0.0001	0	18	6.94E-05	4.47E-05	8.94E-05	2E-09	37.3	0.0894	72	13	-4
Aluminum	mg/L	0.018	0.097	0.079	0.014	21	0.0469	0.0181	0.0362	0.000328	38.65	0.0104	0	0	-39
Cobalt	mg/L	0.0001	0.0011	0.001	0.000275	18	0.0005	0.000259	0.000518	6.7E-08	51.8	0.0131	0	0	131
Chromium	mg/L	0.0005	0.014	0.0135	0.001	21	0.00181	0.00296	0.00592	0.00000877	150.1	0.01207	10	2	-103
Copper	mg/L	0.0011	0.0033	0.0022	0.000525	18	0.00271	0.00053	0.00106	2.81E-07	19.55	0.0131	0	0	29
Iron	mg/L	0.006	0.44	0.434	0.14	21	0.2417	0.1104	0.2208	0.01218	45.7	0.0104	0	0	-35
Manganese	mg/L	0.002	0.024	0.022	0.00425	21	0.01126	0.00538	0.01076	0.0000289	45.6	0.01118	5	1	80
Molibdenum	mg/L	0.001	0.001	0	0	18	0.000583	0	0	0	N/A	0.1925	83	15	0
Nickel	mg/L	0.001	0.003	0.002	0	18	0.002028	0.0006	0.0012	0.00000036	28.34	0.01427	6	1	74
Lead	mg/L	0.0005	0.0021	0.0016	0.0005	18	0.000989	0.000411	0.000823	1.693E-07	41.6	0.0131	0	0	42
Tin	mg/L	0.0001	0.0005	0.0004	0.00015	18	0.000125	0.000151	0.000302	2.286E-08	62.3	0.054	61	11	-13
Thorium	mg/L	0.0001	0.0004	0.0003	0.0001	18	0.000233	8.92E-05	0.000178	7.96E-09	34.8	0.01563	11	2	27
Uranium	mg/L	0.0003	0.0028	0.0025	0.000775	18	0.00124	0.000692	0.001384	4.79E-07	55.9	0.0131	0	0	124
Vanadium	mg/L	0.0009	0.0017	0.0008	0.0002	18	0.00145	0.000215	0.00043	4.62E-08	14.82	0.0131	0	0	49
Zinc	mg/L	0.006	0.013	0.007	0.005	21	0.00431	0.00306	0.00612	0.00000937	34.65	0.068	71	15	-8

STATION PS2OUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	14.47	24.8	10.33	2.91	25	19.56	2.47	4.94	6.1	12.62	0.008	0	0	204
pH (field)		9.72	11.47	1.75	0.3	26	10.17	0.38	0.76	0.1442	3.734	0.00754	0	0	-218
DO	mg/L	25.2	75.9	50.7	23.3	25	47.5	14.37	28.74	206.5	30.26	0.008	0	0	-82
TOC	mg/L	10	58	48	5.25	18	48.6	10.96	21.92	120.1	22.57	0.0131	0	0	-27
TSS	mg/L	1	2	1	1	24	0.938	0.48	0.96	0.2308	36.7	0.02133	46	11	-12
El. Cond.	uS/cm	584	2840	2256	58.3	26	802.9	542.5	1085	294324	67.6	0.00754	0	0	-127
Ca	mg/L	26	575	549	15.3	21	86.7	146.1	292.2	21331.1	168.4	0.0104	0	0	-134
Mg	mg/L	2.5	28.9	26.4	4.2	21	19.8	5.86	11.72	34.36	29.6	0.0104	0	0	165
Na	mg/L	46.5	70.4	23.9	8.9	21	55.9	6.25	12.5	39.1	11.2	0.0104	0	0	75
K	mg/L	7.48	12.5	5.02	1.58	20	9.1	1.246	2.492	1.553	13.68	0.01118	0	0	32
Cl	mg/L	60	148	88	12.5	24	108	15.5	31	240.7	14.37	0.0085	0	0	0
Measured Alkalinity	mg/L	65	109	44	14	24	89.7	12.23	24.46	149.5	13.63	0.0085	0	0	228
SO4	mg/L	35.1	1430	1394.9	21.7	23	134.1	300.7	601.4	90428.8	224.3	0.00907	0	0	-160
F	mg/L	0.05	0.31	0.26	0.0575	24	0.0729	0.0961	0.1922	0.00924	79.6	0.02406	50	12	-39
SiO2	mg/L	2.3	7	4.7	0.425	24	3.49	1.135	2.27	1.287	32.5	0.0085	0	0	-114
Sr	mg/l	0.15	3.7	3.55	0.04	20	0.4775	0.856	1.712	0.733	179.3	0.01118	0	0	-66
Sulfide	mg/L	0.01	0.85	0.84	0.2425	24	0.1954	0.2656	0.5312	0.0706	68.8	0.02406	50	12	-21
DOC	mg/L	10	58	48	4	17	48.5	11.28	22.56	127.1	23.26	0.01427	0	0	-5
TN_tot	mg/L	0.6	2.6	2	0.325	24	2.096	0.395	0.79	0.156	18.85	0.0085	0	0	3
N_org	mg/L	0.51	2.4	1.89	0.325	24	1.91	0.369	0.738	0.136	19.33	0.0085	0	0	14
NH3	mg/L	0.02	0.26	0.24	0.07	24	0.0606	0.0773	0.1546	0.00598	92.8	0.037	63	15	-3
NO3	mg/l	0.06	0.19	0.13	0.08	24	0.0733	0.0455	0.091	0.00207	40.5	0.037	63	15	15
TP_tot	mg/L	0.02	0.25	0.23	0.0675	24	0.0933	0.0531	0.1062	0.00282	52.4	0.0097	8	2	-139
TP	mg/L	0.02	0.18	0.16	0.06	24	0.056	0.0546	0.1092	0.00298	81.2	0.0274	54	13	-8
Cr_VI	mg/L	0.018	0.018	0	0	24	0.003146	0	0	N/A	N/A	1	96	23	0
Cesium	mg/L	0.0001	0.0002	0.0001	0.00005	17	6.47E-05	5.77E-05	0.000115	3.33E-09	43.3	0.1925	82	14	-2
Aluminum	mg/L	0.008	0.068	0.06	0.0095	20	0.03465	0.01238	0.02476	0.0001533	35.7	0.01118	0	0	-26
Cobalt	mg/L	0.0002	0.0009	0.0007	0.00015	17	0.000427	0.000183	0.000365	3.33E-08	40.6	0.01563	6	1	97
Chromium	mg/L	0.0005	0.018	0.0175	0.001	20	0.002038	0.00407	0.00814	0.0000166	173.1	0.01427	15	3	-109
Copper	mg/L	0.001	0.0032	0.0022	0.0005	17	0.00247	0.000538	0.001076	2.897E-07	21.8	0.01427	0	0	79
Iron	mg/L	0.041	0.4	0.359	0.11	20	0.2112	0.0955	0.191	0.00911	43	0.01207	5	1	-72
Manganese	mg/L	0.002	0.019	0.017	0.0025	20	0.01053	0.00429	0.00858	0.0000184	38.8	0.01207	5	1	16
Molibdenum	mg/L	0.001	0.001	0	0	17	0.000529	0	0	N/A	N/A	1	94	16	0
Nickel	mg/L	0.002	0.003	0.001	0	17	0.001794	0.000267	0.000534	7.14E-08	12.9	0.0191	18	3	13
Lead	mg/L	0.0005	0.0027	0.0022	0.0004	17	0.0009	0.000542	0.001084	2.94E-07	60.2	0.01427	0	0	19
Tin	mg/L	0.0001	0.0002	0.0001	0.00005	17	6.18E-05	7.07E-05	0.000141	5E-09	47.1	0.3536	88	15	1
Thorium	mg/L	0.0002	0.0006	0.0004	0.0001	17	0.000232	0.000107	0.000214	1.143E-08	39.4	0.0191	18	3	21
Uranium	mg/L	0.0003	0.0021	0.0018	0.0005	17	0.000888	0.000487	0.000974	2.374E-07	54.8	0.01427	0	0	116
Vanadium	mg/L	0.0008	0.0017	0.0009	0.0002	17	0.001318	0.000224	0.000449	5.03E-08	17.02	0.01427	0	0	34
Zinc	mg/L	0.005	0.009	0.004	0.0015	20	0.00445	0.001506	0.003012	2.267E-06	23.52	0.0316	50	10	3

STATION PS3OUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	15.98	25.2	9.2	3.325	27	20.17	2.5	5	6.25	12.4	0.00713	0	0	234
pH (field)		9.45	10.55	1.1	0.235	28	9.83	0.2744	0.5488	0.0753	2.79	0.00675	0	0	-201
DO	mg/L	15.9	89.7	73.8	17.9	27	47.4	16.82	33.64	283	35.5	0.00713	0	0	-196
TOC	mg/L	9	55	46	2.75	18	46.5	14.23	28.46	202.4	30.6	0.0131	0	0	18
TSS	mg/L	1	120	119	3	27	6.48	27.04	54.08	731	300.4	0.01207	30	8	-4
El. Cond.	uS/cm	554	2620	2066	134.3	28	862.5	613.7	1227.4	376570.9	71.2	0.00675	0	0	-231
Ca	mg/L	23.1	563	539.9	44.2	21	118.5	182.2	364.4	33205.6	153.8	0.0104	0	0	-175
Mg	mg/L	13.6	23.5	9.9	4.1	21	18.9	2.94	5.88	8.65	15.57	0.0104	0	0	123
Na	mg/L	47.6	71.4	23.8	9.2	21	56.9	6.25	12.5	39.05	10.99	0.0104	0	0	64
K	mg/L	7.79	11.7	3.91	1.34	21	9.2	0.94	1.88	0.884	10.22	0.0104	0	0	49
Cl	mg/L	96	126	30	12	25	109.9	8.62	17.24	74.3	7.84	0.008	0	0	80
Measured Alkalinity	mg/L	30	103	73	12	25	79.4	18.76	37.52	351.9	23.6	0.008	0	0	228
SO4	mg/L	15.8	1520	1504.2	75.9	25	243.2	465	930	216185.1	191.2	0.008	0	0	-271
F	mg/L	0.05	0.56	0.51	0.0625	25	0.131	0.133	0.266	0.01766	91.4	0.0097	12	3	-10
SiO2	mg/L	2.3	7.6	5.3	1.4	25	4.39	1.298	2.596	1.686	29.56	0.008	0	0	43
Sr	mg/L	0.14	5.1	4.96	0.17	21	0.729	1.338	2.676	1.79	183.6	0.0104	0	0	-166
Sulfide	mg/L	0.01	0.93	0.92	0.2575	25	0.1526	0.338	0.676	0.1143	125.9	0.0191	44	11	-15
DOC	mg/L	8.8	58	49.2	2	18	47.2	14.7	29.4	215.8	31.15	0.0131	0	0	20
TN_tot	mg/L	0.56	2.7	2.14	0.3	28	2.13	0.516	1.032	0.266	24.2	0.00675	0	0	165
N_org	mg/L	0.45	2.4	1.95	0.225	28	1.957	0.483	0.966	0.2335	24.7	0.00675	0	0	199
NH3	mg/L	0.02	0.14	0.12	0.075	28	0.0555	0.0464	0.0928	0.002156	66.3	0.0316	64	18	29
NO3	mg/L	0.02	0.14	0.12	0.045	28	0.0561	0.0378	0.0756	0.001427	58.9	0.02406	57	16	2
TP_tot	mg/L	0.01	0.3	0.29	0.06	28	0.1014	0.0871	0.1742	0.00759	80	0.00754	7	2	89
TP	mg/L	0.04	0.24	0.2	0.17	28	0.0759	0.085	0.17	0.00723	58.4	0.037	68	19	20
Cr_VI	mg/L	0.007	0.025	0.018	0.009	25	0.00358	0.01273	0.02546	0.000162	79.5	0.3536	92	23	-1
Cesium	mg/L	0.0001	0.0002	0.0001	0.000025	18	6.67E-05	0.00005	0.0001	0	40	0.125	78	14	-3
Aluminum	mg/L	0.019	0.054	0.035	0.009	21	0.0389	0.00792	0.01584	0.0000628	20.37	0.0104	0	0	-2
Cobalt	mg/L	0.0001	0.0021	0.002	0.000625	18	0.000833	0.000558	0.001116	3.12E-07	67	0.0131	0	0	142
Chromium	mg/L	0.0006	0.024	0.0234	0.0007	21	0.002795	0.00514	0.01028	0.00002645	184	0.0104	0	0	-137
Copper	mg/L	0.0008	0.0049	0.0041	0.000975	18	0.003133	0.00117	0.00234	1.367E-06	37.3	0.0131	0	0	111
Iron	mg/L	0.007	0.43	0.423	0.1	21	0.221	0.112	0.224	0.01255	50.7	0.0104	0	0	34
Manganese	mg/L	0.008	0.06	0.052	0.00975	21	0.0231	0.01107	0.02214	0.0001226	41.2	0.0131	14	3	95
Molibdenum	mg/L	0.001	0.002	0.001	0.00025	18	0.000833	0.000463	0.000926	2.143E-07	37	0.0442	56	10	0
Nickel	mg/L	0.002	0.004	0.002	0.001	18	0.00236	0.000799	0.001598	6.38E-07	29.2	0.0172	17	3	67
Lead	mg/L	0.0005	0.0015	0.001	0.000275	18	0.000856	0.000255	0.00051	6.5E-08	29.8	0.0131	0	0	57
Tin	mg/L	0.0001	0.0006	0.0005	0.00025	18	0.000131	0.00019	0.00038	3.62E-08	74	0.054	61	11	-2
Thorium	mg/L	0.0002	0.0004	0.0002	0.0001	18	0.000236	7.04E-05	0.000141	4.95E-09	25.75	0.0172	17	3	24
Uranium	mg/L	0.0003	0.0024	0.0021	0.000275	18	0.00124	0.000549	0.001098	3.013E-07	44.3	0.0131	0	0	112
Vanadium	mg/L	0.0006	0.0012	0.0006	0.0002	18	0.000989	0.000181	0.000362	3.28E-08	18.3	0.0131	0	0	90
Zinc	mg/L	0.006	0.013	0.007	0.00325	21	0.0054	0.00246	0.00492	0.00000604	28.6	0.0316	52	11	-1

STATION PS4OUT

Parameter	Unit	Minimum	Maximum	Range (Max-Min)	Inter Quartile Range (Q75-Q25)	Number of Samples	Arithmetic Mean	Standard deviation	2x Std Dev	Variance	Deviation coefficient	Skewness	Percent Nondetects	ND #	Mann Kendall Statistic indicating increasing or decreasing trend
Temperature	°C	15.98	26.6	10.63	3.37	25	20.4	2.53	5.06	6.4	12.4	0.008	0	0	194
pH (field)		9.55	10.76	1.21	0.205	26	9.85	0.239	0.478	0.0571	2.426	0.00754	0	0	-120
DO	mg/L	33.9	90.2	56.3	10.7	25	53.5	11.78	23.56	138.8	22	0.008	0	0	-25
TOC	mg/L	12	59	47	4.75	18	50.3	11	22	120.9	21.85	0.0131	0	0	-10
TSS	mg/L	1	9	8	1	24	1.52	2.18	4.36	4.76	91.5	0.02133	46	11	-26
El. Cond.	uS/cm	564	2610	2046	71.3	26	802.5	541.4	1082.8	293165.5	67.5	0.00754	0	0	-121
Ca	mg/L	24.1	560	535.9	15.9	21	92.4	155	310	24025.1	167.8	0.0104	0	0	-160
Mg	mg/L	10.4	27.7	17.3	5.2	21	19.14	4	8	15.97	20.87	0.0104	0	0	170
Na	mg/L	48	68.7	20.7	6.8	21	56.7	5.93	11.86	35.2	10.47	0.0104	0	0	40
K	mg/L	7.64	12.5	4.86	1.79	21	9.08	1.142	2.284	1.304	12.58	0.0104	0	0	30
Cl	mg/L	95	129	34	8	25	108.4	9.11	18.22	83	8.4	0.008	0	0	54
Measured Alkalinity	mg/L	43	113	70	25	25	84	18.3	36.6	335.5	21.8	0.008	0	0	286
SO4	mg/L	25.3	1390	1364.7	35	25	181.1	372.6	745.2	138836.8	205.8	0.008	0	0	-282
F	mg/L	0.06	0.48	0.42	0.05	25	0.1198	0.1089	0.2178	0.01186	75.9	0.01118	20	5	-21
SiO2	mg/L	2.9	8.5	5.6	0.6	25	4.26	1.347	2.694	1.814	31.6	0.008	0	0	-138
Sr	mg/L	0.14	4.4	4.26	0.07	21	0.521	1.005	2.01	1.01	192.7	0.0104	0	0	-125
Sulfide	mg/L	0.03	0.95	0.92	0.26	25	0.134	0.3224	0.6448	0.104	127.4	0.02133	48	12	-34
DOC	mg/L	11	61	50	3.75	18	50.7	11.46	22.92	131.4	22.6	0.0131	0	0	4
TN_tot	mg/L	0.63	3	2.37	0.2	25	2.193	0.4254	0.8508	0.181	19.4	0.008	0	0	42
N_org	mg/L	0.54	2.8	2.26	0.3	25	2.006	0.402	0.804	0.1613	20.02	0.008	0	0	42
NH3	mg/L	0.01	0.15	0.14	0.025	25	0.0482	0.0434	0.0868	0.001886	86.8	0.0442	68	17	-1
NO3	mg/L	0.05	0.18	0.13	0.0325	25	0.082	0.03916	0.07832	0.001533	33.56	0.02406	52	13	38
TP_tot	mg/L	0.02	0.18	0.16	0.0725	25	0.1034	0.0451	0.0902	0.002037	42	0.0085	4	1	-98
TP	mg/L	0.01	0.13	0.12	0.0775	25	0.0558	0.0458	0.0916	0.0021	69.6	0.02406	52	13	-3
Cr_VI	mg/L	0.017	0.017	0	0	25	0.00308	0	0	N/A	N/A	1	96	24	0
Cesium	mg/L	0.0001	0.0002	0.0001	0	18	7.22E-05	4.08E-05	8.16E-05	0	35	0.068	67	12	-5
Aluminum	mg/L	0.019	0.088	0.069	0.015	21	0.049	0.0162	0.0324	0.0002626	33.04	0.0104	0	0	-52
Cobalt	mg/L	0.0001	0.0021	0.002	0.00055	18	0.000811	0.000545	0.00109	2.975E-07	67.2	0.0131	0	0	134
Chromium	mg/L	0.0006	0.017	0.0164	0.00095	21	0.001998	0.00354	0.00708	0.00001254	169.9	0.01118	5	1	-128
Copper	mg/L	0.0009	0.0044	0.0035	0.00045	18	0.003217	0.000862	0.001724	7.43E-07	26.8	0.0131	0	0	74
Iron	mg/L	0.009	0.45	0.441	0.16	21	0.23	0.1205	0.241	0.01452	52.4	0.0104	0	0	-71
Manganese	mg/L	0.002	0.031	0.029	0.0025	21	0.0172	0.00674	0.01348	0.0000454	37.3	0.01118	5	1	77
Molibdenum	mg/L	0.001	0.002	0.001	0.001	18	0.00075	0.000548	0.001096	0.0000003	39.1	0.0894	72	13	0
Nickel	mg/L	0.001	0.004	0.003	0.001	18	0.002333	0.000814	0.001628	0	31.76	0.01563	11	2	79
Lead	mg/L	0.0006	0.0015	0.0009	0.00055	18	0.000917	0.000292	0.000583	0	31.8	0.0131	0	0	45
Tin	mg/L	0.0001	0.001	0.0009	0.0001	18	0.000119	0.000394	0.000788	0	131.2	0.0894	72	13	-3
Thorium	mg/L	0.0002	0.0004	0.0002	0	18	0.000247	5.16E-05	0.000103	0	18	0.0172	17	3	7
Uranium	mg/L	0.0005	0.0023	0.0018	0.0004	18	0.001172	0.000487	0.000974	2.374E-07	41.6	0.0131	0	0	107
Vanadium	mg/L	0.0006	0.0014	0.0008	0.000175	18	0.001122	0.00021	0.00042	4.42E-08	18.73	0.0131	0	0	76
Zinc	mg/L	0.005	0.009	0.004	0.0015	21	0.00369	0.001506	0.003012	2.267E-06	22.6	0.068	71	15	-6

APPENDIX 2 CORRELATION CO-EFFICIENTS OF KEY ANALYTES IN EFFLUENT SAMPLES

	Temp	pH_field	DO	TOC	TSS	Cond	Ca	Mg	Na	K	Cl	Meas_Alk	SO4	F	NO3	B	Ba	Si	Sr	TP	N_org	DOC	NH3	CS	Al	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sn	Th	U	V	Zn
	°C		mg/L	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Temp	1	-0.015	-0.472	-0.527	0.157	0.414	0.497	0.392	0.346	0.271	0.143	-0.234	0.287	0.211	0.161	0.114	-0.208	-0.38	0.391	-0.219	-0.38	-0.535	0.235	0.246	-0.225	0.079	0.359	-0.347	-0.195	0.161	0.298	-0.051	-0.153	0.257	0.174	0.029	-0.389	0.288
pH_field		1	-0.459	-0.352	-0.065	0.226	0.237	0.166	-0.103	-0.024	0.019	0.362	0.106	0.207	-0.02	-0.258	-0.936	-0.624	0.177	-0.839	-0.359	-0.361	-0.042	-0.091	-0.912	0.163	0.137	0.387	-0.897	-0.04	-0.319	0.302	0.555	0.01	0.161	-0.273	-0.6	-0.107
DO			1	0.48	-0.075	-0.255	-0.326	-0.419	-0.183	-0.073	0.024	-0.075	-0.246	-0.117	-0.049	0.118	0.562	0.613	-0.386	0.515	0.377	0.496	-0.355	-0.3	0.607	-0.28	-0.303	-0.081	0.481	-0.363	-0.576	-0.205	-0.045	-0.0091	-0.311	-0.147	0.486	0.07
TOC				1	-0.089	-0.956	-0.959	-0.572	0.018	-0.323	0.016	0.658	-0.542	-0.776	-0.204	-0.0027	0.561	0.721	-0.919	0.659	0.975	0.999	-0.312	-0.702	0.515	0.336	-0.727	0.583	0.642	0.206	-0.759	0.241	-0.264	-0.144	0.245	0.314	0.788	0.032
TSS					1	0.162	0.397	0.023	-0.107	-0.013	0.048	-0.127	0.043	0.022	-0.11	0.0041	-0.099	0.051	0.214	-0.245	-0.067	-0.094	-0.084	-0.02	-0.093	-0.181	0.069	-0.237	-0.088	-0.178	0.168	-0.279	-0.208	-0.084	-0.282	-0.099	-0.31	0.142
Cond						1	0.991	0.584	-0.072	0.409	-0.076	-0.714	0.545	0.847	0.356	0.085	-0.504	-0.561	0.881	-0.42	-0.925	-0.96	0.381	0.689	-0.399	-0.439	0.693	-0.655	-0.492	-0.239	0.658	-0.437	0.223	0.187	-0.377	-0.392	-0.734	-0.029
Ca							1	0.504	-0.085	0.322	-0.079	-0.726	0.535	0.795	0.256	0.098	-0.482	-0.567	0.86	-0.427	-0.933	-0.961	0.294	0.569	-0.367	-0.446	0.651	-0.68	-0.451	-0.223	0.649	-0.441	0.173	0.163	-0.397	-0.443	-0.724	-0.014
Mg								1	0.193	0.798	-0.05	-0.371	0.312	0.712	0.882	0.021	-0.376	-0.515	0.712	-0.685	-0.538	-0.603	0.258	0.863	-0.363	0.078	0.774	-0.278	-0.601	0.04	0.575	0.466	0.099	0.174	-0.181	0.201	-0.527	-0.099
Na									1	0.399	0.153	0.133	-0.04	-0.127	0.28	0.149	0.086	-0.057	-0.105	-0.03	0.086	0.051	0.136	0.209	-0.022	0.163	-0.099	0.089	0.097	0.466	-0.114	0.151	-0.037	0.129	-0.146	0.293	0.03	0.08
K										1	0.102	-0.234	0.17	0.559	0.88	0.114	-0.113	-0.207	0.399	-0.233	-0.248	-0.361	-0.054	0.727	-0.124	-0.072	0.491	-0.231	-0.074	0.276	0.163	0.241	0.16	0.207	-0.244	0.231	-0.271	-0.069
Cl											1	0.201	-0.116	-0.182	-0.014	0.173	0.024	0.092	-0.17	-0.199	0.117	0.018	-0.163	-0.015	-0.039	-0.127	-0.152	0.023	-0.075	0.051	-0.126	-0.223	-0.06	0.281	-0.02	-0.197	-0.172	0.049
Meas_Alk												1	-0.44	-0.664	-0.246	-0.173	-0.163	0.098	-0.723	-0.674	0.614	0.678	-0.52	-0.619	-0.435	0.616	-0.555	0.867	-0.496	0.277	-0.801	0.653	0.422	-0.103	0.351	0.489	0.017	-0.043
SO4													1	0.484	0.129	0.089	-0.237	-0.339	0.555	-0.373	-0.547	-0.543	0.191	0.276	-0.197	-0.441	0.416	-0.38	-0.443	-0.228	0.372	-0.449	-0.033	0.172	-0.38	-0.374	-0.733	-0.028
F														1	0.618	0.021	-0.461	-0.509	0.845	-0.256	-0.743	-0.795	0.225	0.784	-0.297	-0.486	0.795	-0.577	-0.354	-0.344	0.591	-0.577	0.275	0.146	-0.43	-0.226	-0.457	-0.1
NO3															1	-0.074	-0.138	-0.271	0.45	-0.355	-0.195	-0.298	0.059	0.827	-0.152	-0.085	0.64	-0.184	-0.305	-0.042	0.331	0.836	-0.0081	0.294	-0.362	0.2	0.141	-0.188
B																1	0.305	0.166	0.087	0.296	0.061	-0.013	-0.417	0.5	0.162	-0.046	0.056	-0.184	0.276	0.384	1	0.02	-0.12	0.313	-0.088	0.113	0.126	-0.055
Ba																	1	0.682	-0.398	0.913	0.571	0.571	-0.165	-0.179	0.943	-0.038	-0.295	-0.296	0.934	0.3	-0.388	-0.51	-0.462	-0.122	-0.068	-0.124	0.682	0.0052
Si																		1	-0.583	0.555	0.715	0.728	-0.357	-0.622	0.734	-0.157	-0.472	0.1	0.701	-0.073	-0.872	-0.278	-0.346	-0.097	-0.117	-0.122	0.605	0.079
Sr																			1	-0.417	-0.865	-0.917	0.364	0.782	-0.303	-0.417	0.86	-0.632	-0.367	-0.222	0.916	-0.436	0.129	0.094	-0.339	-0.292	-0.674	-0.079
TP																				1	0.588	0.675	0.167	-0.237	0.914	-0.273	-0.179	-0.661	0.947	0.11	1	-0.337	-0.655	-0.066	-0.236	-0.29	0.788	-0.109
N_org																					1	0.971	-0.434	-0.576	0.551	0.315	-0.635	0.541	0.655	0.201	-0.717	0.207	-0.188	-0.123	0.248	0.384	0.814	0.056
DOC																						1	-0.319	-0.705	0.513	0.354	-0.715	0.61	0.64	0.221	-0.758	0.284	-0.223	-0.147	0.247	0.36	0.779	0.045
NH3																							1	0.343	0.027	0.124	0.233	-0.21	0.259	0.055	0.586	0.339	-0.256	-0.112	0.151	0.066	-0.061	-0.0009
CS																								1	-0.305	-0.378	0.76	-0.499	-0.335	-0.421	0.643	-0.458	-0.043	-0.0052	-0.511	0.024	-0.68	-0.249
Al																									1	-0.202	-0.228	-0.416	0.948	-0.07	-0.708	-0.354	-0.58	-0.068	-0.139	-0.049	0.773	-0.0066
Co																										1	-0.268	0.695	-0.213	0.592	-0.435	0.881	0.369	-0.117	0.272	0.739	0.036	0.0016
Cr																											1	-0.463	-0.239	-0.163	0.726	-0.384	0.137	0.192	-0.268	-0.163	-0.321	-0.105
Cu																												1	-0.428	0.435	-0.66	0.707	0.36	-0.238	0.33	0.519	-0.039	-0.077
Fe																													1	0.111	-0.401	-0.315	-0.66	-0.145	-0.149	-0.015	0.812	0.00082
Mn																														1	-0.578	0.485	0.105	-0.167	0.205	0.354	-0.076	-0.0011
Mo																															1	-0.503	-0.33	-0.086	-0.63	-0.318	-0.646	-0.234
Ni																																1	0.576	-0.077	0.151	0.764	0.0075	-0.122
Pb																																	1	0.239	0.196	0.291	-0.295	-0.207
Sn																																		1	-0.196	0.095	-0.16	-0.097
Th																																			1	0.235	-0.129	-0.309
U																																				1	0.416	-0.196
V																																					1	-0.0035
Zn																																						1
As																																						
Sb																																						

APPENDIX 3 ELEMENTAL COMPOSITION OF SELECTED SAMPLES FROM PASSIVE SYSTEM TRIALS

TSW Sample ID	Customer Sample ID	Syrinx Code	Depth	Description	Lithium	Beryllium	Boron	Magnesium	Sodium	Aluminium	Silicon	Potassium	Phosphorous	Calcium	Sulfur	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Gallium
mg/kg	**A**	**PS4 40%**	**17-20**	NUA Blend	0.467	0.128	16.250	2415	66.75	825	138.5	25.6	232	4430	301.5	0.935	356.770	17.690	28.330	6949.970	40950	51.000	24.391	9.485	10.283	7.500
	B	**PS3 40%**	**17-20**	NUA Blend	0.325	0.119	23.550	5650	57.25	605	162.5	20.05	232.5	3965	256	0.730	326.770	14.890	23.930	5649.970	33700	42.350	20.591	7.835	8.283	6.250
	C	**PS1(1) 25%**	**17-20**	NUA Blend	0.234	0.054	8.350	5000	32.8	405	94.5	2.4	172	2690	140.5	0.420	215.270	8.440	12.630	3019.970	19800	23.950	12.341	4.045	5.633	3.425
	D	**AS1A(1)**	**2-4**	Fines at surface	1.515	0.327	19.300	4390	113.25	2670	472.5	151.3	361.5	83200	57500	2.170	509.270	37.140	70.380	17549.970	94700	125.500	61.491	23.085	39.833	18.900
	E	**AS1A(2)**	**17-20**	NUA Blend (high pisolites)	0.795	0.132	7.700	2440	45.75	1270	253	34.45	130	36200	26000	1.315	564.270	24.090	32.280	7599.970	46150	54.500	26.591	10.185	13.133	8.500
	F	**QC1 (PS4 40%)**	**17-20**	NUA Blend	0.395	0.109	8.200	2350	56.25	865	153.5	BDL	220.5	4145	303	0.805	367.270	17.240	26.680	6399.970	40100	47.450	21.941	8.685	9.133	7.350
	G	**AS1C(1)**	**17-20**	NUA Blend	0.745	0.102	6.550	2280	38.75	945	202.5	42.55	94.5	36300	26150	0.930	463.770	16.590	23.130	5449.970	32550	39.650	19.341	7.235	15.133	6.050
	H	**AS1A(3)**	**55-58**	NUA Blend (transitional to basal sands	0.535	0.086	2.800	4590	41.45	915	146	25.9	78.5	19100	12550	0.780	387.270	13.890	19.680	4629.970	29950	35.400	17.541	6.485	9.533	5.350
	I	**AS1B**	**17-20**	NUA Blend	0.497	0.096	9.850	2060	47.75	790	172.5	35.75	97.5	11200	4885	0.870	477.770	17.290	26.130	6049.970	38550	44.850	20.991	8.285	9.683	6.800
	J	**PS2 25%**	**17-20**	NUA Blend	0.303	0.067	7.200	3005	53.25	555	112	BDL	156.5	3480	194.5	0.495	300.770	10.690	16.480	3959.970	25550	29.850	14.341	5.485	6.983	4.420
	K	**PS1(2) 25%**	**40-43**	Sands at Base	< 0.0001	< 0.0001	BDL	30.15	6.1	BDL	BDL	5.7	BDL	116	BDL	-0.174	83.270	1.160	0.550	96.470	540	0.670	0.305	0.057	0.198	0.116
	L	**AS1C(3)**	**70-73**	Pisolitic rich sands	0.650	0.102	10.000	2310	59.75	1005	282	51.8	105.5	39050	28900	0.895	478.770	19.740	24.530	5549.970	34500	41.550	20.191	7.535	14.683	6.150
	M	**AS1C(2)**	**62-63**	Plastic Fines / Clays	1.420	0.200	12.200	3860	67.75	2520	360	256.8	258.5	116300	80200	1.455	619.270	26.890	40.880	10949.970	73250	90.500	45.491	16.385	21.433	13.350
	DR	**Replicate of D**	**2-4**	Fines at surface	1.285	0.227	0.150	4290	112.75	2680	510	160.3	346.5	81650	55700	1.970	564.270	38.290	61.880	15499.970	93650	112.000	52.491	20.485	35.283	17.500

TSW Sample ID	Customer Sample ID	Syrinx Code	Depth	Description	Germanium	Arsenic	Selenium	Rubidium	Strontium (ICP)	Strontium (AES)	Yttrium	Zirconium	Niobium	Molybdenum	Ruthenium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium	Cesium	Barium	Lanthanum	Cerium
mg/kg	**A**	**PS4 40%**	**17-20**	NUA Blend	0.165	2.530	0.308	0.118	50.453	60	5.500	1.247	0.100	0.344	0.007	0.020	0.007	0.023	0.029	0.271	< 0.0001	0.009	0.011	13.097	13.450	33.650
	B	**PS3 40%**	**17-20**	NUA Blend	0.150	2.145	0.198	0.100	40.703	47.95	4.875	1.072	0.357	0.327	0.010	0.014	< 0.0001	0.024	0.024	0.206	0.012	0.010	0.008	15.097	11.300	28.800
	C	**PS1(1) 25%**	**17-20**	NUA Blend	0.086	1.185	0.086	0.079	24.353	30.3	2.765	0.677	0.029	0.181	0.013	0.009	< 0.0001	0.018	0.014	0.167	< 0.0001	0.008	0.008	20.097	6.950	17.100
	D	**AS1A(1)**	**2-4**	Fines at surface	0.329	6.795	0.967	2.008	393.453	443	14.100	3.937	0.345	1.370	0.027	0.045	0.008	0.061	0.076	0.667	0.049	0.011	0.151	10.747	27.050	72.500
	E	**AS1A(2)**	**17-20**	NUA Blend (high pisolites)	0.158	3.600	0.357	0.578	155.953	177	6.300	2.317	0.134	0.645	0.023	0.024	< 0.0001	0.027	0.037	0.402	0.016	< 0.0001	0.040	6.997	12.600	33.100
	F	**QC1 (PS4 40%)**	**17-20**	NUA Blend	0.155	2.590	0.239	0.109	49.953	57.5	5.300	1.252	0.084	0.370	0.021	0.016	< 0.0001	0.022	0.029	0.239	0.007	< 0.0001	0.010	11.597	13.900	34.150
	G	**AS1C(1)**	**17-20**	NUA Blend	0.122	2.555	0.342	0.693	148.953	172.5	4.585	1.992	0.254	0.488	0.035	0.026	< 0.0001	0.024	0.025	0.357	0.023	0.009	0.050	6.147	9.750	24.750
	H	**AS1A(3)**	**55-58**	NUA Blend (transitional to basal sands	0.098	1.875	0.144	0.486	83.953	101	4.140	1.672	0.084	0.361	0.036	0.018	< 0.0001	0.024	0.023	0.246	< 0.0001	< 0.0001	0.034	4.392	8.350	21.600
	I	**AS1B**	**17-20**	NUA Blend	0.131	2.380	0.217	0.347	69.453	82	5.200	1.727	0.105	0.472	0.041	0.019	< 0.0001	0.027	0.028	0.288	0.007	< 0.0001	0.027	5.797	12.000	29.800
	J	**PS2 25%**	**17-20**	NUA Blend	0.108	1.550	0.063	0.120	37.253	45.5	3.835	0.962	0.000	0.221	0.036	0.010	< 0.0001	0.019	0.020	0.171	0.009	< 0.0001	0.011	11.247	10.050	24.350
	K	**PS1(2) 25%**	**40-43**	Sands at Base	< 0.0001	0.116	0.000	0.026	1.378	BDL	0.259	0.178	0.000	0.008	0.028	< 0.0001	< 0.0001	0.007	< 0.0001	0.039	< 0.0001	< 0.0001	< 0.0001	0.421	0.293	0.680
	L	**AS1C(3)**	**70-73**	Pisolitic rich sands	0.135	3.060	0.285	0.673	157.453	184	4.785	1.982	0.096	0.472	0.035	0.022	< 0.0001	0.027	0.027	0.294	0.019	0.007	0.051	6.347	10.450	26.700
	M	**AS1C(2)**	**62-63**	Plastic Fines / Clays	0.209	4.905	0.792	3.878	499.953	570	10.550	3.662	0.362	0.416	0.054	0.055	0.015	0.050	0.045	0.757	0.066	0.012	0.244	15.647	23.800	61.500
	DR	**Replicate of D**	**2-4**	Fines at surface	0.278	7.245	0.792	2.108	392.453	435.5	13.600	4.582	0.217	2.185	0.068	0.053	0.012	0.079	0.077	0.817	0.028	0.014	0.151	13.447	25.200	68.000

TSW Sample ID	Customer Sample ID	Syrinx Code	Depth	Description	Praseodymium	Neodymium	Europium	Samarium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium	Hafnium	Tantalum	Tungsten	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Thorium	Uranium
mg/kg	**A**	**PS4 40%**	**17-20**	NUA Blend	4.415	13.550	0.206	2.710	2.675	0.267	1.415	0.220	0.620	0.084	0.510	0.075	0.040	< 0.0001	0.000	0.001	< 0.0001	0.000	0.017	5.653	0.013	23.700	1.020
	B	**PS3 40%**	**17-20**	NUA Blend	3.800	11.400	0.174	2.350	2.725	0.236	1.265	0.200	0.550	0.074	0.464	0.066	0.035	< 0.0001	0.000	0.001	< 0.0001	0.000	0.013	5.003	0.011	19.800	0.855
	C	**PS1(1) 25%**	**17-20**	NUA Blend	2.165	6.600	0.105	1.370	1.400	0.135	0.685	0.113	0.311	0.040	0.254	0.036	0.021	< 0.0001	0.000	< 0.0001	< 0.0001	0.000	0.010	3.058	0.009	10.950	0.451
	D	**AS1A(1)**	**2-4**	Fines at surface	9.300	28.500	0.484	6.000	5.750	0.605	3.245	0.555	1.520	0.206	1.290	0.192	0.120	0.020	0.213	0.001	< 0.0001	0.000	0.053	15.903	0.027	57.000	3.330
	E	**AS1A(2)**	**17-20**	NUA Blend (high pisolites)	4.275	13.200	0.223	2.745	2.575	0.281	1.455	0.245	0.675	0.092	0.575	0.085	0.069	0.007	0.000	< 0.0001	< 0.0001	0.000	0.026	7.903	0.013	27.450	1.525
	F	**QC1 (PS4 40%)**	**17-20**	NUA Blend	4.370	13.550	0.202	2.760	2.695	0.273	1.400	0.214	0.600	0.083	0.570	0.073	0.038	< 0.0001	0.000	< 0.0001	< 0.0001	0.000	0.017	5.553	0.010	25.200	1.075
	G	**AS1C(1)**	**17-20**	NUA Blend	3.180	9.650	0.159	2.015	2.005	0.196	1.080	0.183	0.500	0.069	0.438	0.062	0.074	< 0.0001	0.001	< 0.0001	< 0.0001	0.000	0.021	5.403	0.010	19.300	1.070
	H	**AS1A(3)**	**55-58**	NUA Blend (transitional to basal sands	2.790	8.500	0.139	1.795	1.740	0.178	0.950	0.160	0.451	0.060	0.382	0.056	0.045	< 0.0001	0.000	< 0.0001	0.006	0.000	0.020	5.053	0.017	17.100	0.980
	I	**AS1B**	**17-20**	NUA Blend	3.835	11.750	0.184	2.375	2.440	0.240	1.270	0.208	0.590	0.079	0.490	0.070	0.052	< 0.0001	0.000	< 0.0001	< 0.0001	0.000	0.021	5.703	0.012	23.000	1.340
	J	**PS2 25%**	**17-20**	NUA Blend	3.075	9.600	0.135	1.940	1.930	0.186	0.965	0.151	0.403	0.053	0.335	0.048	0.029	< 0.0001	0.000	< 0.0001	< 0.0001	< 0.0001	0.014	4.873	0.012	15.350	0.675
	K	**PS1(2) 25%**	**40-43**	Sands at Base	0.079	0.244	< 0.0001	0.053	0.060	0.008	0.045	0.009	0.028	< 0.0001	0.025	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	0.170	0.008	0.416	0.028
	L	**AS1C(3)**	**70-73**	Pisolitic rich sands	3.455	10.500	0.165	2.160	2.115	0.217	1.150	0.188	0.525	0.072	0.439	0.067	0.052	0.007	0.000	< 0.0001	< 0.0001	0.000	0.019	5.603	0.013	20.650	1.125
	M	**AS1C(2)**	**62-63**	Plastic Fines / Clays	7.750	23.850	0.403	4.925	4.745	0.491	2.650	0.435	1.190	0.156	0.945	0.136	0.177	0.011	0.000	0.000	0.015	0.015	0.053	14.203	0.012	39.000	3.075
	DR	**Replicate of D**	**2-4**	Fines at surface	8.800	27.450	0.450	5.650	5.300	0.570	3.085	0.525	1.490	0.198	1.240	0.188	0.125	0.015	0.112	< 0.0001	0.010	0.000	0.054	15.603	0.026	57.000	3.275

APPENDIX 4 SELECTED XRD SAMPLES FROM THE PASSIVE SYSTEM

Centre for Materials Research

Consultancy for:

Edward Oldmeadow
Syrinx
12 Monger Street, Perth, WA 6000

Title: Quantitative Phase Abundance Analysis by XRD

Date: 9th January 2012

Authors: Dr Catherine Kealley, Dr Robert Hart and Prof Arie van Riessen
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Disclaimer

This report has been undertaken solely for Edward Oldmeadow, Syrinx. No responsibility is accepted to any third party who may come into possession of this report in whatever manner and who may use of rely on the whole or any part of this report. If any such third party attempts to rely on any information contained in this report such party should obtain independent advice in relation to such information.

Results

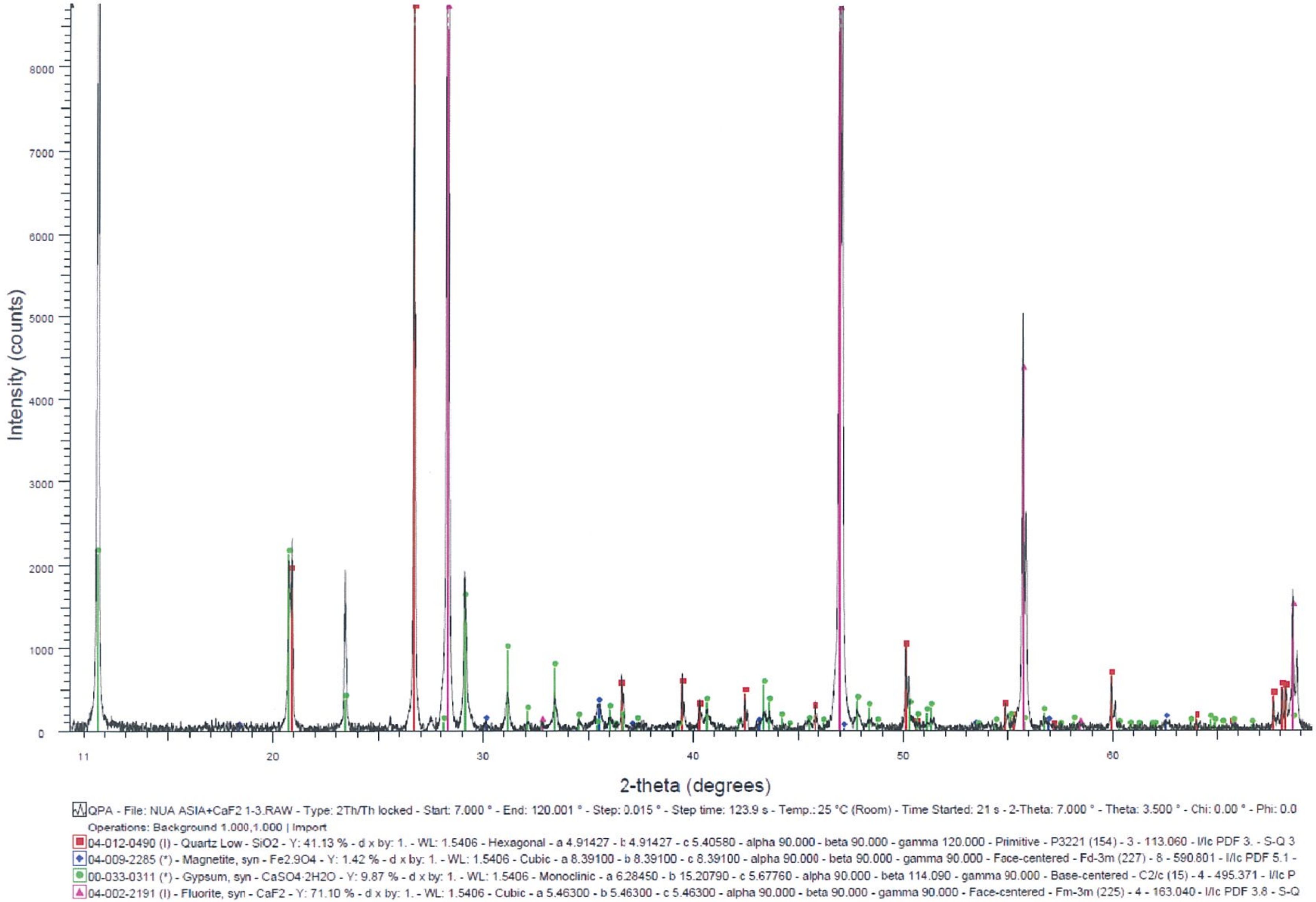

Figure 1 Selected 2-theta region showing phase identification in the "NUA ASIA 1-3" sample.

Table 1 Phase abundance

	NUA ASIA 1-3 (weight %)	NUA ASIA 2-3 (weight %)
Gypsum	47(1)	60(1)
Quartz	38(1)	26(1)
Magnetite	4.7(8)	4.0(8)
Amorphous Component	10(1)	10(1)

Notes:

1. Values in parentheses are the estimated standard deviation of the least significant figure displayed to the left in the table.
2. The fluorite phase identified in Figure 1 is the internal standard. This has not been included in the phase abundance calculations.

The phases present include:

- Gypsum ($Ca[SO_4][H_2O]_2$) – [PDF# 00-033-0311]
- Quartz (SiO_2) – [PDF# 00-033-1161]
- Magnetite ($Fe_{2.9}O_4$) – [PDF# 00-086-1334]
- The amorphous content could include scattering from any non-crystalline material, as well as the differences between the experimental and the calculated data.

Summary

A number of crystalline phases have been identified in the sample, and the abundance of each phase listed in Table 1. The gypsum phase has a large amount of preferred orientation. There are a few small peaks that have not been assigned to a phase – if elemental composition (eg. XRF or EDS) is undertaken, it may be possible to identify the phase(s) associated with these peaks.

APPENDIX 5 REVISED DESIGN CRITERIA

Water Quality

- Maintain, and where possible improve, water quality within Ellen Brook. Investigation into site specific trigger values for the biological and ecological receptors of Ellen Brook is required.
- NUA blends or alternative amendments shall be utilised to provide a majority of TP reductions.
- Wetlands shall be located at the terminal end of the any filtration system to polish flows, primarily for treatment of TN, prior to discharge.
- Disturbance to existing site soils shall be minimised. Sediment and erosion controls shall be implemented.
- The end-of-catchment treatment system shall form part of a suite of management actions (treatment train) implemented within the Ellen Brook catchment. Other management actions may include: riparian revegetation, perennial pastures, fertiliser efficiency, landuse change controls, fertiliser action plans and soil amendments.

Water Quantity

- Treatment systems shall not permanently abstract water from Ellen Brook. Systems such as aquifer recharge and/or land disposal shall not be utilised for nutrient reductions.
- Hydraulic capacity and conveyance of the existing site shall be maintained to a level that protects existing infrastructure and land uses (i.e. residential, agricultural).

Ecological Protection

- Stream morphology shall be maintained to existing conditions to protect environmental flows and existing habitat.
- Riparian and wetland revegetation works shall be integrated with existing significant vegetation. Revegetation works shall be implemented throughout the site to intercept surface runoff and perched groundwater flows, control potential weed spread and enhance habitat and biodiversity opportunities.

Infrastructure Protection

- Access to the treatment system shall preferably be via West Swan Road (Site 1) and Millhouse Road (Site 2).

- Hydraulic capacity and velocity shall be maintained to ensure protection of West Swan Road, Millhouse Road and Cruse Road.

Cultural Protection and Enhancement

- Aboriginal heritage site identification and consultation shall take place following conceptual design works.

- Access to the treatment system via roads adjacent to private properties shall be limited where possible.

- Revegetation works shall maintain existing view corridors from private properties.

- Protection of existing infrastructure and dwellings from potential fire risks.

- Community engagement and involvement prior and post construction.

System Maintenance and Operation

- Configuration of the treatment system shall allow for easy access, maintenance and, when necessary, replacement.

- Gravity fed systems shall be optimised to reduce operation costs.

Monitoring

- Monitoring sites shall be located upstream and downstream of the treatment system. Monitoring programs shall be developed consistent with current standards.