APPENDIX A

Scope of Work for Task 16f&g
(RGC Memo Dated September 16th, 2004)

Robertson GeoConsultants Inc.

Suite 640, 580 Hornby St., Vancouver, B.C., V6C 3B6
Phone: (604) 684-8072 · Fax: (604) 684-8073

Memorandum

DATE: September 16, 2004

TO: Valerie Chort, Deloitte Touche

CC: Cam Scott, SRK;
Daryl Hockley, SRK

FROM: Christoph Wels, Robertson GeoConsultants Inc.

RE: Scope of Work for Tasks 16f & 16g, Rose Creek Tailings Storage Facility, Faro Mine, Yukon Territory

1. INTRODUCTION

One of the primary issues in the context of closure planning for the Anvil Range Mining Complex will be the development and assessment of decommissioning options for the Rose Creek Tailings Facility. As part of the 2004/05 planning meetings, two projects were identified which address water management issues related to closure of the Rose Creek Tailings Facility:

16. Develop Tailings Decommissioning Methods

f) Complete Groundwater Collection Design

Field investigations (including a pump test) for a system to collect contaminated groundwater from beneath the tailings area will be completed. The results from last year's study, which focussed on the assessment of groundwater collection in the tailings area, will be reviewed and integrated into this work. Preliminary engineering designs and cost estimates will be prepared.

g) Assess Surface Water Management Requirements

Assess possible configurations for managing surface water after the tailings areas are stabilized. Estimate quantities of clean and contaminated surface water. Requirement for collecting guard house creek will also be considered. Flow estimates of water quality and quantity will also be conducted.

As will be discussed in more detail below, surface water and groundwater flow are interrelated and their management should be assessed jointly. The two proposed programs will therefore be carried out together as a single project.

This memorandum describes the approach and specific tasks that have been identified to address these projects, and provides a cost estimate for completing these tasks. In order to scope this project an initial data review was completed. The results of this initial data review are presented first, as they provide the rationale for the proposed study approach.

2. INITIAL DATA REVIEW

In order to scope the work required for Tasks 16f&g, a brief review of previous hydrogeological work completed between 2001 and 2003, and selected groundwater quality data collected between 1981 and 2003 in the Rose Creek Valley was completed.

The time available for this review was limited and this review will have to be completed as part of the proposed study to confirm any preliminary conclusions. Nevertheless, some initial findings are presented here to illustrate key issues, which are considered relevant in the overall context of closure planning for the Rose Creek Tailings Facility and which, we believe, should be studied in more detail as part of this project.

2. 1. Water Quality Parameters of Interest

Three different constituents are of particular interest in the context of tailings seepage and its impact on the groundwater system:

- Sodium which tends to be significantly elevated in the tailings process water and therefore represents a "tracer" for process water stored in the tailings prior to cessation of discharge;
- Sulphate which is released during oxidation of the tailings and is not significantly retarded in the tailings and/or aquifer material, and
- Zinc which is also released during oxidation of the tailings but typically reacts with the tailings and/or aquifer material (via sorption, co-precipitation etc) resulting in attenuation and delayed breakthrough along the flow path.

Much of the interpretation of pore water quality in the tailings and groundwater quality in the Rose Creek Valley aquifer presented in the GLL Reports reviewed for this memorandum focuses on sulphate and zinc. I would recommend that future interpretations also include sodium. This constituent is relatively conservative both in the tailings profile and the underlying aquifer and thus provides a very useful tracer for tailings process water. Note that this tracer is introduced with the tailings slurry and therefore represents a different "source release term" than sulphate (which is generated in the uppermost, oxidizing tailings layers). Sodium would have been released from the tailings impoundment immediately after tailings discharge as far back as 1975. Over time, the sodium concentrations in the tailings pore water will be diluted by incoming precipitation. Hence sodium concentrations in tailings pore water provide insight into the degree of "draindown" and dilution with meteoric water. A review of sodium trends in the receiving groundwater provides insight into the degree of physical attenuation (dilution and dispersion) within the aquifer system.

In my opinion, more emphasis should be placed on interpreting historic and current time trends of the more conservative tracers sodium and sulphate, in order to better understand the hydraulic and transport properties of the Rose Creek valley aquifer. For example, the "breakthrough" of sodium and/or sulphate could be used to estimate the transport velocity (and hence effective permeability and porosity) of the aquifer. Similarly, sulphate concentrations in different parts of the aquifer give insight into the degree of dilution provided by the aquifer (see section 2.1.4 below).

A detailed review and interpretation of water quality data is proposed for this study and will include time trends of groundwater quality (in tailings and underlying aquifer material) and surface water quality (e.g. Intermediate Pond, Polishing Pond, X-Valley seeps and Rose Creeks) with emphasis on sodium, sulphate and zinc. The observed time trends will be used to develop a water and load balance model for the Rose Creek Valley which accounts for the interaction of surface water and groundwater (e.g. seepage into groundwater, groundwater discharge into Rose Creek). The observed concentrations of the non-reactive constituents Na and SO4 will be used to calibrate the water and load balance model. The observed zinc concentrations will be compared with predicted zinc concentrations (in the groundwater and Rose Creek) to evaluate the degree of geochemical attenuation of this metal in the aquifer.

2.2. Source of Contamination in Northeastern Part of Intermediate Impoundment

The northeastern section of the Intermediate Dam is of special interest because it shows the highest concentrations of sulphate and in particular zinc in the aquifer underlying the tailings. Figure 1 shows the water quality time trends in X21A/B/C and P01-06 located in this area. X21A is screened in the tailings (including some mix of coarse fill and tailings at the base). The other piezometers are all screened in the underlying aquifer material at different depths.

X21A showed very high concentrations of sulphate and zinc between the start of monitoring in 1999 and 2001 (as high as 20,000 mg/L SO4 and 788 mg/L Zn) followed by significant drop-off in 2002-2003 (Figure 1). In the most recent sampling event (September 2003) sulphate and zinc concentrations were 8170 mg/L and 12 mg/L, respectively. The more recently installed well P01-06 showed comparable concentrations of sulphate (~2,000 mg/L) and zinc (1-10 mg/L) (Figure 1).

This contaminant plume appears to have a very limited vertical extent within the underlying aquifer. For example, at X21B, i.e. only ~3-4m below the bottom of X21A, sulphate concentrations remained below 900 mg/L and zinc concentrations below 1 mg/L between 1996 and 2003 (Figure 1).

Potential sources for the elevated sulphate and zinc in this northeastern section of the Intermediate Impoundment include:

- Vertical percolation of oxidation products from the in-situ tailings profile;
- Shallow seepage flows ("toe seepage") from the tailings deposited upstream of the Secondary Impoundment;
- Groundwater inflow from further upgradient (influenced by seepage originating from the Secondary and/or Original Impoundment); and/or
- Re-infiltration of highly contaminated surface runoff discharging from the Faro Creek channel (X23 and X7) and flowing towards the Intermediate Pond.

Vertical percolation from the upper tailings profile cannot be ruled out but appears unlikely considering the limited extent of oxidation (the tailings profile at X21 was described in 1996 as 0.6m of oxidized tailings over 7.4m of dark-grey tailings).

Seepage from the Second and/or Original Impoundment either via shallow toe seepage and/or groundwater inflow is a plausible source but there is limited information on pore water and groundwater quality immediately upstream of X21 and P01-06. The nearest monitoring wells further upgradient (P03-06 in the Second Impoundment and P03-07 in the Original Impoundment) show much lower sulphate and zinc concentrations in both the tailings and underlying aquifer than observed at X21A and P01-06.

In my opinion, re-infiltration of contaminated seepage from the Faro WRDs (discharging into the Faro Creek channel (X7) as surface runoff) is a distinct possibility and could explain the highly elevated concentrations observed at X21A and P01-06. The tailings in this northeastern portion of the Intermediate Impoundment are relatively coarse and may allow significant recharge. The very high concentrations of sulphate and zinc observed in X21A in 1999-2001 coincide with a relatively wet period during which sulphate and zinc concentrations also peaked at X23. Seepage flows discharging into the Intermediate Impoundment can also be expected to have been higher during this very wet period. Finally, sodium concentration in X21A are surprisingly variable and were very similar to those observed in X23 (~50 mg/L) during the wet period 1999-2001 (Figure 1).

In summary, there is some evidence to suggest that seepage flows from X23 and X7 which is allowed to discharge into the Intermediate Impoundment and flows into the Intermediate Pond may re-infiltrate into the coarser tailings deposited in the northeastern section of the Intermediate Impoundment and from there percolates into the underlying aquifer. This hypothesis should be evaluated in more detail. If this analysis suggests that such seepage occurs or is likely to occur, this highly contaminated seepage should be collected before it enters the tailings impoundments and discharged directly into the Polishing Pond for treatment.

Clearly, the uncertainty about the source(s) of contamination in this area (and other areas) of the tailings impoundment(s) need to be understood before a sound closure plan can be developed for the Rose Creek Tailings Facility. For example, if re-infiltration of WRD seepage from X23/X7 was identified as the major source of contamination to the aquifer in the northern part of the Rose Creek aquifer, a relocation of the tailings (at least from the Intermediate Impoundment) may not be required. In my opinion, a thorough assessment of the various sources potentially contributing to groundwater contamination in the Rose Creek aquifer is therefore a priority and will be completed as part of the proposed study.

2.3. Spatial Distribution of Contaminant Plume at Intermediate Dam

The monitoring wells installed immediately downstream of the Intermediate Dam include X24, P01-03, X25, P01-04 and are all screened in natural aquifer material. Figures 2 and 3 show the time trends of SO4, Na and Zn in the aquifer beneath the northern and southern part of the Intermediate Dam, respectively. The following observations can be made with respect to groundwater quality at the toe of the Intermediate Dam (ID):

- Groundwater beneath the northern portion of the Intermediate Dam shows significantly higher sulphate concentrations (~1,250 mg/L) throughout the aquifer profile than beneath the southern portion of the ID (~300 mg/L);
- Na concentrations are fairly homogeneous in the northern portion of ID (30-50 mg/L) but show significant variation in the southern portion, ranging from ~20 mg/L at shallow depth to ~70 mg/L at 52.5m depth
- Zinc concentrations show significant variations over time but typically remain below 0.1 mg/L; occasional higher concentrations >1 mg/L are typically observed in the shallow wells;

The monitoring data illustrate convincingly that the northern portion of the Rose Creek aquifer is generally more impacted than the southern portion. It is interesting to note that a similar spatial distribution of groundwater quality (i.e. higher sulphate in the northern portion of the aquifer) is also observed downgradient of the Cross Valley Dam. Potential factors, which may explain this spatial distribution of groundwater quality at the Intermediate Dam, include:

- Greater dilution in center valley by groundwater and/or seepage from Rose Creek diversion channel (see also section 2.1.4); and/or
- Higher source of sulphate along northern side further up-gradient (e.g. WRD seepage from X23/X7, tailings seepage in northern portion of Original and Secondary Impoundment).

Recent monitoring data also suggest a gradual increase in SO4 in the monitoring wells screened in the northern portion of the aquifer in 2002/03 (Figure 2). Potential reasons for this recent increase may include:

- A "breakthrough" of the highly elevated SO4 concentrations observed at X21A during the period 2000/2001 (Figure 1);
- An increase in SO4 loading from tailings seepage in Intermediate Dam (either from the tailings and/or the Intermediate Pond; and/or
- Higher rates of seepage (from various sources) entering the aquifer as a result of the relatively wet preceding years.

Additional data analysis (including a detailed review of water quality observed at X7 and in the Intermediate Pond) will be required to better understand the apparent spatial and temporal trends in the Rose Creek aquifer below the Intermediate Dam (and elsewhere in the Rose Creek Valley). A detailed data review and interpretation has therefore been included in the proposed scope of work for this project.

2.4. Natural Attenuation Downstream of the Cross Valley Dam

The groundwater quality in the Rose Creek aquifer downstream of the Cross Valley Dam has remained remarkably constant considering tailings seepage and associated release of oxidation products (in particular sulphate and to a lesser extent zinc) over the last 30 years. Figure 4 shows the water quality observed in selected monitoring wells (X16S/D and X17S/D) located downgradient of the Cross Valley Dam. For example, sulphate concentrations at X16 (about 850m downstream of Cross Valley Dam) has been nearly constant ranging from only 20-30 mg/L between 1981 and 2003 (Figure 4).

One might argue that the "sulphate plume" produced from tailings seepage in the Original, Secondary and/or Intermediate Impoundments has not yet reached X16 (or X17). However, this hypothesis is almost certainly false considering the hydraulic properties of the Rose Creek aquifer. Using representative aquifer parameters for Rose Creek, a solute would require about 2-5 years to travel from the Intermediate Dam to X16 and only 1-3 years to travel from the Polishing Pond to X16. Historic monitoring data indicate that sulphate concentrations in groundwater beneath the Intermediate Dam (at X24) have been elevated for at least the last 8 years and likely much longer (Figure 2). According to our estimates of travel time this "sulphate plume" observed at the Intermediate Dam should have reached X16 many years ago.

Several reasons may explain the apparent lack of a "breakthrough" of sulphate at X16 (and X17):

- the sulphate plume is intercepted by the Cross Valley Pond;
- the sulphate plume by-passes X16 and X17 (heterogeneous flow and transport path); and

- the sulphate plume is diluted significantly by:
    - Rose Creek Diversion water
    - Deeper groundwater discharging in this area
    - Recharge from snowmelt and rainfall

In my opinion, leakage from the Rose Creek diversion and potentially discharge of "pristine" groundwater in this area are the most plausible reasons for the very good (almost pristine) groundwater quality observed at X16 and X17. According to earlier studies, leakage along the Rose Creek diversion is substantial and could represent a significant fraction of all groundwater flowing in the Rose Creek aquifer. For example, SRK estimated the leakage from the Rose Creek diversion to be about 33 L/s (reported in RGC, 1996), which would be equivalent to the entire groundwater flow estimated in the Rose Creek valley aquifer (Table 2 in GLL, 2004).

Recent detailed streamflow measurements carried out in September 2002 along the Rose Creek diversion channel (RCDC) by Laberge Environmental suggested "significant loss of flow" in the Rose Creek Diversion. According to their streamflow measurements, leakage along the entire length of the RCDC represented about 10% of the total flow (or ~320 L/s) with much of this leakage (~190 L/s) occurring between the Intermediate Dam and the rock weirs. Clearly, this amount of leakage has the potential to significantly dilute any seepage from the tailings impoundments (an estimated total of only ~10 L/s) along the southern side of the Rose Creek aquifer, in particular along the reach between the Intermediate Dam and the rock weirs.

Note that P01-11 and P03-09 in closer proximity to the Cross-Valley Dam indicate significantly higher SO4 concentrations (~800 mg/L and ~400 mg/L, respectively) in the upper 40m of aquifer. Hence, the observed dilution in the Rose Creek aquifer at X16 and X17 (presumably via recharge from the Rose Creek diversion and/or discharge of deeper "pristine" groundwater) must occur within a few hundred meters downgradient of the Cross Valley Dam.

It should be pointed out that water quality monitoring in X18A/B located towards the northern side of the Rose Creek Valley (downgradient of Cross Valley Dam) does not show the same trends as X16 and X17. At X18A/B, sulphate concentrations have gradually increased over time and are currently around 500 mg/L (Figure 5). The gradual increase in sulphate concentrations observed at X18 is consistent with the increase in sulphate concentrations observed in the northern toe seepage from Cross Valley Dam (Figure 5). This would suggest that groundwater in the northern portion of the Rose Creek aquifer (below Cross Valley Dam) is not diluted to the same extent as the central and southern side of the Rose Creek aquifer. The lesser degree of dilution on the northern side of the Rose Creek aquifer supports our hypothesis of leakage from the Rose Creek Diversion channel as the primary source of dilution in the central (southern) part of the aquifer.

Considering the proximity to Rose Creek, groundwater conditions in the Rose Creek aquifer downgradient of the Cross Valley Dam are of particular importance for closure planning. The almost pristine groundwater quality observed just a few hundred meters downstream of Cross Valley Dam (at X16 and X17) clearly demonstrates the large potential for dilution in this aquifer system. If it can be shown that current conditions will prevail over the long-term a significant "breakthrough" of sulphate and/or zinc in groundwater and into Rose Creek may never occur. Clearly such a conclusion would have significant implications for closure planning.

In my opinion, a detailed analysis of the groundwater conditions downgradient of the Cross Valley Dam) should be carried out to explain the observed differences in groundwater quality.

This analysis should include a review of the time trends of groundwater quality and surface water quality (in toe seepage and Rose Creek) as well as observed groundwater levels and hydraulic testing data. This analysis should result in the development of a conceptual model of groundwater flow and solute transport in this region of the Rose Creek aquifer. In my opinion, such an analysis is critical for closure planning of the Rose Creek Tailings Facility and should be completed as part of the proposed scope of work for this project.

3. STUDY APPROACH

The proposed scope of work for tasks 16f&g has been modified from the original descriptions stated in the introduction of this memo in order to reflect the findings of the initial data review (see above). First, the data review clearly illustrates the degree of interaction between the surface water components and the groundwater components and the need to evaluate these interactions in a comprehensive study. In order to evaluate these interactions, a comprehensive water and load balance model will be developed for the Rose Creek Valley. This load balance model will allow a quantitative assessment of the interaction of surface and groundwater. There is now ample monitoring data available for the Rose Creek area (in tailings pore water, groundwater and surface waters) to calibrate such a model. Once calibrated, this model will also be used to evaluate the effects of different rehabilitation measures (e.g. “do-nothing”, cover placement, and/or removal) on groundwater quality and surface water quality (in particular Rose Creek).

Second, the initial data review illustrates that there is significant spatial variability in groundwater quality in Rose Creek valley. The reasons for such variability need to be better understood before a sound closure plan for the Rose Creek TSF (including a groundwater collection system) can be designed. While very valuable water quality data (surface water and groundwater) have been collected over the years and in particular over the last three years, a comprehensive data review and interpretation of this data set has not been completed. The study proposed here will therefore emphasize data analysis and interpretation as opposed to further field work. The primary purpose of this data review will be to better understand the contaminant sources and their impacts on the groundwater and surface water (both under current and future conditions). In our opinion, such an assessment is more critical for an evaluation of alternative closure measures than the data, which could be obtained by carrying out a pump test (with an estimated cost of ~$75k). A pump test could still be carried out at a later stage (e.g. next summer) of this data analysis suggests that this would be required to refine the design and costing for a groundwater collection system.

Thirdly, the data review has shown that there is a significant potential for natural attenuation of any contaminants introduced into the aquifer via tailings seepage by way of dilution and/or dispersion. The issue of dilution is of particular relevance to the area downstream of the Cross Valley Dam where groundwater is discharging into Rose Creek, i.e. the nearest surface water receptor downgradient of the tailing facility. Additional stream surveys (flow and water quality) are proposed for this reach of Rose Creek to determine the current rate of groundwater discharge and contaminant load (zinc, sulphate). This data and existing water quality data will be used to calibrate the water and load balance for the Rose Creek area. Once calibrated, the model can be used to predict future contaminant loads to Rose Creek for alternative closure measures (e.g. partial relocation, full relocation, cover placement etc.). Such an analysis is considered a key element in the evaluation of alternative remediation option for the Rose Creek Tailings Facility.

4. SCOPE OF WORK

Task 1. Data Review

The data review will focus on a reconciliation of the observed pore water quality in the tailings and other potential contaminant sources (seepage from X23/X7, Intermediate Pond, Cross Valley Pond) with the groundwater quality observed in various reaches and depths in the Rose Creek aquifer. The objectives of this review include:

- Identify the source(s) of elevated sulphate (and zinc where observed) in the local aquifer;
- Identify the cause for recent increases in sulphate and/or zinc in P01-06 and P01-07C/D/E;
- Identify the cause for recent increases in sulphate at X24;
- Evaluate the potential for natural attenuation (dilution and dispersion) along the various reaches of the Rose Creek Tailings Facility (including dilution from the RCDC); and
- Evaluate the potential loading from groundwater to Rose Creek downstream of Cross Valley Dam.

The following specific tasks will be carried out as part of Task 1:

- Extensive review of all available groundwater monitoring data and relevant surface water monitoring data; this review will include plotting and interpretation of time trends of selected constituents (at least for SO4, Na and Zn) for all monitoring wells and relevant surface water stations (X4&5, X7, X10-X14, R2) in and near the Rose Creek tailings facility;
- Detailed assessment of the interaction of surface water and groundwater in the reach downstream of Cross Valley Dam based on available historic monitoring data, stream flow measurements by Laberge Environmental in September 2002 and GLL in September 2003, and results of proposed streamflow measurements during this field season (see below);
- A limited field investigation (~5 days) to determine (i) seepage losses from X23/X7 along its flow path to Intermediate Pond; (ii) leakage along Rose Creek Diversion; and (iii) groundwater discharge into Rose Creek.

The proposed fieldwork will consist of streamflow measurements and water sampling along, seepage flows from X223/X7, the Rose Creek Diversion and Rose Creek below confluence with Rose Creek Diversion. The fieldwork will be subcontracted to Laberge Environmental, Whitehorse, YT, who has performed similar streamflow and tracer testing at Faro in the past. These field measurements will provide additional calibration data for the water balance model.

Task 1 also includes a 1-day meeting of Dr. Christoph Wels with Mr. Forrest Pearsson (GLL) in Gartner Lee's Whitehorse office to review the earlier groundwater modeling work completed for the Rose Creek aquifer and a 2-day visit to the Rose Creek tailings facility for Dr. Christoph Wels, Mr Martin Guilbeault and Forrest Pearsson for a detailed site reconnaissance and data review. The involvement of GLL personnel will assure that earlier and on-going work by GLL on the Rose Creek tailings facility will be incorporated into the water and load balance model developed in Tasks 2 and 3 (see below).

Task 2. Water Balance Model

The objective of this task is to develop a water balance model for the Rose Creek Tailings Facility, which synthesizes all available information on groundwater and surface water flow and their interaction. The water balance model will be a spreadsheet model using MSExcel. The water balance model will include the following components (among others):
:

- Tailings Impoundments (Original, Second, Intermediate);
- Rose Creek aquifer (likely represented by several compartments along the flow path);
- Intermediate and Cross valley ponds;
- X23/X7 flows entering Intermediate Impoundment;
- Guardhouse Creek, Rose Creek Diversion and Rose Creek;

The interaction of surface water and groundwater (e.g. leakage from Rose Creek diversion, seepage from Cross Valley Pond, discharge of Cross Valley Dam toe seepage and discharge of groundwater into Rose Creek) will be represented as “links” between two compartments with an associated flow rate (and load in the load balance model, see below).

The water balance model will be calibrated using observed or estimated rates of groundwater flow, seepage, and streamflow in Rose Creek Diversion and Rose Creek (current conditions). Once calibrated the water balance model will be used to evaluate the effects of alternative remedial options (e.g. partial or full relocation of tailings; cover placement; groundwater interception; etc) and other related water management strategies (e.g. collecting Guardhouse Creek and/or seepage from X23/X7; upgrading Rose Creek Diversion) on the water balance.

Task 3. Load Balance Model

The primary objective of the load balance modeling is to evaluate the effect of alternative remedial strategies on future groundwater quality and resulting impact on Rose Creek. Load balances will initially be developed for the key constituents sulphate and zinc only. Other constituents may be added at a later stage, if required.

The load balance model will be directly linked to the water balance model (using the same spreadsheet format with the same compartments). Load balance modeling will be carried out in two steps. Firstly, a load balance model will be developed for current conditions. The concentrations for the various source terms (X7 seepage, tailings pore water, pond seepage etc) will be determined using the available monitoring data and ongoing review and test work regarding the attenuation of contaminants within the tailings profile and aquifer material (carried out jointly by SRK and GLL). The load balance model will then be “calibrated” by adjusting selected parameters (e.g. seepage rates, groundwater flow, chemical attenuation rates) within a reasonable range until a good match with observed output concentrations (e.g. in groundwater downstream of Cross Valley Dam and Rose Creek) is achieved.

Secondly, the load balance model will be used to provide first-order predictions of future groundwater quality and surface water quality for different remedial scenarios. This predictive modeling will include a series of sensitivity analyses to assess the influence of uncertainty in model input parameters (in particular future tailings pore water quality) on predicted groundwater and surface water quality.

All load balance modeling will be carried out assuming steady-state flow, constant source concentrations and complete mixing within a given compartment. Where required, analytical solutions of solute transport will be utilized to evaluate the approximate time frame required to achieve such steady-state conditions.

In our opinion, the development of a numerical solute transport model for sulphate and/or zinc is likely not required at this stage. The need for a numerical transport model to assess future solute transport in the Rose Creek aquifer should be reviewed after completion of the proposed load balance study. This (optional) solute transport modeling is estimated to cost about $50-75k depending on the complexity of the flow and solute transport problem.

Task 4. Design and Reporting

In this task, the analytical results (Tasks 1–3) will be used to develop preliminary designs for surface and groundwater management for the Rose Creek Tailings facility. This task includes the following subtasks:

- Assessment of Surface Water Management Requirements;
- Assessment of Groundwater Collection Requirements;
- Preliminary Engineering Design & Costing for Groundwater Collection System;

The findings, along with drawings, will be summarized in a final report. The draft report will be circulated to D&T and key regulatory stakeholders for review/comment. Comments will be considered in the finalization of the report. Provisions have been made in the budget of Task 4 for a 1-day meeting in Whitehorse to be attended by the various stakeholders to present the results of this study and to discuss the implications for remediation of the Rose Creek tailings facility.

Task 5. Project Management

The final task includes communication with Deloitte Touche and various stakeholders throughout the project. If required, this task could include discussions with a technical review committee consisting of representatives from key stakeholders.

5. COST ESTIMATE

Table 1 shows the cost schedule for the proposed scope of work (including professional hours and charge-out rate by person) by subtask. The estimated costs to complete the scope of work described in this memorandum can be summarized as follows:

Task 1. Data Review (incl. Field work)	$42,358
Task 2. Water Balance Model:	$21,259
Task 3. Load Balance Model:	$34,773
Task 4: Engineering Design & Reporting:	$41,269
Task 5: Project Management	$ 9,806
TOTAL:	$149,465 (pre GST)

The disbursements include (see Table 1):

- Subcontract to Laberge Environmental for proposed field work (see Appendix A);
- Cost for 2 trips to Whitehorse;
- Photocopy charge for reproduction of 3 copies of the draft report and 12 copies of the final report

6. SCHEDULE

Task 1 has already been initiated and will be completed by mid-September. The water and load balance analysis will be carried out in September and October 2004. Task 4 and 5 will be carried out in November 2004 and a draft report will be completed by November 30, 2004. A 1-day meeting is planned (tentatively scheduled for early December 2004) to present the findings of this study and discuss the implications for closure planning of the Rose Creek Tailings Facility with the various stakeholders.

Please contact the undersigned if you have any questions regarding this memo.

ROBERTSON GEOCONSULTANTS INC.

Christoph Wels, Ph.D.
Senior Hydrogeologist

Att. Table 1. Detailed Cost estimate
Figures 1-5 (separate pdf file)
Appendix A: Quote from Laberge Environmental for Field Work

Table 1. Cost Estimate for Rose Creek Study

		Professional Feels									Disbursements			
	Description	Dr. Christoph Wels	Daryl Hockley (SRK)	Martin Guilbeault (GLL)	Forrest Pearson (GLL)	John Chapman (SRK)	Staff Hydrologist/Hydrogeologist	Drafting	Clerical	**TOTAL FEES**	Subcontractor (Laberge Environmental)	Others (Lab, Travel, Office, etc..)	Office	**TOTAL COST per TASK**
ITEM	Rate (Can $/hr)	$135	$190	$110	$125	$165	$95	$75	$65					
1	**Data Review & Visualization**	120	4	24	24		64	8		**$29,280**	$8,700	$3,500	$878	**$42,358**
2	**Water Balance Model**	48		24			96	32		**$20,640**			$619	**$21,259**
3	**Load Balance Model**	40	4			80	120	40		**$33,760**			$1,013	**$34,773**
4	**Design & Reporting**	72	16	32			128	88	40	**$37,640**		$2,500	$1,129	**$41,269**
5	**Project Management**	48	16							**$9,520**			$286	**$9,806**
	Hours	328	40	80	24	80	408	168	40					
	Cost	$44,280	$7,600	$8,800	$3,000	$13,200	$38,760	$12,600	$2,600	**$130,840**				
		28.1%	3.4%	6.8%	2.1%	6.8%	34.9%	14.4%	3.4%				**TOTAL**	**$149,465**

APPENDIX B

Geochemical Source Characterization (SRK Consulting)

Steffen, Robertson and Kirsten (Canada) Inc.
Suite 800 – 1066 West Hastings Street
Vancouver, B.C. V6E 3X2
Canada

vancouver@srk.com
www.srk.com

Tel: 604.681.4196
Fax: 604.687.5532

Memorandum

To:	File	**Date:**	June 14, 2005
cc:	Christoph Wels	**From:**	John Chapman
Subject:	Faro Tailings Source Term Calculations	**Project #:**	RGC501

1 Introduction

1.1 Terms of Reference

The purpose of this memorandum is to estimate the solute concentrations in percolate that may be released from the base of the Rose Creek tailings storage facility over time.

The scope of work that was undertaken was defined in a memorandum to Robertson GeoConsultants (RGC), which discussed by a working group that included staff of the Type II Mines Office, Environment Canada and Deloitte, during a series of conference calls. The agreed scope of work was presented in a memorandum from SRK to Christoph Wels of RGC, dated October 14, 2004.

1.2 Background

During deposition, the pore water in the tailings would have approximated process water. Exposure to oxidizing conditions and percolating meteorological water over time modified the pore water and displaced the process water. Previous investigations (GLL, 2002) have shown that a number of fronts have developed in the tailings which include i) an acid front which has a low pH and elevated metal concentrations, ii) an elevated zinc concentration front, and, iii) a neutral high TDS front containing elevated concentrations of sulphate and some metals. There is also evidence of an oxidation front that has developed, which is shallow compared to the TDS and acidic fronts. The development of these fronts will have been influenced by the method and timing of tailings deposition, which will have led to segregation (particle size) and inundation of pre-existing fronts. The following review of the deposition history provides some insight into these effects.

1.2.1 Original Tailings Impoundment

Tailings were deposited in the Original Impoundment until 1975. However, there is evidence that suggests that tailings were deposited in this impoundment intermittently at least until 1979 (as evidenced in aerial photographs). A recent review (Golders, 2004) suggests that tailings may have been deposited as recently as 1982. Because tailings were deposited from both sides of the impoundment, generally inter-layering of fine and coarse tailings resulted across this tailings deposit.

Intermittent tailings discharge after 1979 would have resulted consecutively in the oxidation of the surface tailings, formation of a high TDS/Zn front, and, possibly an acid front. Following deposition of a fresh layer of tailings, the existing oxidation zone would have been inundated by process water, probably neutralizing the acid front, and likely accelerating the rate of transport of the TDS/Zn front.

A new oxidation front would develop at the surface of the newly deposited tailings and the process would be repeated. The net result is that several fronts could have been formed during the period of intermittent deposition which are not necessarily associated with the current oxidation zone. This may also explain some of the ‘smaller’ fronts that have been detected in the tailings.

1.2.2 Secondary Tailings Impoundment

Tailings were deposited in the Second Impoundment from mid 1975 to 1982, at which time production ceased. Tailings deposition occurred again in 1986 (from June to October), which likely raised the tailings surface by between one and two meters.

Various deposition strategies were utilized, including coarse tailings spigoted from the crest of the secondary dam and various discharges at the toe of the original dam. The result would have been to push the fines to the centre of the impoundment.

As for the Original Impoundment, the period of inactivity between 1982 and 1986 would have led to the oxidation of surface tailings and the concurrent formation of TDS/Zn and acid fronts. Inundation occurred in 1986 and the oxidation front would have been re-adjusted to the current surface of the tailings deposit.

1.2.3 Intermediate Tailings Impoundment

Tailings were deposited in the Intermediate Impoundment from 1986 to 1992. Tailings discharge to the impoundment occurred predominantly from the north east corner just below the secondary dam, which resulted in a long beach with fines generally deposited against the intermediate impoundment. A pond remains against the intermediate dam, indicating that the fines are fully saturated.

As noted, the long beach which resulted from the deposition strategy consists predominantly of coarse tailings. These exposed tailings will have been oxidizing since deposition in the impoundment ended. The seasonally variation of the pond size will have affected the extent of oxidation. CPT testing (Golders, 2004) and drill logs (GLL, 2002) have also shown that while the upstream tailings are coarser, some coarse-fines interlayering is evident in these tailings.

1.3 Approach

A series of steps were undertaken to estimate the solute release rates from the tailings as follows:

Estimate Rate of Front Propagation. The historical tailings properties, leach extraction and paste parameter data were reviewed in the context of when tailings deposition occurred to each of the impoundments. The results from the various programs were compared on a proximity and depth basis. Rates at which fronts are being propagated through the tailings were then estimated and from which rates of infiltration were extracted.

Complete Bounding Calculations. Simple one dimensional oxygen diffusion calculations were undertaken to assess the range of sulphate production rates that can be expected for the tailings and the estimate the rates of oxygen entry to the tailings in the future.

Physical Properties of Tailings Deposit. First, the tailings were subdivided into coarse and fine tailings areas. Then, for each area the isopachs for the tailings deposit were used to estimate incremental surface areas at the contact between the tailings and the natural ground surface. These surface areas were then used to estimate the breakthrough curves for the tailings porewater.

Porewater Quality. The existing porewater quality within the tailings were estimated from the solute release determined in the leach extraction tests that have been completed on the tailings, corrected based on measured moisture contents. Average depth profile concentrations were determined for each of the tailings areas (coarse and fines) for each tailings impoundment, and then displaced through the tailings at the estimated rates of propagation to determine solute releases to the Rose Creek aquifer.

This memorandum presents the results from these evaluations.

2 Release of Contained Solutes

2.1 Source Areas

According to RGC's division of the tailings into distinct 'source areas', the average thickness of the tailings and the depth to the water table were determined as shown in Table 2.1.

Table 2.1
Summary of Zone Areas, Thickness and Depth of Water from Surface

Sub-domain	**Area**	**Area**	**Volume**	**Average Thickness**	**Average Depth to Water Table**
	m^2	ha	m^3	m	m
Original Impoundment					
IN-c	114,989	11.5	1,435,133	12.48	11.9
IN-f	271,687	27.2	5,065,763	18.65	10.9
Second Impoundment					
IS-c	91,949	9.2	1,408,759	15.32	5.8
IS-f	185,136	18.5	2,975,008	16.07	4.6
IIN-c	58,092	5.8	970,616	16.71	12.5
IIN-f	117,837	11.8	1,806,868	15.33	10.5
IIS-c	0	0.0	0	n/a	n/a
IIS-f	113,345	11.3	2,493,309	22.00	9.2
Intermediate Impoundment					
IIIN-c	112,869	11.3	850,206	7.53	4.2
IIIN-f	215,049	21.5	2,136,293	9.93	4.5
IIIS-c	72,984	7.3	853,666	11.70	4.2
IIIS-f	368,311	36.8	5,498,602	14.93	4.5
TOTAL	**1,722,248**	**172.2**	**25,494,223**	**-**	**-**

2.2 Rates of Porewater Advancement

2.2.1 Original Tailings Impoundment

Deposition History

Tailings were deposited in the Original Impoundment until 1975. However, there is evidence that suggests that tailings were deposited in this impoundment intermittently at least until 1979 (as evidenced in aerial photographs). A recent review (Golders, 2004) suggests that tailings may have been deposited as recently as 1982. Tailings were deposited from both sides of the impoundment, resulting in inter-layering of fine and coarse tailings across this deposit.

Intermittent tailings discharge after 1979 would have resulted consecutively in the oxidation of the surface tailings, formation of a high TDS/Zinc zone, and, possibly an acidic zone. Following deposition of a fresh layer of tailings, the existing oxidation zone would have been inundated by process water, probably neutralizing the acidity, and likely accelerating the downward transport of the TDS/Zinc zone. A new oxidation front would then have developed at the surface of the newly deposited tailings and the process would be repeated. The result is that several fronts could have been formed during the period of intermittent deposition, which are not necessarily associated with the current oxidation zone. This may also explain some of the 'smaller' fronts that have been detected in the tailings.

Porewater Observations

Drill holes and test pits within the fines zone of the Original Impoundment include A1-1(P01-10), A2-1(P01-08), and P03-07. Auger drill hole A7 and test pit (TP10) were excavated in the coarse zone of the Original Impoundment. Paste parameter and leach extraction results and observations are summarised in Table 2.2. For the purpose of the calculations it was assumed that the uppermost zone of high conductivity commenced developing in 1982; the second in 1979, and the third in 1975. Generally, only data above the water table were considered. Some salient points include:

- Distinct peaks in conductivity, sulphate and acidity are encountered with depth, which were used to calculate the propagation rates shown in Table 2.2;
- Sodium has been flushed from the tailings to low levels which indicate that there is no residual process water remaining in the tailings;
- By 2001 partial breakthrough of the deepest high conductivity front to the water table had occurred for one of the three boreholes located in the fine tailings; breakthrough had also already occurred for the borehole located in the coarse tailings;
- All of the surface tailings have acidified to a low pH, no magnesium dissolution is observed in this zone. Below the acidic zone different buffering zones can be identified which can be broadly defined as follows. The first buffering zone is located immediately below the acidic zone and has a pH in the 3 to 4 range. Conditions are likely oxidizing and pH is controlled by iron precipitation, however, magnesium generally increases suggesting some residual neutralization is occurring. A second buffering zone with a pH between 4 and 6 is located below this where clearly carbonate buffering is occurring. The lower pH is likely due to the presence of excess carbon dioxide. This zone likely represents the extent of the influence of acid release from the acidic zone. Below this a neutral to alkaline pH zone is encountered, where magnesium concentrations drop off again;
- Zinc has been preferentially leached from the near surface tailings. Within the acidic zone, porewater typically has elevated iron concentrations, with lower zinc concentrations. Below this, in the first buffer zone, zinc is elevated probably from oxidation. Iron concentrations are low probably as a result of the precipitation of iron oxy-hydroxides. The solids analyses show zinc depletion from the near surface tailings;
- A slight peak in sodium concentration was detected in drill hole P01-08 (A2-1) at 6.1 m (18.1 mg/L), which coincides with a layer of wet plastic silty tailings, and at 13.7 m (26 mg/L) in drill hole P01-10 (A1-1), also associated with a layer of wet plastic silty sand tailings. These concentrations are below the anticipated process water concentrations, however, below these peaks sodium remained above the detection limit suggesting some residual process water remains in the tailings. Assuming these peaks coincide with the last deposition event, the travel times suggest permeabilities in the order of 1 to 2 x 10^{-6} cm/s, which is in reasonable agreement with field measured values.

As shown in Table 2.2, the estimated rates of propagation of the conductivity and sulphate fronts are in good agreement for the fine tailings locations, ranging typically from about 0.050 to 0.060 m/year. At a porosity of about 48 % and field moisture content of 16 % (from field measurements) this equates to a net annual infiltration rate of about 17 mm per year. Note that this represents a vertical infiltration rate and does not address any lateral flow that may occur due to layering.

Table 2.2
Summary of Original Impoundment Parameter Depth Profiles and Propagation Rates

Parameter	**Description**	**2001**			**2003**
		P01-10	**P01-08**	**P01-A7**	**P03-07**
Zone		Fines	Fines	Coarse	Fines
Conductivity	Peak 1 (m)	1	1.2	2	0.6
	Peak 2 (m)	2.4	2.8	5.5	4.5
	Peak 3 (m)	4.8	4.4	9	6
	Depth of add. peaks [m]	-	-	-	8, 9.5, 12
	Max [µS/cm]	6550	2360	3900	2436
	Rate [m/year] 1982 front	0.053	0.063	0.105	0.029
	Rate [m/year] 1979 front	0.064	0.073	0.159	0.163
	Rate [m/year] 1975 front	0.092	0.062	0.135	0.054
pH	Depth of Acid < 3 (m)	1.2	1	1.4	0.6
	1st Buffering (3 to 4) (m)	5	4	2.4	2
	2nd Buffering (4 to 6) (m)		8.4	> 9	13
	neutral pH (>6) (m)	8	9.4	n/a	13
	Minimum	2.21	2.93	2.3	1.97
	Rate [m/year] 1st Buffering	0.063	0.053	0.074	0.029
	Rate [m/year] 2nd Buffering	0.17	0.14	0.045	0.058
	Rate [m/year] Neutral		0.17	> 0.27	0.039
Acidity	Peak 1 (m)	1	1.2	2	-
	Peak 2 (m)	4.8	2.8	5.5	-
	Peak 3 (m)	12.4	4.4	9	-
	Depth of add. peaks [m]		7.6		-
	Max [pH 8.3, mg CaCO3/L]	9320	1325	2330	-
	Depth [m] - close to 0	13	9.5		-
	Rate [m/year] 1982 front	0.053	0.063	0.105	-
	Rate [m/year] 1979 front	0.173	0.073	0.159	-
	Rate [m/year] 1975 front	0.292	0.062	0.135	-
Sulphate	Peak 1 (m)	1	1.2	2	-
	Peak 2 (m)	2.4	2.8	5.5	-
	Peak 3 (m)	4.8	4.4	9	-
	Depth of add. peaks [m]				-
	Max [mg/L]	13000	2790	3080	-
	Rate [m/year] 1982 front	0.053	0.063	0.105	-
	Rate [m/year] 1979 front	0.064	0.073	0.159	-
	Rate [m/year] 1975 front	0.092	0.062	0.135	-
Magnesium	Depletion (m)	2.4	1	2	-
	Zone 1 (m)	7	2.4	6	-
	Zone 2 (m)		4.4	9	-
	Depth of add. Zones				-
	Max [mg/L]	400	285	240	-
	Rate [m/year] 1982 front	0.126	0.053	0.105	-
	Rate [m/year] 1979 front	0.209	0.064	0.182	-
	Rate [m/year] 1975 front		0.077	0.115	-
Zinc	Peak 1 (m)	2.5	1	2	-
	Peak 2 (m)	4.5	3	4	-
	Peak 3 (m)		4.5	9	-
	Depth of add. peaks [m]		7.6		-
	Max [mg/L]	2270	407	1220	-
	Rate [m/year] 1982 front	0.132	0.053	0.105	-
	Rate [m/year] 1979 front	0.091	0.091	0.091	-
	Rate [m/year] 1975 front		0.058	0.192	-

The results for the coarse tailings are more difficult to interpret because it is apparent that they drain down very rapidly. Also, the influence of direct oxidation would extend much deeper due to the low level of saturation. There are clear peaks or fronts that exist in the coarse tailings, but because breakthrough has already occurred, it is difficult to correlate the peaks with any specific deposition period. Based on the assumed years when the peaks started developing, the estimated rates of propagation of the fronts are in the order of about 0.15 to 0.2 m per year, or about three to four times that in the fine tailings. This corresponds to a net infiltration to the coarse tailings of about 26 to 35 mm per year.

Although the exact locations of the samples are uncertain, paste pH results from a 1988 investigation indicate acidification below pH 3 to a depth of about 0.5 m. Below this the pH was above 4 but below 6 to a depth of about 3 to 5 m. Below this the tailings remained neutral. Based on these results the initial rate of propagation of the acidic front is in the order of 0.083 m per year; the corresponding initial rate of propagation of the buffering zone is in the order of 0.25 to 0.50 m per year. It is not unreasonable that the initial rates of propagation should be higher than those estimated over the longer term because initially drain-down and rapid oxidation near the surface would have assisted in the development of the fronts.

Field observations

A series of test pits were excavated as part of a separate investigation to obtain tailings samples from near surface. The observations for the test pits excavated in the Original Impoundment near P03-07 and P01-10 (both located within the Fines Zone) are as follows:

- Depth of oxidation, as characterized by iron oxy-hydroxides, extends to a depth of between 0.8 and 1.1 m;
- Immediately below the oxidation zone there is an accumulation of ‘ice-blue’ crystals, which occurs in the transition to ‘fresh’ tailings; and,
- Oxidation cap is cemented together to form a ‘hardpan’.

While the composition of the crystals is uncertain, they do not appear to be rapidly soluble in water. The reason for the accumulation at this depth is not clear. The test pits were excavated during the late fall.

2.2.2 Secondary Tailings Impoundment

Deposition History

Tailings were deposited in the Second Impoundment from mid 1975 to 1982, at which time production ceased. Tailings deposition occurred again in 1986 (from June to October), which likely raised the tailings surface by between one and two meters.

Various deposition strategies were utilized, including coarse tailings spigoted from the crest of the secondary dam and various discharges at the toe of the original dam. The result would have been to push the fines to the centre of the impoundment.

As for the Original Impoundment, the period of inactivity between 1982 and 1986 would have led to the oxidation of surface tailings and the concurrent formation of TDS/Zn and acid fronts. Inundation occurred in 1986 and a new oxidation front would have formed at the current surface of the tailings deposit.

Porewater Observations

Drill holes and test pit within the fines zone include P01-07 from the 2001 program, and P03-02, and drill holes P03-05 and P03-06 from the 2003 program (limited to paste parameters only). Drill holes P01-09 as well as P03-01, P03-03 and P03-06 were drilled in the coarse zone of the Secondary Impoundment. Paste parameters and leach extraction test results are summarised in Table 2.3. For the purpose of the calculations it was assumed that the first peak (from surface) commenced developing in 1986; the second in 1982. There is evidence to suggest a third peak and, in some cases, additional peaks. However, these generally appear to be at or below the water table. It is possible that these are the result of lateral transport of contaminants from upstream and therefore they were not included in the evaluation. Observations are similar to those described above for the Original Impoundment, with the following additional comments:

- Evidence of residual process water was found at a depth of about 10.7 m in P01-07 (fine tailings) as indicated by an elevated sodium concentration of about 76 mg/L, and a concentration of about 13 mg/L at 13.7 m for P01-09 (coarse tailings). Assuming the process water originated at surface in 1986, and was transported under saturated conditions, the transport rate indicate saturated permeabilities of about 4.4×10^{-6} cm/s for the fine tailings and about 7.7×10^{-6} cm/s for the coarse tailings.

A comparison of rates between the Original and Second Impoundments further shows that the rates of propagation of the various fronts are similar. However, results for P01-09, P03-03 and P03-06, which are considered to be within the coarse tailings zone, are comparable to the rates observed for the fine tailings. This suggests that these results may be affected by fine tailings inter-layering. The rate of propagation observed for the fine tailings was about 0.033 m/year, which correlates with a net infiltration of about 12 mm/year. The results for the coarse tailings ranged from as low as 0.020 m/year to 0.216 m/year, which correlates to an upper bound net infiltration of about 37 mm per year.

Field observations

The observations for the test pits excavated in the Secondary Impoundment near P01-07 (fines zone) and P03-06 (coarse zone) are as follows:

- Depth of oxidation extends to 0.3 to 0.4 m, characterized by multiple thin bands (order of centimetres) oxy-hydroxides
- Immediately below the oxidation zone there is an accumulation of ‘ice-blue’ crystals, which occurs in the transition to ‘fresh’ tailings;
- Oxidation cap is cemented together to form a ‘hardpan’; and,
- Tailings are slightly moist and some evidence of oxidation is present.

Table 2.3
Summary of Secondary Impoundment Parameter Depth Profiles and Propagation Rates

	Description	2001		2003				
	Location	P01-07	P01-09	P03-01	P03-02	P03-03	P03-05	P03-06
	Zone	**Fines**	**Coarse**	**Coarse**	**Fines**	**Coarse**	**Fines**	**Coarse**
Conductivity	Peak 1	0.5	0.5	1.7	0.5	0.9	0.5	0.3
	Peak 2	2.5	3	3	2.3	5	2	1.4
	Peak 3	4.5	-	5.6	6.1	7.3	5	3
	Depth of add. peaks [m]	9.1, 15.2	-	11.1	11.7	8.7, 11.3	8.1	6.7
	Max [uS/cm]	4950	6240	3630	2734	5370	2910	4180
	Rate [m/year] 1986 front	0.033	0.033	0.10	0.030	0.053	0.030	0.018
	Rate [m/year] 1982 front	0.105	0.132	0.062	0.086	0.195	0.072	0.053
	Rate [m/year] 1975 front	0.077		0.093	0.136	0.082	0.107	0.057
pH	Depth of Acid < 3	1	1.8	1.5	0.5	1.2	0.8	0.5
	1st Buffering (3 to 4)	3	8	3	n/a	6.4	n/a	1.5
	2nd Buffering (4 to 6)	8	14	7	10.5	13.8	9.6	9.6
	neutral pH (>6)	9	n.a.	8	11	14	9.8	10
	Min	2.75	2.42	1.67	2.06	1.96	1.89	2.62
	Rate [m/year] 1986 front	0.067	0.12	0.088	0.029	0.071	0.047	0.029
	Rate [m/year] 1982 front	0.11	0.32	0.32	n/a	0.247	n/a	0.047
	Rate [m/year] 1975 front							
Acidity	Peak 1	0.5	0.5					
	Peak 2	2.5	3					
	Peak 3	4.5	6					
	Depth of add. peaks [m]	18.3, 22.9	-					
	Max [mg CaCO3/L]	5300	9390					
	Depth [m] - close to 0	13	14					
	Rate [m/year] 1986 front	0.033	0.033					
	Rate [m/year] 1982 front	0.11	0.13					
	Rate [m/year] 1975 front	0.077	0.115					
Sulphate	Peak 1	0.5	0.5					
	Peak 2	2.5	3					
	Peak 3	4.5	-					
	Depth of add. peaks [m]	15.2, 18.3	-					
	Max [mg/L]	6520	11100					
	Rate [m/year] 1986 front	0.033	0.033					
	Rate [m/year] 1982 front	0.11	0.13					
	Rate [m/year] 1975 front	0.077	-					
Magnesium	Depletion	0.1	0.1					
	Zone 1	2	5					
	Zone 2	6	9					
	Depth of add. peaks [m]	15.2, 18.3	-					
	Max [mg/L]	200	360					
	Rate [m/year] 1986 front	0.007	0.007					
	Rate [m/year] 1982 front	0.10	0.26					
	Rate [m/year] 1975 front	0.154	0.154					
Zinc	Peak 1	1	3					
	Peak 2	2	12.2					
	Peak 3	7.5	-					
	Depth of add. peaks [m]	15.2, 18.3	-					
	Max [mg/L]	920	2950					
	Rate [m/year] 1986 front	0.067	0.20					
	Rate [m/year] 1982 front	0.053	0.48					
	Rate [m/year] 1975 front	0.212	-					

Note: Shaded cells at or below water table

2.2.3 Intermediate Tailings Impoundment

Deposition History

Tailings were deposited in the Intermediate Impoundment from 1986 to 1992. Tailings discharge to the impoundment occurred predominantly from the north-east corner just below the secondary dam, which resulted in a long beach with fines generally deposited against the intermediate impoundment. A pond remains against the intermediate dam, indicating that the fines may be fully saturated.

As noted, the long beach, which resulted from the deposition strategy, consists predominantly of coarse tailings. These exposed tailings will have been oxidizing since deposition in the impoundment ended. The seasonal variation of the pond size will have affected the extent of oxidation. CPT testing (Golders, 2004) and drill logs (GLL, 2002) have also shown that while the upstream tailings are coarser, some inter-layering of fines is evident in these tailings.

Porewater Observations

In general the porewater quality of the Intermediate Impoundment is less well developed than that of the Original and Secondary Impoundments. However, the results are indicative of trends similar to those observed in the other impoundments. In general, however, the depth to water is shallow, and consequently the depth of oxidation is limited. The corresponding results for the fronts, assumed to have developed in 1986 and in 1992 respectively are shown in Table 2.4. Based on sodium concentrations, it appears that process water has been displaced to a depth of about 7.8 m, which corresponds to a permeability of about 4.8×10^{-6} cm/s.

Field observations

The observations for the drill holes completed in the Intermediate Impoundment near P01-08 (fines zone) and P03-05 (coarse zone) are as follows:

- Depth of oxidation extends to about 0.3 m in the fine tailings and to about 0.45 m in the coarse tailings, characterized by multiple thin bands of oxy-hydroxide stained tailings that coincide with coarser tailings;
- Within the coarser tailings, immediately below the oxidation zone, an accumulation of ‘ice-blue’ crystals, which occurs in the transition to ‘fresh’ tailings, was observed; and,
- Oxidation cap is cemented together to form a ‘hardpan’.

Table 2.4
Summary of Intermediate Impoundment Water Quality Profiles

Location	Description	2001 P01-05	2003 P03-08
	Zone	Coarse	Fines
Conductivity	Peak 1	0.5	0.7
	Peak 2	4	2.5
	Max [uS/cm]	4510	348
	Rate [m/year] 1992 front	0.056	0.064
	Rate [m/year] 1986 front	0.23	0.11
pH	Depth of Acid < 3	0.1	0.2
	1st Buffering (3 to 4)	0.5	1
	2nd Buffering (4 to 6)	1	2
	neutral pH (>6)	2	2
	Minimum	2.55	3.61
	Acidification	0.01	0.02
	Buffer 1	0.056	0.090
	Buffer 2	0.033	0.058
Acidity	Peak 1	0.5	-
	Peak 2	4	-
	Max [pH 8.3, mg CaCO3/L]	3660	-
	Depth [m] - close to 0	5	-
	Rate [m/year] 1992 front	0.056	-
	Rate [m/year] 1986 front	0.23	-
Sulphate	Peak 1	0.5	-
	Peak 2	4	-
	Max [mg/L]	4310	-
	Rate [m/year] 1992 front	0.055	-
	Rate [m/year] 1986 front	0.23	-
Magnesium	Peak 1	1	-
	Peak 2	2	-
	Max [mg/L]	356	-
	Rate [m/year] 1992 front	0.11	-
	Rate [m/year] 1986 front	0.067	-
Zinc	Peak 1	0.5	-
	Peak 2	1	-
	Max [mg/L]	704	-
	Rate [m/year] 1992 front	0.056	-
	Rate [m/year] 1986 front	0.033	-

2.3 Summary

Initially, the tailings pore water would have corresponded to process water.

There is evidence that sodium concentrations were elevated in the process water. Sodium is not generated at elevated concentrations from the oxidation or neutralization processes. Therefore, residual sodium can be used to infer the presence of residual process water. The results suggest that the process water was displaced through the tailings at approximately the same rate as the saturated permeability of the tailings. Draindown has likely occurred in all of the coarse tailings whereas some residual process water remains in the fine tailings.

The review of the deposition history for the original and secondary impoundments indicated that there was at least one inactive period in each of the impoundments during which tailings were deposited over tailings that had been allowed to oxidize for some time. During this time, it s expected that elevated sulphate and zinc concentrations would have been generated in the tailings porewater.

The depths of the peaks encountered in the tailings appear to coincide with the likely sequence of tailings deposition. There are too few peaks, and the passage of the peaks is too slow to be a result of seasonal effects.

The second inference from the distribution of process water in the tailings is that the intermittent deposition (especially in the Second Impoundment) did not lead to the complete displacement of solutes generated during the period that the tailings were allowed to oxidize. Otherwise only one peak would have been detected in the tailings. This suggests that solutes are attenuated in the tailings, even when saturation occurs, as evidenced by the fact that intermittent deposition did not remove all of the solutes generated and stored in the tailings. This effect could be an artefact of lateral movement of porewater. However, the expectation would then have been that process water would not have been displaced from the tailings to the extent that it has occurred to date. However, since there s evidence that not all of the process water has been displaced from the tailings, it is reasonable to expect that multiple peaks would remain in the tailings column. This means that the rates of displacement of all but the most recently formed peak would have been dictated by the saturated permeability of the tailings, and to some extent by the lateral movement of porewater due to the layered nature of the tailings.

The leach extraction results further indicate that zinc is preferentially leached from the surface layer of the tailings. This is supported by solids analyses, which show that zinc is depleted from the solids in the near surface tailings. Preferential leaching of zinc has certain long-term implications. In particular, the rate at which zinc is generated from the surface layer will decrease. This means that the water composition is likely to change with time resulting in lower zinc concentrations in the tailings porewater.

From the above analysis, rates of advance of the fronts and the estimated rates of infiltration have been estimated. The rates adopted for use in further calculations are summarised in Table 2.5 below. These estimates were derived from the first peak data, i.e. they represent the rates if advance of for the peak most recently established and that has not been affected by subsequent deposition. The summary rates represent the average of the conductivity, sulphate, magnesium and zinc rates averaged for each location and then averaged for the coarse and fine tailings respectively. This approach was adopted to minimise the potential error that could be associated with a single parameter (sulphate only) analysis, since all these parameters under ideal conditions should move through the tailings at a similar rate. This approach also allows inclusion of the 2003 conductivity data.

Table 2.5
Summary of Rates of Advance and Infiltration

	Average Advance			**Maximum Advance**		
	Unsaturated	**Saturated**	**Infiltration**	**Unsaturated**	**Saturated**	**Infiltration**
Area	**m/year**	**m/year**	**mm/year**	**m/year**	**M/year**	**mm/year**
Coarse	0.203	0.083	34	0.444	0.181	75
Fine	0.047	0.036	16	0.074	0.056	26

2.4 Leach Extraction Test Results

Porewater quality has been obtained for saturated tailings from the wells installed in the tailings. However, to date, actual porewater from the unsaturated tailings, which is of interest for this evaluation, has not been extracted and analyzed. Therefore, the primary source for estimating solute concentrations in porewater are the results from the leach extraction tests completed in 2001. The results from these tests together with measured moisture contents at corresponding depths were used to estimate the porewater concentrations. It should be noted that the leach extraction tests reflect oxidizing conditions, whereas below the oxidation zone in the tailings anoxic conditions prevail which will effect the concentrations of some parameters including iron. It should also be noted that these calculations are sensitive to the moisture content and hence are likely prone to error, but nonetheless serve as a ‘starting point’ for estimating porewater concentrations.

The results for the Original impoundment are shown in Table 2.6, those for the Second Impoundment in Table 2.7 and the results for the Intermediate Impoundment are shown in Table 2.8. The tables show a corrected sulphate concentration, which has been corrected for gypsum precipitation; however, only the original calcium concentrations are shown. The following observations can be drawn from these tables and graphs:

- The presence of residual process water is clearly evident from the sodium concentrations, which has been discussed in the preceding section. Depending on the sodium concentrations in the process water, it is possible that the porewater concentrations may have been overestimated by a factor of 2 or more in some cases.
- The acid fronts and associated metal concentrations in the Original Impoundment are very similar and appear to be “mature”, i.e. concentrations have peaked and are unlikely to exceed the concentrations shown.
- Iron concentrations are elevated only in the acidic zone, which is an artefact of the leach extraction testing (i.e. oxidizing conditions) since porewater for example in X21A has elevated iron concentrations at depth. The reducing conditions at depth maintain iron as ferrous and prevent oxy-hydroxide formation.
- Maximum zinc concentrations in the porewater appear to be on the order of about 40,000 to 50,000 mg/L. If indeed the porewater concentrations are overestimated by a factor of 2, then the maximum concentrations would be in the order of about 20,000 to 25,000 mg/L.

Solute concentration profiles with depth were obtained by back-calculating the porewater concentrations from leach extraction tests and the measured moisture content of the sample. The average profile for each of the source areas was obtained by averaging the concentrations at approximately the same depth. This profile was then allowed to propagate through the tailings at the solute propagation rates previously obtained. The propagation rates, for unsaturated and saturated conditions, and the corresponding infiltration rates that were adopted are shown in Table 2.5.

Table 2.6
Summary of Calculated Porewater Concentrations in the Original Impoundment

Location		pH	Sulphate (mg/L)	Sulphate Corrected (mg/L)	Calcium (mg/L)	Iron (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Zinc (mg/L)
P01-10 - Original – Fines									
A1-1	0.5	1.1	92321	81348	4972	26509	311	0	1274
A1-1	1	1.0	662278	632671	12736	293440	2802	0	42691
A1-1	1.5	2.2	153497	140795	5693	8031	4134	0	46761
A1-1	2.5	2.3	86128	81737	2230	2489	6169	0	34665
A1-1	3.5	2.4	71005	65607	2649	16659	2130	0	12836
A1-1	4	2.4	72231	70439	1147	27335	1558	0	7819
A1-1	4.5	2.6	100529	90838	4438	20678	4040	0	18133
A1-1	7.6	5.3	27451	15057	5564	1	2311	95	2374
A1-1	12.2	2.9	12052	9058	1647	629	315	287	2731
A1-1	13.7	5.9	6849	2280	2304	0	181	224	626
A1-1	15.2	6.6	5039	1084	2048	0	182	211	45
A1-1	16.8	6.5	1904	764	875	0	124	159	14
P01-08 - Original – Fines									
A2-1	0.5	1.3	123717	103497	8825	9403	4512	0	15836
A2-1	1	0.8	224401	202497	9527	39237	3803	0	32115
A2-1	1.5	1.9	184678	152003	14015	8186	21218	0	16765
A2-1	3	2.3	327267	265448	26158	7789	32961	0	47741
A2-1	4	2.3	211862	177579	14685	6950	26230	0	16478
A2-1	4.5	3.1	411750	367472	18849	20862	52155	**1464**	34404
A2-1	6.1	4.5	25324	23351	1222	918	3588	317	1864
A2-1	7.6	3.2	47283	40558	3202	1826	5216	483	5747
A2-1	9.1	5.3	6229	3885	1376	0	756	83	210
A2-1	10.7	6.2	2137	743	981	0	92	57	44
A2-1	12.2	7.0	2157	235	1200	0	193	53	8
A2-1	13.7	6.5	3118	980	1291	0	57	99	66
A2-1	15.2	6.1	4380	1771	1487	1	208	41	89
Original Coarse									
A7-1	0.5	0.59	136187	117733	8089	38655	937	0	4838
A7-1	2	1.01	196122	167937	12144	23768	974	0	44550
A7-1	2.5	1.87	164081	140663	10157	4818	10591	0	39761
A7-1	4	2.83	88334	76285	5421	4417	3470	0	34990
A7-1	6.1	2.67	85466	71834	6080	25611	2401	0	5707
A7-1	7.6	2.99	46462	40401	2925	685	6654	0	3614
A7-1	9.1	2.93	67398	55624	5306	1007	6969	115	9981

Table 2.7
Summary of Estimated Porewater Concentrations in the Second Impoundment

Location		pH	Sulphate (mg/L)	Sulphate Corrected (mg/L)	Calcium (mg/L)	Iron (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Zinc (mg/L)
P01-09 Second Impoundment Coarse									
A3-1	0.5	1.1	213120	202514	4819	79488	1096	0	8448
A3-1	1.5	1.8	83632	80230	1817	6546	2187	0	24446
A3-1	2	2.4	141708	134732	3307	4760	6335	0	59686
A3-1	3	2.3	85756	80977	2391	1763	4248	0	39405
A3-1	4	2.8	67507	62197	2612	835	4656	0	22502
A3-1	6.1	3.0	33550	32118	997	4972	1276	0	10296
A3-1	7.6	2.9	19484	18149	956	5160	1024	0	1828
A3-1	9.1	3.4	20047	15468	2308	126	2282	53	2229
A3-1	10.7	3.2	36429	30360	2929	886	3191	119	6381
A3-1	12.2	3.2	31201	24461	3208	977	1484	118	7977
A3-1	13.7	3.7	10306	6028	2182	49	375	495	1020
P01-07 - Second – Fines									
A4-1	0.5	1.58	95818	92439	1808	39238	1054	0	4335
A4-1	1	2.19	79255	73010	3002	17412	1397	0	13825
A4-1	1.5	1.81	157978	148303	4431	34789	4078	0	26946
A4-1	2	2.87	76675	73577	1690	18263	2460	0	12497
A4-1	2.5	1.23	164391	146466	7869	15086	10124	0	39043
A4-1	3	2.34	37228	34609	1491	5087	2197	0	5145
A4-1	4	4.81	13452	12397	840	1345	1370	65	2087
A4-1	4.5	5.27	12417	9515	1609	118	1229	76	1432
A4-1	6.1	4.03	11155	3823	3455	2	913	117	586
A4-1	7.6	4.48	7400	5173	1328	1	674	145	380
A4-1	9.1	6.79	5895	2157	1958	0	290	247	50
A4-1	10.7	6.77	2812	2111	692	0	87	414	7
A4-1	13.7	7.08	2951	1064	1186	0	161	304	7
A4-1	15.2	4.56	17003	7413	4396	18	441	329	2492
A4-1	16.8	5.22	1700	1409	522	0	49	88	98
A4-1	18.3	3.33	8830	5883	1628	115	330	304	1218
A4-1	19.8	5.98	4835	2356	1433	0	154	416	17
A4-1	22.9	4.22	5052	3505	1045	2	149	190	978
A4-1	24.4	6.38	3683	1876	1153	0	143	274	15

Table 2.8
Summary of Estimated Porewater Concentrations in the Intermediate Impoundment

Location		pH	Sulphate (mg/L)	Sulphate Corrected (mg/L)	Calcium (mg/L)	Iron (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Zinc (mg/L)
P01-05 Intermediate – Coarse									
TP-7	0	0.8	179705	168673	4997	80893	1229	0	5376
TP-7	0.5	2.6	54940	41889	5838	286	5910	0	2572
TP-7	1	5.4	374174	299084	31688	1641	30906	0	61118
TP-7	1.5	5.1	10382	7006	1807	0	1004	0	860
TP-7	2	5.2	8661	5822	1583	0	1305	57	233
TP7	3.5	6.2	8604	3362	2584	0	789	86	30
A5-1	4.5	5.7	2577	1586	813	0	112	42	79
A5-1	6.1	3.1	1886	2264	243	166	105	28	351
A5-1	7.6	5.7	2825	1813	822	0	135	117	92
A5-1	10.7	3.2	4817	3691	869	215	322	85	520
A5-1	12.2	7.0	2590	1399	896	0	196	125	6
A5-1	13.7	6.7	5188	1983	1735	0	259	141	20

2.5 Solubility Constraints

At the elevated concentrations, the activity coefficients of the aqueous species should be calculated from Pitzer's equations. However, unfortunately the Pitzer database available for the EQ3/6 model does not contain data for a number of relevant minerals, including goslarite and the various hydrated zinc sulphates that may control zinc solubility. Hence, only a preliminary assessment of the potential solubility limits was completed using MINTEQA2.

Based on the preliminary MINTEQA2 results, zinc concentrations of up to 65,000 mg/L are possible based on the solubility of goslarite and/or $Zn_2(OH)_2SO_4$. Similarly, based on the solubility of melanterite, iron concentrations in excess of 70,000 mg/L could be possible. While the solubility of epsomite is very high, it is unlikely that it would form since the magnesium concentration will likely be limited by the magnesium released from the solids. It is however considered that these ‘upper limits of solubility’ indicated by MINTEQA2 are likely high. In contrast, the highest zinc concentration that was detected in tailings porewater (P01-09A, 11.2 m) was 5,500 mg/L, with a sulphate concentration of about 77,000 mg/L and an iron concentration of about 36,000 mg/L. Furthermore, the highest zinc concentration detected during the site seepage monitoring program was 10,900 mg/L (from the low grade ore stockpiles), the maximum sulphate concentration was 59,000 mg/L and the maximum iron concentration was 15,100 mg/L. (It should be noted that the low grade ore stockpiles are acid generating and contain zinc grades similar to the tailings.)

In the loading calculations presented in Section 3, calculated porewater concentrations were used directly to estimate zinc loadings. However, in light of the precipitates that have been observed in the tailings, it is considered that by neglecting the potential effects of secondary mineralization, the loading estimates may be overly conservative.

2.6 Oxidation and Oxygen Diffusion

Infiltration modelling to the tailings was undertaken as part of the cover assessment program. Outputs of that modeling include moisture content profiles within the tailings over time. The results are shown in Figure 2.1 for fine tailings and in Figure 2.2 for coarse tailings. These simulations represent a complete season of infiltration for a tailings layer of 7 m above the water table. As shown, the results suggest that the influence of a single season infiltration should extend to a depth of about 1.5 m for fine tailings and up to 2.5 in coarse tailings. This is somewhat deeper than suggested by estimated rates at which the solute fronts are propagating through the tailings, which suggest that the modelling overestimates the rates at which infiltration is occurring. (The results suggested infiltration rates of 28 mm per year and 92 mm per year respectively for fine and coarse tailings.) Nonetheless, of significance are the saturation profiles that are predicted to occur within the tailings, which govern the rate of oxygen diffusion into the tailings. Again, it appears that the measured field moisture contents are lower than the predicted levels of saturation in the tailings. It is however possible that some loss of moisture had occurred from the tailings during sampling, handling and testing which would result in an underestimation of the saturation levels in the tailings. (This also has bearing on the estimated porewater concentrations calculated in the previous section.) For the purpose of estimating oxygen diffusion, the modeled rather than field measurements of moisture content were utilized. Estimated oxygen flux with time for fine tailings are shown in Table 2.9; the results for the coarse tailings suggest that oxygen flux rates may be as high as five times that estimated for the fine tailings.

Table 2.9
Summary of estimated Oxygen Flux into Fine Tailings

Time Year	**Oxygen Flux** (mol/m^2/s)	**SO_4 Production** (kg/m^2/year)
1	2.71E-06	7.9
5	1.43E-06	4.2
10	8.03E-07	2.3
15	7.09E-07	2.1
20	5.94E-07	1.7
30	5.15E-07	1.5
60	3.58E-07	1.0
120	2.49E-07	0.7
180	1.99E-07	0.6
240	1.62E-07	0.5
300	1.37E-07	0.4
400	1.13E-07	0.3

To verify these estimates, overall sulphate productions were estimated from the sulphate that has accumulated in the tailings. The results are shown in Table 2.10. Based on the oxygen flux derived from the diffusion calculations, the cumulative sulphate productions over 10, 15 and 20 years are 42, 53 and 62 kg/m^2 respectively. The actual sulphate production in the fines in the last column of Table 2.10 compare well with those suggested by the diffusion calculations. The production in the coarse tailings is however only 2 to 3 times that of the fines, which is lower than the diffusion calculations suggested. It should be noted that the modelling did not consider the effects of layering. The presence of a layer of fine tailings within the coarse tailings near the surface will have a significant impact on oxygen diffusion.

Overall, however, the oxygen diffusion calculations show a slowing in the rate of acid generation. This also means that solute production rates will slow down in the future, which means that the current estimates of porewater concentration represent maximum concentrations that will occur in the porewater. It is therefore concluded that it is reasonable to estimate future solute release rates based on the estimated current rates of propagation of solute fronts. The diffusion calculations further suggest that defining the source concentrations as a step function is conservative, and that the solute concentrations are likely to show a logarithmic decay with time. This expected decay has been taken into consideration in long-term predictions where the effects of ongoing oxidation were examined (see Section 3.2).

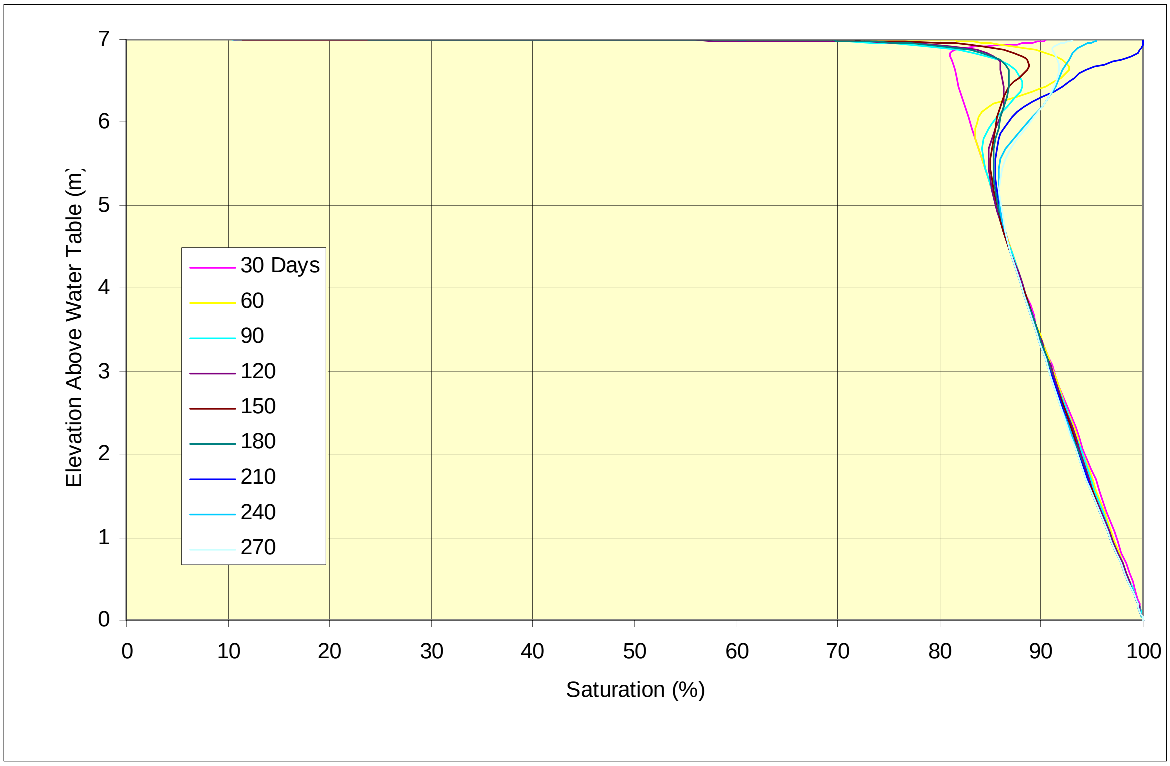


Figure 2.1 Estimated Saturation Profiles in Fine Tailings (Note: Tailings surface 7 m above water table)

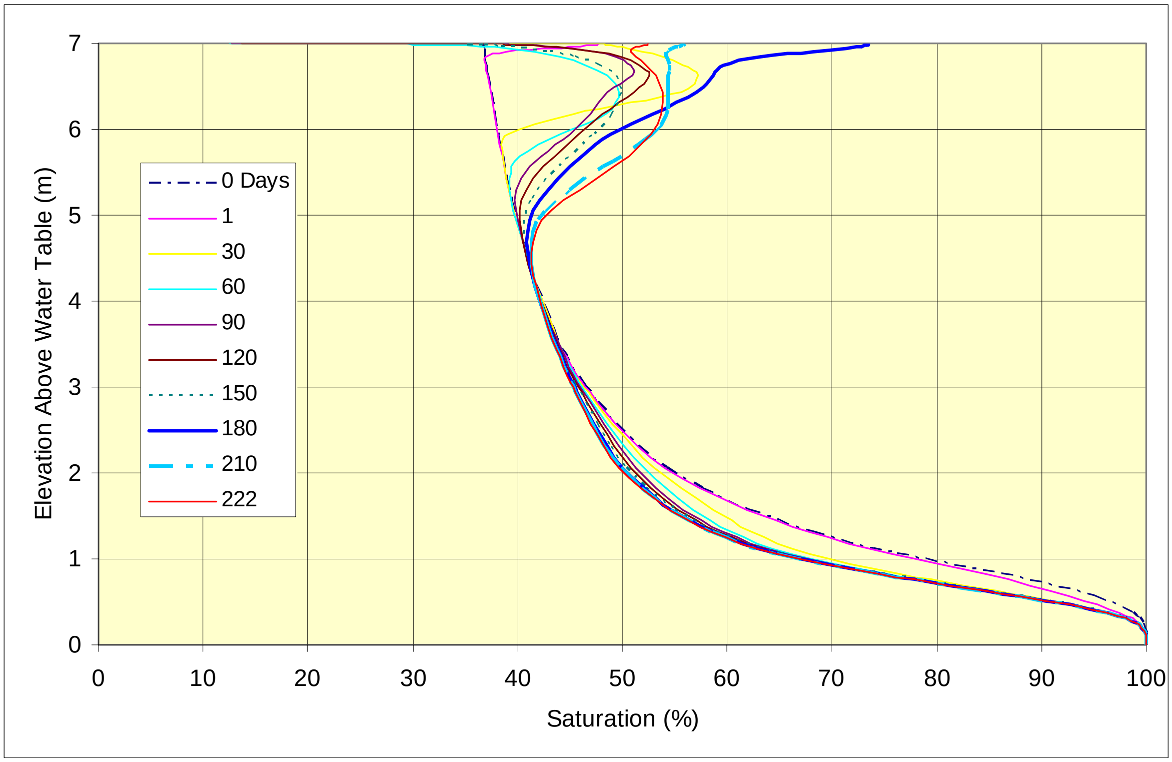


Figure 2.2 Estimated Saturation Profiles in Coarse Tailings (Note: Tailings surface 7 m above water table)

Table 2.10
Summary of Sulphate Production

Impoundment	Location		Zone	Sulphate		2001	Time	Cumulative
				Depth m	Avg. %	tonnes	Oxdtn. years	Production kg/m^2
Original	P01-10	A1-1	Fines	4.50	1.12	28,645	20	105
	P01-08	A2-1	Fines	7.6	0.33	14,147	20	52
		A7-1	Coarse	6	0.55	8,131	20	71
Second	P01-09	A3-1	Coarse	6.1	1.13	21,655	15	144
	P01-07	A4-1	Fines	4.5	0.78	37,344	15	73
Intermediate	P01-05	TP7/A5-1	Coarse	1	1.16	4,514	10	24
			Fines	*1*	*1.16*	*14,127*	10	24

3 Results

3.1 Estimated Release of Contained Solutes

The cumulative release of sulphate and zinc assuming no future oxidation are shown in Table 3.1. There is a minor difference between the two estimates as a result of rounding errors that occur as the peaks pass through the base of the tailings deposit. The total cumulative release shown in Table 3.1 represents our best estimate of the current "inventory" of sulphate and zinc in the various impoundments.

Table 3.1
Summary of Estimated Cumulative Releases of Sulphate and Zinc to Base of Tailings Assuming No Future Oxidation.

	Average Advance (720 years)		Maximum Advance (470 years)	
	SO4 Load	Zn Load	SO4 Load	Zn Load
Area	tonnes	tonnes	tonnes	tonnes
Original Impoundment	153,459	25,838	152,679	25,541
Second Impoundment (East)	75,309	12,435	75,297	12,461
Second Impoundment (West)	93,174	14,790	110,704	17,384
Intermediate Impoundment	131,044	21,257	178,893	29,057
TOTAL	452,985	74,320	517,573	84,443

Breakthrough curves for average advance rates were produced for each as shown in Figure 3.1 (sulphate) and in Figure 3.2 (zinc). As shown the total zinc release peaks at about 2028 at a loading of about 110 tonnes per year as the loading from the northern source area of coarse tailings of the Original Impoundment breaks through. A second peak is reached in about 2150 of 220 tonnes per year, when the southern area of the coarse tailings of the original impoundment breaks through together with the remainder of the coarse areas. The breakthrough curves of the fine tailings are delayed and peak at about 140 tonnes at year 2380.

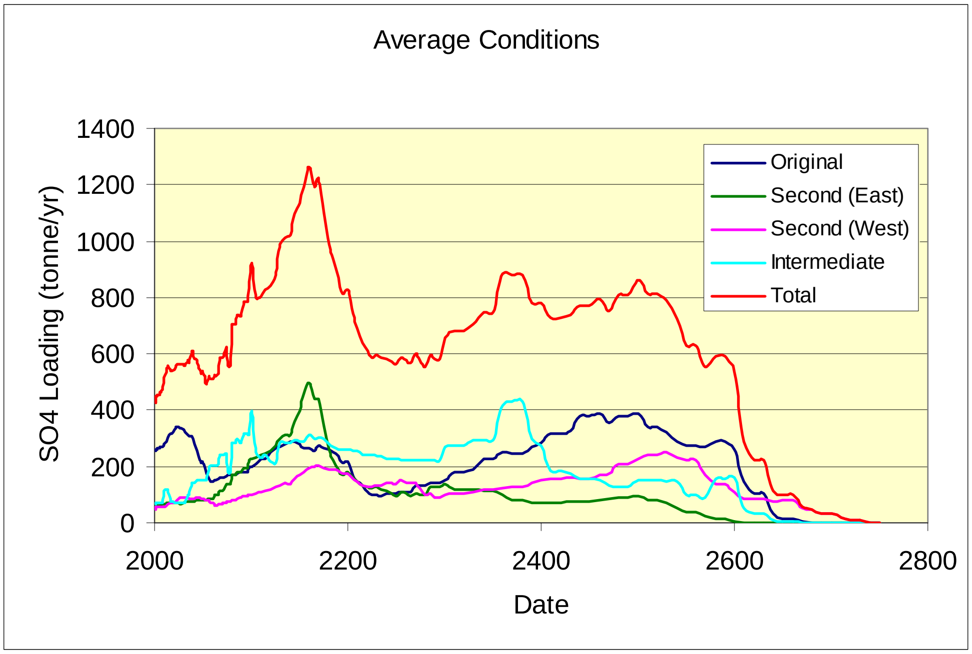


Figure 3.1 Estimated Sulphate Loadings for Average Advance Rates

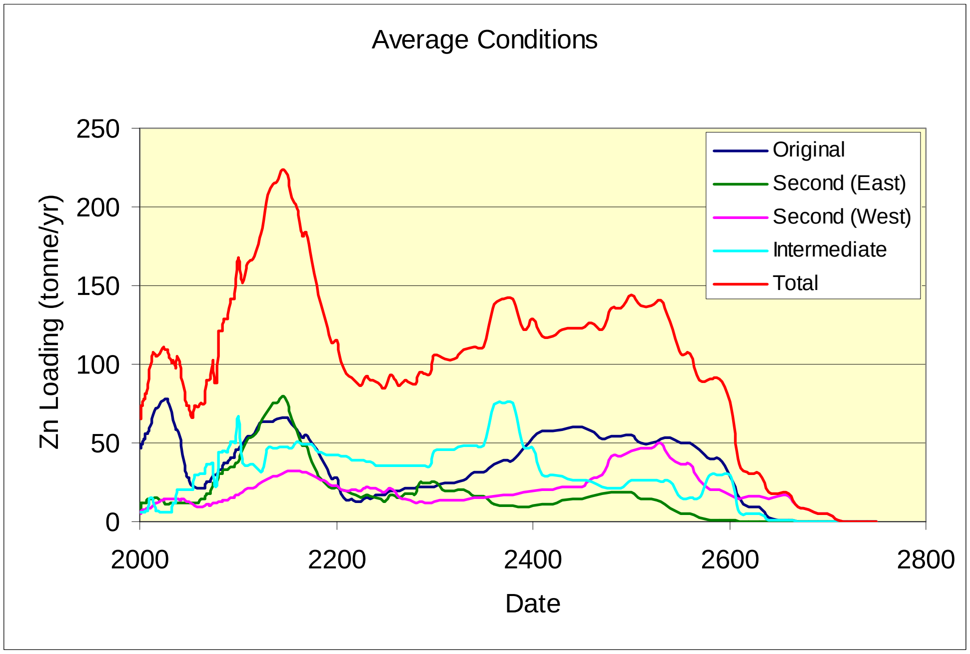


Figure 3.2 Estimated Zinc Loadings for Average Conditions

The estimated loadings for maximum rates of advance are shown in Figure 3.3 and Figure 3.4 for sulphate and zinc respectively. Increasing the rates of advance has two effects. First, the first and second peaks in zinc loading occur much sooner (2012 and 2068 as opposed to 2028 and 2150). Second, the first two peak loadings increase to 240 and 420 tonnes respectively, or about double the estimates for average conditions.

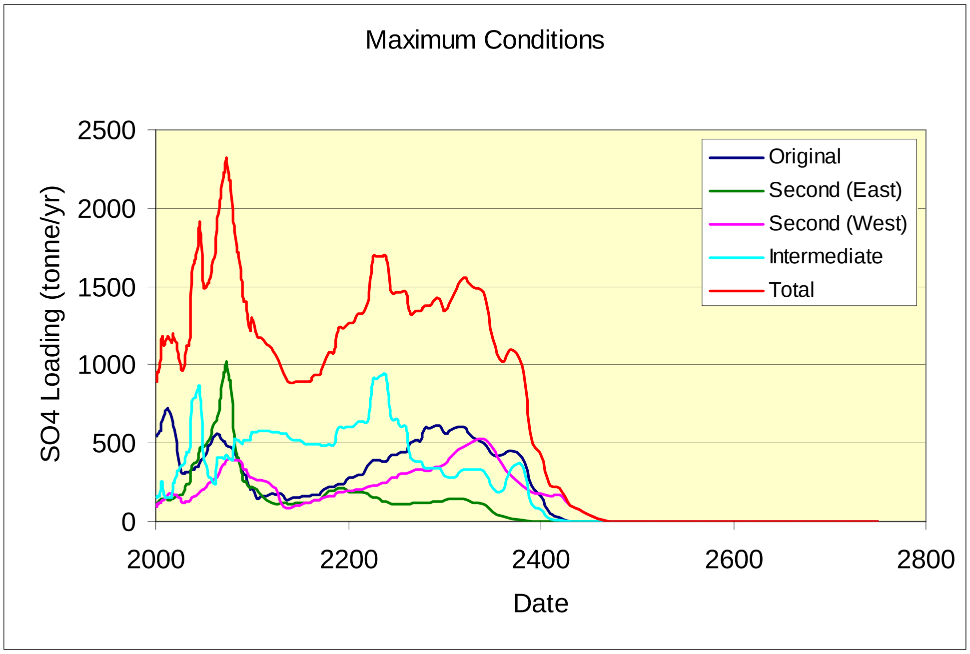


Figure 3.3 Estimated Sulphate Loadings at Maximum Rates of Advance

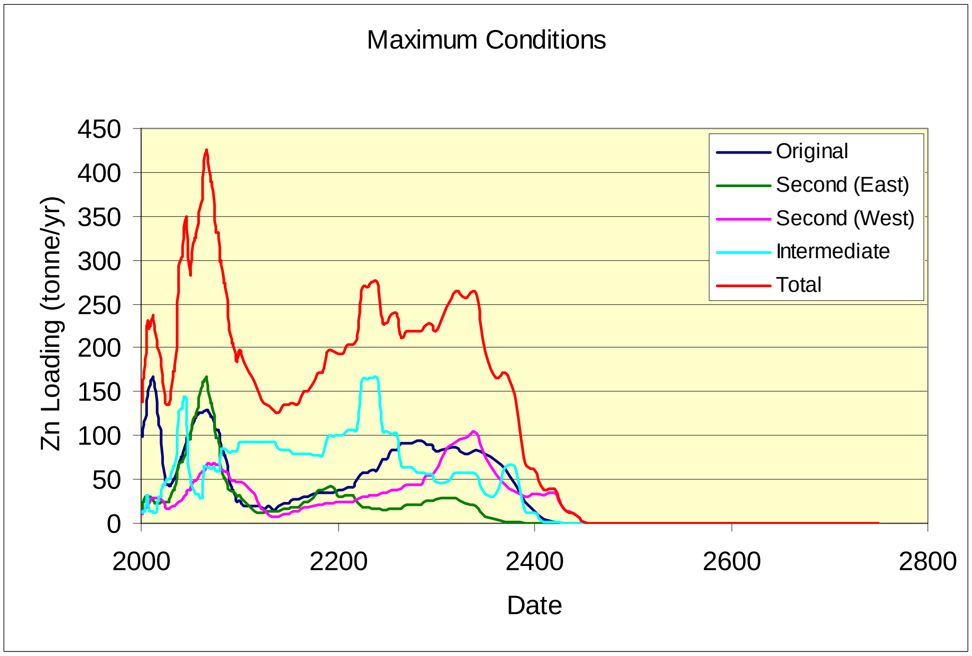


Figure 3.4 Estimated Zinc Loadings at Maximum Rates of Advance

3.2 Ongoing Oxidation

The potential effects of ongoing oxidation were assessed by fitting a simple curve to the estimated change in oxidation rate shown in Table 2.9. The curve that best fits the data is as follows:

$$R(t) = R_0 * t^{-0.532}$$

Where $R(t)$ is the production rate at time t
R_0 is the production rate at time $t = 0$

Using this equation and the current sulphate and zinc production rates at the surface, the future production was estimated and allowed to ‘propagate’ through the tailings as before. The results are summarized in Table 3.2

Table 3.2
Summary of Estimated Cumulative Releases of Sulphate and Zinc to Base of Tailings Assuming Ongoing Oxidation.

	Average Advance (720 years)		Maximum Advance (470 years)	
	SO4 Load	Zn Load	SO4 Load	Zn Load
Area	tonnes	tonnes	tonnes	tonnes
Original Impoundment	176,208	26,916	208,666	28,203
Second Impoundment (East)	104,851	13,872	150,412	16,146
Second Impoundment (West)	113,597	15,739	169,137	20,047
Intermediate Impoundment	161,310	23,115	259,846	34,027
TOTAL	555,966	79,643	788,062	98,422

The results for average conditions with ongoing oxidation are shown in Figure 3.5 and Figure 3.6 for sulphate and zinc respectively. As shown, the ongoing oxidation does not affect the peak release rates; it only extends loadings into the future.

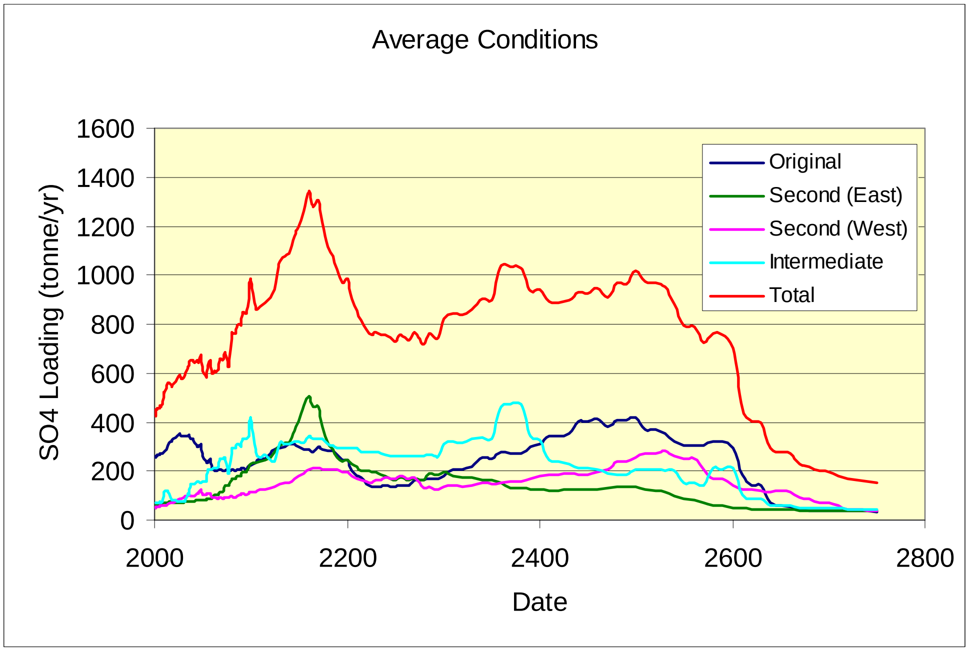


Figure 3.5 Estimated Sulphate Loadings with Ongoing Oxidation for Average Conditions

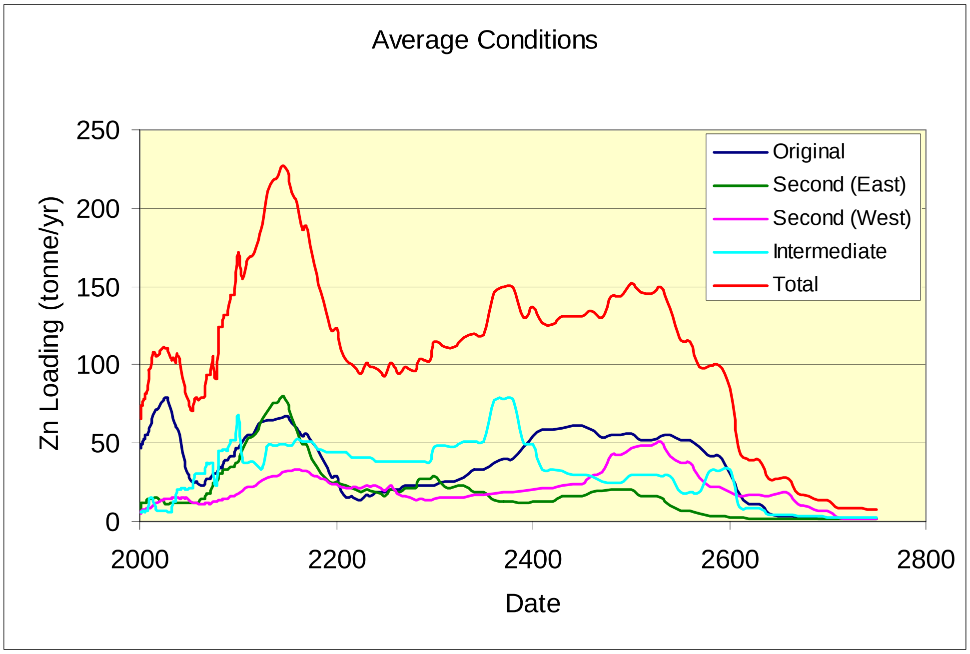


Figure 3.6 Estimated Zinc Loadings with Ongoing Oxidation for Average Conditions

The corresponding plots for maximum propagation rates are shown in Figure 3.7 and Figure 3.8 for sulphate and zinc at maximum rates of advance. The observations are the same as for the average conditions.

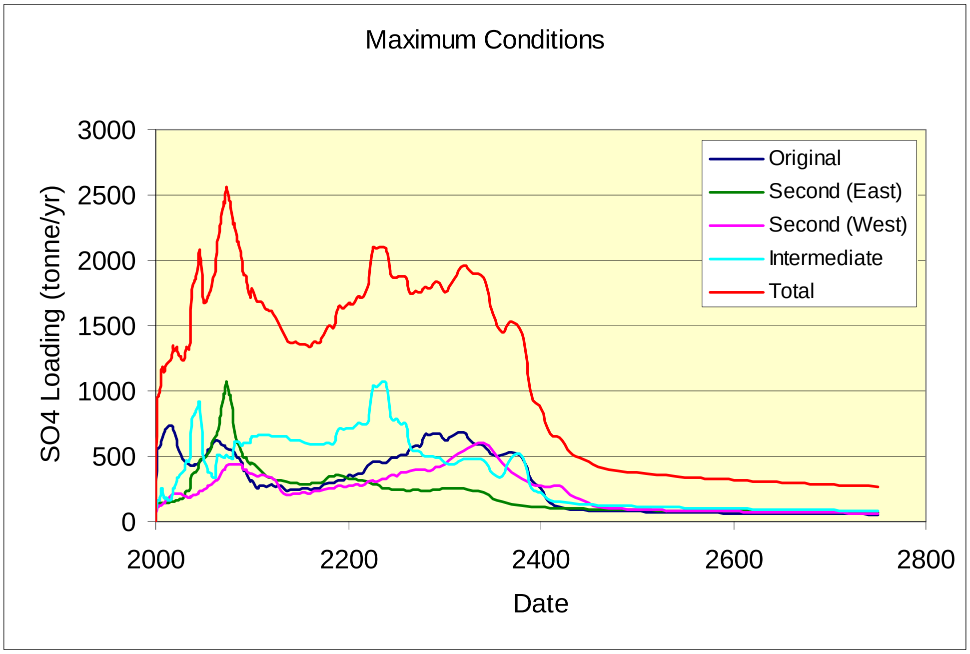


Figure 3.7 Estimated Sulphate Loadings with Ongoing Oxidation and Maximum Rates of Advance

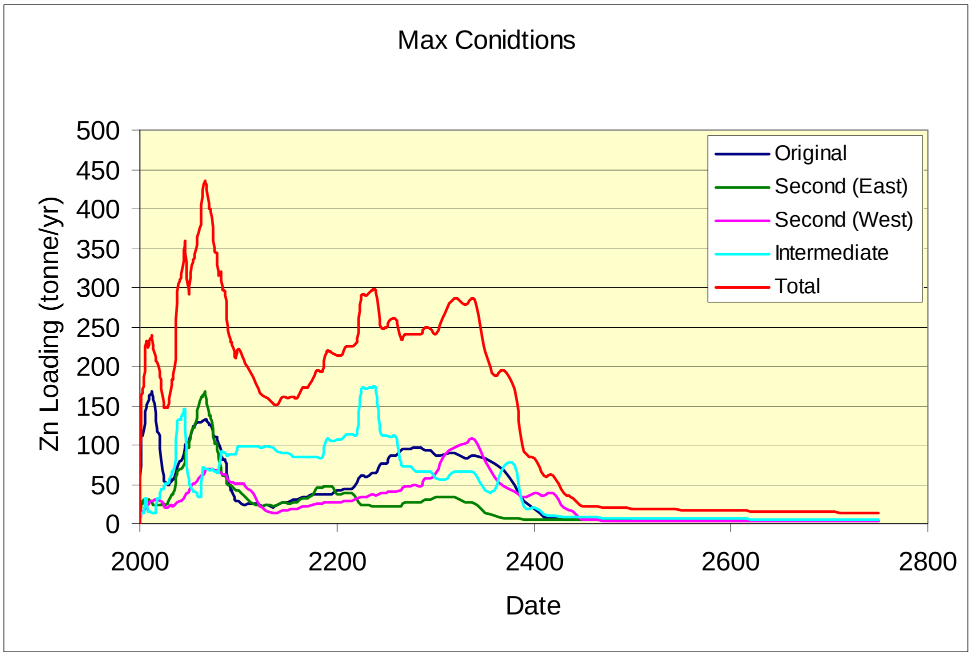


Figure 3.8 Estimated Zinc Loadings with Ongoing Oxidation and Maximum Rates of Advance

3.3 Effects of Remediation Alternatives

A series of runs were also completed to assess the potential source loadings that may result from various rehabilitation approaches. These are presented below.

3.3.1 Partial Relocation – Relocation of Intermediate Tailings

In order to estimate loadings from the tailings for partial relocation of the tailings, the following assumptions were adopted:

- Relocation of the tailings will occur between 2008 and 2014, with the Intermediate Tailings removed by 2014;
- Dry covers will be placed concurrently on the Secondary and Original Tailings by end of 2010.

The results are illustrated in Figure 3.9 and Figure 3.10.

3.3.2 Partial Relocation and Establish Water Cover

The source loadings were estimated for partial relocation of the tailings down to an elevation of 1064 m ASL. A water cover was then assumed to be established over the remaining tailings. It was assumed that the Original Impoundment would be removed to a depth of about 22 m from surface by about 2010, the Second Impoundment to a depth from surface of 19 m by 2014, and the Original Impoundment tailings would be removed to a depth of about 4 m from surface by 2018. The water cover (about 3 m deep) was assumed to be established by about 2020.

The results are illustrated in Figure 3.11 and Figure 3.12 respectively for average and maximum propagation rates.

3.3.3 Complete Water Cover

Source loadings were estimated in the event that the Intermediate Impoundment is raised to establish a water cover to a depth of 3 m over the entire tailings deposit. The results are illustrated in Figure 3.13.

3.3.4 Dry Low Infiltration Covers

The placement of dry covers over the entire tailings deposit were assessed assuming that low infiltration or store and release covers would reduce the net infiltration to the tailings to about 5 mm per annum. It was assumed that the covers would be completed by about 2010. The results are shown in Figure 3.14 and Figure 3.15.

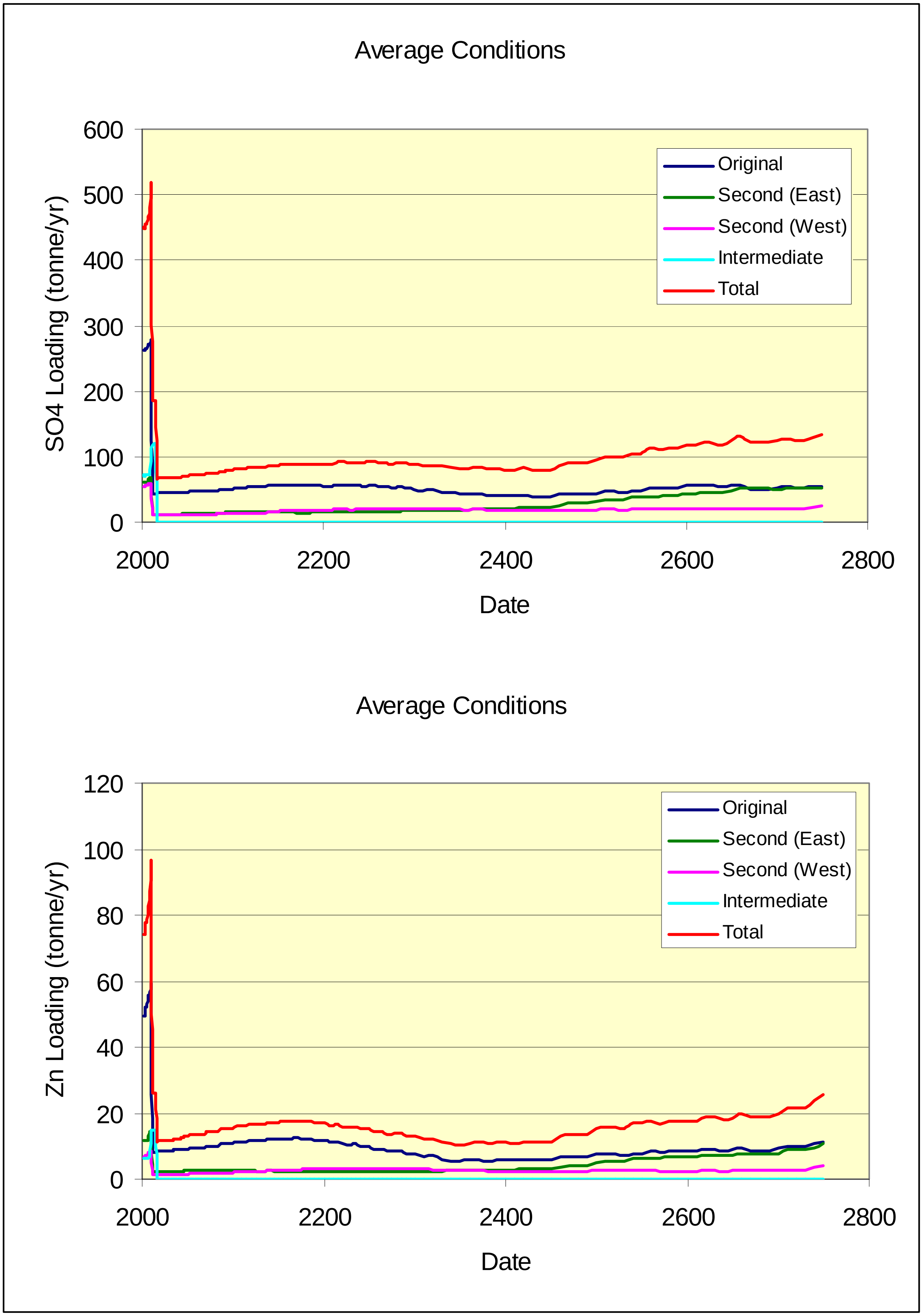


Figure 3.9 Estimated Loadings for Relocation of Intermediate Tailings, Assuming Average Propagation Rates

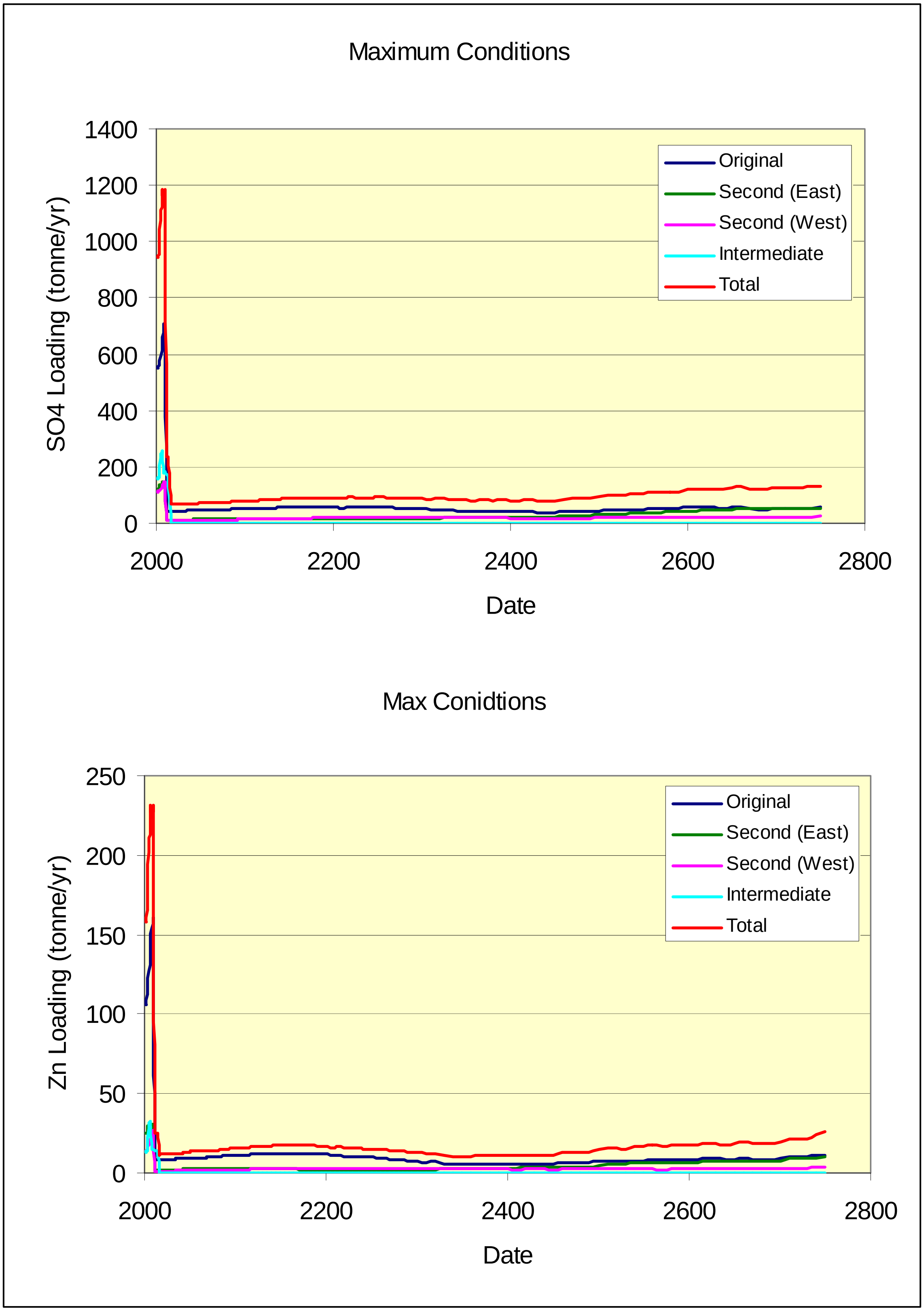


Figure 3.10 Estimated Loadings for Relocation of Intermediate Tailings, Assuming Maximum Propagation Rates

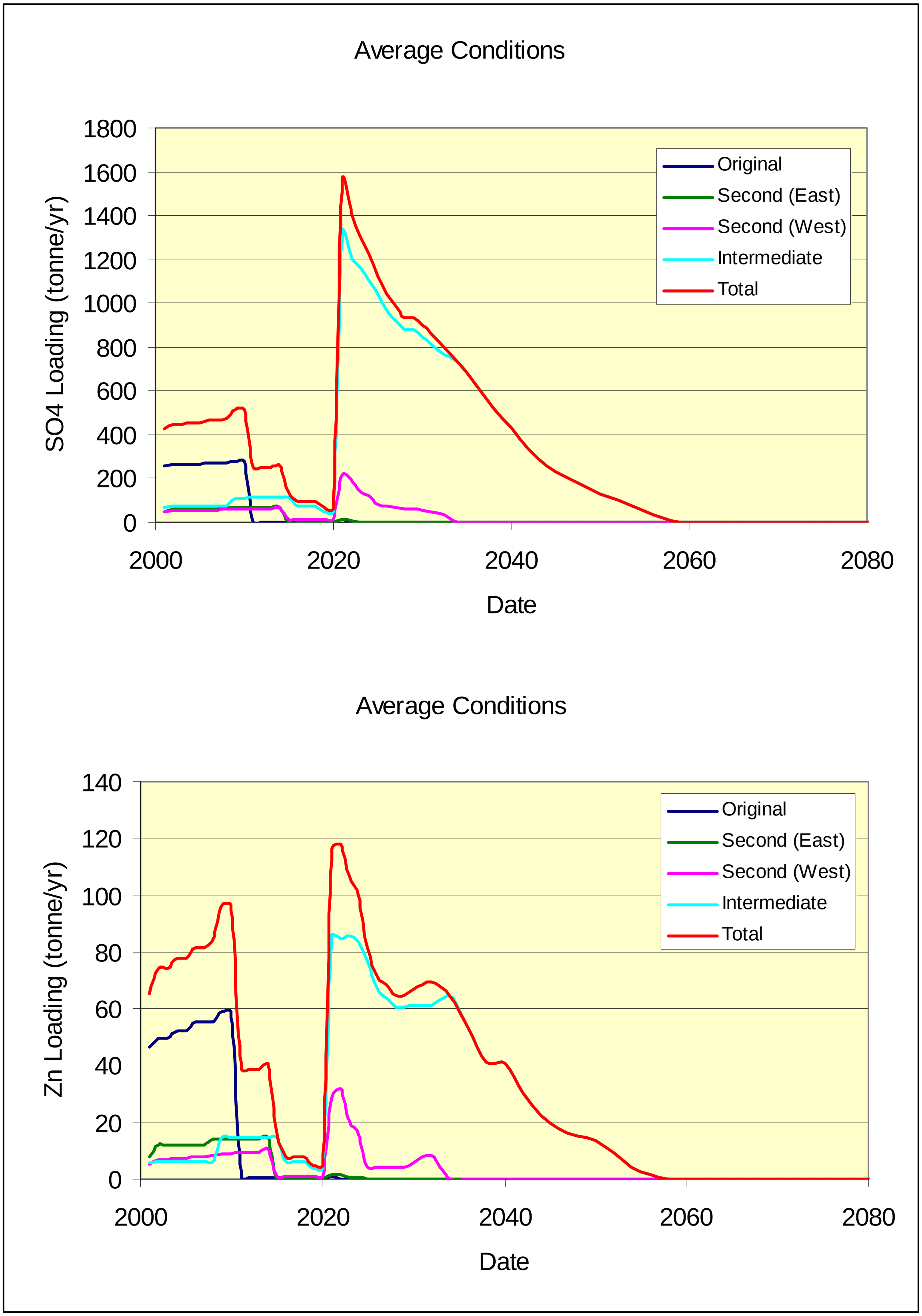
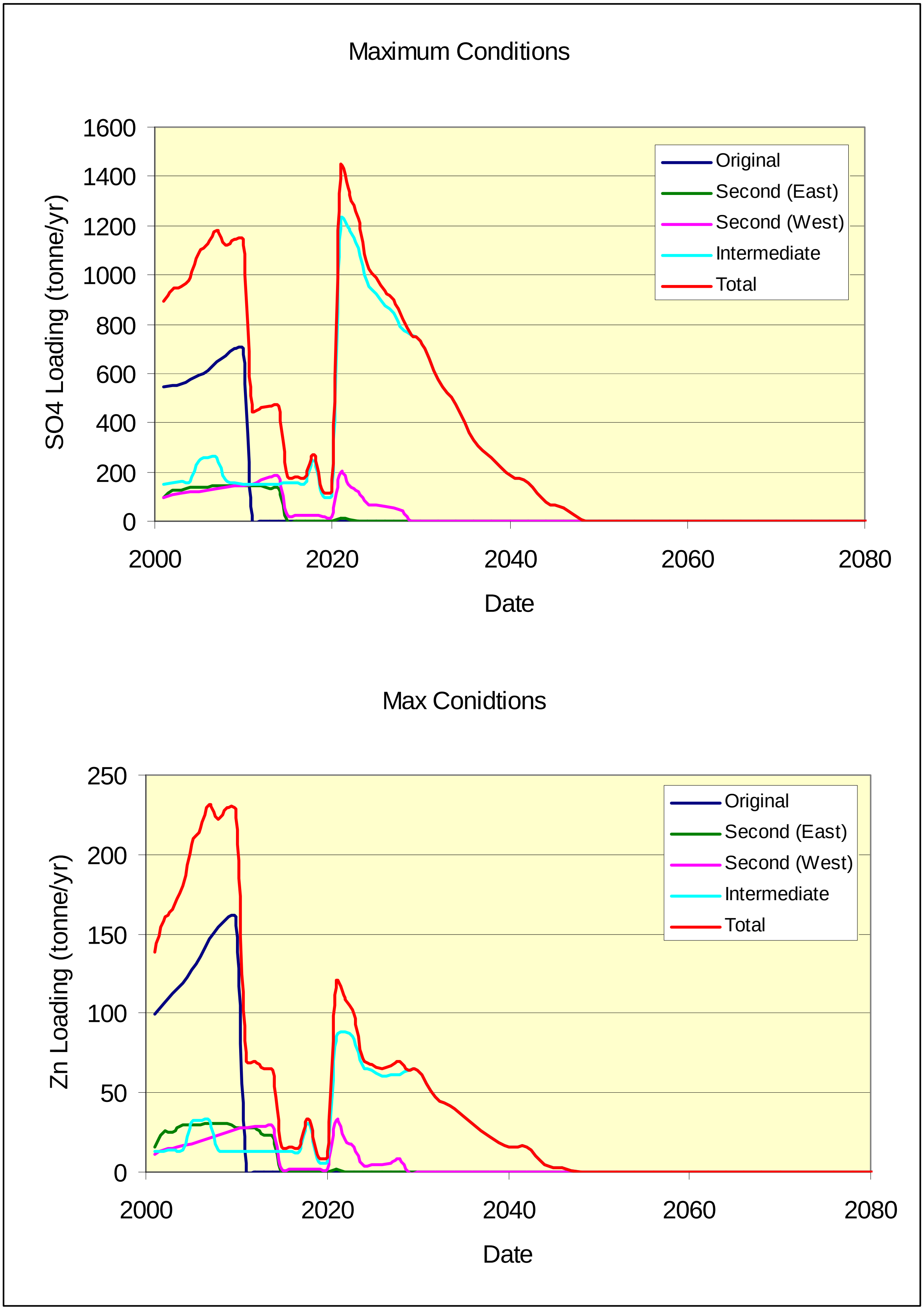


Figure 3.11 Estimated Loadings for Partial Tailings Relocation, Establishing a Water Cover and Assuming Average Propagation Rates


Maximum Conditions

Max Conidtions

Figure 3.12 Estimated Loadings for Partial Tailings Relocation, Establishing a Water Cover and Assuming Maximum Propagation Rates

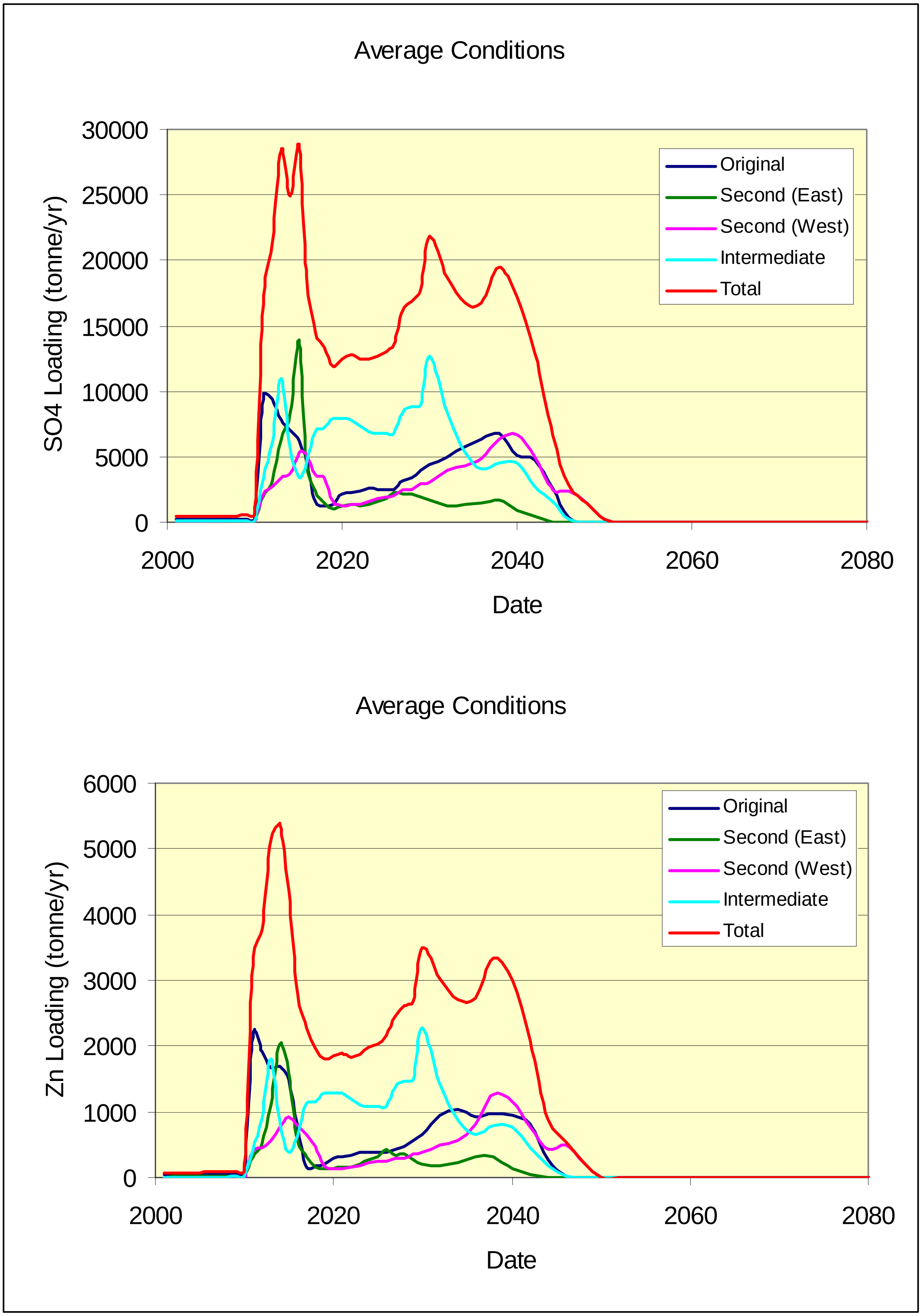


Figure 3.13 Estimated Loadings for Establishing Water Cover Over the Entire Tailings Deposit

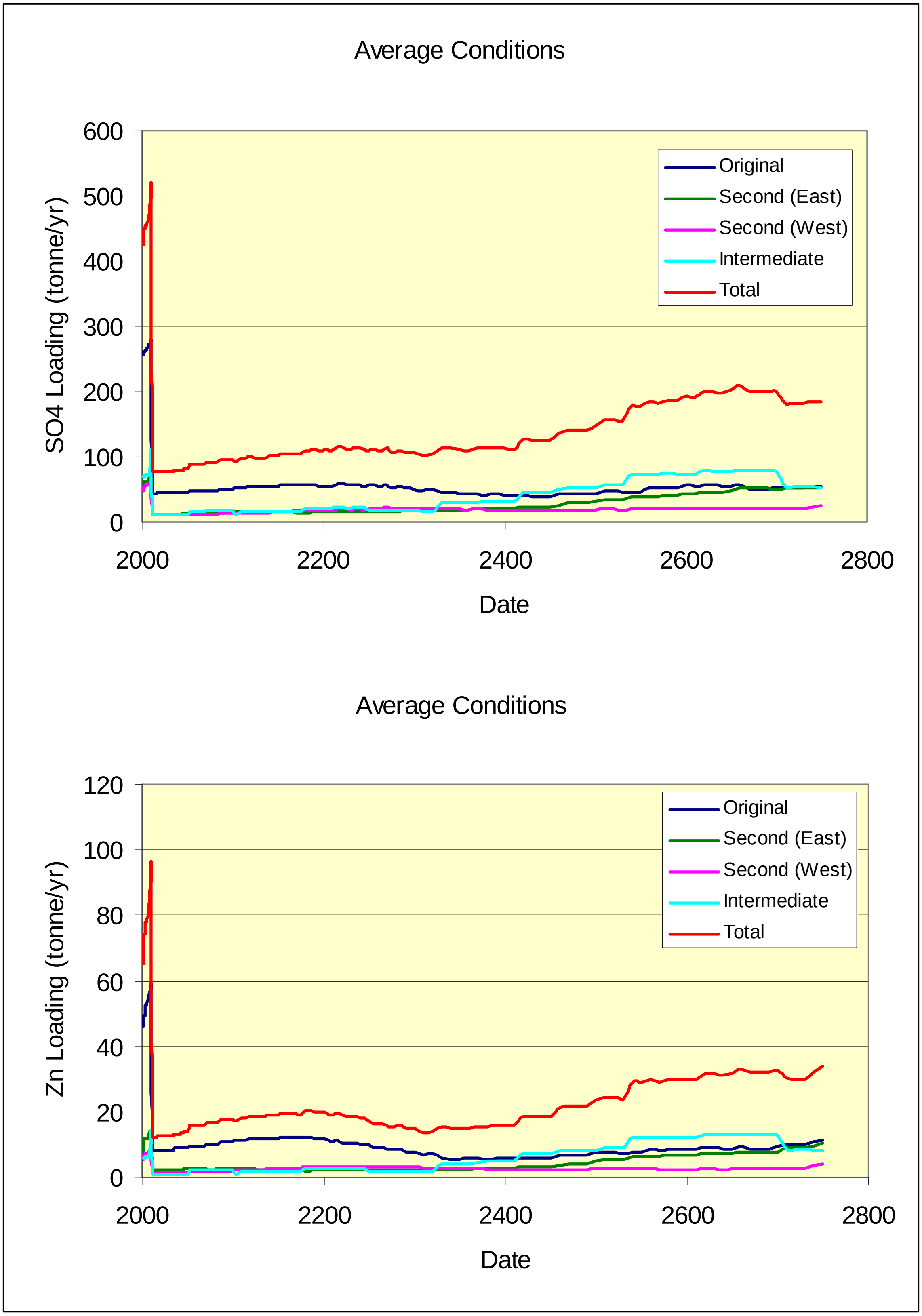


Figure 3.14 Estimated Loadings for Establishing Dry Covers Over the Entire Tailings Deposit Assuming Average Propagation Rates

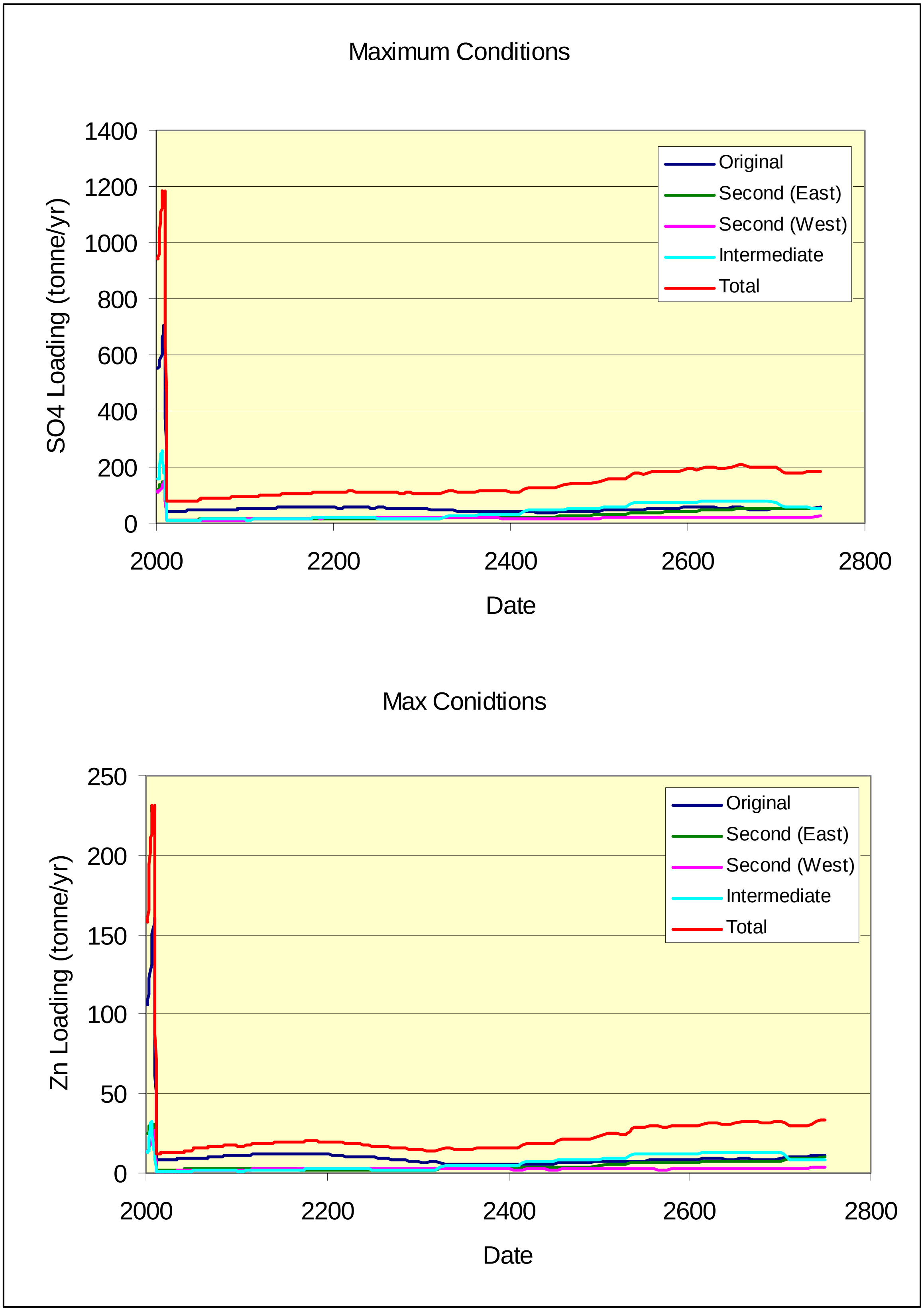


Figure 3.15 Estimated Loadings for Establishing Dry Covers Over the Entire Tailings Deposit Assuming Maximum Propagation Rates

APPENDIX C

Review of Groundwater Monitoring Data

Appendix C
Review of Groundwater Quality

C.1 Original Impoundment

Figure C1 shows the water quality time trends observed in P01-10 and P01-8 and Figure C2 shows water quality depth profiles for P03-7. The following observations can be made:

At P01-10 (located in the eastern section):

- The tailings pore water (screened at P01-10A) shows elevated Na suggesting residual process water; the recent increase in SO4, Mg etc in this piezometer is believed to be a result of leakage through the joints of the piezometer;

- The groundwater in the alluvial aquifer (screened at P01-10B) shows slightly elevated SO4, Mg, Na and Zn suggesting some (limited) impact of tailings seepage; the recent increases in solutes is unlikely to be a result of natural tailings seepage (these tailings have been in place for nearly 30 years) but are more likely a result of leakage from the piezometer (to be confirmed by GLL study);

At P01-08 (located in the western section near the Original Dam):

- The tailings pore water (screened at P01-08A) shows significantly lower Na compared to P01-10A suggesting higher flushing rate; however, this observation is not consistent with field logs suggesting finer tailings at P01-08A (screened in SILT) compared to P01-10A (screened in silty SAND);

- The groundwater in the alluvial aquifer (screened at P01-08B&C) shows elevated SO4 (~370mg/L) and Mg (~23mg/L); these concentrations are higher than observed further upstream (at P01-10) suggesting incremental loading from the Original Impoundment; note that tailings pore water at this location (P01-08A) shows significantly lower SO4 and Mg and can therefore be ruled out as a major source (which is consistent with the presence of frozen tailings at depth at this location);

- Large variations in Zn observed in P01-08B are suspicious and may indicate potential leakage through piezometer (to be confirmed by GLL study);

At P03-07 (located in the northwestern section near the Original Dam):

- The groundwater in the alluvial aquifer at this location shows significantly elevated SO4 (500-1900mg/L), Mg (30-120mg/L) and Zn (0.01-1.4mg/L); these concentrations are significantly higher than observed at P01-08 located near the center of the valley;

- The (limited) sampling at this location suggest an “inverse” profile with higher concentrations at depth within the aquifer; this pattern would suggest that tailings seepage from the coarse beach of the Old Impoundment may NOT be the primary source of contamination; highly contaminated groundwater entering the area from the historic Faro Creek channel (SO4~10,000 mg/L; Mg~500 mg/L and Zn~480 mg/L) might be a more plausible source;

In summary, the aquifer beneath the Original Impoundment shows significantly elevated SO4, Mg and Zn. The highest concentrations were observed in the northwestern section, i.e. in proximity of the mouth of the Faro Creek valley, which was used as a major discharge point. The two potential sources of contaminants in this area would be (i) infiltration through the coarse tailings beach deposited in this area (e.g. at A7) and/or (ii) WRD seepage from the Faro Creek channel (see section 3).

C.2 Secondary Impoundment

Figures C3 and C4 show the water quality time trends observed at P01-09 and P01-07. Figures C5-C10 show water quality depth profiles for P03-01 through to P03-06. The following observations can be made:

At P01-09 (located in the eastern section):

- The tailings pore water (screened at P01-09A) shows highly elevated SO4 (10,000 – 80,000 mg/L), Mg (570-630 mg/L) and Zn (660-5500 mg/L) indicating strong oxidation in the upper tailings profile; note, that this piezometer is screened at greater depth (below the oxidation front); it is therefore likely that leakage through the joints of the PVC (from the upper acidic tailings profile) has caused the recent dramatic increase in all ARD products (in particular SO4 and Zn) in this piezometer (to be confirmed by GLL study);

- The tailings pore water originally sampled showed elevated Na (~155 mg/L) indicative of residual process water; Na has not been detected in subsequent sampling rounds, again suggesting that most of the water sampled in this piezometer now represents leakage from the upper profile (where no process water is present any longer);

- The groundwater in the alluvial aquifer (screened at P01-09B/C/D) shows elevated SO4, Mg and in particular Zn; while initial monitoring results may be representative of true subsurface conditions, recent survey results are very likely impacted by leakage through the joints of the PVC casing (to be confirmed by GLL study);

At P01-07 (located in the southern section near the West Wall):

- The tailings pore water (screened at P01-07A&B) shows highly elevated Na (300-400 mg/L) indicative of historic process water; this would suggest very limited, if any, flushing of ARD products from the upper, oxidized tailings profile into the deeper tailings profile at this location; this observation is consistent with the fine nature of tailings and the high paste pH readings (up to pH 9.4) encountered here;

- SO4, Mg and Zn concentrations observed in P01-07A&B may therefore be representative of tailings process water;

- Initial sampling of groundwater in the alluvial aquifer (screened at P01-097C/D/E) indicated moderately elevated SO4 (400-600 mg/L), Mg (23-40 mg/L) and Zn (~0.01mg/L) (Sept 2001); however, SO4 and Mg have increased significantly over the past 2 years suggesting either seepage from an upstream source and/or well leakage (either at this location and/or at an upstream location); a detailed analysis of the packer testing results (GLL study in progress) will be required to determine to what extent internal well leakage and/or leakage from upgradient wells is responsible for this significant increase in oxidation products in the aquifer;

At P03-01 to 03 (located in the eastern section surrounding P01-09):

- The tailings pore water in P03-01 & 03 (and to a lesser extent P03-02) show highly elevated SO4 (19,000-44,000mg/L), Mg (400-700mg/L), and Zn (100-2200mg/L) indicative of tailings oxidation and downward migration of a “TDS front”; the observed concentrations are the same order of magnitude as observed at P01-09 suggesting that significant oxidation is occurring throughout this (eastern) section of the Secondary Impoundment;

- The concentrations of most oxidation products (SO4, Mg, Zn) in tailings pore water (at P03-01) has increased markedly over the three sampling events (1 year) (e.g. SO4 increased from 14,500-44,500mg/L in P03-01-09); this increase could be due to (i) re-equilibration after installation; (ii) preferential downward flow of tailings pore water along the drill hole and/or (iii) advance of the ARD front; the consistent results for Na do not support hypothesis (i); the paste EC readings indicate that the “TDS front” was still above the highest piezometer tip; it is therefore plausible that well construction and sampling is “pulling” the high TDS water into the lower tailings profile; further analysis may be required to resolve this issue;

- Na in tailings pore water is highly elevated at all three sites (300-650 mg/L) suggesting that it might be dominated by original process water; however, this hypothesis is not consistent with the highly elevated SO4 also observed in tailings pore water; other potential sources of Na include (i) dissolution of primary of secondary minerals containing Na (e.g. Na-feldspar) and/or (ii) evapo-concentration of tailings pore water; further studies are required to explain the highly elevated Na in tailings pore water in this area;

- The groundwater quality in the aquifer varied significantly among the three sites:

    - At P03-01 and P03-02 (upgradient and cross-gradient of P01-09), significant influence of tailings seepage (i.e. SO4 >300 mg/L and Zn >0.01 mg/L) are is only observed within a few meters below the base of the tailings;

    - At P03-03 (downgradient of P01-09), the effect of tailings seepage is more significant and observed to a greater depth (e.g. 1860 mg/L SO4 and 148 mg/L

Zn about 18m below the base of tailings); leakage from P01-09 (in particular from P01-09E) is the most likely cause for the highly elevated SO4 and Zn at depth at this location;

- o Elevated SO4 concentrations (> 100 mg/L) were observed throughout the entire S&G aquifer (to a depth of 20-30m below base of tailings) at all three sites (including the most upstream well P03-01!); this indicates that an upstream source (other than tailings seepage) is contributing SO4 load to the Rose Creek aquifer (potentially WRD seepage from the Intermediate Dump??);

At P03-05 (located in the central section):

- The tailings pore water in P03-05 also shows elevated SO4 and Mg, but these concentrations show a decreasing trend towards the base of the tailings, suggesting that the “TDS front” has not reached the base of the tailings; this observation is consistent with the paste EC profile (Table 3);

- Zn in tailings pore water at P03-05 is still relatively low (~1 mg/L) and Na is elevated (~270 mg/L) supporting the hypothesis that the TDS front has not migrated through the lower portion of the tailings profile (similar to observations in P01-07A);

- The groundwater quality in the aquifer shows a strong dilution profile with elevated SO4 (~1000 mg/L), Mg (~60 mg/L) and Na (~45 mg/L) confined to the upper 3-4m below the base of the tailings; the deeper aquifer profile shows 3-4 times lower concentrations of all major constituents, supporting the conceptual model that tailings seepage is generally confined to a narrow zone at the top of the aquifer;

At P03-06 (located in the northern section):

- At P03-06 saturated conditions are only observed near the base of the tailings and only one sample of tailings pore water has been obtained thus far (at base of tailings in Sep ’03); this initial survey showed that tailings pore water in this area is much more dilute (e.g. SO4 ~1500 mg/L, Zn ~0.6 mg/L) than observed in other parts of the Secondary Impoundment

- Groundwater quality in the aquifer at P03-06 shows a general “dilution profile”, with elevated SO4 (~1000 mg/L), Mg (~65 mg/L) and Zn (10 mg/L); however, elevated SO4 (>>500 mg/L) were also observed at greater depth in the aquifer;

- Seasonal variations in groundwater quality (in particular SO4) were more pronounced at P03-06 than at other locations possibly indicating strong seasonal variations in ARD inputs to the aquifer (e.g. wetting fronts through tailings beach and/or seepage from waste rock dumps);

At P03-04 (located in the southwestern section):

- At P03-04 saturated conditions are also observed only near the base of the tailings (as for P03-06) and tailings pore water has a very similar composition to water moving in the uppermost layers of the aquifer with highly elevated SO4 (~8000-10,000 mg/L), Mg (110 mg/L) and Zn (0.1-2.0 mg/L);

- Groundwater quality in the aquifer shows a typical dilution profile with a narrow zone of high TDS water beneath the tailings; however, the deeper aquifer also shows significantly elevated SO4 (400-880 mg/L); the SO4 and Mg profiles are similar (in shape and concentrations) to those observed further upgradient; however, Na concentrations are generally higher in the deeper aquifer at P03-04 (relative to P03-05);

In summary, tailings pore water quality within the Secondary Impoundment shows significant variability with highest levels of SO4, Mg and Zn reported for the eastern section. However, there is some uncertainty about the depth of the “TDS front”, with paste EC profiles generally suggesting a slower advance than water quality sampling. The lowest levels of ARD products (SO4, Mg and Zn) were observed in the well-drained (coarse) beach in the northern section (P03-06). Pore water quality in the southern section appears to be very heterogeneous, ranging from “dilute” water dominated by process water (P01-07A) to high TDS water characteristic of tailings seepage (P03-04).

The groundwater quality in the aquifer beneath the Secondary Impoundment suggests an incremental loading from east (upstream) to west (downstream) with SO4, Mg, Zn and Na generally increasing in a downstream direction. At most locations, concentrated ARD seepage is observed in a narrow zone beneath the tailings. However, ARD products are also observed (at lower concentrations) at significant depth. Potential reasons for this occurrence include (i) leakage from deep piezometers (P01 series), (ii) vertical dispersion along the flow path and/or (iii) seepage of WRD from the Faro site (along the north side).

C.3 Intermediate Impoundment

Figures C11 & C12 show the water quality time trends observed at X21 and P01-05& -06, respectively. Figure C13 shows the water quality depth profile for P03-08 completed near the Intermediate Pond. The following observations can be made:

At X21 (located in the northeastern section):

- The tailings pore water (at X21A) has shown very high variations in SO4, Mg, and Zn over the last 8 years (e.g. SO4 from ~1000 to ~20,000); potential reasons for this variation include (i) flushing of oxidation products from the tailings profile and/or (ii) significant variations in loading from an upstream source (e.g. seepage from Secondary Impoundment);

- Early sampling of groundwater at this location (in the original wells X21A/B/C) in 1981 showed very low sulphate (~35 mg/L) and zinc (0.03-0.05) suggesting very limited impact of tailings seepage from the Original/Secondary Impoundment up to this point; by 1987, SO4 concentrations had increased significantly in all three wells (~100 – 1000 mg/L)

- Over the last 8 years groundwater in the upper aquifer (at X21B redrilled in 1996) has been relative stable with elevated SO4 (~700-1000 mg/L), Mg (30-40 mg/L) and Na (60-80 mg/L) but fairly low Zn (~0.1 mg/L); these concentrations are consistent with those observed further up-gradient (at P03-06) suggesting limited incremental loading from the Secondary Impoundment;

- The groundwater in the deeper aquifer (at X21C redrilled in 1996) has consistently shown very low SO4, Mg, Na and Zn indicative of background concentrations; the presence of a thick silt layer separating the upper and lower portion of the aquifer apparently limits any downward migration of ARD products in this area;

At P01-06 (located in the northeastern section):

- The groundwater collected at P01-06 (just below the base of the tailings) shows elevated SO4 (1,000-2,500 mg/L), Mg (90-280 mg/L) and Zn (1-8 mg/L); these concentrations are generally consistent with those observed further up-gradient (at P03-06) and cross-gradient (at X21A/B);

- As observed at other locations along the northern side of the valley (X21A/B; P03-06), groundwater concentrations show significant variations over time, with a gradual decrease in SO4 and Mg, but a consistent rise in Zn over time;

At P01-05 (located in the southeastern section):

- The tailings pore water (in P01-05A) shows elevated concentrations of Na (~150-200mg/L) which is indicative of residual process water; SO4 concentrations are also elevated (~800-1,200 mg/L) suggesting some contribution from the upper oxidizing) tailings profile;

- The groundwater monitored at P01-05B (immediately below the base of the tailings) shows elevated SO4 (~600-800 mg/L), Mg (35-45 mg/L) and Na (50-65 mg/L) but typically fairly low Zn (~0.1 mg/L); these concentrations are significantly lower than concentrations observed in the aquifer immediately below the tailings at P03-04 (in the much older Secondary Impoundment);

At P03-08 (located in the southwestern section):

- The tailings pore water (at P03-08A) shows elevated Na (~150-175 mg/L) and low Mg (~20 mg/L) and Zn (~0.01 mg/L) suggesting the presence of residual process water (at least at depth); the observed SO4 (~1,500 mg/L) are likely higher than in the original process water suggesting some contribution from oxidized tailings;

- The groundwater with elevated TDS is limited to a narrow zone (<5m) beneath the tailings; at greater depth, the groundwater shows very little influence of tailings seepage, with SO4, Zn, Na and Mg all approaching background values;

In summary, tailings pore water in the Intermediate Dam appears to be generally more dilute than in the Original and Secondary Impoundment, primarily because of more recent tailings deposition. Preliminary analysis would also suggest that the process water used for the Intermediate Impoundment was more dilute (wrt Na, SO4 and other constituents) than for the older impoundments, presumably because of changes to the milling circuit and/or abandoning the practice of recycling (to be confirmed).

There are only a few wells completed in the aquifer beneath the Intermediate Impoundment, most of which are located either relatively close to the upstream end of the impoundment (e.g. X21, P01-06) and/or near the perimeter of the valley (P03-08), thus limiting an interpretation of groundwater quality in this reach. Nevertheless, the limited data would suggest that concentrations of ARD products (SO4, Mg, Zn) are generally lower in this reach than observed further up-gradient, likely as a result of relatively dilute process water entering the aquifer from the Intermediate Impoundment. Longer term monitoring at one location (X21B&C) suggests that groundwater quality in the aquifer has not changed significantly since the mid-1990s.

The only multi-level piezometer installed in the Intermediate Impoundment (P03-08) shows a relatively narrow zone of groundwater influenced by tailings seepage (as opposed to much deeper influence observed further upgradient). This observation might, however, be a result of the general proximity of this well to the side of the valley where inflow from the hillside and seepage from the Rose Creek Diversion could provide significant dilution.

C.4 Intermediate Dam

Figures C14 and C15 show the water quality time trends observed in wells screened in the northern section and southern section of the Intermediate Dam. The following observations can be made:

In the northern portion of the Intermediate Dam (X24A/B/C/D and P01-03):

- The groundwater quality in the aquifer beneath the northern portion of the Intermediate Dam shows elevated SO4 and Mg similar to concentrations further upstream; zinc concentrations typically range from non-detect to ~0.1 mg/L;

- The “TDS plume” in the aquifer extends to significant depth (~30m bgs) and generally shows higher SO4 and Mg at greater depth; the lower (and more variable) concentrations observed in the upper aquifer (<10m bgs) are believed to be a result of significant contributions of seepage from the Intermediate Pond, which has lower SO4, Mg and Na than groundwater (see section 3);

- Both SO4 and Mg show a gradual increase since about 2002; for example, SO4 has increased from an average of ~1000 mg/L prior to 2002 to about 1,500mg/L in 2003/2004; a similar increase has not been observed for zinc (or Na);

In the southern portion of the Intermediate Dam (X25A/B, P01-04A/B):

- The groundwater quality in the aquifer beneath the southern portion of the Intermediate Dam shows significantly (2-3 times) lower SO4 and Mg concentrations than in the northern portion; zinc concentrations are typically < 0.1 mg/L;

- The groundwater quality does not show a significant increase in SO4 and Mg as observed along the north side;

In summary, groundwater beneath the northern side of the Intermediate Dam shows significantly higher influence of ARD (SO4, Mg) than on the southern side. Such a distinct difference has not been observed further up-gradient. Potential reasons for the higher TDS along the north side of the aquifer include (i) higher ARD loading on the northern side (e.g. from the coarse tailings beaches and/or seepage from X23) and/or (ii) dilution from the Rose Creek Diversion along the south side.

Groundwater along the northern side has also experienced a significant increase in ARD products over the last three years. Additional analysis will be required to evaluate whether this increase is related to a recent increase in loading (e.g. X23 seepage, oxidation of coarse intermediate tailings) and/or represents a gradual breakthrough of a TDS plume from a near constant source.

C.5 Downstream of Cross Valley Dam

Figures C16 and C17 show the water quality time trends observed at X16 to X18 and P01-01, P01-02 and P01-11, respectively. Figure C18 shows the show water quality depth profile for P03-09. The following observations can be made:

- The groundwater in the northern portion of the aquifer (X18A/B; P01-11) has shown a gradual increase in SO4 and Mg over time; current SO4 concentrations range from ~850 mg/L near the X-Valley Dam to ~500-600 mg/L at X18 (near the spillway); zinc concentrations have remained in the range of 0.01-0.1 mg/L;

- The groundwater in the southern portion of the aquifer (X16 and P01-02) has not experienced the same increase in ARD products; current SO4 concentrations range from ~120 mg/L near the X-Valley Dam to ~30 mg/L at X16;

- The groundwater in the central portion of the aquifer (at P03-09 and X17) shows intermediate SO4 and Mg concentrations; note that the monitoring well located further downgradient (X17) shows significantly lower SO4 (~40 mg/L) than observed at P03-09 (~320-420 mg/L) suggesting significant dilution by “clean” groundwater;

- detailed depth monitoring at P03-09 indicates fairly uniform groundwater quality throughout the aquifer with only slightly higher SO4 and Mg concentrations in the upper portion of the aquifer;

In summary, groundwater quality downstream of the X Valley Dam shows significant spatial variability with a trend of decreasing TDS (SO4, Mg) towards the southern side of the valley. This spatial pattern is consistent with trends observed along the Intermediate Dam suggesting that the X Valley Pond does not contribute significantly to the aquifer flow. Furthermore, groundwater quality improves significantly within a few hundred meters from the toe of the X Valley Dam suggesting significant dilution by “clean” groundwater, likely due to seepage from the Rose Creek Diversion Channel.

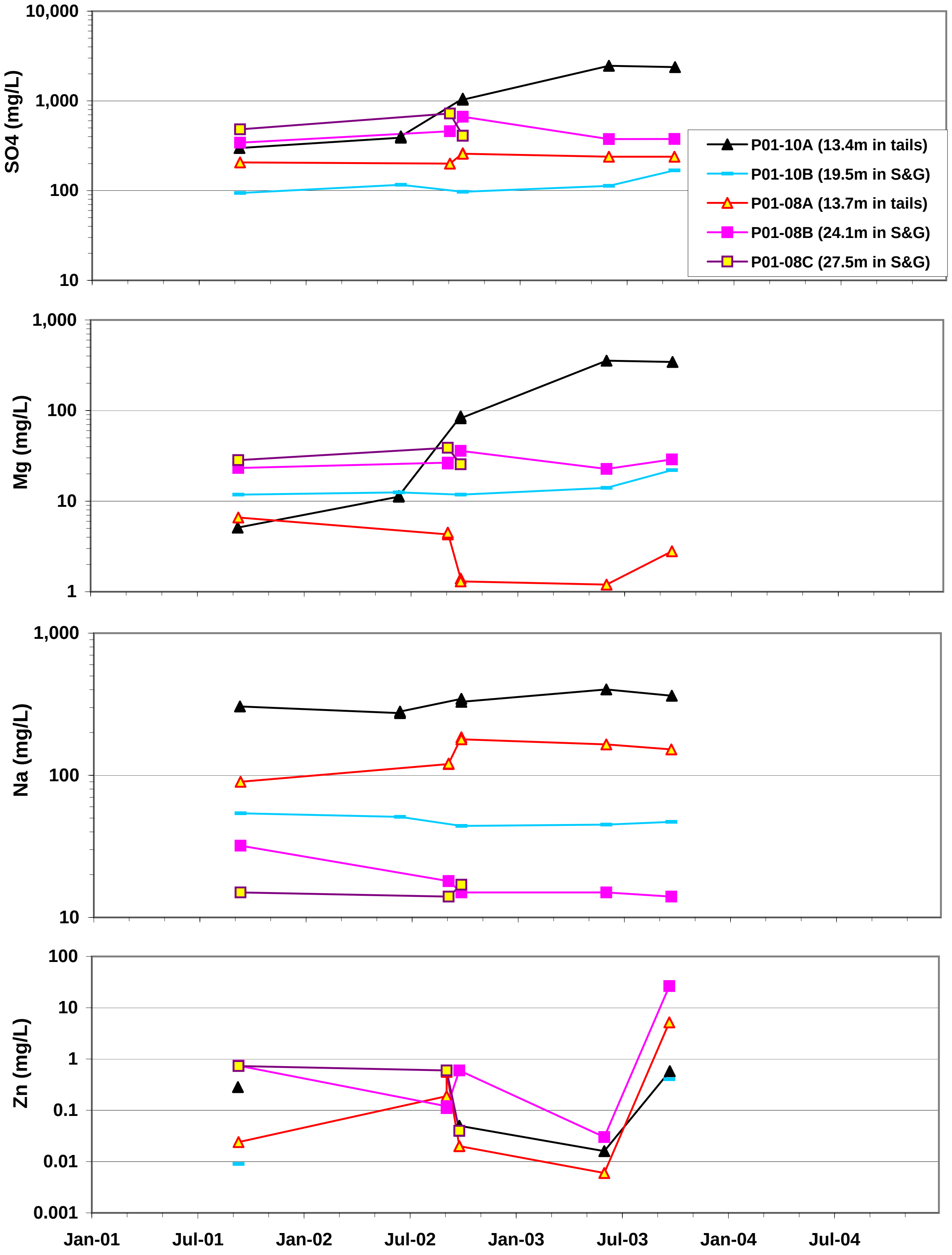


Figure C1. Water quality in P01-10 and P01-08 (Original Impoundment).

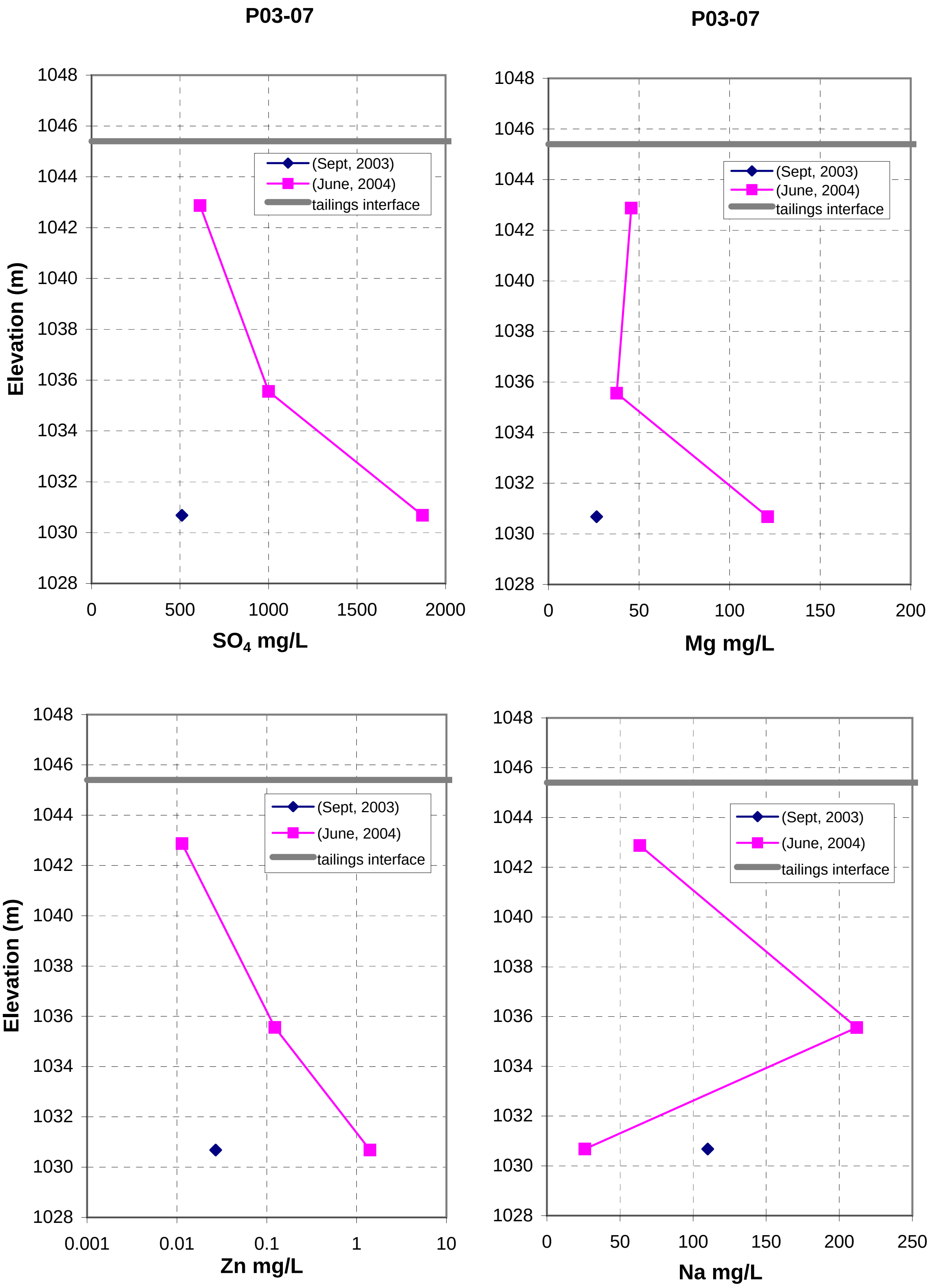


Figure C2. Water quality depth profiles of SO$_4$, Mg, Zn and Na at P03-07.

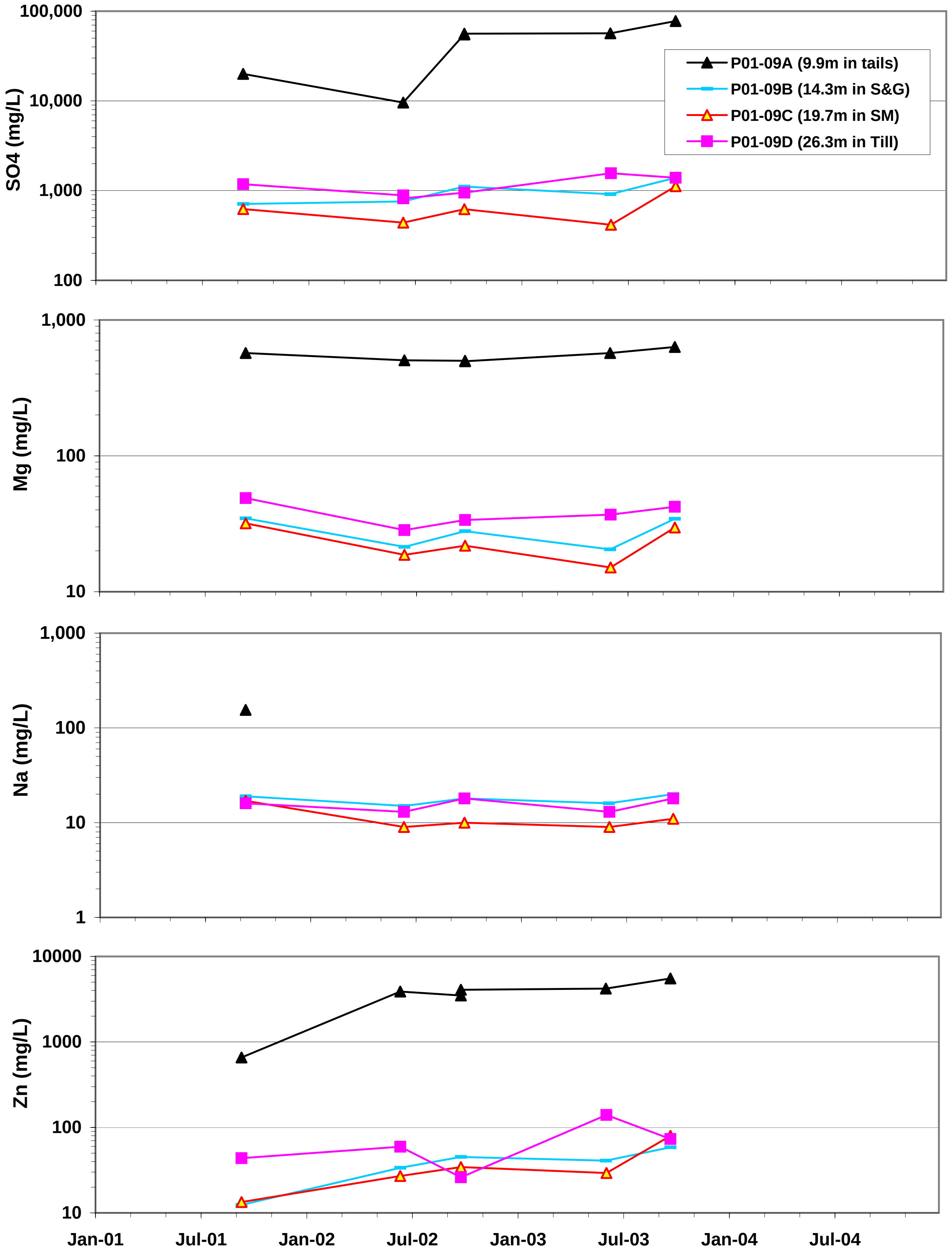


Figure C3. Water quality in P01-09 (2nd Impoundment).

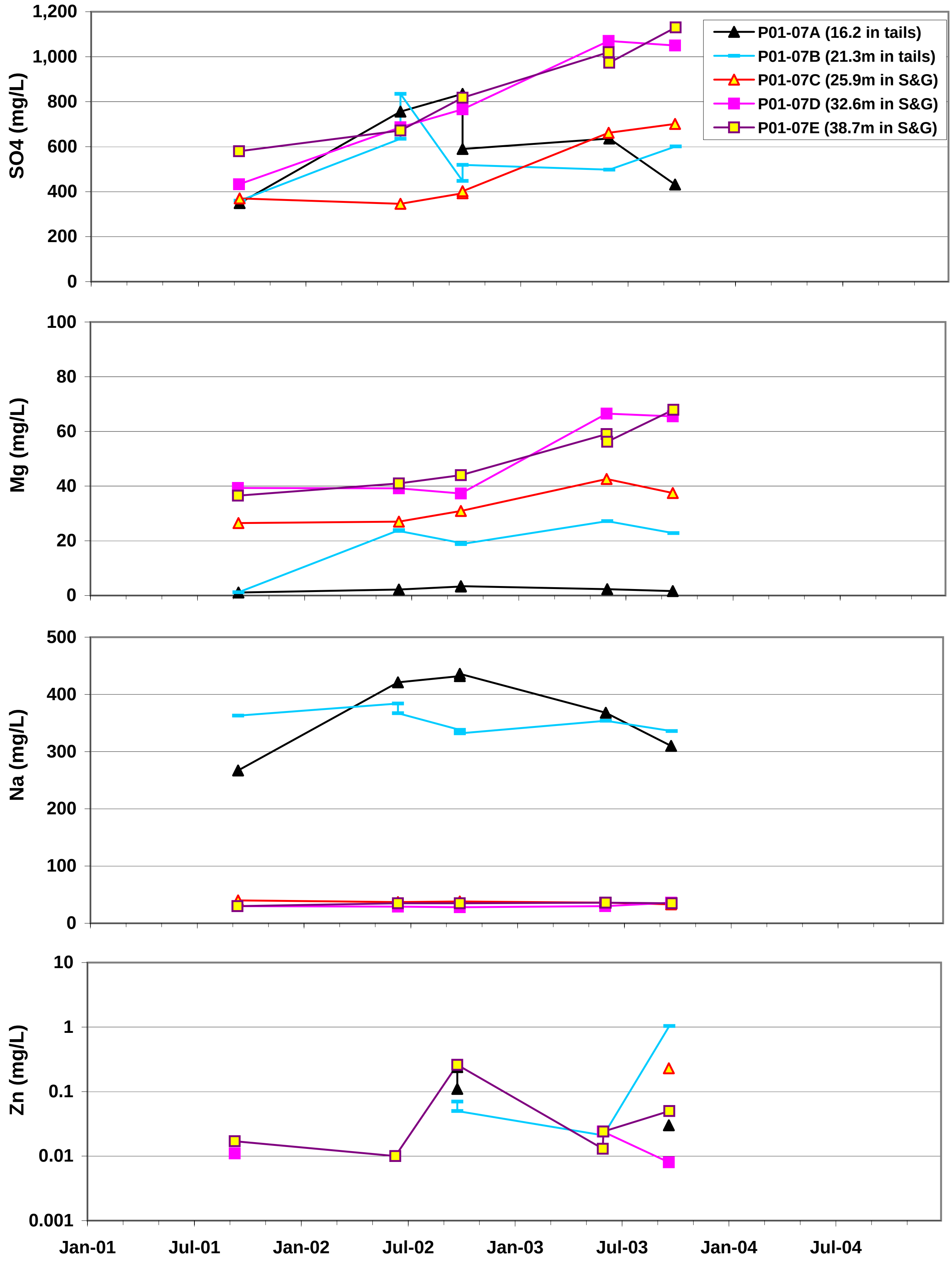


Figure C4. Water quality in P01-07 (2nd Impoundment).

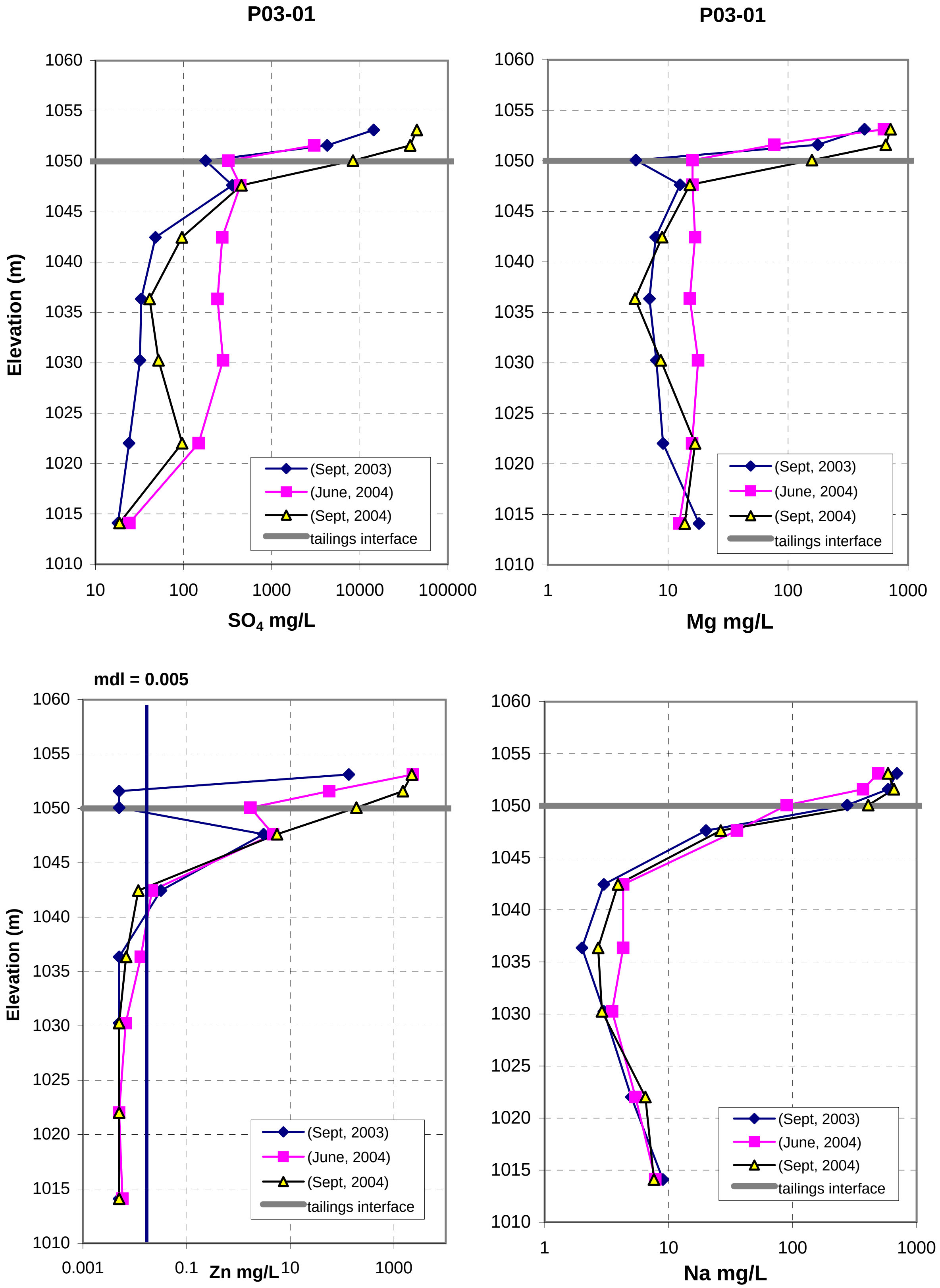


Figure C5. Water quality depth profiles of SO_4, Mg, Zn and Na at P03-01.

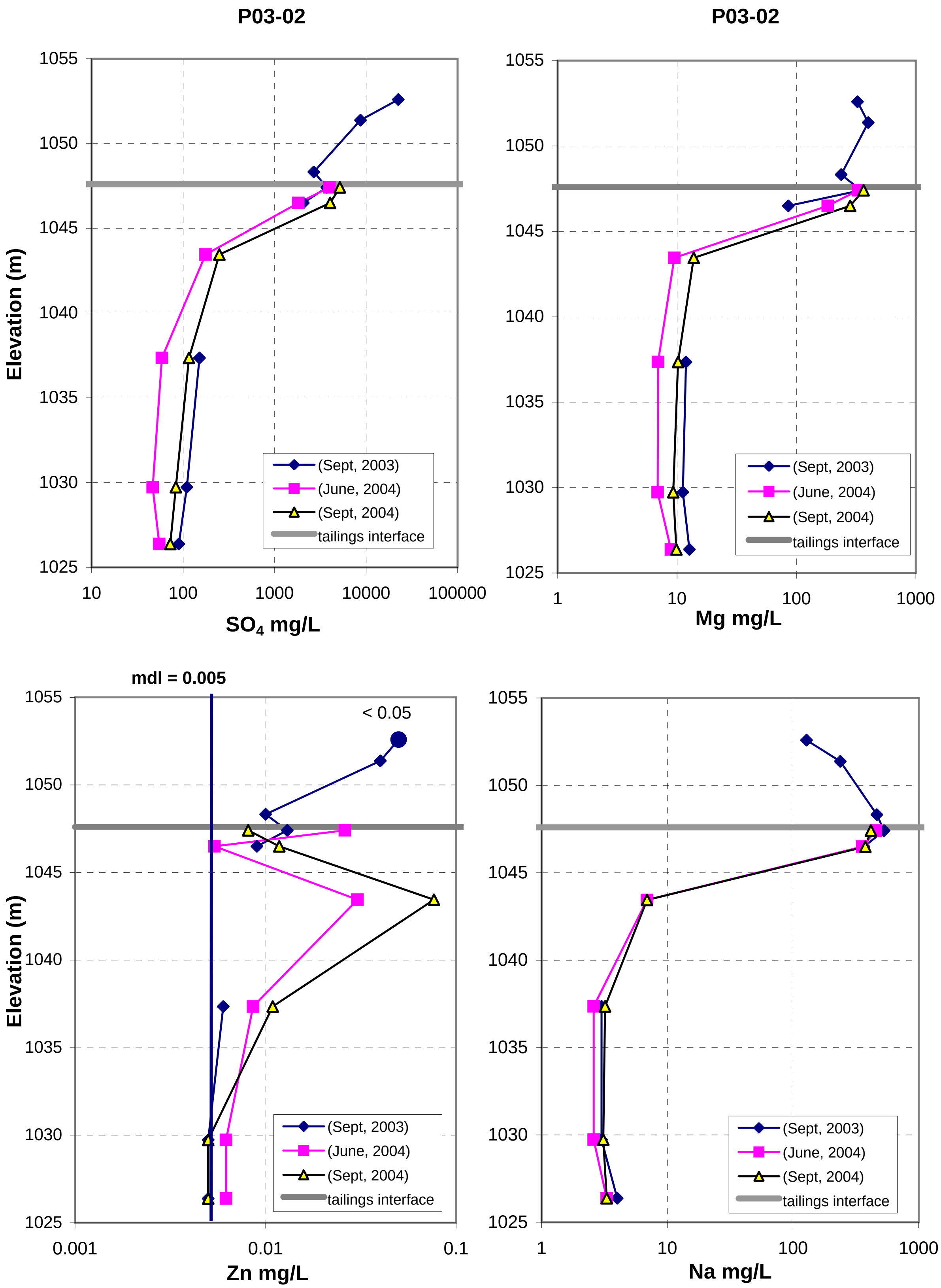


Figure C6. Water quality depth profiles of SO_4, Mg, Zn and Na at P03-02.

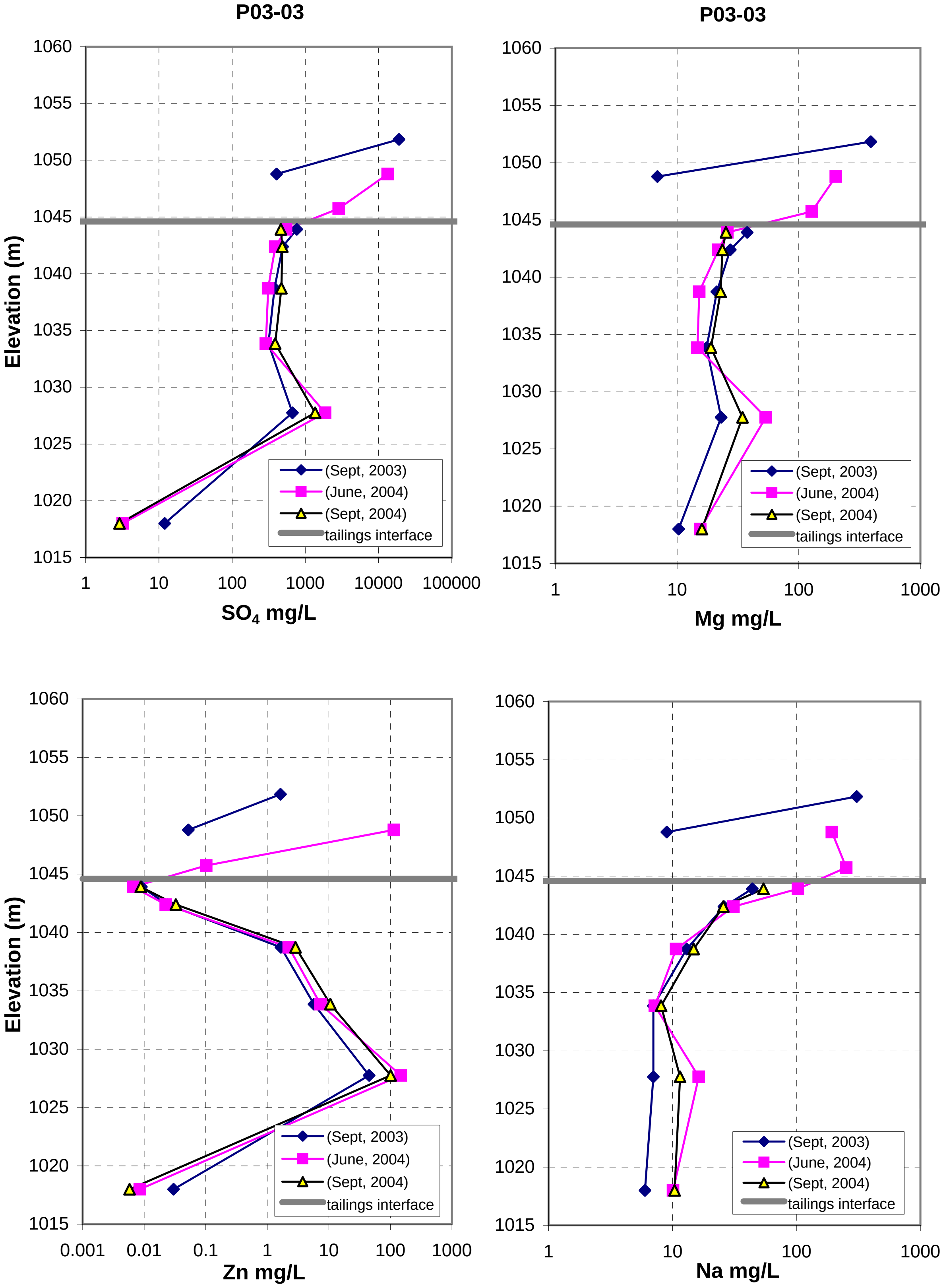


Figure C7. Water quality depth profiles of SO4, Mg, Zn and Na at P03-03.

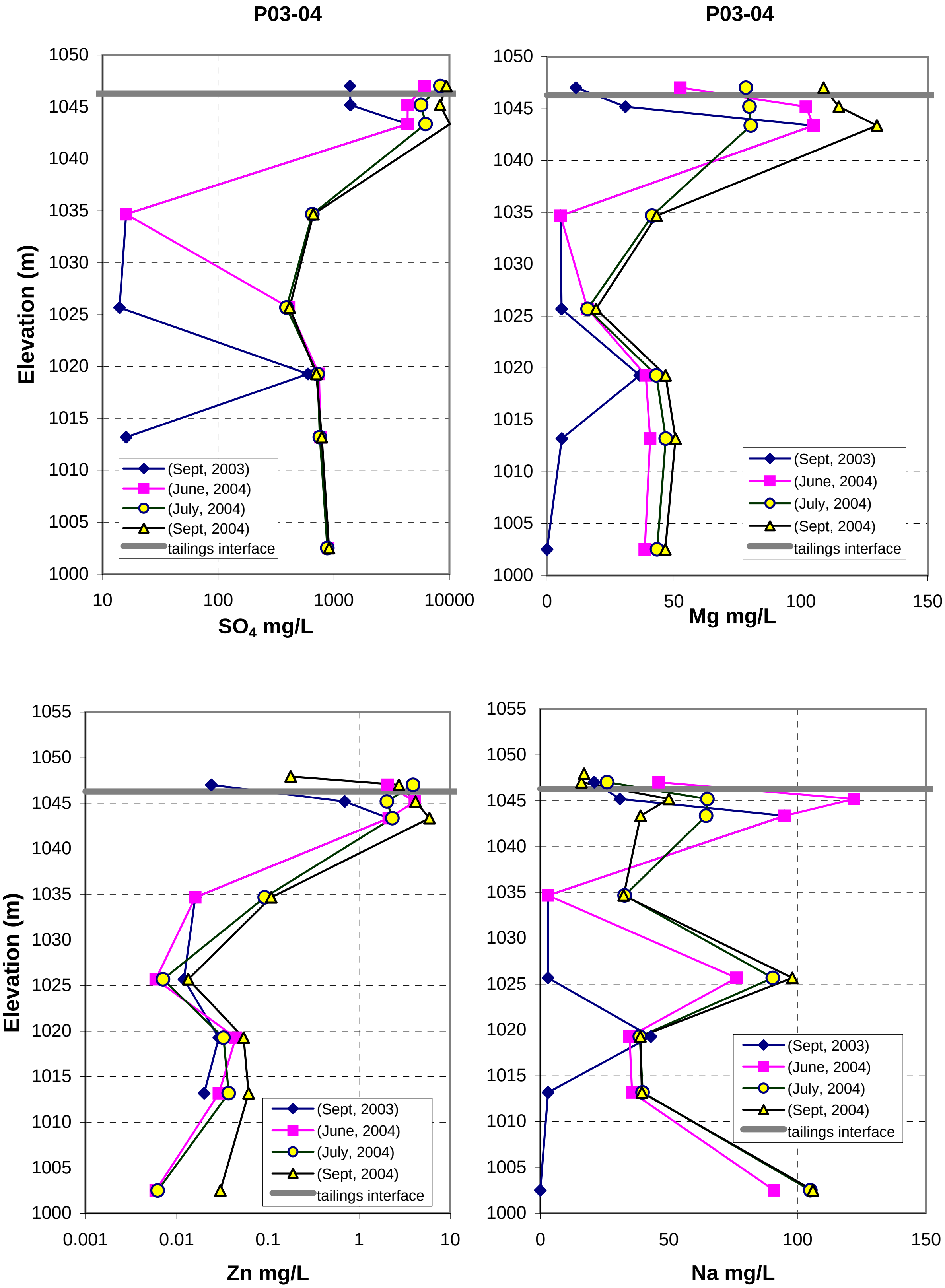


Figure C8. Water quality depth profiles of SO_4, Mg, Zn and Na at P03-04.

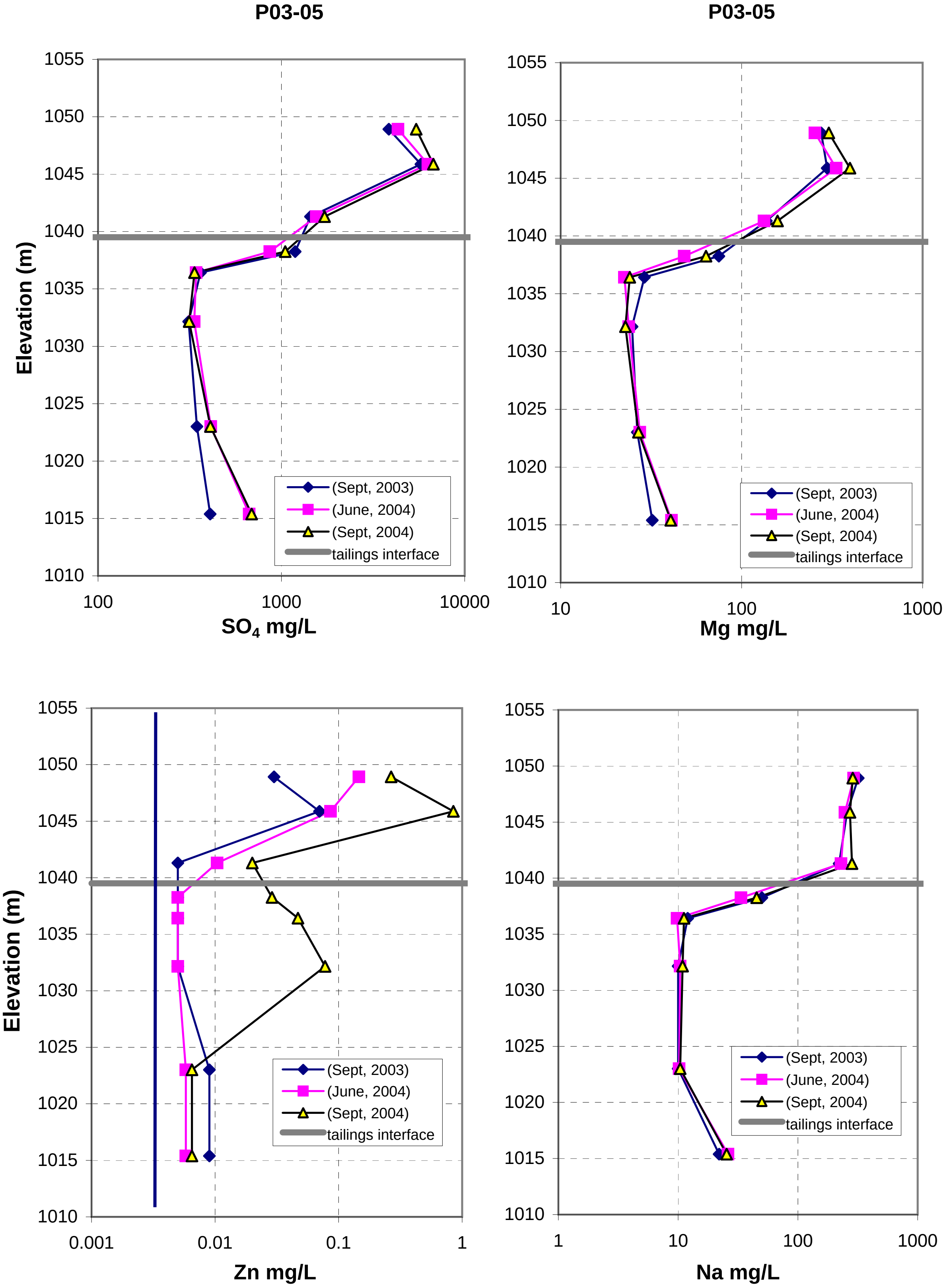


Figure C9. Water quality depth profiles of SO_4, Mg, Zn and Na at P03-05.

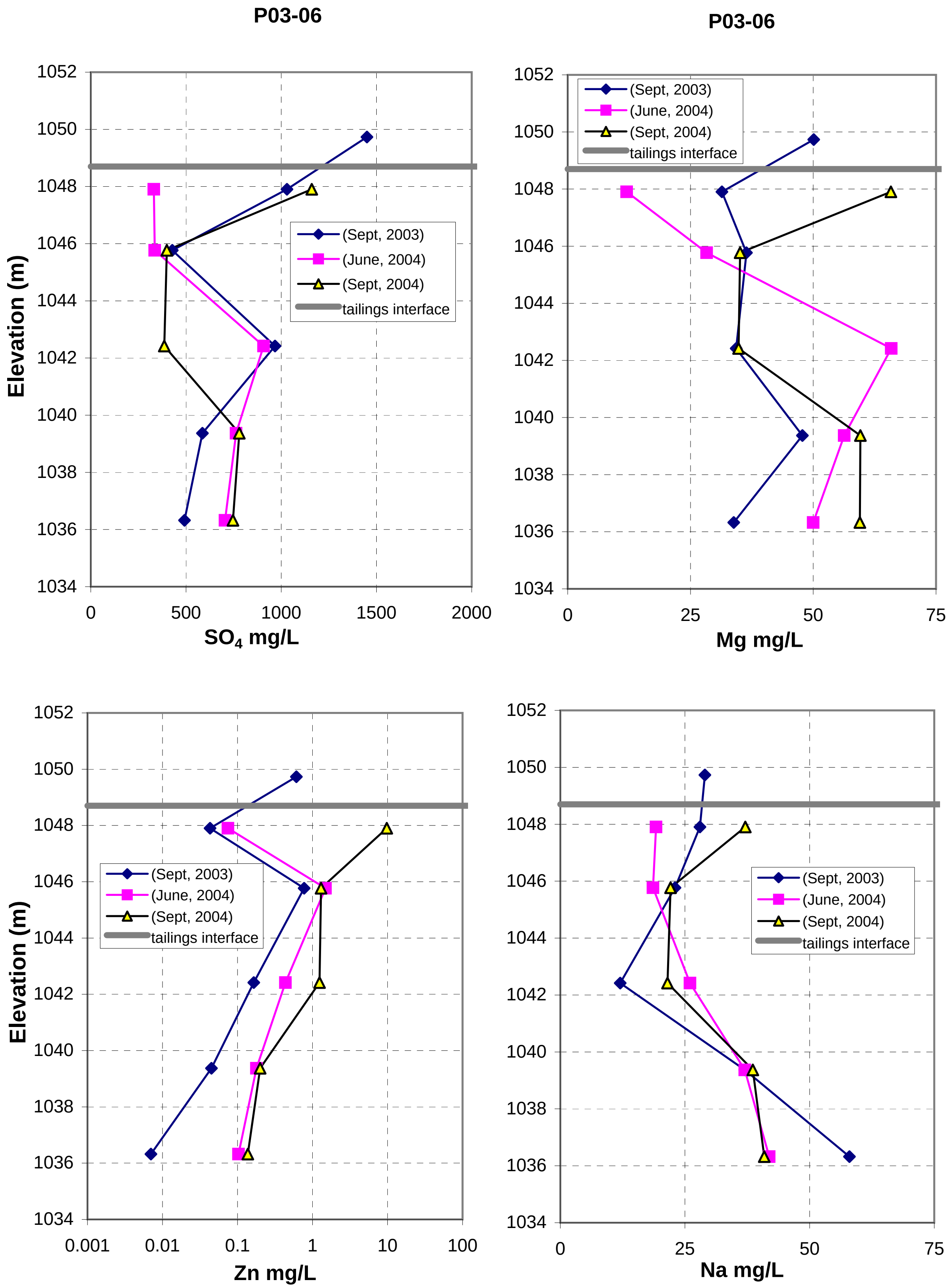


Figure C10. Water quality depth profiles of SO_4, Mg, Zn and Na at P03-06.

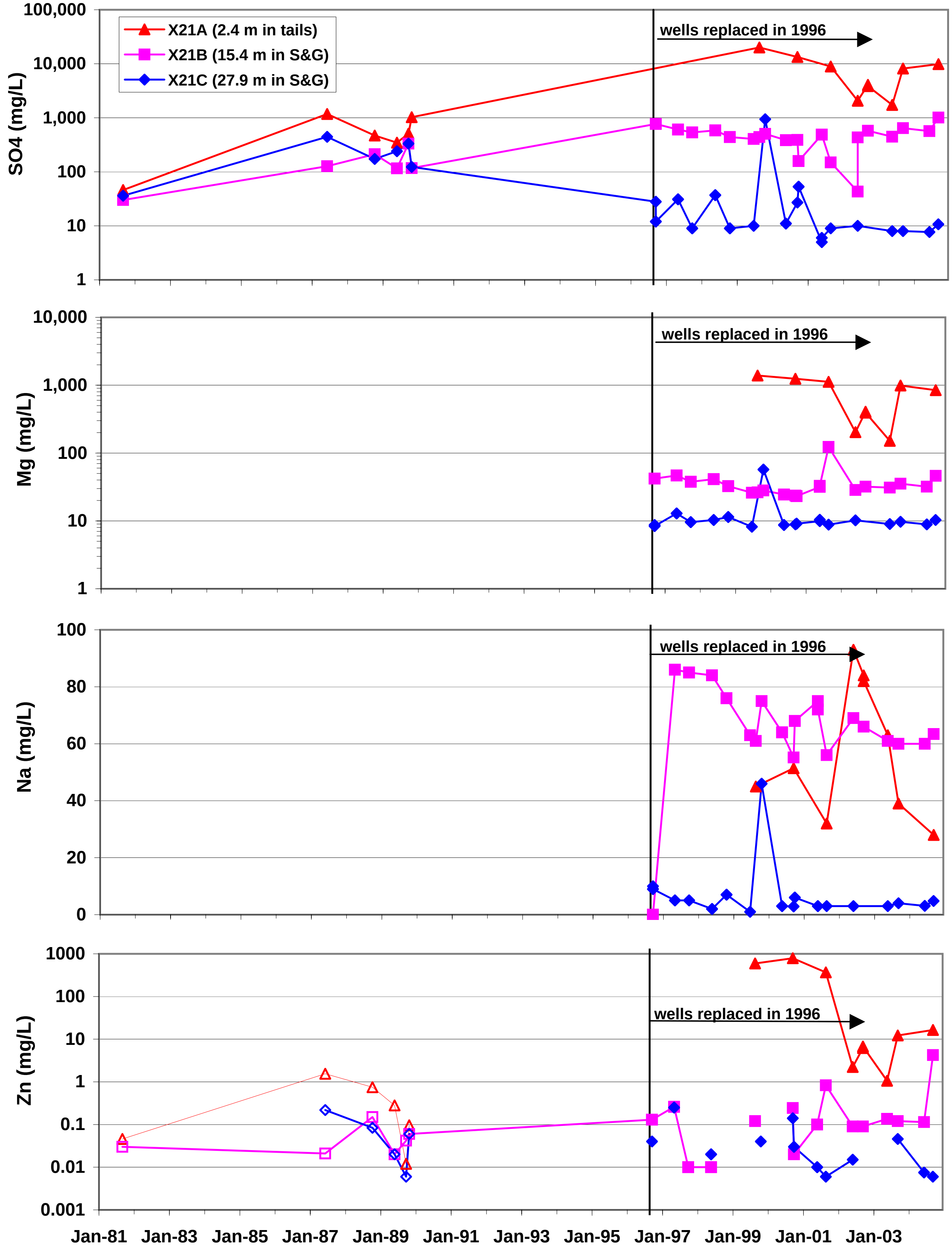


Figure C11. Water quality in X21 (Intermediate Impoundment).

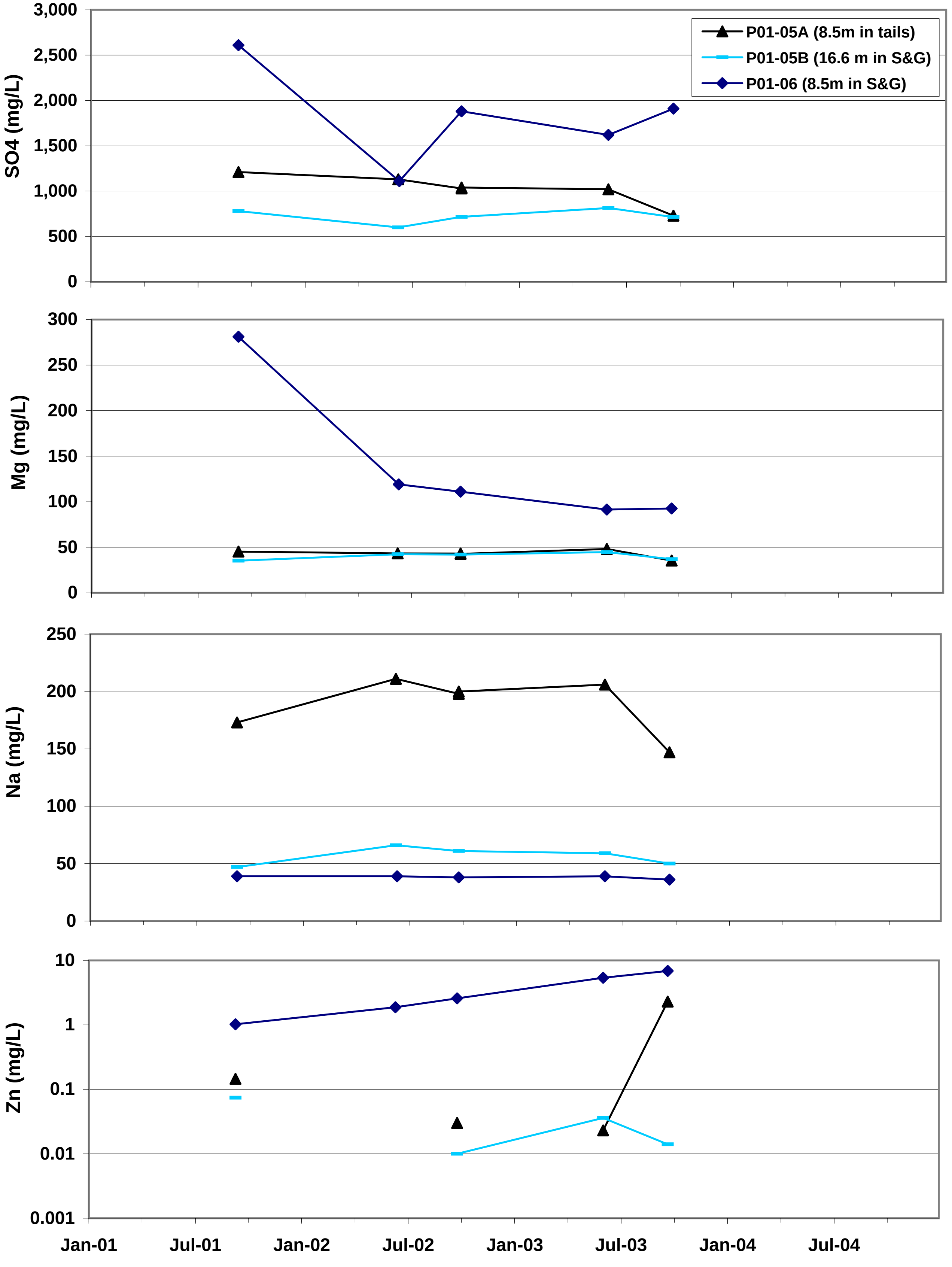


Figure C12. Water quality in the area of the Intermediate Impoundment.

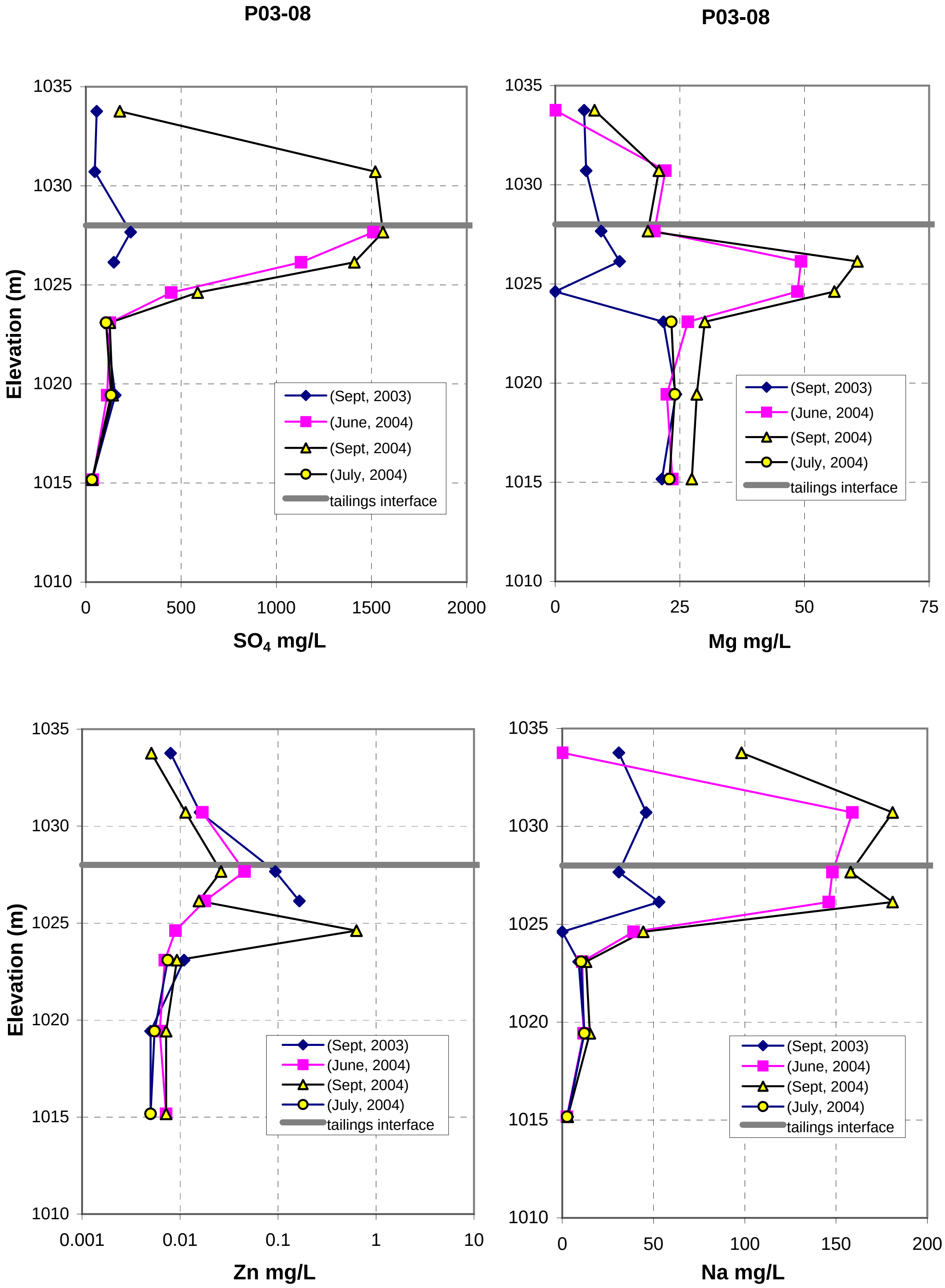


Figure C13. Water quality depth profiles of SO_4, Mg, Zn and Na at P03-08.

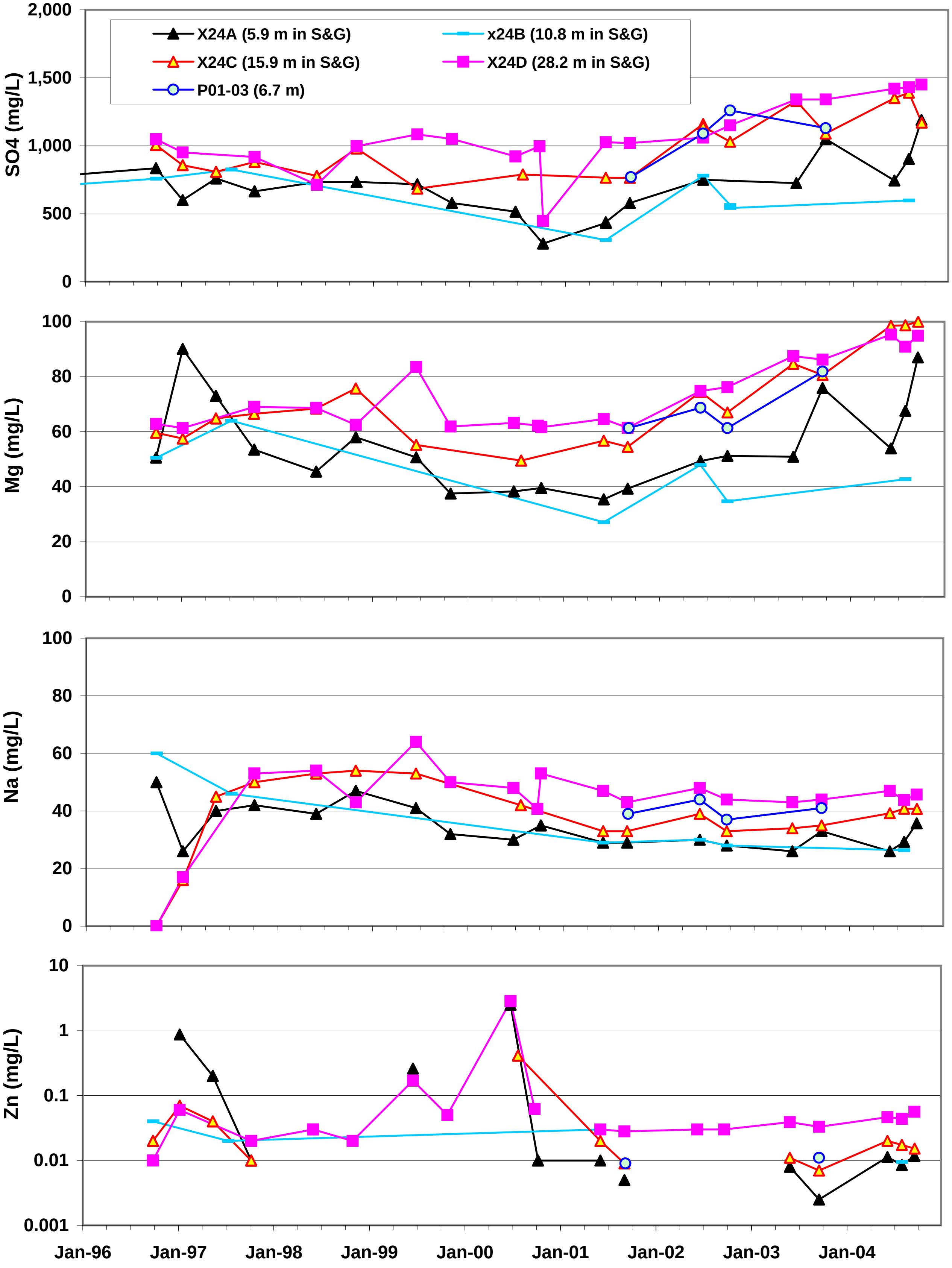


Figure C14. Water quality in X24 and P01-03 (north Intermediate Dam).

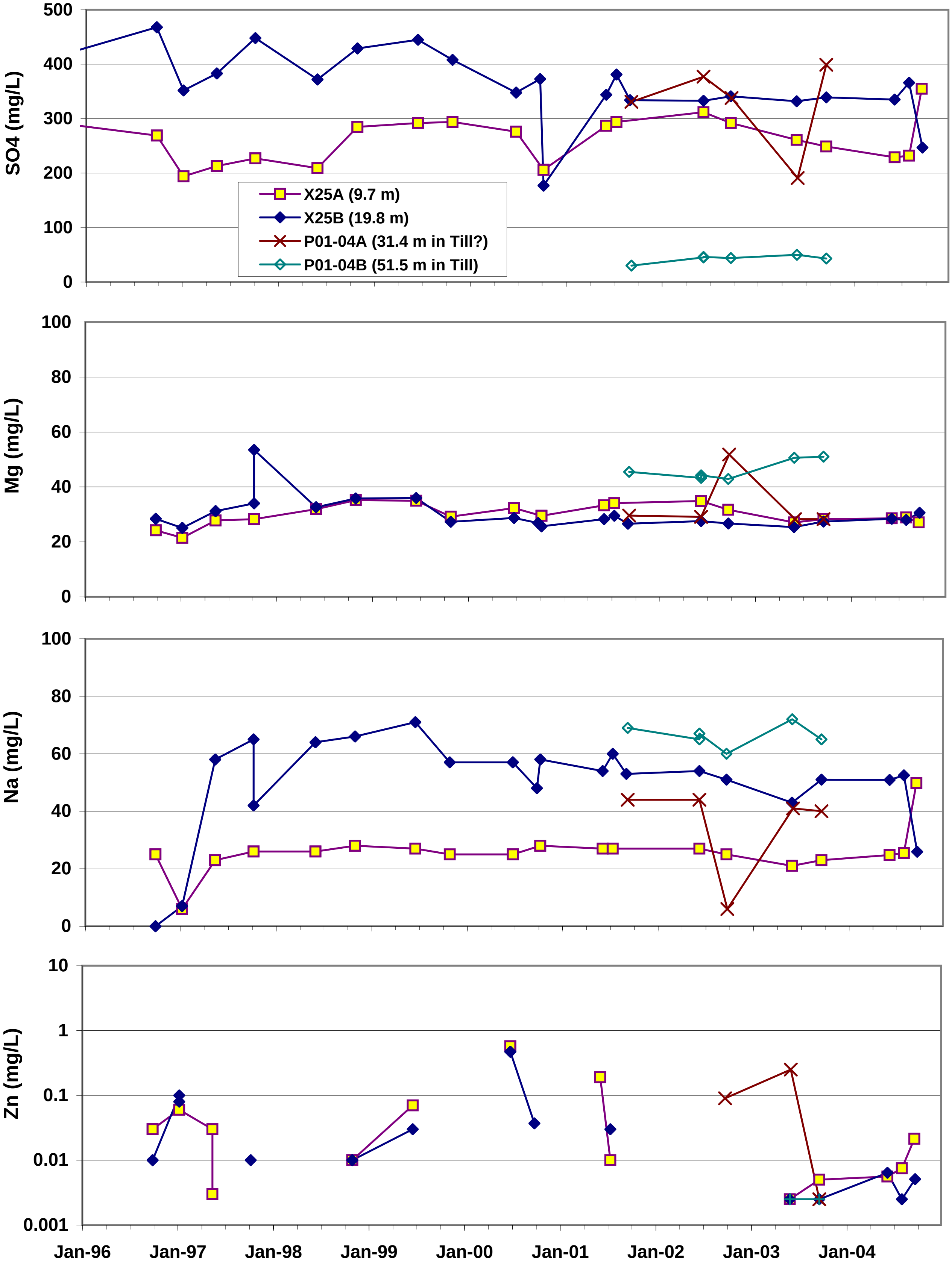


Figure C15. Water quality in P01-04 and X25 (south Intermediate Dam).

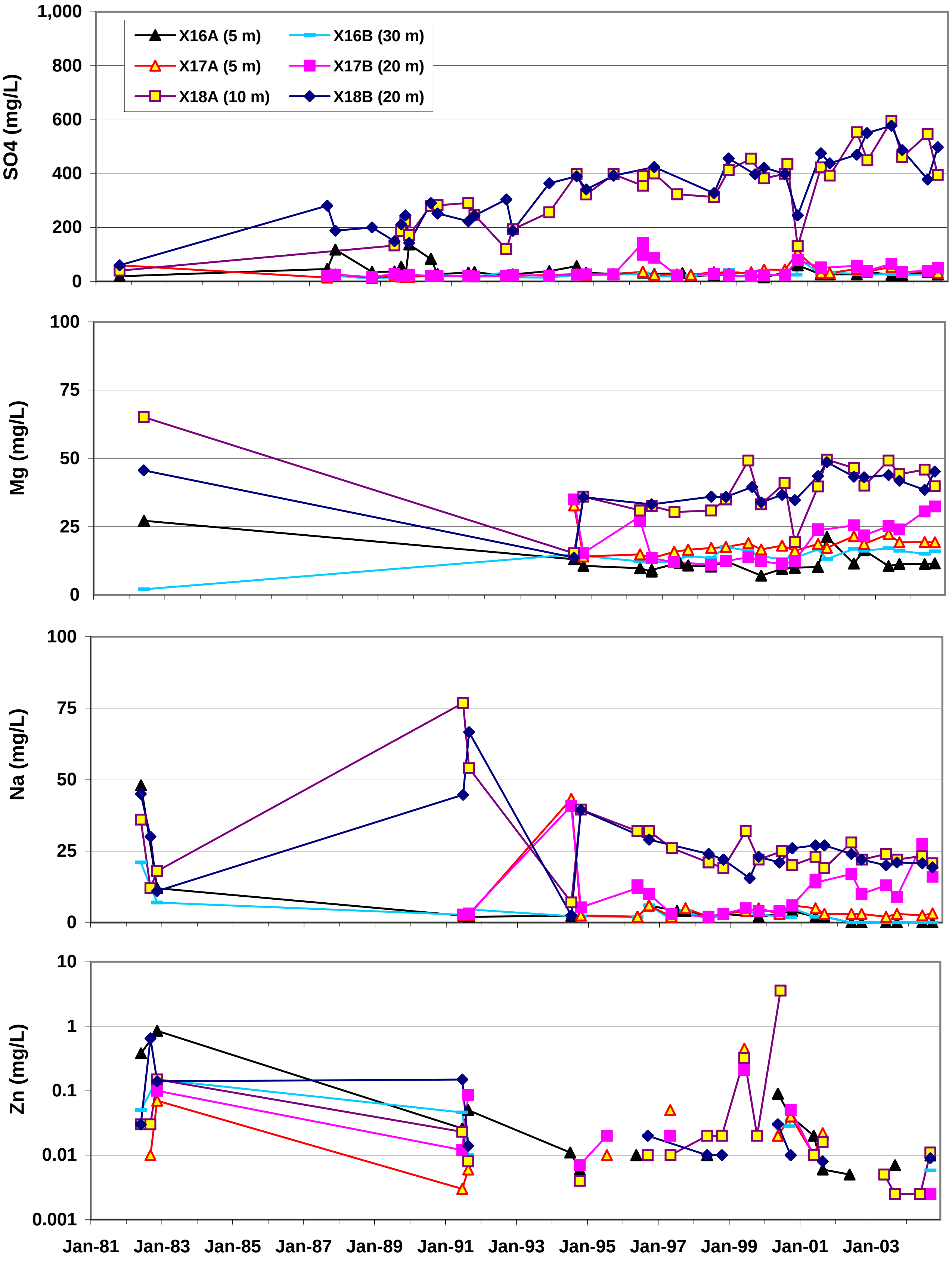


Figure C16. Water quality in X16, X17 and X18 (downstream of Cross Valley Dam).

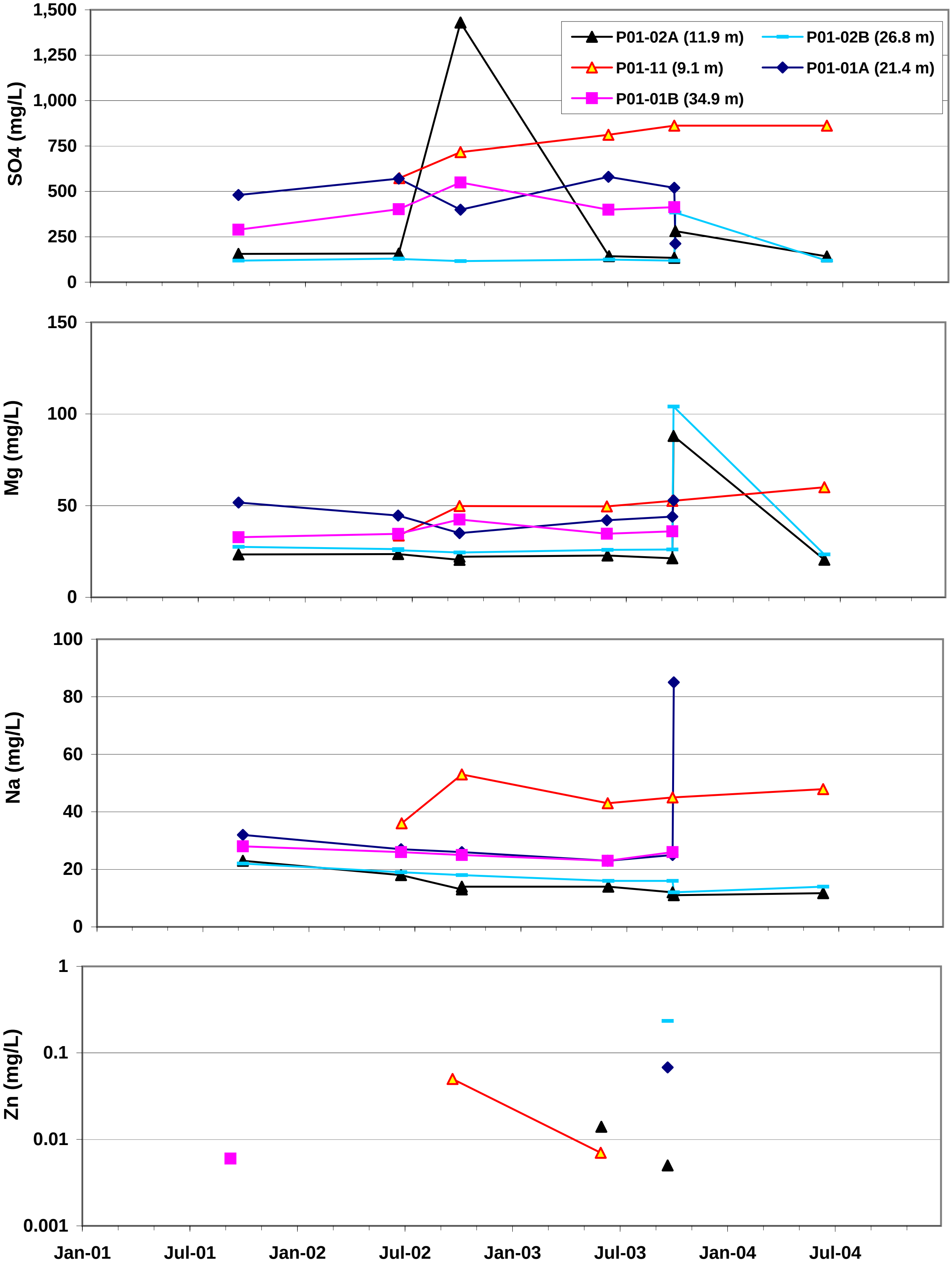


Figure C17. Water quality in P01-01, P01-02 and P01-11 (Cross Valley Dam).

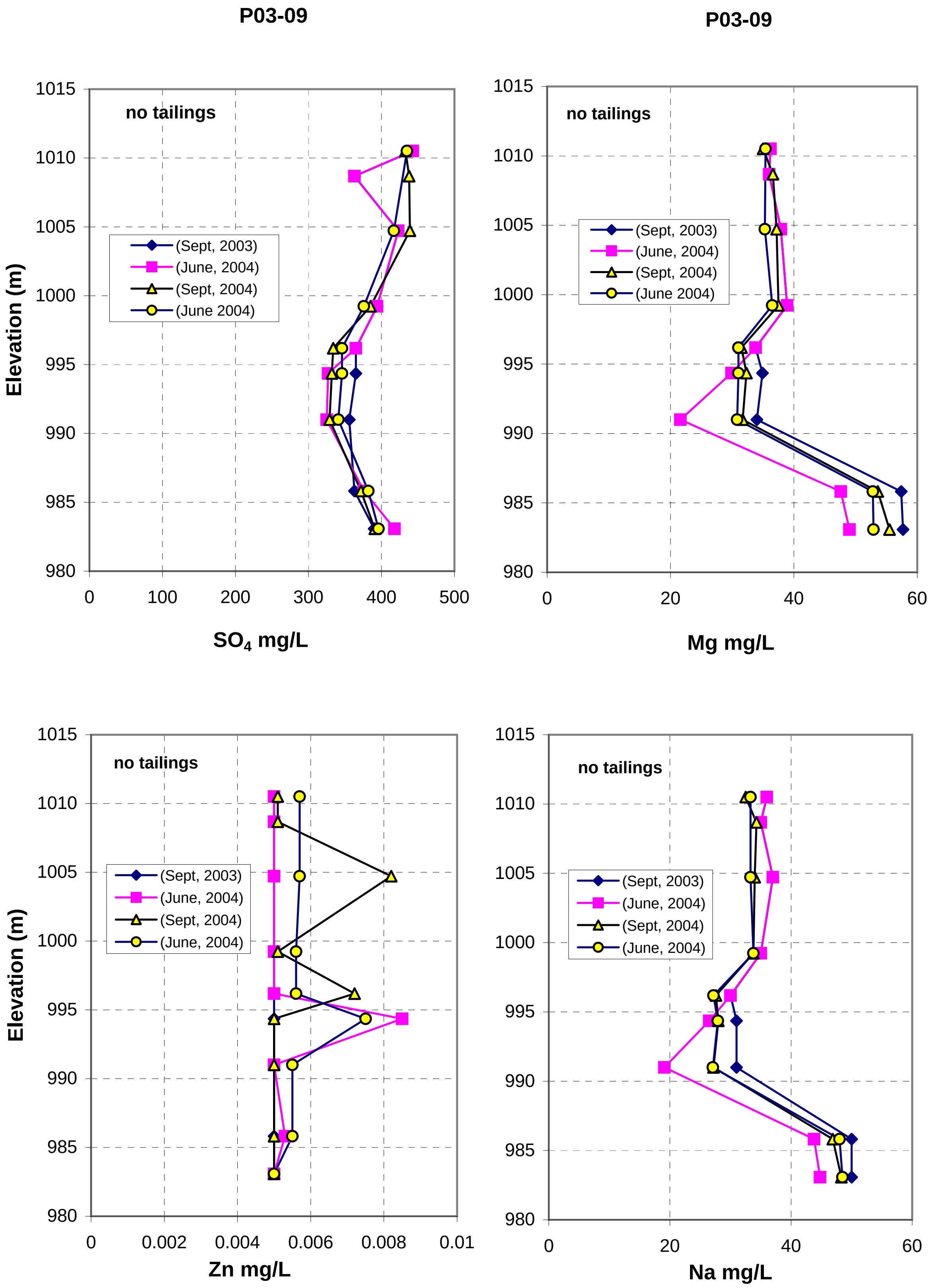


Figure C18. Water quality depth profiles of SO_4, Mg, Zn and Na at P03-09.

APPENDIX D

Chemical Analyses Reports (ALS Reports U9854, V7141r)

ALS Environmental

CHEMICAL ANALYSIS REPORT

Date:	November 15, 2004
ALS File No.	U9854
Report On:	Stream Survey_Rose Ck Water Analysis
Report To:	**Robertson Technologies Corp.** Suite 640 580 Hornby Street Vancouver, BC V6C 3B6
Attention:	**Mr. Christoph Wels**
Received:	October 22, 2004

ALS ENVIRONMENTAL
per:

Can Dang, B.Sc. - Project Chemist
Janice Pearson, - Client Services Assistant

File No. U9854

RESULTS OF ANALYSIS - Water

Sample ID		RC-1	RC-2	RC-4	CVS-1	CVS-2
Sample Date		04-10-19	04-10-19	04-10-19	04-10-19	04-10-19
Sample Time		15:20	15:00	12:00	10:00	17:00
ALS ID		*1*	*2*	*3*	*4*	*5*
Physical Tests						
Conductivity	(uS/cm)	492	500	507	1310	1410
Dissolved Anions						
Sulphate	SO4	108	112	116	532	587

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		RC-1	RC-2	RC-4	CVS-1	CVS-2
Sample Date		04-10-19	04-10-19	04-10-19	04-10-19	04-10-19
Sample Time		15:20	15:00	12:00	10:00	17:00
ALS ID		*1*	*2*	*3*	*4*	*5*
Total Metals						
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.073	0.072	0.075	0.080	0.081
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	71.5	72.8	76.0	208	229
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	T-Co	<0.010	<0.010	<0.010	<0.010	<0.010
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	0.458	0.459	0.527	1.04	0.967
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.010	<0.010	<0.010	0.013	<0.010
Magnesium	T-Mg	16.1	16.5	17.3	43.8	48.1
Manganese	T-Mn	1.12	1.18	1.30	6.93	8.14
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	2.6	<2.0	<2.0	5.3	4.9
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	4.87	4.91	5.07	5.93	6.23
Silver	T-Ag	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	6.4	6.5	7.1	26.8	30.5
Strontium	T-Sr	0.258	0.263	0.273	0.571	0.625
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.0328	0.0317	0.0348	0.0196	0.0054

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		CVS-3	CVS-4	CVS-5	CVS-6	CVS-7
Sample Date		04-10-19	04-10-19	04-10-19	04-10-19	04-10-19
Sample Time		17:30	18:00	17:45	18:20	18:40
ALS ID		*6*	*7*	*8*	*9*	*10*
Physical Tests						
Conductivity	(uS/cm)	774	1610	1960	1380	1020
Dissolved Anions						
Sulphate	SO4	236	719	942	550	380

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. U9854

RESULTS OF ANALYSIS - Water

Sample ID		CVS-3	CVS-4	CVS-5	CVS-6	CVS-7
Sample Date		04-10-19	04-10-19	04-10-19	04-10-19	04-10-19
Sample Time		17:30	18:00	17:45	18:20	18:40
ALS ID		*6*	*7*	*8*	*9*	*10*
Total Metals						
Aluminum	T-Al	0.23	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.039	0.080	0.060	0.076	0.043
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	110	255	312	203	144
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	T-Co	<0.010	<0.010	0.019	<0.010	<0.010
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	0.636	3.57	2.28	3.95	0.095
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.010	0.011	0.011	<0.010	<0.010
Magnesium	T-Mg	25.0	54.0	68.6	41.2	33.6
Manganese	T-Mn	0.121	11.5	16.0	7.02	0.365
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	3.9	5.7	6.9	4.0	4.3
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	4.27	6.58	6.74	6.39	4.81
Silver	T-Ag	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	10.7	34.1	36.6	30.2	19.9
Strontium	T-Sr	0.372	0.681	0.833	0.546	0.444
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	0.011	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.100	0.0054	<0.0050	<0.0050	<0.0050

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. U9854

RESULTS OF ANALYSIS - Water

Sample ID		RCDC-1	SCH SEEP	RCDC-4	FCS-1	FCS-3
Sample Date		04-10-19	04-10-20	04-10-20	04-10-20	04-10-20
Sample Time		19:00	12:30	14:30	15:00	15:50
ALS ID		*11*	*12*	*13*	*14*	*15*
Physical Tests						
Conductivity	(uS/cm)	326	985	290	6320	7470
Dissolved Anions						
Sulphate	SO4	33.2	480	27.9	5580	5790

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. U9854

RESULTS OF ANALYSIS - Water

Sample ID		RCDC-1	SCH SEEP	RCDC-4	FCS-1	FCS-3
Sample Date		04-10-19	04-10-20	04-10-20	04-10-20	04-10-20
Sample Time		19:00	12:30	14:30	15:00	15:50
ALS ID		*11*	*12*	*13*	*14*	*15*
Total Metals						
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.40	4.22
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.40	<0.40
Arsenic	T-As	<0.20	<0.20	<0.20	<0.40	<0.40
Barium	T-Ba	0.069	0.681	0.069	<0.020	<0.020
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.010	<0.010
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.40	<0.40
Boron	T-B	<0.10	<0.10	<0.10	<0.20	<0.20
Cadmium	T-Cd	<0.010	<0.010	<0.010	0.056	<0.020
Calcium	T-Ca	45.3	147	42.8	512	478
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.020	<0.020
Cobalt	T-Co	<0.010	0.030	<0.010	0.717	0.418
Copper	T-Cu	<0.010	<0.010	<0.010	0.035	0.025
Iron	T-Fe	0.461	58.2	0.319	123	1650
Lead	T-Pb	<0.050	0.097	<0.050	<0.10	<0.10
Lithium	T-Li	<0.010	<0.010	<0.010	0.167	0.113
Magnesium	T-Mg	10.9	25.0	9.39	784	477
Manganese	T-Mn	0.143	12.6	0.154	72.4	53.8
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.060	<0.060
Nickel	T-Ni	<0.050	<0.050	<0.050	0.86	0.53
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.60	<0.60
Potassium	T-K	<2.0	2.9	<2.0	15.4	11.2
Selenium	T-Se	<0.20	<0.20	<0.20	<0.40	<0.40
Silicon	T-Si	4.71	5.50	4.95	6.98	15.0
Silver	T-Ag	<0.010	<0.010	<0.010	<0.020	<0.020
Sodium	T-Na	2.8	9.5	2.9	58.8	159
Strontium	T-Sr	0.204	0.455	0.198	3.77	3.49
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.40	<0.50
Tin	T-Sn	<0.030	<0.030	<0.030	<0.060	<0.060
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.020	<0.020
Vanadium	T-V	<0.030	<0.030	<0.030	<0.060	<0.060
Zinc	T-Zn	0.0437	3.43	0.0182	371	309

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		FCS-4	FCS-7	GHC-a	DUP-1	DUP-2
Sample Date		04-10-20	04-10-20	04-10-20	04-10-19	04-10-20
Sample Time		16:15	17:05	18:15		
ALS ID		*16*	*17*	*18*	*19*	*20*
Physical Tests						
Conductivity	(uS/cm)	6900	1380	1100	504	1970
Dissolved Anions						
Sulphate	SO4	5490	610	448	117	974

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. U9854

RESULTS OF ANALYSIS - Water

Sample ID		FCS-4	FCS-7	GHC-a	DUP-1	DUP-2
Sample Date		04-10-20	04-10-20	04-10-20	04-10-19	04-10-20
Sample Time		16:15	17:05	18:15		
ALS ID		*16*	*17*	*18*	*19*	*20*
Total Metals						
Aluminum	T-Al	4.69	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.40	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.40	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.079	0.054	0.042	0.075	0.064
Beryllium	T-Be	<0.010	0.0056	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.40	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.20	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	0.028	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	536	242	185	74.6	349
Chromium	T-Cr	<0.020	<0.010	<0.010	<0.010	<0.010
Cobalt	T-Co	0.431	<0.010	<0.010	<0.010	0.016
Copper	T-Cu	0.041	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	572	0.158	0.126	0.531	2.85
Lead	T-Pb	0.25	0.118	<0.050	<0.050	<0.050
Lithium	T-Li	0.147	0.018	0.011	<0.010	0.011
Magnesium	T-Mg	711	48.1	43.6	16.7	75.1
Manganese	T-Mn	67.3	0.182	0.147	1.28	17.8
Molybdenum	T-Mo	<0.060	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	0.84	<0.050	<0.050	<0.050	<0.050
Phosphorus	T-P	<0.60	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	15.4	5.5	4.9	<2.0	6.6
Selenium	T-Se	<0.40	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	12.5	6.72	6.10	5.00	7.46
Silver	T-Ag	<0.020	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	105	10.2	9.0	6.9	40.1
Strontium	T-Sr	3.79	0.901	0.717	0.272	0.942
Thallium	T-Tl	<0.40	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.060	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	<0.020	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.060	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	319	3.56	2.83	0.0412	0.0065

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Appendix 1 - QUALITY CONTROL - Replicates

Water		CVS-2	CVS-2	CVS-6	CVS-6
		04-10-19 17:00	QC # 413167	04-10-19 18:20	QC # 413168
Dissolved Anions					
Sulphate	SO4	587	592	550	550

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Appendix 1 - QUALITY CONTROL - Replicates

Water		CVS-2	CVS-2	CVS-6	CVS-6
		04-10-19 17:00	QC # 413167	04-10-19 18:20	QC # 413168
Total Metals					
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.081	0.077	0.076	0.077
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	229	215	203	203
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.010
Cobalt	T-Co	<0.010	<0.010	<0.010	<0.010
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	0.967	0.915	3.95	3.97
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.010	0.013	<0.010	0.013
Magnesium	T-Mg	48.1	45.5	41.2	41.5
Manganese	T-Mn	8.14	7.67	7.02	7.03
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.050	<0.050	<0.050	<0.050
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	4.9	4.4	4.0	4.4
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	6.23	5.91	6.39	6.42
Silver	T-Ag	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	30.5	29.6	30.2	30.6
Strontium	T-Sr	0.625	0.593	0.546	0.549
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.0054	<0.0050	<0.0050	<0.0050

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Appendix 2 - METHODOLOGY

Outlines of the methodologies utilized for the analysis of the samples submitted are as follows

Conductivity in Water

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

Recommended Holding Time:
Sample: 28 days
Reference: APHA
For more detail see ALS Environmental "Collection & Sampling Guide"

Dissolved Anions in Water by Ion Chromatography

This analysis is carried out using procedures adapted from APHA Method 4110 "Determination of Anions by Ion Chromatography" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Anions are determined by filtering the sample through a 0.45 micron membrane filter and injecting the filtrate onto a Dionex IonPac AG17 anion exchange column with a hydroxide eluent stream. Anions routinely determined by this method include: bromide, chloride, fluoride, nitrate, nitrite and sulphate.

Recommended Holding Time:
Sample: 28 days (bromide, chloride, fluoride, sulphate)
Sample: 2 days (nitrate, nitrite)
Reference: APHA and EPA
For more detail see ALS Environmental "Collection & Sampling Guide"

Metals in Water

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" 20th Edition 1998 published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotplate or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by atomic absorption/emission spectrophotometry (EPA Method 7000 series), inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B), and/or inductively coupled plasma - mass spectrometry (EPA Method 6020).

Recommended Holding Time:
Sample: 6 months
Reference: EPA
For more detail see: ALS "Collection & Sampling Guide"

Appendix 2 - METHODOLOGY - Continued

Results contained within this report relate only to the samples as submitted.

This Chemical Analysis Report shall only be reproduced in full, except with the written approval of ALS Environmental.

End of Report

CHEMICAL ANALYSIS REPORT

Date:	May 10, 2005
ALS File No.	V7141r
Report On:	Faro Q Survey 2005-1 Water Analysis
Report To:	**Robertson Technologies Corp.** Suite 640 580 Hornby Street Vancouver, BC V6C 3B6
Attention:	**Mr. Christoph Wels**
Received:	April 19, 2005

ALS ENVIRONMENTAL
per:

Andre Langlais, M.Sc. - Project Chemist
Can Dang, B.Sc. - Project Chemist

cc: Ken Nordin,
Laberge Environmental Services.
Whitehorse, YT.

File No. V7141r

REMARKS

This report, ALS file V7141r, supersedes the previous file V7141. The data for the Dissolved Ions were modified for sample CVS-3 and CVS-4.

Please note the sample, "FCS-5", as noted on the chain of custody form was not received. An extra sample, "FCS-7", was received instead.

For some of the submitted water samples, the measured concentration of specific dissolved parameters is greater than the corresponding total parameters concentration. The explanation for these findings is one or a combination of the following:

* laboratory method variability;
* field sampling method variability;
* bias introduced during general handling, storage, transportation and/or analysis of the sample;
* field sample grab bias - where separate grab samples are processed to produce total and dissolved samples;
* field sample split bias - where total and dissolved parameters samples are produced from the same grab sample.

For further clarification on any of the above information, please contact us.

RESULTS OF ANALYSIS - Water

Sample ID			RC-1	RC-2	RC-3	RC-4	RC-5
Sample Date			05-04-15	05-04-15	05-04-15	05-04-15	05-04-15
Sample Time			10:15	11:35	12:45	13:50	15:20
ALS ID			*1*	*2*	*3*	*4*	*5*
Physical Tests							
Conductivity	(uS/cm)		617	620	615	620	629
Dissolved Anions							
Bromide	Br		<0.050	<0.050	<0.050	<0.050	<0.050
Chloride	Cl		0.72	0.71	0.72	0.71	0.73
Fluoride	F		0.151	0.132	0.162	0.154	0.168
Sulphate	SO4		161	162	161	164	166
Nutrients							
Nitrate Nitrogen		N	0.20	0.19	0.19	0.19	0.19
Nitrite Nitrogen		N	<0.10	<0.10	<0.10	<0.10	<0.10

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID		RC-1	RC-2	RC-3	RC-4	RC-5
Sample Date		05-04-15	05-04-15	05-04-15	05-04-15	05-04-15
Sample Time		10:15	11:35	12:45	13:50	15:20
ALS ID		*1*	*2*	*3*	*4*	*5*
Total Metals						
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.083	0.083	0.083	0.083	0.086
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	97.3	97.5	96.9	97.7	99.6
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	T-Co	<0.010	<0.010	<0.010	<0.010	<0.010
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	0.280	0.250	0.228	0.197	0.189
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium	T-Mg	20.3	20.5	20.4	20.6	21.1
Manganese	T-Mn	1.55	1.59	1.60	1.65	1.71
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	5.72	5.59	5.56	5.62	5.69
Silver	T-Ag	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	9.7	9.7	9.6	9.9	10.3
Strontium	T-Sr	0.327	0.329	0.328	0.332	0.342
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.0186	0.0180	0.0173	0.0180	0.0188

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		RC-1	RC-2	RC-3	RC-4	RC-5
Sample Date		05-04-15	05-04-15	05-04-15	05-04-15	05-04-15
Sample Time		10:15	11:35	12:45	13:50	15:20
ALS ID		*1*	*2*	*3*	*4*	*5*
Dissolved Metals						
Aluminum	D-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	D-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	D-Ba	0.083	0.084	0.083	0.081	0.085
Beryllium	D-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	D-Bi	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	D-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	D-Ca	98.7	99.3	96.1	94.3	99.9
Chromium	D-Cr	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	D-Co	<0.010	<0.010	<0.010	<0.010	<0.010
Copper	D-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	D-Fe	<0.030	<0.030	<0.030	0.170	<0.030
Lead	D-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	D-Li	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium	D-Mg	20.8	21.0	20.4	20.0	21.0
Manganese	D-Mn	1.54	1.61	1.57	1.64	1.71
Molybdenum	D-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus	D-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	D-K	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium	D-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	D-Si	5.77	5.68	5.48	5.41	5.65
Silver	D-Ag	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	D-Na	10.0	10.0	9.6	9.6	10.2
Strontium	D-Sr	0.336	0.336	0.328	0.321	0.341
Thallium	D-Tl	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	D-Sn	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	D-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	D-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	D-Zn	0.0165	0.0172	0.0168	0.0178	0.0180

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID			CVS-1	CVS-2	CVS-3	CVS-4	CVS-5
Sample Date			05-04-15	05-04-15	05-04-15	05-04-15	05-04-15
Sample Time			16:00	16:30	16:40	17:10	17:40
ALS ID			*6*	*7*	*8*	*9*	*10*
Physical Tests							
Conductivity	(uS/cm)		1450	1540	1370	1400	2110
Dissolved Anions							
Bromide	Br		<0.50	<0.50	<0.50	<0.50	<1.0
Chloride	Cl		<5.0	<5.0	<5.0	<5.0	<10
Fluoride	F		<0.20	0.27	0.20	<0.20	<0.40
Sulphate	SO4		592	650	586	551	1060
Nutrients							
Nitrate Nitrogen		N	<1.0	<1.0	<1.0	<1.0	<2.0
Nitrite Nitrogen		N	<1.0	<1.0	<1.0	<1.0	<2.0

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID		CVS-1	CVS-2	CVS-3	CVS-4	CVS-5
Sample Date		05-04-15	05-04-15	05-04-15	05-04-15	05-04-15
Sample Time		16:00	16:30	16:40	17:10	17:40
ALS ID		*6*	*7*	*8*	*9*	*10*
Total Metals						
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.094	0.091	0.058	0.098	0.059
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	239	254	234	240	333
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	T-Co	<0.010	<0.010	<0.010	<0.010	0.021
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	0.462	0.639	<0.030	2.13	1.64
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	0.013	0.012	<0.010	0.012	0.013
Magnesium	T-Mg	48.3	49.4	49.7	46.3	74.0
Manganese	T-Mn	6.98	7.94	0.363	9.48	19.1
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	4.1	4.3	4.7	4.2	5.4
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	6.43	6.63	5.21	6.91	7.16
Silver	T-Ag	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	34.1	36.4	25.5	37.0	39.9
Strontium	T-Sr	0.654	0.672	0.735	0.641	0.836
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.0129	0.0069	0.202	0.0186	0.0066

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID		CVS-1	CVS-2	CVS-3	CVS-4	CVS-5
Sample Date		05-04-15	05-04-15	05-04-15	05-04-15	05-04-15
Sample Time		16:00	16:30	16:40	17:10	17:40
ALS ID		*6*	*7*	*8*	*9*	*10*
Dissolved Metals						
Aluminum	D-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	D-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	D-Ba	0.090	0.091	0.054	0.100	0.058
Beryllium	D-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	D-Bi	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	D-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	D-Ca	232	265	222	246	339
Chromium	D-Cr	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	D-Co	<0.010	<0.010	<0.010	<0.010	0.023
Copper	D-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	D-Fe	<0.030	<0.030	<0.030	<0.030	<0.030
Lead	D-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	D-Li	0.011	0.012	<0.010	<0.010	0.012
Magnesium	D-Mg	46.5	48.6	46.4	44.3	76.1
Manganese	D-Mn	6.78	8.20	0.354	9.63	18.9
Molybdenum	D-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus	D-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	D-K	3.9	4.4	4.3	4.1	5.5
Selenium	D-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	D-Si	6.22	6.83	4.96	7.30	7.24
Silver	D-Ag	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	D-Na	32.7	35.9	23.4	36.4	40.0
Strontium	D-Sr	0.637	0.671	0.673	0.615	0.823
Thallium	D-Tl	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	D-Sn	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	D-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	D-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	D-Zn	0.0152	0.0086	0.192	<0.0050	0.0071

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID			CVS-6	CVS-7	DUP-1	RCD-1	RCD-2
Sample Date			05-04-15	05-04-15	05-04-15	05-04-15	05-04-16
Sample Time			18:10	18:30	19:00	19:00	10:30
ALS ID			*11*	*12*	*13*	*14*	*15*
Physical Tests							
Conductivity	(uS/cm)		1430	1200	2120	334	333
Dissolved Anions							
Bromide	Br		<0.50	<0.50	<1.0	<0.050	<0.050
Chloride	Cl		<5.0	<5.0	<10	<0.50	<0.50
Fluoride	F		<0.20	<0.20	<0.40	0.184	0.186
Sulphate	SO4		572	460	1000	34.6	34.3
Nutrients							
Nitrate Nitrogen		N	<1.0	<1.0	<2.0	0.26	0.25
Nitrite Nitrogen		N	<1.0	<1.0	<2.0	<0.10	<0.10

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		CVS-6	CVS-7	DUP-1	RCD-1	RCD-2
Sample Date		05-04-15	05-04-15	05-04-15	05-04-15	05-04-16
Sample Time		18:10	18:30	19:00	19:00	10:30
ALS ID		*11*	*12*	*13*	*14*	*15*
Total Metals						
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.088	0.039	0.058	0.081	0.079
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	215	155	321	48.8	47.1
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	T-Co	<0.010	<0.010	0.021	<0.010	<0.010
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	1.09	0.047	1.72	0.155	0.207
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.010	<0.010	0.014	<0.010	<0.010
Magnesium	T-Mg	38.9	33.8	73.0	11.6	11.2
Manganese	T-Mn	8.38	0.469	18.4	0.0174	0.0476
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	3.6	3.7	5.5	<2.0	<2.0
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	6.53	4.72	7.05	5.38	5.24
Silver	T-Ag	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	31.6	22.2	38.6	3.3	3.2
Strontium	T-Sr	0.532	0.458	0.798	0.230	0.223
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	<0.0050	0.0051	0.0063	0.0277	0.0289

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		CVS-6	CVS-7	DUP-1	RCD-1	RCD-2
Sample Date		05-04-15	05-04-15	05-04-15	05-04-15	05-04-16
Sample Time		18:10	18:30	19:00	19:00	10:30
ALS ID		*11*	*12*	*13*	*14*	*15*
Dissolved Metals						
Aluminum	D-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	D-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	D-Ba	0.075	0.035	0.057	0.078	0.080
Beryllium	D-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	D-Bi	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	D-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	D-Ca	194	135	328	47.1	47.5
Chromium	D-Cr	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	D-Co	<0.010	<0.010	0.021	<0.010	<0.010
Copper	D-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	D-Fe	0.068	<0.030	<0.030	<0.030	<0.030
Lead	D-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	D-Li	<0.010	<0.010	0.013	<0.010	<0.010
Magnesium	D-Mg	35.0	30.2	75.3	11.2	11.3
Manganese	D-Mn	7.20	0.395	18.2	0.0085	0.0439
Molybdenum	D-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus	D-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	D-K	3.2	3.4	5.4	<2.0	<2.0
Selenium	D-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	D-Si	5.84	4.12	7.16	5.23	5.24
Silver	D-Ag	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	D-Na	27.3	20.2	36.5	3.2	3.3
Strontium	D-Sr	0.481	0.411	0.791	0.222	0.225
Thallium	D-Tl	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	D-Sn	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	D-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	D-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	D-Zn	<0.0050	0.0055	0.0057	0.0186	0.0239

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID			CCR	RCDC-3	RCDC-4	SCH	FCS-1
Sample Date			05-04-16	05-04-16	05-04-16	05-04-16	05-04-17
Sample Time			08:10	14:30	15:30	13:00	
ALS ID			*16*	*17*	*18*	*19*	*20*
Physical Tests							
Conductivity	(uS/cm)		451	332	330	672	6110
Dissolved Anions							
Bromide	Br		<0.050	<0.050	<0.050	<0.050	<1.0
Chloride	Cl		<0.50	<0.50	<0.50	<0.50	18
Fluoride	F		0.134	0.187	0.192	0.130	<0.40
Sulphate	SO4		45.9	34.3	34.3	306	5030
Nutrients							
Nitrate Nitrogen		N	0.14	0.24	0.24	0.12	9.0
Nitrite Nitrogen		N	<0.10	<0.10	<0.10	<0.10	<2.0

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		CCR	RCDC-3	RCDC-4	SCH	FCS-1
Sample Date		05-04-16	05-04-16	05-04-16	05-04-16	05-04-17
Sample Time		08:10	14:30	15:30	13:00	
ALS ID		*16*	*17*	*18*	*19*	*20*
Total Metals						
Aluminum	T-Al	<0.20	<0.20	<0.20	0.36	<0.40
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.40
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.40
Barium	T-Ba	0.146	0.080	0.076	0.306	<0.020
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.010
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.20	<0.40
Boron	T-B	<0.10	<0.10	<0.10	<0.10	<0.20
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	0.026
Calcium	T-Ca	57.5	45.8	45.7	94.4	451
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.010	<0.020
Cobalt	T-Co	<0.010	<0.010	<0.010	0.013	0.570
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010	0.025
Iron	T-Fe	<0.030	0.254	0.230	85.6	88.9
Lead	T-Pb	<0.050	<0.050	<0.050	0.226	<0.10
Lithium	T-Li	<0.010	<0.010	<0.010	<0.010	0.127
Magnesium	T-Mg	22.7	10.7	11.5	13.7	721
Manganese	T-Mn	<0.0050	0.0941	0.101	2.59	70.4
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.060
Nickel	T-Ni	<0.050	<0.050	<0.050	<0.050	0.75
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30	<0.60
Potassium	T-K	<2.0	<2.0	<2.0	2.0	13.6
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.40
Silicon	T-Si	4.01	5.13	5.28	4.72	6.46
Silver	T-Ag	<0.010	<0.010	<0.010	<0.010	<0.020
Sodium	T-Na	<2.0	3.1	2.9	4.1	68.1
Strontium	T-Sr	0.175	0.216	0.230	0.306	3.57
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.20	<0.40
Tin	T-Sn	<0.030	<0.030	<0.030	<0.030	<0.060
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010	<0.020
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	0.122
Zinc	T-Zn	0.0093	0.0326	0.0284	4.69	295

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		CCR	RCDC-3	RCDC-4	SCH	FCS-1
Sample Date		05-04-16	05-04-16	05-04-16	05-04-16	05-04-17
Sample Time		08:10	14:30	15:30	13:00	
ALS ID		*16*	*17*	*18*	*19*	*20*
Dissolved Metals						
Aluminum	D-Al	<0.20	<0.20	<0.20	<0.20	0.56
Antimony	D-Sb	<0.20	<0.20	<0.20	<0.20	<0.40
Arsenic	D-As	<0.20	<0.20	<0.20	<0.20	<0.40
Barium	D-Ba	0.152	0.076	0.076	0.031	<0.020
Beryllium	D-Be	<0.0050	<0.0050	<0.0050	<0.0050	<0.010
Bismuth	D-Bi	<0.20	<0.20	<0.20	<0.20	<0.40
Boron	D-B	<0.10	<0.10	<0.10	<0.10	<0.20
Cadmium	D-Cd	<0.010	<0.010	<0.010	<0.010	0.024
Calcium	D-Ca	59.2	45.6	46.3	95.0	440
Chromium	D-Cr	<0.010	<0.010	<0.010	<0.010	<0.020
Cobalt	D-Co	<0.010	<0.010	<0.010	0.013	0.558
Copper	D-Cu	<0.010	<0.010	<0.010	<0.010	<0.020
Iron	D-Fe	<0.030	<0.030	<0.030	18.5	34.4
Lead	D-Pb	<0.050	<0.050	<0.050	<0.050	<0.10
Lithium	D-Li	<0.010	<0.010	<0.010	<0.010	0.126
Magnesium	D-Mg	23.5	10.6	11.6	13.7	710
Manganese	D-Mn	<0.0050	0.0918	0.101	2.61	68.5
Molybdenum	D-Mo	<0.030	<0.030	<0.030	<0.030	<0.060
Nickel	D-Ni	<0.050	<0.050	<0.050	<0.050	0.73
Phosphorus	D-P	<0.30	<0.30	<0.30	<0.30	<0.60
Potassium	D-K	<2.0	<2.0	<2.0	<2.0	13.4
Selenium	D-Se	<0.20	<0.20	<0.20	<0.20	<0.40
Silicon	D-Si	4.15	5.09	5.40	3.40	5.29
Silver	D-Ag	<0.010	<0.010	<0.010	<0.010	<0.020
Sodium	D-Na	<2.0	3.1	3.0	4.1	66.6
Strontium	D-Sr	0.182	0.212	0.233	0.302	3.46
Thallium	D-Tl	<0.20	<0.20	<0.20	<0.20	<0.40
Tin	D-Sn	<0.030	<0.030	<0.030	<0.030	<0.060
Titanium	D-Ti	<0.010	<0.010	<0.010	<0.010	<0.020
Vanadium	D-V	<0.030	<0.030	<0.030	<0.030	0.118
Zinc	D-Zn	<0.0050	0.0285	0.0250	3.70	278

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID			FCS-3	FCS-4	GHC	FCS-6
Sample Date Sample Time			05-04-17	05-04-17	05-04-17	05-04-17
ALS ID			*21*	*22*	*23*	*24*
Physical Tests						
Conductivity	(uS/cm)		6920	5770	1070	5600
Dissolved Anions						
Bromide	Br		<5.0	<5.0	<1.0	<5.0
Chloride	Cl		<50	<50	<10	<50
Fluoride	F		<2.0	<2.0	<0.40	<2.0
Sulphate	SO4		5550	4170	416	3750
Nutrients						
Nitrate Nitrogen		N	<10	<10	<2.0	<10
Nitrite Nitrogen		N	<10	<10	<2.0	<10

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		FCS-3	FCS-4	GHC	FCS-6	FIELD BLANK-1
Sample Date		05-04-17	05-04-17	05-04-17	05-04-17	05-04-16
Sample Time						06:00
ALS ID		*21*	*22*	*23*	*24*	*25*
Total Metals						
Aluminum	T-Al	1.53	1.69	<0.20	3.49	<0.20
Antimony	T-Sb	<0.40	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.40	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	<0.020	0.014	0.073	0.021	<0.010
Beryllium	T-Be	<0.010	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.40	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.20	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.020	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	402	479	214	450	<0.050
Chromium	T-Cr	<0.020	0.012	<0.010	0.011	<0.010
Cobalt	T-Co	0.393	0.306	<0.010	0.280	<0.010
Copper	T-Cu	<0.020	0.021	<0.010	0.050	<0.010
Iron	T-Fe	1210	801	0.094	785	<0.030
Lead	T-Pb	<0.10	0.073	<0.050	0.210	<0.050
Lithium	T-Li	0.087	0.095	<0.010	0.088	<0.010
Magnesium	T-Mg	526	494	41.4	449	<0.10
Manganese	T-Mn	54.7	52.4	0.0292	47.8	<0.0050
Molybdenum	T-Mo	<0.060	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	0.48	0.385	<0.050	0.361	<0.050
Phosphorus	T-P	<0.60	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	8.2	11.2	4.3	10.6	<2.0
Selenium	T-Se	<0.40	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	12.3	12.9	7.28	13.5	<0.050
Silver	T-Ag	<0.020	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	99.1	88.6	10.2	84.0	<2.0
Strontium	T-Sr	3.34	3.32	0.784	3.13	<0.0050
Thallium	T-Tl	<0.40	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.060	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	<0.020	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	0.198	0.092	<0.030	0.112	<0.030
Zinc	T-Zn	309	174	1.21	164	0.0076

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

Sample ID		FCS-3	FCS-4	GHC	FCS-6
Sample Date		05-04-17	05-04-17	05-04-17	05-04-17
Sample Time					
ALS ID		*21*	*22*	*23*	*24*
Dissolved Metals					
Aluminum	D-Al	<0.40	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.40	<0.20	<0.20	<0.20
Arsenic	D-As	<0.40	<0.20	<0.20	<0.20
Barium	D-Ba	<0.020	0.011	0.075	0.014
Beryllium	D-Be	<0.010	<0.0050	<0.0050	<0.0050
Bismuth	D-Bi	<0.40	<0.20	<0.20	<0.20
Boron	D-B	<0.20	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.020	<0.010	<0.010	<0.010
Calcium	D-Ca	397	452	215	382
Chromium	D-Cr	<0.020	<0.010	<0.010	<0.010
Cobalt	D-Co	0.380	0.287	<0.010	0.227
Copper	D-Cu	<0.020	<0.010	<0.010	<0.010
Iron	D-Fe	1090	604	<0.030	502
Lead	D-Pb	<0.10	<0.050	<0.050	<0.050
Lithium	D-Li	0.080	0.076	0.010	0.075
Magnesium	D-Mg	506	458	42.1	347
Manganese	D-Mn	52.6	45.0	0.0125	30.9
Molybdenum	D-Mo	<0.060	<0.030	<0.030	<0.030
Nickel	D-Ni	0.46	0.364	<0.050	0.284
Phosphorus	D-P	<0.60	<0.30	<0.30	<0.30
Potassium	D-K	7.7	9.6	4.4	8.1
Selenium	D-Se	<0.40	<0.20	<0.20	<0.20
Silicon	D-Si	10.5	9.17	7.44	6.63
Silver	D-Ag	<0.020	<0.010	<0.010	<0.010
Sodium	D-Na	93.5	76.4	10.5	80.9
Strontium	D-Sr	3.17	2.92	0.798	2.91
Thallium	D-Tl	<0.40	<0.20	<0.20	<0.20
Tin	D-Sn	<0.060	<0.030	<0.030	<0.030
Titanium	D-Ti	<0.020	<0.010	<0.010	<0.010
Vanadium	D-V	0.160	0.128	<0.030	0.079
Zinc	D-Zn	291	150	1.20	129

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID			FCS-7
Sample Date			
Sample Time			
ALS ID			*29*
Physical Tests			
Conductivity	(uS/cm)		5580
Dissolved Anions			
Bromide	Br		<5.0
Chloride	Cl		<50
Fluoride	F		<2.0
Sulphate	SO4		4870
Nutrients			
Nitrate Nitrogen		N	<10
Nitrite Nitrogen		N	<10

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID		FIELD BLANK-1	FCS-7
Sample Date		05-04-17	
Sample Time		14:00	
ALS ID		*26*	*29*
Total Metals			
Aluminum	T-Al	<0.20	1.72
Antimony	T-Sb	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20
Barium	T-Ba	<0.010	0.013
Beryllium	T-Be	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20
Boron	T-B	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010
Calcium	T-Ca	<0.050	350
Chromium	T-Cr	<0.010	<0.010
Cobalt	T-Co	<0.010	0.217
Copper	T-Cu	<0.010	0.020
Iron	T-Fe	<0.030	537
Lead	T-Pb	<0.050	0.078
Lithium	T-Li	<0.010	0.056
Magnesium	T-Mg	<0.10	332
Manganese	T-Mn	<0.0050	29.5
Molybdenum	T-Mo	<0.030	<0.030
Nickel	T-Ni	<0.050	0.271
Phosphorus	T-P	<0.30	<0.30
Potassium	T-K	<2.0	6.8
Selenium	T-Se	<0.20	<0.20
Silicon	T-Si	<0.050	8.33
Silver	T-Ag	<0.010	<0.010
Sodium	T-Na	<2.0	66.6
Strontium	T-Sr	<0.0050	2.53
Thallium	T-Tl	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030
Titanium	T-Ti	<0.010	<0.010
Vanadium	T-V	<0.030	0.089
Zinc	T-Zn	<0.0050	125

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

RESULTS OF ANALYSIS - Water

Sample ID		FILTER BLANK-1	FILTER BLANK-2	FCS-7
Sample Date		05-04-16	05-04-17	
Sample Time		08:00	09:00	
ALS ID		*27*	*28*	*29*
Dissolved Metals				
Aluminum	D-Al	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20
Arsenic	D-As	<0.20	<0.20	<0.20
Barium	D-Ba	<0.010	<0.010	0.012
Beryllium	D-Be	<0.0050	<0.0050	<0.0050
Bismuth	D-Bi	<0.20	<0.20	<0.20
Boron	D-B	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010	<0.010
Calcium	D-Ca	<0.050	<0.050	329
Chromium	D-Cr	<0.010	<0.010	<0.010
Cobalt	D-Co	<0.010	<0.010	0.202
Copper	D-Cu	<0.010	<0.010	<0.010
Iron	D-Fe	<0.030	<0.030	473
Lead	D-Pb	<0.050	<0.050	<0.050
Lithium	D-Li	<0.010	<0.010	0.058
Magnesium	D-Mg	<0.10	<0.10	303
Manganese	D-Mn	<0.0050	<0.0050	30.2
Molybdenum	D-Mo	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.050	<0.050	0.254
Phosphorus	D-P	<0.30	<0.30	<0.30
Potassium	D-K	<2.0	<2.0	7.3
Selenium	D-Se	<0.20	<0.20	<0.20
Silicon	D-Si	<0.050	<0.050	5.74
Silver	D-Ag	<0.010	<0.010	<0.010
Sodium	D-Na	<2.0	<2.0	67.7
Strontium	D-Sr	<0.0050	<0.0050	2.61
Thallium	D-Tl	<0.20	<0.20	<0.20
Tin	D-Sn	<0.030	<0.030	<0.030
Titanium	D-Ti	<0.010	<0.010	<0.010
Vanadium	D-V	<0.030	<0.030	0.047
Zinc	D-Zn	<0.0050	0.0101	128

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

Appendix 1 - QUALITY CONTROL - Replicates

Water			CVS-2	CVS-2	RCD-1	RCD-1
			05-04-15 16:30	QC # 437438	05-04-15 19:00	QC # 437439
Physical Tests						
Conductivity	(uS/cm)		1540	1540	334	333
Dissolved Anions						
Bromide	Br		<0.50	<0.50	<0.050	<0.050
Chloride	Cl		<5.0	<5.0	<0.50	<0.50
Fluoride	F		0.27	0.25	0.184	0.188
Sulphate	SO4		650	602	34.6	34.4
Nutrients						
Nitrate Nitrogen		N	<1.0	<1.0	0.26	0.26
Nitrite Nitrogen		N	<1.0	<1.0	<0.10	<0.10

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Appendix 1 - QUALITY CONTROL - Replicates

Water		CVS-2	CVS-2	RCD-1	RCD-1
		05-04-15 16:30	QC # 437438	05-04-15 19:00	QC # 437439
Total Metals					
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.091	0.099	0.081	0.082
Beryllium	T-Be	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20	<0.20	<0.20
Boron	T-B	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	254	277	48.8	48.9
Chromium	T-Cr	<0.010	<0.010	<0.010	<0.010
Cobalt	T-Co	<0.010	<0.010	<0.010	<0.010
Copper	T-Cu	<0.010	<0.010	<0.010	<0.010
Iron	T-Fe	0.639	0.693	0.155	0.158
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	0.012	0.014	<0.010	<0.010
Magnesium	T-Mg	49.4	52.7	11.6	11.7
Manganese	T-Mn	7.94	8.57	0.0174	0.0170
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.050	<0.050	<0.050	<0.050
Phosphorus	T-P	<0.30	<0.30	<0.30	<0.30
Potassium	T-K	4.3	4.8	<2.0	<2.0
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	6.63	7.11	5.38	5.53
Silver	T-Ag	<0.010	<0.010	<0.010	<0.010
Sodium	T-Na	36.4	39.5	3.3	3.4
Strontium	T-Sr	0.672	0.742	0.230	0.232
Thallium	T-Tl	<0.20	<0.20	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030	<0.030	<0.030
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.0069	0.0079	0.0277	0.0280

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

Appendix 1 - QUALITY CONTROL - Replicates

Water		CVS-2	CVS-2	RCD-1	RCD-1
		05-04-15 16:30	QC # 437438	05-04-15 19:00	QC # 437439
Dissolved Metals					
Aluminum	D-Al	<0.20	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20	<0.20
Arsenic	D-As	<0.20	<0.20	<0.20	<0.20
Barium	D-Ba	0.091	0.086	0.078	0.078
Beryllium	D-Be	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	D-Bi	<0.20	<0.20	<0.20	<0.20
Boron	D-B	<0.10	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010	<0.010	<0.010
Calcium	D-Ca	265	235	47.1	47.0
Chromium	D-Cr	<0.010	<0.010	<0.010	<0.010
Cobalt	D-Co	<0.010	<0.010	<0.010	<0.010
Copper	D-Cu	<0.010	<0.010	<0.010	<0.010
Iron	D-Fe	<0.030	<0.030	<0.030	<0.030
Lead	D-Pb	<0.050	<0.050	<0.050	<0.050
Lithium	D-Li	0.012	0.012	<0.010	<0.010
Magnesium	D-Mg	48.6	47.2	11.2	11.3
Manganese	D-Mn	8.20	7.35	0.0085	0.0084
Molybdenum	D-Mo	<0.030	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.050	<0.050	<0.050	<0.050
Phosphorus	D-P	<0.30	<0.30	<0.30	<0.30
Potassium	D-K	4.4	4.1	<2.0	<2.0
Selenium	D-Se	<0.20	<0.20	<0.20	<0.20
Silicon	D-Si	6.83	6.09	5.23	5.25
Silver	D-Ag	<0.010	<0.010	<0.010	<0.010
Sodium	D-Na	35.9	34.4	3.2	3.2
Strontium	D-Sr	0.671	0.653	0.222	0.223
Thallium	D-Tl	<0.20	<0.20	<0.20	<0.20
Tin	D-Sn	<0.030	<0.030	<0.030	<0.030
Titanium	D-Ti	<0.010	<0.010	<0.010	<0.010
Vanadium	D-V	<0.030	<0.030	<0.030	<0.030
Zinc	D-Zn	0.0086	0.0079	0.0186	0.0185

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

Appendix 1 - QUALITY CONTROL - Replicates

Water			FCS-6 05-04-17	FCS-6 QC # 437440
Physical Tests				
Conductivity	(uS/cm)		5600	5600
Dissolved Anions				
Bromide	Br		<5.0	<5.0
Chloride	Cl		<50	<50
Fluoride	F		<2.0	<2.0
Sulphate	SO4		3750	3390
Nutrients				
Nitrate Nitrogen		N	<10	<10
Nitrite Nitrogen		N	<10	<10

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Appendix 1 - QUALITY CONTROL - Replicates

Water		FCS-6 05-04-17	FCS-6 QC # 437440
Total Metals			
Aluminum	T-Al	3.49	3.39
Antimony	T-Sb	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20
Barium	T-Ba	0.021	0.020
Beryllium	T-Be	<0.0050	<0.0050
Bismuth	T-Bi	<0.20	<0.20
Boron	T-B	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010
Calcium	T-Ca	450	433
Chromium	T-Cr	0.011	0.012
Cobalt	T-Co	0.280	0.277
Copper	T-Cu	0.050	0.046
Iron	T-Fe	785	767
Lead	T-Pb	0.210	0.209
Lithium	T-Li	0.088	0.086
Magnesium	T-Mg	449	438
Manganese	T-Mn	47.8	47.6
Molybdenum	T-Mo	<0.030	<0.030
Nickel	T-Ni	0.361	0.352
Phosphorus	T-P	<0.30	<0.30
Potassium	T-K	10.6	10.5
Selenium	T-Se	<0.20	<0.20
Silicon	T-Si	13.5	13.4
Silver	T-Ag	<0.010	<0.010
Sodium	T-Na	84.0	81.4
Strontium	T-Sr	3.13	3.08
Thallium	T-Tl	<0.20	<0.20
Tin	T-Sn	<0.030	<0.030
Titanium	T-Ti	<0.010	<0.010
Vanadium	T-V	0.112	0.086
Zinc	T-Zn	164	161

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

File No. V7141r

Appendix 1 - QUALITY CONTROL - Replicates

Water		FCS-6 05-04-17	FCS-6 QC # 437440
Dissolved Metals			
Aluminum	D-Al	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20
Arsenic	D-As	<0.20	<0.20
Barium	D-Ba	0.014	0.017
Beryllium	D-Be	<0.0050	<0.0050
Bismuth	D-Bi	<0.20	<0.20
Boron	D-B	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010
Calcium	D-Ca	382	402
Chromium	D-Cr	<0.010	0.011
Cobalt	D-Co	0.227	0.242
Copper	D-Cu	<0.010	<0.010
Iron	D-Fe	502	618
Lead	D-Pb	<0.050	<0.050
Lithium	D-Li	0.075	0.111
Magnesium	D-Mg	347	366
Manganese	D-Mn	30.9	38.0
Molybdenum	D-Mo	<0.030	<0.030
Nickel	D-Ni	0.284	0.309
Phosphorus	D-P	<0.30	<0.30
Potassium	D-K	8.1	10.5
Selenium	D-Se	<0.20	<0.20
Silicon	D-Si	6.63	7.02
Silver	D-Ag	<0.010	<0.010
Sodium	D-Na	80.9	102
Strontium	D-Sr	2.91	3.15
Thallium	D-Tl	<0.20	<0.20
Tin	D-Sn	<0.030	<0.030
Titanium	D-Ti	<0.010	<0.010
Vanadium	D-V	0.079	<0.030
Zinc	D-Zn	129	158

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Appendix 2 - METHODOLOGY

Outlines of the methodologies utilized for the analysis of the samples submitted are as follows

Conductivity in Water

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

Recommended Holding Time:
Sample: 28 days
Reference: APHA
For more detail see ALS Environmental "Collection & Sampling Guide"

Dissolved Anions in Water by Ion Chromatography

This analysis is carried out using procedures adapted from APHA Method 4110 "Determination of Anions by Ion Chromatography" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Anions are determined by filtering the sample through a 0.45 micron membrane filter and injecting the filtrate onto a Dionex IonPac AG17 anion exchange column with a hydroxide eluent stream. Anions routinely determined by this method include: bromide, chloride, fluoride, nitrate, nitrite and sulphate.

Recommended Holding Time:
Sample: 28 days (bromide, chloride, fluoride, sulphate)
Sample: 2 days (nitrate, nitrite)
Reference: APHA and EPA
For more detail see ALS Environmental "Collection & Sampling Guide"

Metals in Water

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" 20th Edition 1998 published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotplate or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by atomic absorption/emission spectrophotometry (EPA Method 7000 series), inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B), and/or inductively coupled plasma - mass spectrometry (EPA Method 6020).

Recommended Holding Time:
Sample: 6 months
Reference: EPA
For more detail see: ALS "Collection & Sampling Guide"

Appendix 2 - METHODOLOGY - Continued

Results contained within this report relate only to the samples as submitted.

This Chemical Analysis Report shall only be reproduced in full, except with the written approval of ALS Environmental.

End of Report