Report No. 118012/1

2007 GROUNDWATER REVIEW

ANVIL RANGE MINING COMPLEX, YUKON TERRITORY



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On behalf of

Faro Mine Closure Planning Office

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EXECUTIVE SUMMARY

Recent time trends in groundwater quality were reviewed in different reaches of the Anvil Range Mining Complex to re-assess the extent of groundwater impacts and implications for on-going closure planning. In addition, the current scope of groundwater monitoring at the Anvil Range Mine Site was reviewed and recommendations given for future monitoring (number and frequency of sampling, suite of analytes, etc).

The following sections summarize the main conclusions and recommendations of this review (by reach), with emphasis on any recent changes in groundwater quality.

Faro Mine Site

The main conclusions of the groundwater quality review at the Faro Mine Site are as follows:

- The groundwater quality data collected in the Emergency Tailings Area (ETA) are generally consistent with the results of the Faro Creek seepage surveys which had concluded that the ETA area represents a major source of contaminant loading, both by surface and subsurface pathways. These findings support earlier conclusions that the ETA area should be a priority for seepage interception.
- The groundwater quality in the S-cluster area has deteriorated dramatically over the last five years. Of particular concern is the rapid increase in dissolved zinc concentrations which have increased by as much as 100 mg/L in the last 20 months (Sep 2005 to June 2007) in selected wells (e.g. S1A, S2B, S3). These recent time trends emphasize the need for seepage interception. Note that the affected monitoring wells are all in close proximity of the North Fork of Rose Creek and, hence there is a potential for significant increase in zinc concentrations in NFRC along this reach of NFRC. We therefore recommend that the impact of contaminated groundwater discharge into NFRC be re-assessed and that an action plan be developed on how to manage potential future increases in zinc concentrations in local groundwater in this area.
- Recent seepage investigations in the Zone 2 Outwash Area (completed in 2005) had indicated the presence of moderately impacted groundwater (primarily elevated zinc concentrations) in the permeable alluvial sediments of the NFRC valley. Monitoring over the last two years has confirmed this assessment implying that earlier estimates of zinc loading and the resulting requirement for seepage interception in this area have not changed.
- Groundwater quality downgradient of the Northeastern Dump (at BH14A/B) has shown recent increases in zinc concentrations, with peak concentrations around 0.4 to 0.5 mg/L zinc (observed in 2006). The observed increases in zinc concentrations were preceded by a systematic and substantial increase in sulphate, magnesium and alkalinity. Geochemical characterization work has identified sulphide-rich waste rock in this portion of the Northeast Dumps and it is possible that groundwater quality will continue to deteriorate in this area with sulphate and eventually zinc concentrations reaching similar concentrations as currently observed in the Faro Creek and S-cluster areas.

Rose Creek Tailings Facility

The main conclusions of the groundwater quality review at the Rose Creek Tailings facility are as follows:

- Tailings pore water quality (in the tailings) has generally deteriorated further over the last three years, as evidenced by significant increases in sulphate, magnesium and metals (in particular zinc, manganese and iron). In most cases these increases were accompanied by a significant decrease in pH and alkalinity. These changes were particularly evident in the Second Impoundment (e.g. at P03-01, P03-02, P03-03, P03-05) but may also be present in other parts of the facility (e.g. coarse tailings beaches in the Original Impoundment) where no such detailed monitoring is available.

- Groundwater quality in the underlying Rose Creek aquifer has also significantly deteriorated in the last three years in all reaches of the Rose Creek Tailings Facility, i.e. not only within the foot print area of the tailings impoundments but also further downstream at the Intermediate Dam and the Cross Valley Dam. Of particular concern are the significant increases in sulphate, magnesium and metal concentrations (including iron, zinc and manganese) at greater depth in the aquifer and shallow bedrock, in particular in the northern portion of the aquifer (see for example P03-06, X21B, X24D). These recent time trends clearly indicate that the entire depth of the aquifer is affected by seepage from the tailings (and possibly the ETA area).

- The recent increases in oxidation products and metal concentrations in the northern portion of the Rose Creek aquifer are significant and their cause should be further investigated. The most likely sources of ARD seepage include (i) coarse tailings beaches located in the northern portion of the Intermediate, Second or Original Impoundments and/or seepage from the Faro Creek canyon/diversion channel. We recommend that a more detailed hydrogeologic and geochemical analysis be carried out, including assessment of hydraulic gradients and geochemical fingerprinting, to determine the cause for the recent deterioration in groundwater quality in this portion of the Rose Creek aquifer.

- Additional wells screened at shallow depth in the aquifer sediments underlying shallow tailings deposits (NA wells) show significantly elevated zinc concentrations (e.g. 22 mg/L at NA11) suggesting that the attenuation capacity of the tailings and/or organic soils underlying the tailings profile is slowly being exhausted; this process may explain the recent increases in zinc concentrations in many parts of the Rose Creek aquifer;

- Recent monitoring in multilevel well P03-03, located about 140m downgradient of the “leaky wells” P01-09A/B/C/D has shown a significant decrease in zinc concentrations at depth in the aquifer (P03-03-02, -03 and -04) in May 2007. This recent decrease may have been caused by decommissioning (sealing) of the “leaky wells” P01-09A/B/C/D in October 2005. However, additional monitoring will be required to confirm this initial assessment.

Grum/Vangorda Mine Site

The main conclusions of the groundwater quality review at the Grum/Vangorda mine site are as follows:

- Recent groundwater quality time trends observed in wells located downgradient of the Grum Rock Dump confirm earlier interpretations which had suggested that seepage from the Grum rock dump is responsible for the gradual increase in ARD products (SO4, Mg, and to a lesser extent Zn) in shallow groundwater draining towards Vangorda Creek. The more recent monitoring data also support earlier conclusions that metal concentrations (in particular zinc) are (still) attenuated along the flow path. It can therefore be concluded that seepage interception along the toe of the Grum rock dump is not yet required but will likely be required in the future (when the attenuation capacity is exhausted).
- The new deeper monitoring wells drilled in 2004 near Grum Creek and in 2005 at P96-9B also confirmed that seepage from the Grum rock dump appears to be limited to fairly shallow depth. In other words, a shallow seepage interception system may be adequate for the Grum rock dump area, at least until such time that a breakthrough of waste rock seepage is also observed in the deeper sediment/bedrock units.
- Recent monitoring of groundwater quality in wells located downgradient of the Vangorda Rock Dump supports earlier conclusions that groundwater quality impacts are generally more delayed at Vangorda, compared to anywhere else at the Anvil Range Mining Complex, due to the low permeability of the local till deposits. Nevertheless, one monitoring well (V35) has shown a recent increase in some contaminants of concern (SO4, Mg, Zn) raising the possibility that some seepage interception may also be required downgradient of the Vangorda Rock Dump at some time in the future. We therefore recommend that a preliminary design study be completed to assess the options for seepage interception downgradient of the Vangorda Rock Dump.

Recommendations for Future Groundwater Monitoring

One objective of this study was to provide an independent review of the current scope of groundwater quality monitoring and to provide recommendations for future groundwater monitoring, including the number of wells routinely sampled, the sampling frequency and the suite of parameters to be analysed.

Tables E-1 to E-3 summarize the selected monitoring wells, listed by reach, which are proposed for future routine groundwater monitoring at the Anvil Range Mining Complex. The proposed list includes 38 monitoring wells at the Faro mine site, 29 monitoring wells (including 7 multilevel wells) at the Rose Creek Tailings site and 13 at the Grum/Vangorda site.

We propose to introduce two different sampling and analysis regimes:

(i) Bi-Annual Sampling (with a “full suite” of analytes) in all wells listed as part of the existing water licence and in other selected monitoring wells located at strategic locations where there is a specific concern of groundwater impact to a near-by creek and

(ii) Annual sampling (with a “reduced suite” of analytes) in selected wells which are located at strategically less critical locations (typically upgradient of other compliance wells and/or at greater distance from a creek).

Additional recommendations for improved QA/QC procedures and reporting are provided in section 5.2 of this report.

Table E-1.

Proposed List of Monitoring Wells for Faro Mine Site

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Faro Mine Site					
P96-8B	ETA Area	6913898	583328	bi-annual	Full
SRK04-3A	ETA Area	6913824	582977	Annual	Reduced
SRK05-ETA-BR1	ETA Area	6913846	582972	Annual	Reduced
SRK05-ETA-BR2	ETA Area	6913825	582987	Annual	Reduced
S1A	S-cluster Area	6912942	584539	bi-annual	Full
S1B	S-cluster Area	6912942	584539	bi-annual	Full
S2A	S-cluster Area	6912944	584577	bi-annual	Full
S2B	S-cluster Area	6912944	584577	bi-annual	Full
S3	S-cluster Area	6912918	584585	bi-annual	Full
P96-7	S-cluster Area	6913105	584225	bi-annual	Full
SRK05-SP-1A	S-cluster Area	6912901	584727	Annual	Reduced
SRK05-SP-1B	S-cluster Area	6912901	584726	Annual	Reduced
SRK05-SP-2	S-cluster Area	6912861	584791	Annual	Reduced
SRK05-SP-3A	S-cluster Area	6912924	584651	Annual	Reduced
SRK05-SP-3B	S-cluster Area	6912924	584652	Annual	Reduced
SRK05-SP-4A	S-cluster Area	6912939	584612	bi-annual	Full
SRK05-SP-4B	S-cluster Area	6912939	584611	bi-annual	Full
SRK05-SP-5	S-cluster Area	6912956	584576	bi-annual	Full
SRK05-SP-6	S-cluster Area	6912975	584492	Annual	Reduced
BH1	Zone 2 Outwash	6913532	585267	bi-annual	Full
BH2	Zone 2 Outwash	6913523	585206	bi-annual	Full
BH4	Zone 2 Outwash	6913467	585247	bi-annual	Full
BH5	Zone 2 Outwash	6913377	585194	bi-annual	Full
BH6	Zone 2 Outwash	6913466	585198	bi-annual	Full
BH8	Zone 2 Outwash	6913599	585253	Annual	Full
BH10A	Zone 2 Outwash	6913533	585190	Annual	Full
BH10B	Zone 2 Outwash	6913533	585191	Annual	Full
P05-04	Zone 2 Outwash	6913475	585224	bi-annual	Full
Zone 2 Pumping Well (X26)	Zone 2 pit	6913770	584868	bi-annual	Full
BH12A	NE Dumps	6914068	585871	Annual	Full
BH12B	NE Dumps	6914068	585871	Annual	Full
BH13A	NE Dumps	6914339	585844	Annual	Full
BH13B	NE Dumps	6914339	585844	Annual	Full
BH14A	NE Dumps	6913826	585676	bi-annual	Full
BH14B	NE Dumps	6913826	585676	bi-annual	Full
P96-6	Intermediate Dump (NFRC)	6913133	584999	bi-annual	Full

Table E-2

Proposed List of Monitoring Wells for Rose Creek Tailings Facility.

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Rose Creek Tailings Facility					
TH86-17	upgradient	6912489	583943	Annual	Full
P03-01 (all ports)	Second Impoundment	6912580	583301	Annual	Reduced
P03-03 (all ports)	Second Impoundment	6912698	583068	Annual	Reduced
P03-04 (all ports)	Second Impoundment	6913186	582085	Annual	Reduced
P03-06 (all ports)	Second Impoundment	6913309	582573	Annual	Reduced
X21A-96	Intermediate Impoundment	6913417	581989	Bi-annual	Full
X21B-96	Intermediate Impoundment	6913417	581989	Bi-annual	Full
P03-08 (all ports)	Intermediate Impoundment	6913514	580980	Annual	Reduced
X24D-96	Intermediate Dam	6914124	580655	Bi-annual	Full
X25A-96	Intermediate Dam	6913945	580519	Bi-annual	Full
X25B-96	Intermediate Dam	6913945	580519	Bi-annual	Full
P01-03	Intermediate Dam	6914071	580639	Bi-annual	Full
P01-04A	Intermediate Dam	6913893	580496	Bi-annual	Full
P01-04B	Intermediate Dam	6913893	580496	Bi-annual	Full
P01-02A	Cross Valley Dam	6914044	580051	Bi-annual	Full
P01-02B	Cross Valley Dam	6914044	580051	Bi-annual	Full
P01-11	Cross Valley Dam	6914306	580214	Bi-annual	Full
P03-09 (all ports)	Cross Valley Dam	6914229	580065	Bi-annual	Full
P05-01 (all ports)	Cross Valley Dam	6914335	580165	Annual	Full
P05-02	Cross Valley Dam	6914265	580144	Bi-annual	Full
P05-03	Cross Valley Dam	6914171	580088	Bi-annual	Full
X16A	Downgradient of CVD	6914672	579574	Bi-annual	Full
X16B	Downgradient of CVD	6914672	579574	Bi-annual	Full
X17A	Downgradient of CVD	6914475	579874	Bi-annual	Full
X17B	Downgradient of CVD	6914475	579874	Bi-annual	Full
X18A	Downgradient of CVD	6914539	580105	Bi-annual	Full
X18B	Downgradient of CVD	6914539	580105	Bi-annual	Full
P01-01A	Downgradient of CVD	6914675	579819	Bi-annual	Full
P01-01B	Downgradient of CVD	6914675	579819	Bi-annual	Full

Table E-3

Proposed List of Monitoring Wells for Grum/Vangorda Mine Site

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Grum/Vangorda Mine Site					
P96-9A	Grum Rock Dump	6903165	592753	Bi-annual	Full
BH05-9B-R	Grum Rock Dump	6903172	592747	Bi-annual	Full
SRK05-05C	Grum Rock Dump	6903208	592873	Bi-annual	Full
SRK05-07	Grum Rock Dump	6903011	592477	Bi-annual	Full
SRK05-08	Grum Rock Dump	6903063	592690	Bi-annual	Full
SRK05-09 ("Moose Well 2")	Grum Rock Dump	6902986	593058	Bi-annual	Full
V34	Vangorda Rock Dump	6902295	593553	Bi-annual	Full
V35	Vangorda Rock Dump	6902371	593293	Bi-annual	Full
V36	Vangorda Rock Dump	6902733	593243	Bi-annual	Full
V37	Vangorda Rock Dump	6902913	593420	Bi-annual	Full
P2001-02A	Vangorda Rock Dump	6902880	593098	Bi-annual	Full
P2001-02B	Vangorda Rock Dump	6902880	593098	Bi-annual	Full
P2001-03	Vangorda Rock Dump	6902865	593131	Bi-annual	Full

REPORT NO. 118012/1

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Table of Contents

EXECUTIVE SUMMARY 1

1 INTRODUCTION 1

1.1 TERMS OF REFERENCE 1
1.2 STUDY OBJECTIVES 1
1.3 SCOPE OF WORK 2
1.4 ORGANIZATION OF REPORT 2

2 FARO MINE SITE 3

2.1 GEOGRAPHIC OVERVIEW 3
2.2 EMERGENCY TAILINGS AREA (ETA) 3
2.2.1 Background 3
2.2.2 Review of Time Trends 4
2.2.3 Implications for Closure Planning 6
2.2.4 Recommended Modifications to the Water Quality Monitoring Program 7
2.3 S-CLUSTER AREA 7
2.3.1 Background 7
2.3.2 Review of Time Trends 8
2.3.3 Implications for Closure Planning 10
2.3.4 Recommended Modifications to the Water Quality Monitoring Program 11
2.4 ZONE 2 OUTWASH AREA 11
2.4.1 Background 11
2.4.2 Review of Time Trends 12
2.4.3 Implications for Closure Planning 14
2.4.4 Recommended Modifications to the Water Quality Monitoring Program 14
2.5 NORTHEAST AND INTERMEDIATE DUMPS TOWARDS NFRC 15
2.5.1 Background 15
2.5.2 Review of Time Trends 16
2.5.3 Implications for Closure Planning 18
2.5.4 Recommended Modifications to the Water Quality Monitoring Program 18

3 ROSE CREEK VALLEY (TAILINGS FACILITY) 20

3.1 GEOGRAPHIC OVERVIEW 20

3.2 UPSTREAM OF ROSE CREEK TAILINGS FACILITY 21
3.2.1 Background 21
3.2.2 Review of Time Trends 21
3.2.3 Recommended Modifications to the Water Quality Monitoring Program 21
3.2.4 Background 21
3.2.5 Review of Time Trends 22
3.2.6 Influence of Decommissioning of P01 Wells 24
3.2.7 Recommended Modifications to the Water Quality Monitoring Program 24
3.3 SECOND IMPOUNDMENT 24
3.3.1 Background 24
3.3.2 Review of Time Trends 26
3.3.3 Influence of Decommissioning of P01 Wells 30
3.3.4 Recommended Modifications to the Water Quality Monitoring Program 30
3.4 INTERMEDIATE IMPOUNDMENT 31
3.4.1 Background 31
3.4.2 Review of Time Trends 32
3.4.3 Influence of Decommissioning of P01 Wells 34
3.4.4 Recommended Modifications to the Water Quality Monitoring Program 34
3.5 TOE OF INTERMEDIATE DAM 35
3.5.1 Background 35
3.5.2 Review of Time Trends 35
3.5.3 Influence of Decommissioning of P01 Wells 37
3.5.4 Recommended Modifications to the Water Quality Monitoring Program 37
3.6 TOE OF CROSS VALLEY DAM 38
3.6.1 Background 38
3.6.2 Review of Time Trends 39
3.6.3 Influence of Decommissioning of P01 Wells 41
3.6.4 Recommended Modifications to the Water Quality Monitoring Program 41
3.7 DOWNSTREAM OF CROSS VALLEY DAM 41
3.7.1 Background 41
3.7.2 Review of Time Trends 42
3.7.3 Influence of Decommissioning of P01 Wells 43
3.7.4 Recommended Modifications to the Water Quality Monitoring Program 43
3.8 IMPLICATIONS FOR CLOSURE PLANNING 44

4 GRUM & VANGORDA MINE SITE 46

4.1 GEOGRAPHIC OVERVIEW 46
4.2 DOWNSTREAM OF GRUM ROCK DUMP 46
4.2.1 Background 46
4.2.2 Review of Time Trends 47
4.2.3 Implications for Closure Planning 48
4.2.4 Recommended Modifications to the Water Quality Monitoring Program 49
4.3 VANGORDA WRD AREA 50
4.3.1 Background 50
4.3.2 Review of Time Trends 50

4.3.3 Implications for Closure Planning 51
4.3.4 Recommended Modifications to the Water Quality Monitoring Program 52

5 REVIEW OF GROUNDWATER QUALITY MONITORING PROGRAM 53

5.1 PROPOSED SCOPE OF ROUTINE GROUNDWATER MONITORING 53
5.1.1 Proposed "Routine" Monitoring Wells 53
5.1.2 Proposed Monitoring Frequency 53
5.1.3 Proposed Suite of Analytes 56
5.1.4 Detection Limits 56
5.2 QA/QC PROCEDURES & REPORTING 57
5.2.1 QA/QC Procedures 57
5.2.2 Reporting 58

6 CONCLUSIONS & RECOMMENDATIONS 59

6.1 FARO MINE SITE 59
6.2 ROSE CREEK TAILINGS FACILITY 60
6.3 GRUM/VANGORDA MINE SITE 61
6.4 RECOMMENDATIONS FOR FUTURE GROUNDWATER MONITORING 61

7 CLOSURE 63

8 REFERENCES 64

LIST OF TABLES

Table 2-1 Monitoring wells in Emergency Tailings Area (ETA), Faro Mine Site.

Table 2-2 Monitoring wells in S-Cluster Area, Faro Mine Site.

Table 2-3 Monitoring wells in Zone 2 Outwash Area, Faro Mine Site.

Table 2-4 Monitoring wells at toe of Northeast Dumps & Intermediate Dump (NFRC), Faro Mine Site.

Table 3-1 Monitoring wells upgradient and in the Original Impoundment, Rose Creek Tailings Facility.

Table 3-2 Monitoring wells in the Second Impoundment, Rose Creek Tailings Facility.

Table 3-3 Monitoring wells in the Intermediate Impoundment, Rose Creek Tailings Facility.

Table 3-4 Monitoring wells at the Toe of the Intermediate Dam.

Table 3-5 Monitoring wells at the Toe of the Cross Valley Dam.

Table 3-6 Monitoring wells downgradient of Cross Valley Dam.

Table 4-1 Monitoring wells downgradient of Grum Rock Dump.

Table 4-2 Monitoring wells downgradient of Vangorda Rock Dump.

LIST OF FIGURES

Figure 2-1 Layout of Faro Mine Site.

Figure 2-2 Groundwater Monitoring Wells, ETA Area, Faro Mine Site.

Figure 2-3a Precipitation and water quality (SO_4, Mg, and Zn) in X23 and P96-8A/B.

Figure 2-3b Water quality (Alkalinity, pH, Fe and Mn) in X23 and P96-8A/B.

Figure 2-4a Precipitation and water quality (SO_4, Mg, and Zn) in SRK wells in ETA Area.

Figure 2-4b Water quality (Alkalinity, pH, Fe and Mn) in SRK wells in ETA Area.

Figure 2-5 Groundwater Monitoring Wells, S-Cluster Area, Faro Mine Site.

Figure 2-6a Precipitation and water quality (SO_4, Mg, and Zn) in S-Cluster wells.

Figure 2-6b Water quality (Alkalinity, pH, Fe and Mn) in S-Cluster Wells.

Figure 2-7a Precipitation and water quality (SO_4, Mg, and Zn) in SRK wells in S-Cluster Area.

Figure 2-7b Water quality (Alkalinity, pH, Fe and Mn) in SRK Wells in S-Cluster Area.

Figure 2-8 Groundwater Monitoring Wells, North Fork of Rose Creek, Faro Mine Site.

Figure 2-9 Groundwater Monitoring Wells, Zone 2 Pit Outwash Area, Faro Mine Site.

Figure 2-10a Precipitation and water quality (SO_4, Mg, and Zn) in Zone 2 Outwash Area.

Figure 2-10b Water quality (Alkalinity, pH, Fe and Mn) in Zone 2 Outwash Area.

Figure 2-11a Precipitation and water quality (SO_4, Mg, and Zn) at toe of Northeast Dumps.

Figure 2-11b Water quality (Alkalinity, pH, Fe and Mn) at toe of Northeast Dumps.

Figure 2-12a Precipitation and water quality (SO_4, Mg, and Zn) at toe of Intermediate Dump (P96-6).

Figure 2-12b Water quality (Alkalinity, pH, Fe and Mn) at toe of Intermediate Dump (P96-6).

Figure 3-1 Groundwater Monitoring Wells, Rose Creek Tailings Facility.

Figure 3-2a Water quality (SO_4, Mg, Na and Zn) in P01-10, P01-08 & TH86-17 (Original Impoundment).

Figure 3-2b Water quality (Alkalinity, pH, Fe and Mn) in P01-10, P01-08 & TH86-17 (Original Impoundment).

Figure 3-3a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-07 (Original Impoundment).

Figure 3-3b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-07 (Original Impoundment).

Figure 3-4a Water quality (SO_4, Mg, Na and Zn) in P01-09 (Second Impoundment).

Figure 3-4b Water quality (Alkalinity, pH, Fe and Mn) in P01-09 (Second Impoundment).

Figure 3-5a Water quality (SO_4, Mg, Na and Zn) in P01-07 (Second Impoundment).

Figure 3-5b Water quality (Alkalinity, pH, Fe and Mn) in P01-07 (Second Impoundment).

Figure 3-6a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-01 (Second Impoundment).

Figure 3-6b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-01 (Second Impoundment).

Figure 3-7a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-02 (Second Impoundment).

Figure 3-7b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-02 (Second Impoundment).

Figure 3-8a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-03 (Second Impoundment).

Figure 3-8b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-03 (Second Impoundment).

Figure 3-9a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-04 (Second Impoundment).

Figure 3-9b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-04 (Second Impoundment).

Figure 3-10a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-05 (Second Impoundment).

Figure 3-10b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-05 (Second Impoundment).

Figure 3-11a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-06 (Second Impoundment).

Figure 3-11b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-06 (Second Impoundment).

Figure 3-12a Water quality (SO_4, Mg, Na and Zn) in P03-03 (aquifer only).

Figure 3-12b Water quality (Alkalinity, pH, Fe and Mn) in P03-03 (aquifer only).

Figure 3-13a Water quality (SO_4, Mg, Na and Zn) in P03-04 (aquifer only).

Figure 3-13b Water quality (Alkalinity, pH, Fe and Mn) in P03-04 (aquifer only).

Figure 3-14a Water quality (SO_4, Mg, Na and Zn) in X21(96) (Intermediate Impoundment).

Figure 3-14b Water quality (Alkalinity, pH, Fe and Mn) in X21(96) (Intermediate Impoundment).

Figure 3-15a Water quality (SO_4, Mg, Na and Zn) in P01-05 and P01-06 (Intermediate Impoundment).

Figure 3-15b Water quality (Alkalinity, pH, Fe and Mn) in P01-05 and P01-06 (Intermediate Impoundment).

Figure 3-16a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-08 (Intermediate Impoundment).

Figure 3-16b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-08 (Intermediate Impoundment).

Figure 3-17a Water quality (SO_4, Mg, Na and Zn) in X24(96) and P01-03 (north side of Intermediate Dam).

Figure 3-17b Water quality (alkalinity, pH, Fe and Mn) in X24(96) and P01-03 (north side of Intermediate Dam).

Figure 3-18a Water quality (SO_4, Mg, Na and Zn) in X25(96) and P01-04 (south side of Intermediate Dam).

Figure 3-18b Water quality (alkalinity, pH, Fe and Mn) in X25(96) and P01-04 (south side of Intermediate Dam).

Figure 3-19a Water quality (SO_4, Mg, Na and Zn) in wells along toe of Cross Valley Dam.

Figure 3-19b Water quality (Alkalinity, pH, Fe and Mn) in wells along toe of Cross Valley Dam.

Figure 3-20a Water quality depth profiles of SO_4, Mg, Na and Zn in P03-09 (at Cross Valley Dam).

Figure 3-20b Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-09 (at Cross Valley Dam).

Figure 3-21a Water quality depth profiles of SO_4, Mg, Na and Zn in P05-01 (at Cross Valley Dam).

Figure 3-21b Water quality depth profiles of alkalinity, pH, Fe and Mn in P05-01 (at Cross Valley Dam).

Figure 3-22a Water quality (SO_4, Mg, Na and Zn) in wells downgradient of Cross Valley Dam.

Figure 3-22b Water quality (Alkalinity, pH, Fe and Mn) in wells downgradient of Cross Valley Dam.

Figure 4-1 Layout of Grum/Vangorda Mine Site.

Figure 4-2 Groundwater Monitoring Wells, Grum Rock Dump Area, Grum/Vangorda Mine Site.

Figure 4-3a Precipitation and water quality (SO_4, Mg, and Zn) in wells in Grum Creek drainage.

Figure 4-3b Water quality (Alkalinity, pH, Fe and Mn) in wells in Grum Creek drainage.

Figure 4-4a Precipitation and water quality (SO_4, Mg, and Zn) in wells located west of Grum Creek.

Figure 4-4b Water quality (Alkalinity, pH, Fe and Mn) located west of Grum Creek.

Figure 4-5 Groundwater Monitoring Wells, Vangorda Rock Dump Area, Grum/Vangorda Mine Site.

Figure 4-6a Precipitation and water quality (SO_4, Mg, and Zn) in wells d/s of Vangorda Rock Dump.

Figure 4-6b Water quality (Alkalinity, pH, Fe and Mn) in wells d/s of Vangorda Rock Dump.

2007 GROUNDWATER REVIEW

ANVIL RANGE MINING COMPLEX, YUKON TERRITORY

1 INTRODUCTION

1.1 Terms of Reference

At present, most groundwater monitoring wells at the Anvil Range Mine are sampled twice a year as part of a routine groundwater monitoring program carried out by Gartner Lee Limited (GLL). The various monitoring wells were installed by various consultants over several decades with different objectives. In 2004, the author carried out an initial review of the groundwater quality monitoring data near the Faro and Grum/Vangorda rock dumps to assist in designing additional field programs in those areas (Robertson GeoConsultants inc., 2004). In addition, the groundwater quality monitoring data in the Rose Creek Tailings area were reviewed as part of the development of a water and load balance for the Rose Creek Tailings area (Robertson GeoConsultants inc., 2006a).

Since completion of these reviews, a series of new monitoring wells have been installed across the site (including Rose Creek valley, Faro and Grum rock dumps) and several "leaky" wells in the Rose Creek tailings area were decommissioned. During the 2007/2008 study planning meetings the need for an updated review of the groundwater quality monitoring program was identified ("Task #35 – Review Groundwater Quality Monitoring Program").

In July 2007, Robertson GeoConsultants Inc. was commissioned to carry out this comprehensive review of the recent groundwater monitoring data collected across the Anvil Range Mining Complex (ARMC) between 2005 and mid-2007. This report summarizes the findings of this review and is a deliverable under Task #35 of the 2007/08 study program for the Anvil Range Mining Complex.

This report has been prepared as part of the ongoing technical evaluation for the closure planning of the Faro Mine. Aspects of this report may have been superceded by subsequent technical studies.

1.2 Study Objectives

The main objectives of this groundwater review are as follows:

- Identify significant trends in groundwater quality, if any, and assess their importance for current closure planning;
- Re-evaluate earlier conclusions on groundwater impacts from WRD seepage (Faro Grum, Vangorda) and tailings seepage (Rose Creek Valley) based on the most recent monitoring data;

- Assess the effect of decommissioning of several “leaky wells” in the Rose Creek Valley on groundwater quality in the Rose Creek aquifer;

- Review the current scope of groundwater monitoring at the Anvil Range Mine Site and provide recommendations for future monitoring (number and frequency of sampling, suite of analytes, etc).

The results of this review will also assist in the finalization of any field programs to be carried out during the 2008/09 season.

1.3 Scope of Work

A scope of work for this study was presented in a memorandum from Robertson GeoConsultants Inc. (RGC) to Deloitte & Touche Inc., dated April 30, 2007.

The scope of work for Task #35 consists of four main tasks:

- Task 1. Data Visualization (Time trends & depth profiles)
- Task 2. Data Review & Interpretation
- Task 3. Review of Monitoring Program; and
- Task 4. Reporting

This review covers the following geographic areas of the Anvil Range Mining Complex:

- Faro Mine Site (Faro WRDs & ETA);
- Rose Creek Valley (tailings facility); and
- Grum & Vangorda Mine Site (Grum & Vangorda WRDs);

For ease of reference, these three geographic areas are discussed separately in this report.

This groundwater review covers groundwater quality data collected up to the end of July 2007. The groundwater monitoring data for this review were downloaded from the ACCESS database maintained on the GLL ftp site (status August 16, 2007)

1.4 Organization of Report

Sections 2, 3 and 4 comprise a review of the groundwater quality time trends, including implications for closure planning, for the Faro mine site, Rose Creek tailings facility and Grum/Vangorda mine site, respectively. Section 5 provides recommendations for future groundwater monitoring at the Anvil Range Mining Complex. Section 6 summarizes the main conclusions and recommendations.

2 FARO MINE SITE

2.1 Geographic Overview

Figure 2-1 shows the general layout of the Faro mine site, including the mine waste units and all available groundwater monitoring wells in the area. The Faro mine site comprises the Faro Pit, the surrounding Faro waste rock dumps (WRDs), the mill area and the Emergency Tailings Area (ETA). Those monitoring wells routinely sampled as part of the ARMC groundwater quality monitoring program are shown in red. Monitoring wells no longer monitored are shown in yellow and abandoned wells are shown in white.

Groundwater monitoring is generally concentrated in specific geographic areas where an impact from mine waste seepage has been observed historically (at surface). Those geographic "priority areas" include:

- Emergency Tailings Area (ETA);
- S-cluster area; and
- Zone 2 Outwash area.

In addition, several monitoring wells are located along the toe of the WRDs draining towards the North Fork of Rose Creek (NFRC) and the main Rose Creek valley to provide additional spatial coverage of groundwater monitoring. In the following we review the recent time trends in groundwater water quality in these geographic areas.

2.2 Emergency Tailings Area (ETA)

2.2.1 Background

Figure 2-2 shows the general layout of the ETA area and all groundwater monitoring wells located in this area. Again, those monitoring wells routinely sampled as part of the ARMC groundwater quality monitoring program are shown in red. All other monitoring wells are shown in yellow (not monitored routinely) or white (abandoned).

Table 2-1 lists pertinent information of all groundwater monitoring wells located in the ETA area, including year of construction, installation details (total depth, screening interval) and status of monitoring. Historically, only one nested monitoring well (P96-8A/B) was available for groundwater monitoring. In 2004, two additional monitoring wells and one pumping well (SRK-04-04) were installed to carry out a pumping test (SRK Consulting, 2006a). In 2005, several shallow wells were installed to characterize the tailings ("ETA wells") and two additional monitoring wells were installed in overburden and underlying bedrock (SRK Consulting, 2006b).

Table 2-1
Monitoring wells in the Emergency Tailings Area (ETA), Faro Mine Site.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
ETA Area							
P96-8A	1996	4.2	1.15	4.17	1109.39	bi-annual	Alluvium
P96-8B	1996	8.6	5.50	8.52	1109.48	bi-annual	Alluvium
SRK04-3A	2004	11.9	10.40	11.90	1104.55	bi-annual	Tailings/All
SRK04-3B	2004	7.1	5.50	7.00	1104.63	bi-annual	All/BR
SRK04-4	2004	11.6	7.64	11.6	1104.80	not routinely monitored	Alluvium
SRK05-ETA-BR1	2005	12.4	9	12	1105.21	bi-annual	Alluvium
SRK05-ETA-BR2	2005	18.4	14.6	18.9	1103.75	bi-annual	BR (Schist)
ETA-05-1	2005	7.3	4.3	7.3	1105.13	not routinely monitored	Tailings
ETA-05-2	2005	7.5	5	7.5	1105.06	not routinely monitored	Till
ETA-05-3	2005	8.8	7	8.8	1103.98	not routinely monitored	All/Till
ETA-05-4	2005	9.0	6.7	9	1105.37	not routinely monitored	All/Till
ETA-05-5	2005	5.2	2	5.2	1105.44	not routinely monitored	Tailings

The most recent review of groundwater quality time trends in the ETA area was completed in 2004, i.e. prior to installation of the recent monitoring wells (Robertson GeoConsultants Inc., 2004). The 2005 installation report also provided initial water quality results from the new monitoring wells (up to November 2005) (SRK Consulting, 2006b).

In addition, detailed seep surveys were carried out in the ETA area between October 2005 and September 2006 to estimate the contaminant load (surface and subsurface flow) reporting from this area. The results of these seep surveys are summarized in Robertson GeoConsultants Inc. (2007).

2.2.2 Review of Time Trends

Figure 2-3a/b shows selected water quality time trends for monitoring well P96-8A/B, located at the toe of the Main Dump. The water quality of the seepage (X23) discharging from the toe of the Faro Main Dump is also shown for comparison.

The water quality in surface and subsurface seepage at the toe of the Faro Main Dump has significantly deteriorated since 1996. The toe seepage (at X23) has seen a gradual increase in SO4, Mg, and various metals (Zn, Fe, Mn). The most dramatic increases occurred in the summer of 2000, in particular for the metals zinc, iron and manganese. Flushing of accumulated oxidation products in response to the high summer precipitation of 2000 is believed to be the main cause for this rapid increase in contaminants at X23.

Since 2000, contaminant concentrations have generally remained highly elevated in X23, with all contaminants (SO4, Mg, Zn, Fe and Mn) near historic highs. The observed year-to-year variations are likely caused by annual variations in precipitation pattern, influencing recharge and seepage through the waste rock dumps.

Note that the field pH of the WRD seepage at X23 has remained in the range of 6.0 to 7.0, suggesting some remaining buffering capacity along the flow path. At the same time, alkalinity showed a steep decline in X23 in 1999 indicating that the buffering capacity may become depleted. Unfortunately, no alkalinity measurements were available for X23 in the database after 1999.

Nevertheless, recent sampling of X23 carried out between October 2005 and September 2006 as part of the ETA Interim Collection Study showed alkalinity concentrations ranging from 25-214 mg/L CaCO3 eq (Robertson GeoConsultants Inc., 2007). For comparison, the acidity in X23 seepage during the same time period ranged from 479 to 774 mg/L CaCO3 eq. These recent measurements suggest that the buffering capacity in seepage from the Faro Main Dump is gradually being depleted.

Groundwater quality time trends in the two nested piezometers P96-8A/B generally followed the time trends observed at X23, in particular for the less reactive constituents sulphate and magnesium. Note, however, that the rapid "breakthrough" of metals (Zn, Fe, and Mn) observed in X23 in the summer of 2000 was delayed by about 1.5 years in the nested piezometers, occurring instead in late 2002. This delay is believed to be due to limited attenuation (sorption and/or precipitation) of these metals in the alluvial sediments. Since about 2002, the concentrations of zinc, manganese, and iron (for P96-8B) in groundwater are virtually identical to those observed in surface seepage suggesting that any assimilative capacity of the alluvial soils has been exhausted.

The pH and alkalinity observed in the shallow groundwater is also very similar to that observed in the surface seepage flow suggesting very little, if any additional buffering in the alluvial sediments of the Faro Creek channel.

Note that the groundwater quality reported for P96-8A/B shows significantly more variability ("noise") than the surface water quality at X23. It is suspected that this variability is primarily a result of problems with sampling/ sample handling rather than an indication of natural variability.

Figure 2-4a/b shows selected water quality time trends for the four monitoring wells located in the ETA area, immediately upgradient of the mine access road. The water quality in these wells differs significantly, primarily due to differences in the screened lithologies.

SRK04-3A and SRK05-ETA-BR1 are screened in alluvial sediments of the Faro Creek channel and show very similar water quality. The groundwater in the alluvial sediments of the ETA has a slightly acidic pH (field pH 5.5 to 7.0), low alkalinity (40-110 mg/L) and elevated SO4 (5,000-6,000 mg/L) and magnesium (600-780 mg/L). The key metals of concern are also significantly elevated, with Zn ranging from 200-300 mg/L, Fe from 400 to 1,000 mg/L and Mn from 50-80 mg/L. Note that the lab-pH is significantly lower than the field pH (by 1 to 2 pH units) likely due to oxidation of Fe(II) to Fe(III) en route to the laboratory.

SRK04-3B is screened primarily in tailings. However, the wetted portion of the screen is screened in a mixture of tailings and alluvial sands (SRK Consulting, 2006a). The water quality in this shallow monitoring well is generally more impacted than the groundwater in the deeper wells screened in alluvium, in particular with higher sulphate (up to 18,000 mg/L), zinc (up to 750 mg/L) and Fe (up to 7,700 mg/L). These highly elevated contaminant levels are characteristic of tailings pore water quality.

However, water quality in this shallow well has significantly improved since start of sampling in 2005 and is gradually approaching the water quality observed in the deeper wells screened in "clean" alluvium. This gradual improvement is believed to be an artefact of well installation/completion rather than a reflection of improving pore water quality of the ETA tailings. We suspect that tailings and associated pore water from higher up in the profile were introduced into the screening interval during drilling. The observed improvement in water quality in this well could therefore be a reflection of a

gradual well development due to repeated purging of the well bore (this well is routinely pumped dry during sampling).

SRK05-ETA-BR2 is screened in slightly weathered and fractured schist bedrock at a depth of 14.6 to 18.9 m below ground, i.e. well below the alluvium-bedrock contact (at ~9.5m). The groundwater in this bedrock unit has a circum-neutral pH (field pH 6.8 to 7.4), low alkalinity (~120 mg/L) and moderate to low concentrations of SO4 (~1,300 mg/L) and magnesium (~80 mg/L). The key metals of concern are 1 to 2 orders of magnitude lower than in the overlying alluvium, with Zn and Fe concentrations ranging from 4-15 mg/L and 13-45 mg/L, respectively. Although these metal concentrations are much lower than in the highly impacted alluvial channel, they are still significantly elevated above natural background values in local bedrock and suggest direct impact by seepage from the ETA area and/or WRD seepage from further upgradient.

2.2.3 Implications for Closure Planning

The groundwater quality data collected in the ETA area are generally consistent with the results of the Faro Creek seepage surveys which had concluded that the ETA area represents a major source of contaminant loading, both by surface and subsurface pathways (Robertson GeoConsultants, 2007). These findings support the conclusion that the ETA area should be a priority for seepage interception. As a result seepage from the ETA area is now collected immediately downstream of the mine access road by a series of drains, directed into a manhole and pumped to the Intermediate Pond for later treatment at the mill (as an interim measure).

Note that this seepage interception system does not capture any impacted groundwater moving in the bedrock. At present, there is only a single monitoring well available in the ETA area to assess contaminant loading via bedrock pathways (SRK05-ETA-BR2). Assuming this bedrock well is representative, contaminant loading in the bedrock should be orders of magnitudes lower than in the alluvial sediments of the Faro Creek channel (which pinch out in the Faro Creek canyon). For example, assuming an average bedrock permeability of 1x10-7 m/s, a width of 200m, a depth of 100m, and a hydraulic gradient of 0.064, the groundwater flow in bedrock would be about 0.13 L/s (see also SRK Consulting, 2006a). Assuming a zinc concentration of 10 mg/L, the associated contaminant load of zinc in groundwater flow through bedrock would be about 0.04 t/yr. For comparison, the average zinc load from surface flow and subsurface flow combined currently captured below the mine access road has been estimated to range from 25 to 80 t/yr (Robertson GeoConsultants, 2007).

In the author's opinion, the current collection system (without interception of bedrock seepage) is adequate as an interim measure. However, for final closure planning additional characterization work in the local bedrock of the ETA area will be required (including drilling of additional monitoring wells and hydraulic testing in bedrock) to better quantify the potential contaminant load in bedrock. In the interim, the performance of the current seepage interception system should be reviewed, including a survey of bedrock seepage entering the Faro Creek canyon downstream of the seepage interception system.

The groundwater and surface water quality monitoring data also indicate that the tailings stored in the ETA area represent a separate source of contaminant loading, in particular for iron. Recharge and/or seepage through these historic tailings produces highly elevated iron concentrations in the ETA seepage (primarily as Fe(II)). These high Fe(II) concentrations cause problems for seepage collection

(formation of Fe precipitates) and water treatment (representing a significant source of acidity). Hence, consideration should be given to relocating these historic tailings from the ETA area (even as an interim reclamation measure).

2.2.4 Recommended Modifications to the Water Quality Monitoring Program

The following recommendations are provided for modifications to the groundwater quality monitoring program in the ETA area:

- Monitoring well P96-8A has repeatedly shown erratic water quality results (e.g. very low TDS, sulphate, metals etc) suggesting ingress of very dilute surface runoff and/or problems with sampling; this well should therefore no longer be sampled as part of the routine groundwater quality monitoring program (note that P96-8A is also redundant because the deeper monitoring well P96-8B (at the same location) is screened in the same material (alluvium) and shows very similar water quality time trends);
- Monitoring well SRK04-3B is screened in a mixture of tailings and alluvium and has very limited water for sampling (screened across the water table); results from this well are ambiguous and this well should therefore no longer be sampled as part of the routine groundwater quality monitoring program;
- Samples from station “X23” should be analysed for “alkalinity” (at least at quarterly intervals); alkalinity provides a measure of the buffering capacity of the system and a decline of alkalinity in waste rock seepage (as recently observed in X23) often precedes a decline in pH and increase in metal concentrations.

In addition, the following monitoring data are missing in the current version of the Faro water quality data base and should be added;

- The results of the Faro Creek seepage surveys conducted between October 2005 and September 2006 (Robertson GeoConsultants, 2007a/b);
- The results of the initial round of groundwater quality sampling of the ETA wells completed in May and November 2005 and reported in SRK Consulting (2006a);

2.3 S-Cluster Area

2.3.1 Background

Figure 2-5 shows the general layout of the “S cluster area” and all groundwater monitoring wells located in the area. Again, those monitoring wells routinely sampled as part of the ARMC groundwater quality monitoring program are shown in red. All other monitoring wells are shown in yellow (not monitored routinely) or white (abandoned). Drive points are shown in green.

Table 2-2 lists pertinent information of all groundwater monitoring wells located in the S-cluster area, including year of construction, installation details (total depth, screening interval) and status of monitoring. Historically, groundwater monitoring in this area commenced in 1989 with the installation

of three nested standpipe piezometers ("S" wells)[1]. An additional monitoring well (P96-7) was installed in 1996 further northwest of the S-cluster area (Robertson GeoConsultants Inc, 1996b). In 2005, a fence of 6 nested piezometers ("SRK05-SP" series) and several drive points ("DPs") were installed in the S cluster area to better define the spatial extent of the contaminant plume along this reach (SRK Consulting, 2006c).

Table 2-2
Monitoring wells in the S-cluster Area, Faro Mine Site.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
S-cluster Area							
S1A	1989	12.0	9.2	12.2	1085.43	bi-annual	BR (phyllite)
S1B	1989	3.8	1.3	4.3	1085.27	bi-annual	Till
S2A	1989	11.2	9.2	12.2	1086.03	bi-annual	BR (phyllite)
S2B	1989	7.0	3.7	6.7	1086.30	bi-annual	Till
S3	1989	4.8	2.6	5.6	1085.53	bi-annual	Till
P96-7	1996	9.2	6.26	9.24	~1127	bi-annual	Overburden/BR
SRK05-SP-1A	2005	19.2	13.7	19.2	1091.99	bi-annual	Overburden/BR
SRK05-SP-1B	2005	12.3	9	12.3	1091.94	bi-annual	Overburden
SRK05-SP-2	2005	11.0	7.9	11	1086.70	bi-annual	Alluvium/BR
SRK05-SP-3A	2005	22.9	17.4	21.9	1088.50	bi-annual	Overburden
SRK05-SP-3B	2005	12.3	8.3	11.4	1088.41	bi-annual	Overburden
SRK05-SP-4A	2005	21.6	16.5	21	1087.27	bi-annual	Overburden/BR
SRK05-SP-4B	2005	4.0	0.6	3.5	1087.44	bi-annual	Overburden
SRK05-SP-5	2005	14.0	9.4	12.5	1087.53	bi-annual	Overburden/BR
SRK05-SP-6	2005	11.0	3.1	11	1097.73	bi-annual	BR(Schist)
DP1	2005	n/a	1.14	1.14	1083.97	not routinely monitored	NFRC sediments
DP2	2005	n/a	0.53	0.53	1082.55	not routinely monitored	NFRC sediments
DP3	2005	n/a	0.75	0.75	1081.89	not routinely monitored	NFRC sediments
DP4	2005	n/a	0.94	0.94	1082.19	not routinely monitored	NFRC sediments
SRK04-2B	2004					abandoned	Alluvium
SRK04-2A	2004					abandoned	Alluvium

A brief review of historical groundwater quality time trends in the S-cluster area was completed in 2004 (Robertson GeoConsultants Inc., 2004). An updated review of groundwater quality in the S cluster area, including initial water quality results (September 2005) from the newly installed monitoring wells in the area, was provided in the S-cluster installation and assessment report (SRK Consulting, 2006c).

2.3.2 Review of Time Trends

Figures 2-6a/b and 2-7a/b show selected water quality time trends for the historical "S" wells, monitoring well P96-7 and the recently installed "SRK05-SP" wells, respectively. As discussed in earlier reviews, groundwater quality in this area shows significant spatial variation, both in space and with depth, indicating very heterogeneous subsurface conditions. Furthermore, groundwater quality in this area has deteriorated dramatically over the last five years.

The groundwater quality in the S-cluster area can be grouped into three broad categories:

[1] The Faro water quality database only includes groundwater quality results obtained since 1996. A review of older groundwater quality results can be found in the ICAP (Robertson GeoConsultants Inc., 1996)

- Highly impacted groundwater (S1A, S1B, S2A, S3, SRK05-SP4B and -SP5);
- Moderately impacted groundwater (SRK05-SP1A, -SP3A, SP3B and -SP4A);
- Slightly impacted groundwater (S1B, SRK05-SP1B and SRK05-SP2).

The highly impacted groundwater has a slightly acidic pH (field pH 5.5 to 6.5), moderate alkalinity (~200 mg/L) and elevated SO4 (~5,000 mg/L) and magnesium (~800 mg/L). The key metals of concern are also significantly elevated, with Zn currently around 200-300 mg/L and Mn ranging from 75-100 mg/L. Fe concentrations in this highly impacted groundwater were generally low (<1 mg/L) except in monitoring well S2B (~100 mg/L).

Note that contaminant concentrations in this highly impacted groundwater are still increasing year over year, suggesting that the system has not yet reached equilibrium. **Of particular concern is the rapid increase in dissolved zinc concentrations which have increased by as much as 100 mg/L in the last 20 months (Sep 2005 to June 2007) in selected wells (e.g. S1A, S2B, S3).**

It should be noted that the nature and timing of contaminant "breakthrough" in the S-cluster wells is remarkably similar to that observed at the toe of the Faro Main Dump (see X23 and P96-8A/B; Figure 2-3a/b). In both areas, the breakthrough of sulphate and magnesium preceded the breakthrough of zinc and other metals by several years. Furthermore, the breakthrough of SO4 and Mg occurred very gradual, i.e. over tens of years, whereas the breakthrough of zinc and other metals (e.g. Fe and Mn) occurred over a few years. The similarity in seepage water quality suggests that similar geochemical controls are present in both areas. Based on this comparison, zinc concentrations in impacted groundwater in the S-cluster area can be expected to reach maximum concentrations as high as 1,000 mg/L (or more) within a few years.

The moderately impacted groundwater also has a slightly acidic pH (field pH 5.5 to 6.5) and moderate alkalinity (~200-300 mg/L), but much lower SO4 (~300-500 mg/L) and magnesium (~50-60 mg/L) concentrations than the highly impacted groundwater. The key metals of concern are also significantly lower, with Zn and Mn concentrations around 1-2 mg/L. Note however, that Fe concentrations are typically higher (10-50 mg/L) than most of the highly impacted groundwater.

Most of the moderately impacted groundwater is observed in deeper monitoring wells (SRK05-SP1A, -SP3A and -SP4A) suggesting that this groundwater is a mixture of (highly impacted) seepage from the Intermediate Dump (and associated sulphide cells) and relatively unimpacted groundwater moving in the Rose Creek valley sediments. This hypothesis is supported by hydraulic testing which indicated relatively high transmissivities (in the order of 1..7x10-4 m2/s) in all wells with moderately impacted groundwater quality.

The defining characteristic of the "slightly impacted" groundwater are the very low metal concentrations, including zinc and iron concentrations of <0.5 mg/L. However, there are significant differences in major ion chemistry in this category, suggesting significant differences in the contributions from mine waste seepage. Groundwater quality in monitoring well SRK-05-SP2 is generally very dilute (with SO4 and Mg around 40 and 15 mg/L, respectively), suggesting very little, if any, impact from mine waste seepage.

In contrast, monitoring wells S1B and SRK05-SP1B show moderately elevated SO4 and Mg concentrations, similar to those observed in the "moderately impacted" wells in the S-cluster area.

The lower metal concentrations in those wells are therefore likely a result of greater attenuation (e.g. sorption) and may still increase in time.

Monitoring well P96-7, located further to the northwest of the S-cluster drainage area (Figure 2-5) shows a distinctly different water quality signature. Groundwater in this well shows significantly higher sulphate and magnesium concentrations (~1,500-2,000 mg/L SO4 and 100-130 mg/L Mg, respectively) than even the moderately impacted wells in the S-cluster area, but very low zinc and other metal concentrations. The currently observed groundwater quality in P96-7 is similar to the water quality observed in the "highly impacted" wells of the S-cluster area about 12 years ago (1996).

Note that both sulphate and magnesium concentrations have gradually increased over the last 12 years of monitoring suggesting that this area has not reached steady-state conditions with respect to groundwater quality. Further monitoring will be required to determine whether groundwater quality in vicinity of P96-7 will gradually approach that observed at the S-cluster area (and the Faro Creek channel) or whether the source of mine waste seepage differs significantly in that portion of the mine site (e.g. lower zinc concentrations).

A water quality sample taken on June 5, 2006 from the shallow sediments beneath the NFRC at drive point DP4 showed sulphate concentrations of 5,390 mg/L, i.e. characteristic of "highly impacted" groundwater. This measurement confirms that the highly impacted groundwater extends to beneath the NFRC and can discharge to the NFRC along this reach, as has been inferred from zinc loading to NFRC (SRK Consulting, 2006c). However, subsequent sampling of DP4 in September 20, 2006 and May 29, 2007 showed very low sulphate (<13 mg/L) and zinc concentrations (<0.5 mg/L) suggesting that the NFRC was recharging the groundwater system at those times. These results indicate a highly transient interaction between the NFRC and the underlying aquifer system.

2.3.3 Implications for Closure Planning

The detailed site investigation completed in 2005 in the S cluster area had confirmed the presence of highly impacted groundwater in this area (SRK Consulting 2006c). Based on the drilling and initial (Sep 2005) water quality results, SRK provided preliminary recommendations for a seepage interception system in this S-cluster area to protect the North Fork of Rose Creek.

The recent monitoring results (2006-07) are generally consistent with the initial interpretation of the spatial extent of the "shallow" and "deep" contaminant plumes in the S-cluster area (SRK Consulting 2006c). However, the recent sampling results have shown a continued deterioration of groundwater quality (in particular for zinc) in the S-cluster area further emphasizing the need for seepage interception. Note that the affected monitoring wells (e.g. S1A, S2B, S3) are all in close proximity of the North Fork of Rose Creek (Figure 2-5) and, hence there is a potential for significant increase in zinc concentrations in NFRC along this reach of NFRC[2]. We therefore recommend that the impact of contaminated groundwater discharge into NFRC be re-assessed and that an action plan be developed on how to manage potential future increases in zinc concentrations in local groundwater in this area. For example, zinc concentration thresholds (in groundwater and/or surface water) may be established which "trigger" additional investigations and/or certain remedial actions such as seepage interception.

[2] A review of surface water quality was beyond the scope of this work.

Furthermore, consideration should be given to implementing interim measures to collect and treat the "highly impacted" groundwater observed in the S-cluster, including pumping of impacted groundwater in the deeper strata (sediments and weathered bedrock) of SRK05-SP5 and S2 and collection of shallow seepage in a sump in vicinity of SRK05-SP4B.

2.3.4 Recommended Modifications to the Water Quality Monitoring Program

In the author's opinion, all existing monitoring wells in the S-cluster area should be retained in the routine (semi-annual) water quality monitoring program. This monitoring effort is justified considering the highly elevated metal concentrations and the proximity to the North Fork of Rose Creek.

It should be noted that SRK Consulting had recommended a more detailed groundwater/surface water monitoring program for this area, consisting of monthly water level measurements in all monitoring wells and drive points ("DP") and quarterly water quality sampling in all wells, drive points and selected surface water stations along this reach of the NFRC (SRK Consulting, 2006c). This monitoring program was recommended to (i) better understand the interaction of the impacted groundwater with the NFRC and (ii) develop a baseline for future performance monitoring of a seepage interception system (as a part of an adaptive management plan). To the best of our knowledge, this detailed monitoring plan has not been implemented.

Considering the recent deterioration of groundwater quality in this area, the author supports the detailed monitoring proposed by SRK Consulting (2006c). However, this monitoring should not be included in the routine water quality monitoring program but instead only be carried out for a period of one year as part of a separate study aimed at assessing the impact of discharge of impacted groundwater from the S cluster area on water quality and zinc load in the NFRC.

Consideration should also be given to installing additional monitoring wells further downgradient of the S-cluster area to get a better understanding of the extent of groundwater contamination in the Rose Creek valley sediments.

In addition, the following monitoring data are missing in the current version of the Faro water quality data base and should be added:

- The results of the initial round of groundwater quality sampling in the new S-cluster wells ("SRK05-SP" series) completed in September 2005 (SRK Consulting, 2006c);

Finally, several samples of the S-cluster wells analysed in 2006 and 2007 show erroneous sulphate concentrations (too low by a factor of 10) as evidenced by a high deficit in the charge balance and inconsistent time trends (see section 5.2). These errors were corrected in our time trend plots but should also be corrected in the Faro water quality database.

2.4 Zone 2 Outwash Area

2.4.1 Background

Figure 2-8 shows the general layout of the Faro waste rock dumps draining towards the North Fork of Rose Creek (upgradient of the rock drain) and all available monitoring wells in the area. Again, those monitoring wells routinely sampled as part of the ARMC groundwater quality monitoring program are shown in red. All other monitoring wells are shown in yellow (not routinely monitored) or white (abandoned). Drive points are shown in green.

The majority of groundwater monitoring wells is located in the Zone 2 outwash area. Additional monitoring wells are located along the toe of the Northeast Dumps and the Intermediate Dump (discussed in section 2.5 below). Figure 2-9 shows a blow-up of the "Zone 2 Outwash Area" and all groundwater monitoring wells located in this area.

Table 2-3 lists pertinent information of all groundwater monitoring wells located in the Zone 2 Outwash area, including year of construction, installation details (total depth, screening interval) and status of monitoring. Historically, groundwater monitoring in this area commenced in 1991 with the installation of four shallow standpipe piezometers ("BH1" to "BH-4") in the outwash area. In 1994, several additional nested piezometers were installed ("BH5" to "BH-10") in the outwash area and in closer proximity of the Zone 2 pit (Steffen, Robertson & Kirsten, 1994). An additional monitoring well (P05-04) and two drive points (DP5 and DP6) were installed in 2005, as part of the recent seepage investigation in this area (SRK Consulting, 2007a).

Table 2-3
Monitoring wells in the Zone 2 Outwash Area, Faro Mine Site.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Zone 2 Outwash Area							
BH1	1992	5.2				bi-annual	n/a
BH2	1992	4.8			1099.70	bi-annual	n/a
BH4	1992	2.5			1097.02	bi-annual	n/a
BH5	1994	7.6	6.01	7.62	1095.57	not routinely monitored	Alluvium
BH6	1994	6.3	4.72	6.25	1097.84	not routinely monitored	Alluvium
BH7D (A)	1994	8.8	6.71	8.84	1100.70	not routinely monitored	Overburden (?)
BH7S (B)	1994	6.4	4.27	6.4	1101.16	not routinely monitored	BR (phyllite?)
BH8	1994	20.6	19.05	20.57	1123.37	not routinely monitored	BR (phyllite?)
BH9	1994	54.9	53.34	54.86	1141.30	abandoned	BR (Biotite-schist)
BH10A	1994	36.6	35.05	36.58	1101.73	not routinely monitored	BR (Biotite-schist)
BH10B	1994	54.9	53.34	54.84	1101.72	not routinely monitored	BR (phyllite/schist)
BH05-01	2005	3.8	2.3	3.81	1095.57	abandoned	Outwash Sed
P05-04	2005	6.3	2.19	6.34	1097.70	bi-annual	Alluvium
RGC-PW3	2005	7.4	5.5	7	1097.92	not routinely monitored	Alluvium
DP5	2005	n/a	n/a	n/a	1095.73	not routinely monitored	NFRC sediments
DP6	2005	n/a	n/a	n/a	1094.71	not routinely monitored	NFRC sediments
Zone 2 Pumping Well (X26)	n/a						waste rock (?)

A brief review of historical groundwater quality time trends in the Zone 2 outwash area was completed in 2004 (Robertson GeoConsultants Inc., 2004). An updated review of groundwater quality, including initial water quality results (September 2005) from a pumping test in the area, was provided in the Zone 2 seepage assessment report (SRK Consulting, 2007a).

2.4.2 Review of Time Trends

Figure 2-10a/b shows selected water quality time trends for the monitoring wells located in the Zone 2 outwash area. Note that several monitoring wells in this area are currently either damaged (BH9) and/or no longer monitored routinely (BH5, BH7S/D, BH8 and BH10S/D).

The Zone 2 outwash area is located immediately downgradient of the Zone 2 pit which is backfilled with waste rock. The water accumulating in the backfilled Zone 2 Pit ("X26") is slightly acidic (pH ~6),

has elevated sulphate (2,000-3,000 mg/L) and magnesium (~300 mg/L) as well as elevated metal concentrations (Zn ~100 mg/l, Fe ~100 mg/L). Historically, “spills” from the Zone 2 pit occurred and impacted groundwater quality in the outwash area (Robertson GeoConsultants Inc., 1996). Since 1991, the water level in the Zone 2 pit is controlled by seasonal pumping to prevent spills of contaminated water and to minimize seepage through the bedrock rim.

Historically, contaminant concentrations in the shallow sediments in the Zone 2 outwash area (BH1, BH2, BH4) had shown significant variations, both in space and time, with the poorest water quality observed in monitoring well BH4. Note that historic concentrations of sulphate, zinc and other contaminants observed in BH4 (in 1991) were very similar to those observed in the Zone 2 pit suggesting that historic spills from the Zone 2 pit were the most likely source of this contamination. Since start of pumping in the Zone 2 pit, the water quality in BH4 has continuously improved further supporting this hypothesis. At present, groundwater quality in BH4 is very similar to the water quality observed in the other monitoring wells in the area.

The groundwater quality in the sediments of the Zone 2 outwash area currently has a slightly acidic pH (~6.0), with moderate alkalinity (100-160 mg/L) and only slightly elevated sulphate and magnesium (50-100 mg/L SO4 and ~20 mg/L Mg, respectively). Metal concentrations are also very low, with iron and manganese concentrations typically less than 1 mg/L and 0.1 mg/L, respectively. Despite the significant improvement in overall water quality, zinc concentrations have remained elevated, typically ranging from 1-10 mg/L.

Note that the shallow wells (BH1, 2 and 4), at least partially screened in the outwash sediments, show a very similar general water quality (or “finger print”) to that observed in the deeper wells screened in the alluvial sediments (BH5, BH6, P05-04). The groundwater quality in this area differs from other seepage areas (e.g. ETA and S-cluster) in that elevated zinc concentrations are observed in groundwater with relatively low concentrations of sulphate, magnesium, iron and manganese.

The most likely source for the elevated zinc concentrations presently observed in the groundwater of the Zone 2 outwash area is seepage from the Zone 2 pit and associated WRDs. If the primary source is indeed seepage from the Zone 2 pit, such seepage would be diluted greatly by unimpacted groundwater moving in the NFRC sediments. Assuming conservative mixing for sulphate, magnesium and zinc the rate of dilution would be in the order of 10-30 times. Assuming groundwater flow rates in the NFRC valley in the order of 1.7 to 4.5 L/s (SRK Consulting 2007a), actual seepage rates from the Zone 2 pit would range from 0.45 L/s to less than 0.1 L/s. These seepage rates are generally consistent with earlier estimates of seepage rates from the Zone 2 pit (SRK Consulting 2007a),

In recent years, the highest zinc concentrations have been recorded consistently in BH2 which is located closer to the toe of the WRDs and is screened in the top 5m of the sediments. Zinc concentrations in this shallow well have shown significant variations, ranging from 10-45 mg/L over the last five years. The higher zinc concentrations in this well (compared to other shallow wells BH1 and BH4) could be a result of less dilution (due to the proximity of BH2 to the Zone 2 pit and associated WRDs). Note, however, that this well goes routinely dry during purging, i.e. is not representative of groundwater moving in the more permeable alluvial sediments of the NFRC valley. Oxidation and/or leaching of zinc from the overlying mineralized outwash sediments in this area may be a secondary source of zinc contamination at BH2 and possibly elsewhere in this area. Additional monitoring of groundwater quality immediately upstream of the mineralized outwash sediments (e.g.

in BH10A/B, BH7A/B and/or additional monitoring bores) would be required to better assess the relative contributions of the mineralized outwash sediments versus Zone 2 seepage to zinc loading of the groundwater in the NFRC valley.

Initial water level measurements obtained in the drive points DP5 and DP6 shortly after installation in 2005 had indicated a downward gradient from the North Fork Rose Creek to the groundwater in the alluvial sediments along the Zone 2 reach (SRK Consulting 2007a). A single water quality sample taken on Sept 18, 2006 at DP5 (screened in the shallow sediments of NFRC) showed SO4=81 mg/L and Zn = 0.23 mg/L, suggesting a mixture of groundwater and NFRC water. This finding is consistent with the observed downward hydraulic gradients indicating leakage of dilute surface water from NFRC into the underlying (impacted) groundwater.

2.4.3 Implications for Closure Planning

Additional seepage investigations completed in 2005 in the Zone 2 Outwash Area had indicated the presence of moderately impacted groundwater (primarily elevated zinc concentrations) in the permeable alluvial sediments of the NFRC valley (SRK Consulting 2007a). Preliminary estimates of zinc loads in the NFRC aquifer ranged from 0.13 to 0.35 t/yr. Preliminary recommendations for a seepage interception system in the Zone 2 outwash sediments were provided to protect the North Fork of Rose Creek (SRK Consulting 2007a).

The recent monitoring results (2006-07) are generally consistent with the initial interpretation of the spatial extent of the zinc “plume” in the Zone 2 outwash sediments. Sampling of the deeper monitoring wells BH6 and P05-01, screened in the more permeable alluvial sediments, showed zinc concentrations similar to those observed in the pumping well PW3 (used for loading estimates). Sampling of these deeper wells confirmed the widespread presence of elevated zinc concentrations in the NFRC alluvial aquifer, extending well beneath the shallow mineralized sediments of the Zone outwash area.

The recent groundwater quality results have shown no significant deterioration in groundwater quality. In fact, groundwater quality in the shallow well with the poorest water quality (BH2) actually improved slightly in the last two years. This implies that earlier estimate of zinc loading and the resulting requirement for seepage interception in this area have not changed.

2.4.4 Recommended Modifications to the Water Quality Monitoring Program

The 2005 study had recommended to increase the scope of groundwater monitoring in this area by sampling the newly installed monitoring well P05-04 and other monitoring wells, already existing in this area but not currently sampled (BH5, BH6, BH7S/D, BH8 and BH10A/B) (SRK Consulting, 2007). In 2006/07, only two of those recommended wells were sampled routinely (P05-04 and BH6).

The author supports the earlier recommendation to re-introduce all existing monitoring wells in the Zone 2 area into the routine groundwater monitoring program. Note that several of the recommended existing monitoring wells are screened in bedrock (BH7A/B, BH8 and BH10A/B) for which currently no groundwater quality is available. Furthermore, these monitoring wells are all located upgradient of the mineralized outwash sediments, thus providing insight into the relative importance of zinc loading from the Zone 2 pit versus loading from the outwash sediments.

The 2006 groundwater monitoring report indicated that BH7A/B may be affected by frost heave and should therefore be abandoned (GLL, 2006). This report also noted that the piezometers BH10A/B were inclined, possibly due to frost action. In the author's opinion, the possibility of breakage due to frost heave in BH7S/D should be investigated with a downhole camera. If the well is damaged it should be properly decommissioned. Otherwise these piezometers should be included in the routine monitoring program.

According to the original borehole logs, monitoring wells BH10A and 10B were drilled intentionally at an angle of 60 degrees to the horizontal. Hence there is no reason to assume that the monitoring wells are damaged and this monitoring well should be reintroduced into the monitoring network.

SRK Consulting had also recommended a more detailed groundwater/surface water monitoring program for this area, consisting of quarterly water level measurements in all monitoring wells and drive points, as well as quarterly stream flows and stream water quality at selected stations along this reach of the NFRC (R8a, R9, R10 and NF1) (SRK Consulting, 2007a). This monitoring program was recommended to (i) better understand the interaction of the impacted groundwater with the NFRC and (ii) develop a baseline for future performance monitoring of a seepage interception system (as a part of an adaptive management plan). To the best of our knowledge, this detailed monitoring plan has not been implemented.

Considering the uncertainty about zinc loading via groundwater pathways to the NFRC along the Zone 2 outwash area, the author supports the detailed monitoring proposed by SRK Consulting (2007). However, this monitoring should not be included in the routine water quality monitoring program but instead only be carried out for a period of one year as part of a separate study aimed at assessing the impact of discharge of impacted groundwater from the Zone 2 outwash area on water quality and zinc load in the NFRC.

2.5 Northeast and Intermediate Dumps towards NFRC

2.5.1 Background

Figure 2-8 shows the monitoring wells located along the toe of the Northeast Dumps and the Intermediate Dump. Table 2-4 lists pertinent information of all groundwater monitoring wells located downgradient of the Northeast Dumps and the Intermediate Dump, respectively. In 1994, a series of three nested piezometers were installed along the toe of the Northeast Dumps (Steffen, Robertson & Kirsten, 1994). In 1996, a single monitoring well (P96-6) was installed at the eastern toe of the Intermediate Dump draining towards the NFRC (Robertson GeoConsultants Inc, 1996b).

A brief review of historical groundwater quality time trends in these areas was completed in 2004 (Robertson GeoConsultants Inc., 2004). An updated review of groundwater quality in the general area of the NFRC was provided in the Zone 2 seepage assessment report (SRK Consulting, 2007).

Table 2-4

Monitoring wells at the toe of Northeast Dumps and Intermediate Dump (NFRC), Faro Mine Site.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Toe of Northeast Dumps (NFRC)							
BH12A	1994	3.1	1.53	3.05	1157.39	bi-annual	BR (weath)
BH12B	1994	8.2	6.1	8.23	1157.50	bi-annual	BR (phyllite/schist)
BH13A	1994	3.8	2.29	3.81	1187.91	bi-annual	A
BH13B	1994	8.2	6.71	8.23	1188.18	bi-annual	BR (phyllite/schist)
BH14A	1994	6.3	4.72	6.25	1157.52	bi-annual	BR (weath)
BH14B	1994	9.3	7.77	9.3	1158.16	bi-annual	BR (Qtz/diorite)
Toe of Intermediate Dump (NFRC)							
P96-6	1996	20.1	18.07	20.12	~1102	bi-annual	Alluvium

2.5.2 Review of Time Trends

Figure 2-11a/b shows selected water quality time trends for the wells located along the toe of the Northeast Dumps. The three sets of nested piezometers show distinct differences in the degree of impact by waste rock dump seepage.

BH14A/B has shown the greatest impact of WRD seepage in this area. Groundwater in both nested piezometers is well buffered with circum-neutral (field pH ~7.0) and high alkalinity (~400 mg/L). However, sulphate and magnesium concentrations have increased significantly since start of monitoring in 1994, and currently are at around 1,750 mg/L SO4 and 200 mg/L Mg, respectively. Zinc concentrations have also started to increase in recent years, with peak concentrations around 0.4 to 0.5 mg/L zinc (observed in 2006). Iron and manganese concentrations have generally remained very low (<0.1 and <0.5 mg/L, respectively).

The recent increase in zinc at BH14A/B, while still at relatively low concentrations, is of concern. The observed increases in zinc concentrations were preceded by a systematic and substantial increase in sulphate, magnesium and alkalinity. Similar increases in those parameters preceded the breakthrough of zinc at the Faro Creek area (X23) and in the S-cluster area. **Geochemical characterization work has identified sulphide-rich waste rock in this portion of the Northeast Dumps (J. Chapman, pers. Comm.) and it is possible that groundwater quality will continue to deteriorate in this area with sulphate and eventually zinc concentrations reaching similar concentrations as currently observed in the Faro Creek and S-cluster areas.**

BH12A/B, located to the north of BH14A/B, shows a more moderate impact of waste rock dump seepage. Groundwater in those piezometers generally shows lower concentrations of all major constituents, including alkalinity (~200 mg/L), sulphate (500-1,000 mg/L) and magnesium (~50-150 mg/L) than observed in BH14A/B. However, zinc concentrations have been routinely above the detection limit confirming the presence of waste rock dump seepage. Iron and manganese concentrations have generally remained at or below the detection limit.

Groundwater quality time trends have generally been more erratic at this location, in particular in BH12B, showing no consistent increase over time. Sulphate and magnesium concentrations have actually decreased over the last three years suggesting reduced loading from waste rock seepage. Note, however, that BH12B has shown significant spikes in zinc, most recently in 2006 (~0.7mg/L zinc). This particular sample also showed elevated magnesium concentrations but lower sulphate concentrations. Hence, there is uncertainty about the veracity of this recent spike in zinc at BH12B.

BH13A/B has shown the least impact of waste rock dump seepage in this area to date. Groundwater in both nested piezometers is slightly alkaline (field pH ~7.0-8.0) and all major ions, including alkalinity (~100-200 mg/L), sulphate (250-500 mg/L) and magnesium (~50 mg/L), are significantly lower than observed in BH14A/B. Zinc concentrations have remained very low (<0.1 mg/L) throughout the observation period. Iron and manganese concentrations have generally remained at or below the detection limit. Historical spikes in those trace metal concentrations are likely related to problems in sampling and sample handling.

The relatively low impact observed at BH13A/B is likely a combination of (i) less reactive waste rock resulting in lower contaminant concentrations in seepage from the upgradient waste rock dumps and (ii) dilution by seepage from the Faro Creek diversion.

Figure 2-12a/b shows selected water quality time trends for P96-6 located along the toe of the Intermediate Dump draining towards the NFRC. Groundwater quality in this monitoring well is characteristic of “moderately impacted” groundwater, similar to that observed in selected wells in the S-cluster area (e.g. SRK05-SP1A, -SP3A, SP3B and -SP4A). The groundwater in slightly acidic (field pH ~5.5 to 6.5) but has significant alkalinity (300-350 mg/L). Sulphate and magnesium concentrations are moderately elevated (~300 mg/L SO4 and ~50 mg/L Mg) and have shown no significant increase since start of monitoring in 1996 (the “spike’ observed in Nov 2005 is likely due to problems with sampling, sample handling and/or lab analysis).

Zinc concentrations have also remained stable, generally fluctuating between 0.5 and 1.5 mg/L. Iron concentrations have shown significant variations over time, ranging from non-detect to as high as 10 mg/L. Manganese has also shown significant fluctuations but has been <0.2 mg/L in the last five years.

The similarity in groundwater quality in P96-6 and several of the monitoring wells in the S–cluster area is not surprising considering both areas are drained by the Intermediate Dump. As observed in most of the “moderately impacted” wells in the S-cluster area, P96-6 is screened at greater depth in very permeable alluvial sediments. Note that the 1996 installation report specifically mentioned the presence of alluvial sediments (sand and gravel) at greater depth with an estimated hydraulic conductivity of ~1x10-2 m/s (Robertson GeoConsultants Inc., 1996). Hence, the groundwater in P96-6 is likely a mixture of (highly impacted) seepage from the Intermediate Dump (and associated sulphide cells) and relatively unimpacted groundwater moving in the sediments of the North Fork of Rose Creek.

Note that the sediments encountered at depth in P96-6 are similar to those observed in the Zone 2 outwash area and it is possible that they form part of a contiguous “alluvial aquifer” along the NFRC. In other words, it is possible that impacted groundwater from the Zone 2 outwash area is influencing water quality at P96-6. A review of the geodetic water levels in this area would be required to assess

the direction of groundwater flow in this area. Unfortunately, monitoring well P96-6 has never been surveyed (for location nor top-of-casing elevation), hence such a review is presently not possible.

2.5.3 Implications for Closure Planning

An initial review of historic time trends in groundwater quality in the wells located downgradient of the Northeast Dumps and the Intermediate Dump (above the rock drain) concluded that these areas have a "low priority" for seepage interception because of the significantly lower zinc concentrations observed in those areas (Robertson GeoConsultants Inc, 2004). As a result, no additional seepage investigations and/or designs of seepage interception systems have been completed in those areas in recent years.

The recent monitoring results (2006-07) indicate that these drainage areas may require more attention in the future, in particular if a very high collection efficiency is required for post-closure. First, monitoring well BH14A/B has shown first signs of an increase in zinc concentrations, which, in combination with recent increases at other locations such as the S-cluster area, raises the possibility that the Northeast Dumps (or at least portions thereof) may also become a significant contributor of zinc loading to the NFRC in the future.

Second, additional investigations and monitoring in the NFRC alluvial sediments suggest that the elevated zinc concentrations observed at P96-6 may be indicative of a greater zinc load either originating directly from the Intermediate Dump and/or seepage from the Zone 2 area which is migrating downgradient in the alluvial sediments.

In the author's opinion, additional work will be required before the seepage interception system along the entire reach of the NFRC can be finalized. Recommendations for further work in the Zone 2 area have already been provided in the Zone 2 investigation report (SRK Consulting, 2007a). This recommended work should be expanded to include the Northeast and Intermediate Dump areas. Additional work should include drilling and installation of additional monitoring wells in the NFRC valley upgradient and downgradient of the Zone 2 area to determine the spatial extent and hydraulic characteristics of the alluvial sediments (and underlying bedrock) and the associated zinc load. Based on these results, a conceptual model of groundwater flow and contaminant loading should be developed for the NFRC valley (upstream of the rock drain).

2.5.4 Recommended Modifications to the Water Quality Monitoring Program

In the author's opinion, all existing monitoring wells at the toe of the Northeast and Intermediate Dumps (draining towards the NFRC) should be retained in the routine water quality monitoring program. This monitoring effort is justified considering the elevated zinc concentrations and the proximity to the North Fork of Rose Creek.

As outlined earlier, monitoring well P96-6 should be surveyed for location and the top of casing elevation to allow a calculation of geodetic water levels and an assessment of the direction of groundwater flow. Furthermore, a review of construction details indicated a discrepancy between the borehole log and the "measured" depth of P96-6 (as reported by GLL). The borehole log indicates a total depth of 20.1 m bgs and a screening level of 18.1 to 20.1 m bgs. Yet, the GLL database reports a "measured depth" of only 17.26m bgs. This would suggest that the well has filled with sediments and/or is broken. The condition of P96-6 should be checked with a downhole camera. If the screen is "silted up" with sediments the well should be purged clean.

Finally, several historic and recent (2005 and 2006) samples of the wells near the Northeast Dumps show erroneous sulphate concentrations (too low by a factor of 10) as evidenced by a high deficit in the charge balance and inconsistent time trends .These errors were corrected in our time trend plots but should also be corrected in the Faro water quality database.

3 ROSE CREEK VALLEY (TAILINGS FACILITY)

3.1 Geographic Overview

Figure 3-1 shows the general layout of the Rose Creek tailings facility and all available groundwater monitoring wells in the area. The Rose Creek tailings facility comprises the Original Impoundment, Second Impoundment, Intermediate Impoundment (w/ Intermediate Dam), and the Polishing Pond (w/ Cross Valley Dam). Conventional wells are shown in red and multilevel wells are shown in blue. Those monitoring wells not routinely monitored are shown in yellow and decommissioned wells are indicated by a "cross".

The groundwater monitoring network in the Rose Creek tailings facility is extensive and covers all impoundments. The primary installation campaigns included:

- "X" series of wells installed in 1981 (Klohn Crippen, 1981);
- "X" series of wells installed in 1996 (Robertson GeoConsultants Inc., 1996);
- "P01" series of wells installed in 2001 (Gartner Lee Limited, 2001);
- "P03" series of wells installed in 2003 (Gartner Lee Limited, 2003); and
- "P05" series of wells installed in 2005 (Robertson GeoConsultants Inc., 2006c).

In addition, SRK Consulting completed several boreholes primarily drilled for soil sampling ("NA" series) as monitoring wells (SRK Consulting, 2006).

A comprehensive review of groundwater quality time trends for the entire Rose Creek Tailings Facility area was last carried out in 2004 as part of water and load balance study (Robertson GeoConsultants Inc., 2006a). An updated review of groundwater quality time trends, including results of initial sampling of new wells installed at the toe of Cross Valley Dam (September 2005), was provided in Robertson GeoConsultants Inc., 2006c.

For the purpose of this review, the recent time trends of groundwater quality in the Rose Creek valley are discussed separately for the following geographic areas:

- Upstream of Rose Creek Tailings Facility;
- Original Impoundment;
- Second Impoundment;
- Intermediate Impoundment;
- Toe of Intermediate Dam;
- Toe of Cross Valley Dam; and
- Downstream of Cross Valley Dam.

The region-specific discussions include a review of the time trends, an assessment of the potential effects of decommissioning of leaky wells (where applicable) and recommended modifications to the list of monitoring wells to be monitored routinely. The implications of the observed time trends for on-

going closure planning of the entire Rose Creek Tailings Facility are described in a separate section thereafter.

3.2 Upstream of Rose Creek Tailings Facility

3.2.1 Background

Groundwater quality upstream of the Rose Creek tailings facility is routinely monitored in monitoring well TH86-17, located about 450m upgradient of the Original Impoundment. TH86-17 is a test well originally drilled for a water supply project (International Water Supply, 1987). The GLL database indicates that this monitoring well has a depth of ~14m bgs. However, no drilling/installation details are currently available for this borehole; hence the exact screening interval and screened lithology are not known.

Routine groundwater monitoring in this well commenced in 2002.

3.2.2 Review of Time Trends

Figure 3-2a/b shows selected water quality time trends for TH86-17. Groundwater quality at TH86-17 is very dilute with calcium (~25 mg/L) and bicarbonate (70-80 mg/L CaCO3eq) the dominant major ions. Concentrations of all contaminants of concern are very low (~15 mg/L SO4, ~6 mg/L Mg, ~0.01 mg/L Zn, <1.0 mg/L Fe and <0.02 mg/L Mn).

Groundwater quality in TH86-17 shows no sign of impact by mine waste seepage and is believed to be representative of natural baseline conditions in the Rose Creek valley sediments. Note, however, that this well is located in close proximity of the North Fork of Rose Creek; hence groundwater quality in this well may be influenced by local recharge from the creek.

3.2.3 Recommended Modifications to the Water Quality Monitoring Program

In the author's opinion, groundwater monitoring upstream of the Rose Creek tailings facility is important not only for the purpose of establishing baseline groundwater quality, but also to assess any potential loading from other mining areas located upstream of the Rose Creek tailings facility (e.g. Zone 2, S-cluster area etc). Consideration should therefore be given to increasing the scope of groundwater quality monitoring in this area of the Rose Creek valley.

For this purpose, a review of historic drilling/installation records should be carried out to ascertain the hydrogeologic conditions in this area (including review of the drill log of TH86-17). Based on this review, suitable locations and screening intervals for additional monitoring wells in this area should be identified. If any suitable (historic) monitoring wells can be identified, those wells should be inspected in the field, and if found to be operational, routinely monitored. If no suitable, operational monitoring wells can be identified, consideration should be given to installing additional monitoring wells upgradient of the Rose Creek tailings facility.

3.2.4 Background

Table 3-1 lists pertinent information of all groundwater monitoring wells located in the Original Impoundment, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 3-1

Monitoring wells upgradient and in the Original Impoundment, Rose Creek Tailings Facility.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Original Impoundment							
TH86-17	1986	13.9	n/a	n/a	~1070	bi-annual	n/a
P01-8A	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	Tailings
P01-8B	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	Alluvium
P01-8C	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	Alluvium
P01-10A	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	Tailings
P01-10B	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	Alluvium
P03-07-01	2003	38.4	38.10	38.40	1064.98	bi-annual	Alluvium
P03-07-02	2003	33.8	33.53	33.83	1064.98	bi-annual	Alluvium
P03-07-03	2003	29.0	28.65	28.96	1064.98	bi-annual	Alluvium
P03-07-04	2003	21.6	21.34	21.64	1064.98	bi-annual	Alluvium
P03-07-05	2003	20.1	19.81	20.12	1064.98	bi-annual	Alluvium
P03-07-06	2003	18.3	17.98	18.29	1064.98	bi-annual	Tailings
P03-07-07	2003	16.8	16.46	16.76	1064.98	bi-annual	Tailings
P03-07-08	2003	13.7	13.41	13.72	1064.98	bi-annual	Tailings
NA05-11A	2005	14.3	12.8	14.3	1068.35	not routinely monitored	Alluvium

Groundwater monitoring in the foot print area of the Original Impoundment commenced in 2001 with the installation of two nested piezometers (P01-08A/B/C and P01-10A/B). However, these wells were decommissioned (sealed with bentonite) in October 2005 due to concerns about the integrity of these wells (Robertson GeoConsultants Inc., 2006b).

At present, groundwater quality within the foot print of the original Impoundment is only monitored routinely in one multi-level piezometer (P03-07).

3.2.5 Review of Time Trends

Figure 3-2a/b shows selected water quality time trends for P01-8A/B/C and P01-10A/B (prior to decommissioning). Figure 3-3a/b shows the depth profiles of selected water quality parameters in P03-07. The following observations can be made:

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

- The tailings pore water (screened at P01-10A) showed elevated pH and Na suggesting residual process water; the observed increase in SO4, Mg, Fe etc after installation was likely a result of leakage through the joints of the piezometer casing;

- The groundwater in the alluvial aquifer (screened at P01-10B) initially showed slightly elevated SO4, Mg, Na and Zn suggesting some (limited) impact of tailings seepage; subsequent increases in SO4, Mg and in particular Zn and Fe were very likely caused by leakage from the piezometer (leakage confirmed);

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

- The tailings pore water (screened at P01-08A) initially showed lower Na concentrations compared to P01-10A suggesting higher flushing rate; metal concentrations (Zn, Fe., Mn)

showed significant variation over time suggesting influence of leakage from the upper tailings profile;

- The groundwater in the alluvial aquifer (screened at P01-08B&C) initially showed elevated SO4, Mg, Zn (0.8 mg/L), Fe (~25 mg/L) and Mn (~7 mg/L); these concentrations were 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);

- Subsequent monitoring in P01-8B showed increasing and erratic concentrations of Zn and other metals (Fe, Mn) indicative of leakage through the piezometer from the upper tailings profile.

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

- P03-07 is affected by permafrost (at depth of ~12m bgs) causing problems with sampling of all monitoring points except P03-07-05 (Gartner Lee Limited, 2007); these problems severely limit the use of this monitoring well in establishing reliable water quality time trends (in depth and time);

- The limited sampling of groundwater in the alluvial aquifer 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 a source located further upgradient, i.e. either the coarse and well-drained tailings located further east in the Original Impoundment and/or seepage from the Faro Creek channel/diversion channel;

Monitoring well NA05-11A, located in the northeastern section of the Original Impoundment and screened about 3-5m beneath the tailings in sand and gravel was sampled once in September 2006. Groundwater in this well was well-buffered, with a circum-neutral pH (lab pH 7.27) and alkalinity of 256 mg/L CaCO3eq. Sulphate and magnesium concentrations were only moderately elevated (487 mg/L and 84.8 mg/L, respectively). In contrast, zinc and other metal concentrations (Fe, Mn) were significantly elevated (Zn = 22.6 mg/L, Fe=20.4 mg/L and Mn = 26.6 mg/L) indicating the influence of tailings seepage with significantly elevated metal concentrations.

The much higher zinc concentrations observed in this well compared to other wells in the Original Impoundment may be caused by more advanced oxidation and/or TDS/Zn front of the (shallower) tailings profile at this location. Note, however, that this well has only been sampled once and repeated sampling would be required to confirm these preliminary results.

In summary, historic groundwater monitoring in the aquifer beneath the Original Impoundment shows elevated SO4, Mg, Zn and other metals (Fe, Mn). However, an assessment of recent time trends

along this reach is difficult due to limited sampling along this reach of the Rose Creek aquifer (decommissioning of leaky wells and problems with permafrost).

3.2.6 Influence of Decommissioning of P01 Wells

In October 2001, the nested monitoring wells P01-08A/B/C and P01-10A/B were decommissioned by filling the piezometer with a bentonite slurry (Robertson GeoConsultants, 2006b). However, there are no monitoring wells located immediately downgradient (<150m) of those decommissioned wells to assess any potential effects of this decommissioning work on the groundwater quality in the Rose Creek sediments.

3.2.7 Recommended Modifications to the Water Quality Monitoring Program

At present, only one multi-level piezometer (P03-07) is routinely monitored within the foot print area of the Original Impoundment. However, the majority of the eight monitoring points cannot be sampled due to permafrost (GLL, 2007). In the author's opinion, routine monitoring of P03-07 (in all eight monitoring points) should be discontinued considering the difficulty of sampling and lack of consistency.

Routine monitoring in another multilevel well P03-04, located only about 140m further downgradient of P03-07, is considered adequate for assessing the impact of tailings seepage on the Rose Creek aquifer (see section 3.3 below).

In the author's opinion, routine monitoring in well NA05-11A is not required at this time. Note, however, that this well should **NOT** be decommissioned to allow future sampling for targeted investigations, if required.

3.3 Second Impoundment

3.3.1 Background

Table 3-2 lists pertinent information of all groundwater monitoring wells located in the Second Impoundment, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Groundwater monitoring in the foot print area of the Second Impoundment commenced in 2001 with the installation of two nested piezometers (P01-07A/B/C/D/E and P01-9A/B/C/D). However, these wells were decommissioned (sealed with bentonite) in October 2005 due to concerns about the integrity of these wells (Robertson GeoConsultants Inc., 2006b).

In 2003, six multilevel monitoring wells were installed in the foot print of the Second impoundment to complement the P01 series of wells. All six multi-level wells in the Second Impoundment are presently included in the routine groundwater monitoring program.

Table 3-2

Monitoring wells in the Second Impoundment, Rose Creek Tailings Facility.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Second Impoundment							
P01-7A, B, C, D, E	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	n/a
P01-9A, B, C, D	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	n/a
P03-01-01	2003	46.8	46.48	46.79	1061.11	bi-annual	Alluvium
P03-01-02	2003	38.9	38.56	38.86	1061.11	bi-annual	Alluvium
P03-01-03	2003	30.6	30.33	30.63	1061.11	bi-annual	Alluvium
P03-01-04	2003	24.5	24.23	24.54	1061.11	bi-annual	Alluvium
P03-01-05	2003	18.4	18.14	18.44	1061.11	bi-annual	Alluvium
P03-01-06	2003	13.3	12.95	13.26	1061.11	bi-annual	Alluvium
P03-01-07	2003	10.8	10.52	10.82	1061.11	bi-annual	Alluvium
P03-01-08	2003	9.3	8.99	9.30	1061.11	bi-annual	Tailings
P03-01-09	2003	7.8	7.47	7.77	1061.11	bi-annual	Tailings
P03-02-01	2003	33.8	33.53	33.83	1060.60	bi-annual	Alluvium
P03-02-02	2003	30.5	30.18	30.48	1060.60	bi-annual	Alluvium
P03-02-03	2003	22.9	22.56	22.86	1060.60	bi-annual	Alluvium
P03-02-04	2003	16.8	16.46	16.76	1060.60	bi-annual	Alluvium
P03-02-05	2003	13.7	13.41	13.72	1060.60	bi-annual	Alluvium
P03-02-06	2003	12.8	12.50	12.80	1060.60	bi-annual	Alluvium
P03-02-07	2003	11.9	11.58	11.89	1060.60	bi-annual	Tailings
P03-02-08	2003	8.8	8.53	8.84	1060.60	bi-annual	Tailings
P03-02-09	2003	7.6	7.32	7.62	1060.60	bi-annual	Tailings
P03-03-01	2003	43.0	42.67	42.98	1061.49	bi-annual	Alluvium
P03-03-02	2003	33.2	32.92	33.22	1061.49	bi-annual	Alluvium
P03-03-03	2003	27.1	26.82	27.13	1061.49	bi-annual	Alluvium
P03-03-04	2003	22.3	21.95	22.25	1061.49	bi-annual	Alluvium
P03-03-05	2003	18.6	18.29	18.59	1061.49	bi-annual	Alluvium
P03-03-06	2003	17.1	16.76	17.07	1061.49	bi-annual	Alluvium
P03-03-07	2003	15.2	14.94	15.24	1061.49	bi-annual	Tailings
P03-03-08	2003	12.2	11.89	12.19	1061.49	bi-annual	Tailings
P03-03-09	2003	9.1	8.84	9.14	1061.49	bi-annual	Tailings
P03-04-01	2003	58.2	57.91	58.22	1061.21	bi-annual	Alluvium
P03-04-02	2003	47.5	47.24	47.55	1061.21	bi-annual	Alluvium
P03-04-03	2003	41.5	41.15	41.45	1061.21	bi-annual	Alluvium
P03-04-04	2003	35.1	34.75	35.05	1061.21	bi-annual	Alluvium
P03-04-05	2003	26.1	25.76	26.06	1061.21	bi-annual	Alluvium
P03-04-06	2003	17.4	17.07	17.37	1061.21	bi-annual	Alluvium
P03-04-07	2003	15.5	15.24	15.54	1061.21	bi-annual	Alluvium
P03-04-08	2003	13.7	13.41	13.72	1061.21	bi-annual	Tailings
P03-04-09	2003	12.8	12.50	12.80	1061.21	bi-annual	Tailings
P03-05-01	2003	44.5	44.20	44.50	1060.43	bi-annual	Alluvium
P03-05-02	2003	36.9	36.58	36.88	1060.43	bi-annual	Alluvium
P03-05-03	2003	27.7	27.43	27.74	1060.43	bi-annual	Alluvium
P03-05-04	2003	23.5	23.16	23.47	1060.43	bi-annual	Alluvium
P03-05-05	2003	21.6	21.34	21.64	1060.43	bi-annual	Alluvium
P03-05-06	2003	18.6	18.29	18.59	1060.43	bi-annual	Tailings
P03-05-07	2003	14.0	13.72	14.02	1060.43	bi-annual	Tailings
P03-05-08	2003	11.0	10.67	10.97	1060.43	bi-annual	Tailings
P03-06-01	2003	25.9	25.60	25.91	1062.79	bi-annual	Bedrock
P03-06-02	2003	22.9	22.56	22.86	1062.79	bi-annual	Alluvium
P03-06-03	2003	19.8	19.51	19.81	1062.79	bi-annual	Alluvium
P03-06-04	2003	16.5	16.15	16.46	1062.79	bi-annual	Alluvium
P03-06-05	2003	14.3	14.02	14.33	1062.79	bi-annual	Alluvium
P03-06-06	2003	12.5	12.19	12.50	1062.79	bi-annual	Tailings
P03-06-07	2003	11.0	10.67	10.97	1062.79	bi-annual	Tailings
NA05-9D	2005	11.0	7.9	10.9	1060.81	not routinely monitored	Alluvium
NA05-9S	2005	6.1	1.4	4.4	1060.57	not routinely monitored	Tailings

3.3.2 Review of Time Trends

Figures 3-4a/b and 3-5a/b show the water quality time trends observed at P01-09 and P01-07. Figures 3-6 to 3-11 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) showed 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; it is suspected that leakage through the joints of the PVC casing (from the upper acidic tailings profile) had caused the dramatic increase in all ARD products, but leakage was never confirmed in this well prior to decommissioning;

- All three piezometers screened in the underlying alluvial aquifer and basal till (P01-09B/C/D) showed elevated SO4, Mg and highly elevated metals (Zn, Fe and Mn); subsequent testing indicated that all three piezometers were allowing "leakage" of tailings pore water with very poor water quality to the well screens (Gartner Lee Limited, 2005); the groundwater quality historically observed in those three wells is therefore not considered representative of actual groundwater quality in the Rose Creek aquifer;

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

- Initial sampling of tailings pore water (screened at P01-07A&B) showed low sulphate concentrations, highly elevated Na (300-400 mg/L) and alkaline pH (~9.5) indicative of historic process water; subsequently, sulphate concentrations increased and pH dropped significantly, suggesting leakage of ARD products from the upper, oxidized tailings profile; however, leakage was never confirmed prior to decommissioning of these wells;

- Initial sampling of groundwater in the alluvial aquifer (screened at P01-07C/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 increased significantly after the initial round of sampling also suggesting leakage of tailings pore water within the piezometer; subsequent testing confirmed this contention for all three piezometers (Gartner Lee Limited, 2005); the groundwater quality historically observed in those three wells is therefore not considered representative of actual groundwater quality in the Rose Creek 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 (19,000-60,000mg/L), Mg (400-700mg/L), Zn (100-2,700mg/L) and Fe (13,000-27,000 mg/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;

- **Tailings pore water in P03-01 & 02 (and to a lesser extent P03-03) has generally deteriorated further over the last three years, as evidenced by significant increases in sulphate, magnesium and metals (in particular zinc, manganese and iron); in most cases these increases were accompanied by a significant decrease in pH and alkalinity**;

- 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), concentrations of sulphate, magnesium, and various metals (Zn, Fe and Mn) initially showed a decreasing trend with depth in the alluvial sediments as would be expected with seepage from the overlying tailings deposit being the source of contamination; **however, zinc and manganese concentrations at deeper monitoring points (in particular at P03-01-4 and P03-02-4) have shown significant increases over the last 3 years of monitoring;**

    - At P03-03 (downgradient of P01-09), contaminant concentrations showed an inverse depth profile with significantly higher concentrations of SO4, Zn and Fe to much greater depth (e.g. 1860 mg/L SO4 and 148 mg/L Zn about 18m below the base of tailings); previous analyses had suggested that 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 (Robertson GeoConsultants Inc.; 2006b); the observed decline in contaminant concentrations in the deeper monitoring points of P03-03 since decommissioning of the "leaky wells' in late 2005 supports this contention (see section 3.3.3 below);

    The recent increases in zinc and manganese concentrations at greater depth in the Rose Creek aquifer (at P03-01 and P03-02) are cause for concern and should be further monitored. Note that both wells are located upgradient (or cross-gradient) of the P01-09 wells, hence leakage effects can be ruled out as a source for the recent increases. The most likely source for the observed increases in contaminants (in particular zinc) at greater depth is seepage from tailings located further upgradient (i.e. in the Second Impoundment). However, this would indicate a very high degree of vertical dispersion (i.e. up to 15m over a horizontal distance of only ~120m). Alternatively, an upstream source (other than tailings seepage) may be contributing Zn load to the Rose Creek aquifer (potentially WRD seepage from the Intermediate Dump??). Additional monitoring upstream of the Rose Creek tailings facility would be required to clarify the source of contamination at greater depth in the Rose Creek aquifer at P03-01.

In 2005, two additional nested monitoring wells (NA05-9S/D) were installed in vicinity of P03-02 as part of a study to assess zinc attenuation in the organic layer underlying the tailings (SRK Consulting, 2006d). Monitoring well NA05-9S is screened in silty tailings but was dry in September 2006. Monitoring well NA05-9D is screened about 1-4m beneath the tailings in sandy gravel and was sampled once in September 2006. Groundwater in this well was slightly acidic, with a lab-pH of 6.3 and alkalinity of 64 mg/L CaCO3eq. Sulphate and magnesium concentrations were only moderately elevated (785 mg/L and 24 mg/L, respectively). In contrast, zinc and iron concentrations were

significantly elevated (Zn = 16.2 mg/L, Fe=373 mg/L) indicating the influence of tailings seepage with significantly elevated metal concentrations. The groundwater quality observed in this well is generally consistent with that observed in the Rose Creek aquifer at shallow depth beneath the tailings at P03-01 and P03-02.

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

- The tailings pore water in P03-05 also shows elevated SO4, Mg, Fe and Mn 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; note, however, that the May 2007 sample for P03-05-6 showed significantly reduced alkalinity and increased metals; it is unclear whether this is an error or indicates significant deterioration in tailings pore water quality and should be checked;

- 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 has remained very constant over time showing 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 (in the southern portion of the Rose creek aquifer);

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

- At P03-06 saturated conditions are only observed near the base of the tailings; tailings pore water shows elevated concentrations of major ions (e.g. SO4 ~10,000 mg/L, Mg 1,800 mg/L) and various metals (Zn ~700 mg/L, Fe ~350 mg/L, Mn ~350 mg/L); the well-drained conditions in this area (caused by coarse texture of the tailings) is likely responsible for the full penetration of the TDS and metal front to the base of the tailings;

- Groundwater quality in the aquifer at P03-06 also shows a general "dilution profile", with the highest contaminant concentrations (SO4, Mg, Zn etc) in the shallow monitoring point immediately below the tailings; however, the deeper layers of the aquifer (ports #2 and #3) also show significantly elevated contaminant concentrations;

- **Groundwater quality in the aquifer at P03-06 has shown significant deterioration since start of monitoring in 2003, both immediately beneath the tailings and at greater depth in the aquifer and shallow bedrock:**

    - **P03-06-05 (~2m beneath the base of the tailings) has shown a significant increase in sulphate from 331 mg/L in June 2004 to 2740 mg/L in May 2007; zinc concentrations have also increased from ~0.1 mg/L in June 2004 to 63.3 mg/L (!) in May 2007;** contaminant concentrations are typically higher during the

spring sampling suggesting seasonal recharge from the overlying, oxidizing tailings profile;

- **The deeper portion of the aquifer (at P03-06-02 and P03-06-03) and shallow bedrock (P03-06) has also shown a significant increase in all contaminants, including SO4, Mg, Zn, Fe and Mn; for example,** sulphate concentrations have increased from ~800 mg/L to ~2,000 mg/L over the past three years and zinc has increased from ~0.2 to ~2.6 mg/L; the most dramatic increases were observed for iron which reached ~100 mg/L in May 2007;

- **Note also that alkalinity has significantly decreased in the shallow as well as in the two deeper monitoring points suggesting that the buffering capacity of the aquifer is gradually being depleted; this raises concerns about the potential for further increases in metal concentrations in the near future;**

The recent increases in oxidation products and metal concentrations in the aquifer at P03-06 (in particular at depth) are significant and their cause should be further investigated. The most likely cause for the contamination at shallow depth in the aquifer is seepage from the coarse, oxidizing tailings in the immediate vicinity of P03-06; however, the recent increases in contaminant concentrations at greater depth in the aquifer are more likely caused by a source located further upgradient, i.e. either the coarse and well-drained tailings located in the Original Impoundment and/or seepage from the Faro Creek channel/diversion channel. A more detailed hydrogeologic and geochemical analysis, including assessment of hydraulic gradients and geochemical fingerprinting would be required to determine the cause for the recent deterioration in groundwater quality in this portion of the Rose Creek aquifer (such an analysis was beyond the scope of this site-wide review).

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); however, tailings pore water at this location shows a different chemical composition with highly elevated SO4 (~8000-10,000 mg/L) but comparatively low concentrations of Mg (~100 mg/L), Zn (3-4 mg/L) and other metals;

- 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 southeastern section (P03-01, P03-03) and the northwestern section (at P03-06). The lowest levels of ARD products (SO4, Mg, Zn etc) were observed in the southwestern section (at P03-05 and P01-07).

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 significant depth, in particular in recent years at P03-06. 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 (in particular the Faro Creek canyon and diversion channel) along the north side.

The recent increases in ARD products, and in particular zinc, in the Rose Creek aquifer underlying the Second Impoundment indicate that the assimilative capacity along the flow path (i.e. tailings and/or aquifer) is slowly being depleted. Further increases in metal concentrations in the groundwater flowing in the Rose Creek aquifer beneath the Second Impoundment can therefore be expected and should be monitored.

3.3.3 Influence of Decommissioning of P01 Wells

In October 2001, the nested monitoring wells P01-07A/B/C/D/E and P01-09A/B/C/D were decommissioned by filling the piezometer with a bentonite slurry. At both locations, multilevel piezometers are located within a relatively short distance (<150m) downgradient of the decommissioned wells allowing a preliminary assessment of any potential effects of this decommissioning work on the groundwater quality in the Rose Creek sediments.

Figure 3-12a/b shows the time trends of selected water quality parameters for P03-03, located about 140m downgradient of the decommissoned wells P01-09A/B/C/D. The date of well decommissioning is also shown for reference. The most recent sampling event (May 2007) showed a clear decrease in zinc concentrations at depth in the aquifer (P03-03-02, -03 and -04) suggesting that well leakage may indeed have been the cause for the earlier increase in zinc concentrations. This contention is plausible considering the very high zinc concentrations in the upgradient leaky wells which had been introduced prior to well decommissioning into the aquifer through the well screens up to 28m depth below ground. However, additional monitoring will be required to confirm this initial assessment.

Figure 3-13a/b shows the time trends of selected water quality parameters for P03-04, located about 140m downgradient of the decommissoned wells P01-07A/B/C/D/E. The date of well decommissioning is also shown for reference. At this location, no consistent decrease in zinc and other ARD products has been observed since decommissioning of the leaky wells. In fact, most of the monitoring points screened in the aquifer show a slight increasing trend in zinc and other ARD products (SO4, Mg). Note, however, that tailings pore water at P01-07 never showed the same highly elevated sulphate, magnesium and zinc concentrations as observed at P01-09. Hence, leakage from P01-07 likely also never had the same significant impact on groundwater quality in the Rose Creek aquifer as inferred for P01-09. Again, additional monitoring will be required to confirm this initial assessment.

3.3.4 Recommended Modifications to the Water Quality Monitoring Program

At present, six multi-level wells are routinely monitored within the foot print area of the Second Impoundment. In the author's opinion, monitoring of all six multilevel wells (for a total of 58 monitoring points) on a routine basis is not required. We recommend that routine monitoring be discontinued in

P03-02 and P03-05 (all monitoring points). Note, however, that these multi-level monitoring wells should **NOT** be decommissioned to allow future sampling for targeted investigations, if required.

Routine monitoring at multilevel wells P03-01, P03-03, P03-04 and P03-06 should be continued. Monitoring to date has shown that groundwater quality in the tailings and underlying aquifer vary significantly in space and contaminant concentrations (including zinc) continue to deteriorate justifying this high effort of monitoring. These four wells provide adequate spatial coverage of the Second Impoundment, including the highly oxidized southeastern portion (P03-01 and P03-03), the southwestern portion (P03-04) and the northwestern portion (P03-06). Furthermore, future monitoring of P03-03 will allow a better assessment of the effects of decommissioning of P01-09 on the Rose Creek aquifer.

In the author's opinion, routine monitoring in the nested wells NA05-2S/D is not required at this time. Note, however, that this well should **NOT** be decommissioned to allow future sampling for targeted investigations, if required.

3.4 Intermediate Impoundment

3.4.1 Background

Table 3-3 lists pertinent information of all groundwater monitoring wells located in the Intermediate Impoundment, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 3-3

Monitoring wells in the Intermediate Impoundment, Rose Creek Tailings Facility.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Intermediate Impoundment							
X21A-96	1996	8.5	2.43	8.53	1052.09	bi-annual	Tailings
X21B-96	1996	14.7	11.64	14.69	1052.14	bi-annual	Alluvium
X21C-96	1996	29.4	27.86	29.37	1052.21	bi-annual	Alluvium
P01-05A	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	Tailings
P01-05B	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	Alluvium
P01-06	2001 - decommissioned (sealed w/ bentonite slurry) in Oct 2005					decommissioned	Alluvium (?)
P03-08-01	2003	32.6	32.31	32.61	1048.35	bi-annual	Alluvium
P03-08-02	2003	28.3	28.04	28.35	1048.35	bi-annual	Alluvium
P03-08-03	2003	24.7	24.38	24.69	1048.35	bi-annual	Alluvium
P03-08-04	2003	23.2	22.86	23.16	1048.35	bi-annual	Alluvium
P03-08-05	2003	21.6	21.34	21.64	1048.35	bi-annual	Alluvium
P03-08-06	2003	20.1	19.81	20.12	1048.35	bi-annual	Tailings
P03-08-07	2003	17.1	16.76	17.07	1048.35	bi-annual	Tailings
P03-08-08	2003	14.0	13.72	14.02	1048.35	bi-annual	Tailings
NA05-2D	2005	13.7	10.7	13.7	1052.13	not routinely monitored	Alluvium
NA05-2S	2005	8.8	4.5	7.5	1052.11	not routinely monitored	Tailings

Groundwater monitoring in the foot print area of the Intermediate Impoundment commenced in 1981 with installation of the historic compliance well X21A/B/C. These piezometers were subsequently destroyed and replaced in 1996 with a set of nested piezometers (P96-5A/B/C) at similar location and screening interval (Robertson GeoConsultants Inc., 1996). In 2001, additional piezometers (P01-

05A/B and P01-06) were installed (Gartner Lee Limited, 2002). However, these wells were decommissioned (sealed with bentonite) in October 2005 due to concerns about the integrity of these wells (Robertson GeoConsultants Inc., 2006b).

In 2003, one multilevel monitoring well was installed in the foot print of the Intermediate Impoundment to complement the P01 series of wells. All wells listed above are presently included in the routine groundwater quality monitoring program.

3.4.2 Review of Time Trends

Figures 3-14a/b and 3-15a/b show the water quality time trends observed at X21A (P96-5), P01-05 and P01-06, respectively. Figure 3-16a/b shows water quality depth profiles for P03-08. 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 11 years (e.g. SO4 from ~1000 to ~20,000); note, that sulphate and in particular zinc concentrations have generally increased over the last 3 years, reaching ~18,500 mg/L SO4 and ~100 mg/L Zn in May 2007; 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);

- Over the last 3 years groundwater in the upper aquifer (at X21B redrilled in 1996) has also shown an increase in ARD products, with sulphate concentrations reaching ~1,100 mg/L and zinc concentrations reaching ~6 mg/L; the groundwater quality time trends observed at X21B are generally consistent with those observed further up-gradient (at depth in P03-06) suggesting limited incremental loading from the Secondary Impoundment;

- Note that groundwater quality in X21B has shown consistent seasonal variations in recent years with higher contaminant levels in the fall; similar seasonal variations have been observed in P03-06, located further upgradient in the Original Impoundment; these seasonal variations in contaminant levels in the aquifer would suggest higher seepage and contaminant loading from the overlying tailings during the summer/fall period;

- 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) showed 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); this well was decommissioned in 2005 due to concerns about leakage of tailings pore water through the screen into the underlying aquifer;

In 2005, two additional nested monitoring wells (NA05-2S/D) were installed about 100m downgradient of X21 as part of a study to assess zinc attenuation in the organic layer underlying the tailings (SRK, 2006). Monitoring well NA05-2S is screened in coarse, partly oxidized tailings. Sampling in September 2006 indicated acidic conditions (lab pH ~3.76) and highly elevated concentrations of sulphate (18,100 mg/L), magnesium (2,010 mg/L), iron (7,780 mg/L) and manganese (485 mg/L). However, zinc concentrations were relatively low (8.7 mg/L). Tailings pore water quality at NA05-2S is generally similar to that observed at X21A, except for the significantly lower zinc concentrations.

Monitoring well NA05-2D is screened about 1.5 to 4.5 m beneath the tailings in sand and gravel and was sampled once in September 2006. Groundwater quality in this well was generally very similar to that observed further upgradient at X21B. The groundwater was buffered, with a lab-pH of 6.74 and alkalinity of 168 mg/L CaCO3eq. and elevated concentrations of most ARD products (SO4=1,230 mg/L; Mg=99.3 mg/L, Fe=107 mg/L). In contrast, zinc concentrations were only slightly elevated at 0.3 mg/L.

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

- The tailings pore water (in P01-05A) initially showed elevated concentrations of Na (~150-200mg/L) which is indicative of residual process water; SO4 concentrations initially observed (~1,200 mg/L) are likely higher than in the original process water suggesting some contribution from oxidized tailings however, concentrations of sulphate (and magnesium) decreased significantly until decommissioning in 2005, suggesting flushing of those ARD products from the tailings profile;

- The groundwater monitored at P01-05B (immediately below the base of the tailings) showed elevated SO4 (~600-800 mg/L), Mg (35-45 mg/L), and Na (50-65 mg/L) but typically fairly low metal concentrations (Zn ~0.1 mg/L, Fe ~1 mg/L and Mn ~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 Second Impoundment); this well was also decommissioned in 2005 due to concerns about leakage of tailings pore water through the screen into the underlying aquifer;

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

- The tailings pore water (at P03-08) 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); initially, SO4 was elevated in the deeper tailings profile (~1,500 mg/L) indicating some contribution from oxidized tailings; however, sulphate (and magnesium) concentrations have decreased significantly since start of monitoring in 2003 suggesting flushing of those ARD products from the tailings profile (as observed in P01-05A); this contention is consistent with the much more dilute tailings pore water observed at the shallowest port (P03-08-8) very dilute

- The groundwater with elevated TDS is limited to a narrow zone (<5m) beneath the tailings (as observed at P03-04); 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 Impoundment 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 (w.r.t. 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. Thus far, only one monitoring well (X21B) has shown a significant increase in contaminant concentrations (SO4, Zn, Fe and Mn). The recent increases at X21B may be related to the observed deterioration in groundwater quality at P03-06, located further upgradient in the (much older) Second Impoundment.

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.

3.4.3 Influence of Decommissioning of P01 Wells

In October 2001, the nested monitoring wells P01-05A/B and P01-06 were decommissioned by filling the piezometer with a bentonite slurry. However, there are no monitoring wells located immediately downgradient (<150m) of those decommissioned wells to assess any potential effects of this decommissioning work on the groundwater quality in the Rose Creek sediments.

3.4.4 Recommended Modifications to the Water Quality Monitoring Program

At present, one set of nested piezometers (at X21A/B/C) and one multi-level well (P03-08) are routinely monitored within the foot print area of the Intermediate Impoundment. In the author's opinion, both sets of monitoring wells should be retained in the routine monitoring program.

Note that the deep well X21C has repeatedly produced tailings during sampling (Gartner Lee Limited, 2007). The presence of tailings in this deep well was already observed during initial well development and confirmed by geochemical analysis of the purged sediments (Robertson GeoConsultants Inc., 1996). Subsequent monitoring of groundwater quality in this well over the last 11 years has shown consistently very dilute groundwater quality (approaching background water quality) suggesting that the entrained tailings are not influencing groundwater quality. Nevertheless, the long-term effects of the presence of tailings in the screening interval are not known and we therefore support the recommendation by Gartner Lee Limited to discontinue monitoring of water quality of well X21C. In the author's opinion, a replacement well for X21C is not required at this time.

In the author's opinion, routine monitoring in the nested set of wells NA05-2S/D is not required at this time as these wells provide very similar information to that observed at X21A/B. Note, however, that this well should **NOT** be decommissioned to allow future sampling for targeted investigations, if required.

3.5 Toe of Intermediate Dam

3.5.1 Background

Table 3-4 lists pertinent information of all groundwater monitoring wells located at the toe of the Intermediate Dam, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 3-4

Monitoring wells at the toe of the Intermediate Dam, Rose Creek Tailings Facility.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Intermediate Dam							
X24A-96	1996	6.5	6.46	6.48	1033.10	bi-annual	Alluvium
X24B-96	1996	11.3	9.8	11.3	1033.05	not routinely monitored	Alluvium
X24C-96	1996	16.5	14.97	16.47	1033.00	not routinely monitored	Alluvium
X24D-96	1996	28.3	26.84	28.34	1032.90	bi-annual	Alluvium
X25A-96	1996	8.9	7.44	8.97	1032.08	bi-annual	Alluvium
X25B-96	1996	19.1	17.7	19.17	1032.03	bi-annual	Alluvium
P01-03	2001	9.3	7.78	9.3	1032.21	bi-annual	Alluvium
P01-04A	2001	34.1	32.53	34.05	1031.90	bi-annual	Alluvium
P01-04B	2001	53.4	51.89	53.41	1031.89	bi-annual	Till

Groundwater monitoring along the toe of the Intermediate Dam commenced in 1987 with installation of the historic compliance wells X24A/B and X25A/B. These piezometers were lost due to dam raising in 1989 and subsequently replaced in 1996 with two sets of nested piezometers (P96-3A/B and P96-4A/B/C/D) at similar locations and screening interval (Robertson GeoConsultants Inc., 1996). In 2001, an additional shallow piezometer (P01-03) and a pair of deep piezometers (P01-04A/B) were installed to complement the existing monitoring wells at X24 and X25, respectively (Gartner Lee Limited, 2002).

At present, all wells listed above (except X24B/C) are included in the routine groundwater quality monitoring program. The older compliance wells X24B/C have not been sampled in recent years because of problems with sand heaving (see section 3.5.4).

3.5.2 Review of Time Trends

Figures 3-17a/b and 3-18a/b show the water quality time trends in wells screened in the northern section and southern section of the Intermediate Dam, respectively. The following observations can be made:

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

- Historically, the groundwater quality in the aquifer beneath the northern portion of the Intermediate Dam has shown a greater impact than along the southern portion, showing elevated SO4, Mg and alkalinity but generally low metal concentrations; note that this "TDS plume" in the aquifer extends to significant depth (~30m bgs)

- **In recent years (since about 2001), sulphate and magnesium concentrations have increased significantly in all (still functional) wells screened in the aquifer along the north side of the Intermediate Dam**; in May 2007, sulphate and magnesium concentrations in the deep well X24D had reached 1,700 mg/L and 120 mg/L, respectively; very similar increases in SO4 and Mg have been observed recently in the shallow well P01-03 suggesting a "breakthrough" of this TDS front across the entire depth of the aquifer;

- **Manganese and zinc have also increased significantly in the aquifer along the north side of the Intermediate Dam**; in May 2007, manganese and zinc concentrations in the deep well X24D had reached 50 mg/L and 0.1 mg/L, respectively; the shallow well P01-03 showed very similar increases in Mn but Zn has remained significantly lower (<0.02 mg/L) at shallow depth;

The recent increases in oxidation products and metal concentrations in the aquifer at X24 are significant and their cause should be further investigated. Note that the SO4 and Mg concentrations observed recently in the aquifer are significantly higher than observed in the Intermediate Pond (SO4 <1,000mg/L and Mg <70 mg/L), hence seepage from the Intermediate Pond can be ruled out as the main source of contamination. Instead, the source for this seepage must be located further upgradient. Possible upstream sources include (i) coarse tailings beaches located in the northern portion of the Intermediate, Second or Original Impoundments and/or seepage from the Faro Creek channel/diversion channel.

It is noted that SO4 and Mg concentrations observed at depth in X24 are significantly higher than observed at depth in X21 and, until 2007, in P03-06. This would suggest that additional loading occurs along the reach of the Intermediate Impoundment and/or that the shallow contaminant plume is dispersed to greater depths along the flow path. A more detailed hydrogeologic and geochemical analysis, including assessment of hydraulic gradients and geochemical fingerprinting would be required to determine the cause for the recent deterioration in groundwater quality in this portion of the Rose Creek aquifer (such an analysis was beyond the scope of this review).

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 (3 to 4 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, except possibly in well P01-04A[3];

In summary, groundwater in the northern portion of the aquifer shows significantly higher influence of ARD products (SO4, Mg, Zn, Mn) than on the southern side at the Intermediate Dam. 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 the Faro Creek canyon 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 six years. Additional analysis will be required to evaluate whether this increase is related to a recent increase in loading (e.g. X23 seepage, breakthrough of a TDS front in the coarse intermediate tailings) and/or represents a gradual breakthrough of a TDS plume from a near constant source.

3.5.3 Influence of Decommissioning of P01 Wells

All P01 wells installed in this reach were drilled through native materials (not tailings), hence there was no concern of leakage and decommissioning of these wells was not required.

3.5.4 Recommended Modifications to the Water Quality Monitoring Program

At present, four historic compliance wells (X24A-96, X24D-96, X25A-96 and X24B-96) and three additional monitoring wells (P01-03, P01-04A/B) are routinely monitored along the toe of the Intermediate Dam.

A detailed investigation into the conditions of the historic X24 wells had indicated that wells X24B and X24C were partially blocked by sand which had entered the well and filled the PVC casing to above the screening interval. Hence, sampling in both wells was discontinued due to concerns about the representativeness of the sample (Gartner Lee Limited, 2007). Gartner Lee Limited also noticed some build-up of sediment in the shallow well X24A, completed in the same borehole. However, the screen of this shallow well is still exposed to the aquifer and can be sampled. In the author's opinion, all three wells X24A, X24B and X24C should no longer be sampled and the piezometers properly decommissioned by sealing with bentonite.

Monitoring wells P01-03 (shallow) and X24D (deep) are judged to be adequate for routine groundwater monitoring along the north side of the Intermediate Dam.

No problems were noted with the historic compliance wells X25A-96 and X25B-96, located along the south side of the Intermediate Dam; hence these wells should be retained in the routine monitoring program. In the author's opinion, the two deeper monitoring wells installed in this area (P01-04A/B)

[3] The time trends strongly suggest that the nested wells P01-04A and P01-04B were mislabeled sometime between the fall 2005 and spring 2006 sampling events; this should be checked by sounding the depth of each well during future sampling

should also be retained in the monitoring program. However, the depth of those two wells should be checked to determine whether these wells are correctly identified in the field.

3.6 Toe of Cross Valley Dam

3.6.1 Background

Table 3-5 lists pertinent information of all groundwater monitoring wells located along the toe of the Cross Valley Dam, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 3-5

Monitoring wells at the toe of the Cross Valley Dam, Rose Creek Tailings Facility.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Toe of Cross Valley Dam							
P01-02A	2001	14.1	12.54	14.06	1019.73	bi-annual	Alluvium
P01-02B	2001	28.4	26.88	28.4	1019.71	bi-annual	Till
P01-11	2001	10.7	9.15	10.67	1017.83	bi-annual	Alluvium
P03-09-01	2003	35.1	34.75	35.05	1018.51	bi-annual	Alluvium
P03-09-02	2003	32.3	32.00	32.31	1018.51	bi-annual	Alluvium
P03-09-03	2003	27.1	26.82	27.13	1018.51	bi-annual	Alluvium
P03-09-04	2003	23.8	23.47	23.77	1018.51	bi-annual	Alluvium
P03-09-05	2003	21.9	21.64	21.95	1018.51	bi-annual	Alluvium
P03-09-06	2003	18.9	18.59	18.90	1018.51	bi-annual	Alluvium
P03-09-07	2003	13.4	13.11	13.41	1018.51	bi-annual	Alluvium
P03-09-08	2003	9.4	9.14	9.45	1018.51	bi-annual	Alluvium
P03-09-09	2003	7.6	7.32	7.62	1018.51	bi-annual	Alluvium
MW1	2005	17.7	1.95/12.19	9.74/17.67	1016.97	not routinely monitored	Alluvium
MW2	2005	14.9	2.19	14.89	1018.23	not routinely monitored	Alluvium
P05-01-01	2005	25.5	25.15	25.45	1018.00	not routinely monitored	Till/BR
P05-01-02	2005	19.8	19.67	19.82	1018.00	not routinely monitored	Alluvium
P05-01-03	2005	16.8	16.62	16.77	1018.00	not routinely monitored	Alluvium
P05-01-04	2005	11.3	11.13	11.28	1018.00	not routinely monitored	Alluvium
P05-01-05	2005	5.5	5.33	5.48	1018.00	not routinely monitored	Alluvium
P05-01-06	2005	3.4	3.20	3.35	1018.00	not routinely monitored	Alluvium
P05-02	2005	5.2	1.83	4.88	1016.67	not routinely monitored	Alluvium
P05-03	2005	7.6	3.44	7.62	1019.79	not routinely monitored	Alluvium
RGC-PW1	2005	21.1	4.19/16.38	5.79/19.59	1017.31	not routinely monitored	Alluvium
RGC-PW2	2005	16.9	4.19	15.39	1018.64	not routinely monitored	Alluvium

Groundwater monitoring along the toe of the Cross Valley Dam commenced in 2001 with the installation of a set of nested piezometers on the south side (P01-03A/B) and one shallow piezometer on the north side (P01-11). In 2001, an additional shallow piezometer (P01-03) and a pair of deep piezometers (P01-04A/B) were installed to complement the existing monitoring wells at X24 and X25, respectively. In 2003, one multilevel monitoring well (P03-09) was installed in the center of the valley to complement the P01 series of wells.

In 2005, one additional multilevel well (P05-01) and two single piezometers (P05-02 and P05-03) were installed as part of a study to design a seepage interception system in this area (Robertson GeoConsultants Inc., 2006). At present, only the P01 and P03 wells are included in the routine groundwater quality monitoring program. The P05 wells have been monitored less frequently in 2006 and 2007 due to seasonal freezing (into May).

3.6.2 Review of Time Trends

Figures 3-19a/b show the water quality time trends in all wells screened near the toe of the Cross Valley Dam. Figures 3-20a/b and 3-21a/b show water quality depth profiles for selected dates in P03-09 and P05-01, respectively. The groundwater quality in vicinity of the Cross Valley Dam shows significant transverse variations (from north to south) suggesting greater impact from mine waste seepage along the northern portion of the valley aquifer. The following observations can be made:

North Side of Cross Valley Dam (P01-11, P05-01 and P05-02);

- Groundwater in the northern portion generally shows elevated sulphate (~1,000 mg/L), magnesium (~75 mg/L), and alkalinity (~300 mg/L CaCO3eq); selected metal concentrations are also above background, including iron (10-20 mg/L), manganese (10-15 mg/L) and zinc (~0.03 mg/L);

- The depth profile at P05-01 suggests that groundwater quality is fairly uniform across the entire depth of the valley sediments; only the deepest monitoring point (P05-01-01) screened in highly cemented basal till shows a different composition, including lower sulphate (~400 mg/L) but higher sodium (120-140 mg/L) and higher alkalinity (400-500 mg/L); metal concentrations are also significantly lower at P05-01-01;

- **Time trends at P01-11 indicate a gradual increase in SO4 and Mg over time; current SO4 and Mg concentrations are ~1,100 mg/L and ~80 mg/L (May 2007)**; alkalinity has also shown an increase over time (currently at ~300 mg/L CaCO3 eq); manganese and iron concentrations have also shown a moderate increase at P01-11 since start of monitoring in 2001 (currently at 27 mg/L Fe and 17 mg/L Mn, respectively);

- Despite this significant increase in oxidation products, zinc concentrations at P01-11 have remained at comparatively low concentrations, ranging from 0.01 to 0.1 mg/L; note that the method of detection limit (MDL) for zinc analysis have been very high in recent years (e.g. 0.025 mg/L for the May 2007 survey) making it difficult to assess zinc time trends in this portion of the aquifer (see RGC 2007 for a more in-depth discussion on QA/QC issues);

- The initial (limited) monitoring at P05-01 and P05-02 carried out since 2006 suggest that the increases in ARD products (SO4, Mg etc) observed at P01-11 are representative of the entire northern portion of the Rose Creek aquifer; future monitoring at P05-01 and P05-02 will be required to confirm this contention;

Central Portion of Cross Valley Dam (P03-09, P05-03);

- The groundwater in the central portion of the aquifer at the Cross Valley Dam (at P03-09 and P05-03) shows significantly lower concentrations of all ARD products: SO4 and Mg concentrations range from 300-500 mg/L SO4 and 30-40 mg/L Mg, respectively and all metals (including iron, manganese and zinc) show significantly lower concentrations (note that zinc was generally non-detect but the MDL for zinc was as high as 0.025 mg/L so the actual zinc concentrations in the middle portion of the aquifer are uncertain);

- Detailed depth monitoring at P03-09 indicates fairly uniform groundwater quality throughout the central portion of the sand & gravel aquifer with only slightly higher SO4 and Mg concentrations in the upper portion of the aquifer; only the two deepest ports (screened in very compact basal TILL) show slightly higher sulphate, magnesium, and iron but lower manganese concentrations; zinc was also non-detect in the basal TILL unit;

- The initial (limited) time trend monitoring carried out at P05-03 since 2006 suggests that sulphate and magnesium concentrations are also increasing in the central portion of the aquifer. Note, however that such an increase is not readily apparent at P03-09, possibly due to the seasonal variations in groundwater quality observed at this location (more dilution in the spring sampling); additional monitoring will be required to confirm whether this portion of the aquifer is also showing a gradual deterioration in groundwater quality;

South Side of Cross Valley Dam (artesian wells P01-2A/B);

- Groundwater in the southern portion of the aquifer is much more dilute than the northern, or even the central portion of the aquifer: SO4 and Mg concentrations range from 100-150 mg/L SO4 and ~25 mg/L Mg, respectively; zinc concentrations are usually below detection and iron and manganese are 1-2 orders of magnitude lower than in the central portion of the aquifer; note that sodium concentrations are also significantly lower (~15 mg/L) than observed elsewhere in the Rose Creek aquifer along this reach suggesting dilution by seepage from the Rose Creek Diversion Canal;

- The groundwater quality in the upper well (P01-02A screened in alluvium) and the lower well (P01-02B screened in basal Till) is generally very similar, except for slightly higher manganese in the upper S&G aquifer (~1 mg/L) and higher iron concentrations (0.8 mg/L) in the deeper till; groundwater quality in both wells has remained very stable over the last six years except for some initial changes in metal concentrations (possibly due to re-equilibration after drilling);

The recent increases in oxidation products and metal concentrations in the northern, and to a lesser extent, in the central portion of the Rose Creek aquifer at the Cross Valley Dam are significant and their cause should be further investigated. Note that the SO4 and Mg concentrations observed recently in the aquifer are significantly higher than observed in the Polishing Pond (SO4 <700mg/L and Mg <40 mg/L), hence seepage from the Polishing Pond can be ruled out as the main source of contamination. Instead, the source for this seepage must be located further upgradient. Note that the chemical composition of the impacted groundwater on the northern side of Cross Valley Dam (P01-11, P05-01 and P05-02) is very similar to that observed on the north side further upgradient at the toe of the Intermediate Dam (at X24C/D) around 2002 (c. Figures 3-16a/b). **It is therefore likely that the breakthrough of ARD products observed at the Cross Valley Dam represents the "leading edge" of the breakthrough observed further upgradient at the Intermediate Dam.** If this hypothesis is correct, concentrations of ARD products (including metals such as Mn and Zn) can be expected to further increase in the wells located downgradient of the Cross Valley Dam over time.

Considering the proximity of the Cross Valley Dam to Rose Creek and the potential for groundwater discharge and contaminant loading to Rose Creek (in particular under baseflow conditions) we recommend that a more detailed hydrogeologic and geochemical analysis, including assessment of hydraulic gradients and geochemical fingerprinting be completed, in particular in the reach between the Second Impoundment and the Cross Valley Dam, to determine the cause for the recent deterioration in groundwater quality along the northern portion of the Rose Creek aquifer. As part of this study it should be investigated to what extent seepage from the Faro Creek canyon (as opposed to seepage from the tailings impoundments) is responsible for the recent increases. In the author's opinion, this issue is relevant for predicting future groundwater quality time trends in the Rose Creek aquifer, and may also have a bearing on the selection of a final closure option for the Rose Creek Tailings Facility.

3.6.3 Influence of Decommissioning of P01 Wells

All P01 wells installed in this reach were drilled through native materials (not tailings), hence there was no concern of leakage and decommissioning of these wells was not required.

3.6.4 Recommended Modifications to the Water Quality Monitoring Program

At present, two multi-level wells (P03-09 and P05-01) and three conventional monitoring wells (P01-02A/B, P01-11) are routinely monitored along the toe of the Cross Valley Dam. In the author's opinion, the new "P05 series" of wells (P05-01, P05-02 and P05-03) should be added to the routine monitoring program considering the proximity to Rose Creek. Note that sampling of the new multilevel well P05-01 is typically not possible in the spring/early summer due to freezing of the sampling tubes (Gartner Lee Limited, 2007). Hence this multilevel well should only be sampled during the fall sampling campaign.

As discussed earlier, the high detection limits (MDL) for zinc analyses were frequently too high (as high as 0.03 mg/L) to allow a meaningful assessment of zinc time trends in this area. An attempt should be made to reduce the MDL for zinc (to say <0.005 mg/L) by switching the method of analysis and/or the laboratory.

3.7 Downstream of Cross Valley Dam

3.7.1 Background

Table 3-6 lists pertinent information of all groundwater monitoring wells located downgradient of the Cross Valley Dam, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Groundwater monitoring downstream of the Cross Valley Dam commenced in 1981 with the installation of the historic compliance wells X16A/B, X17A/B and X18A/B (Klohn Crippen, 1981). In 2001, another set of nested monitoring wells (P01-01A/B) was installed along the north side of the valley.

All monitoring wells in this reach are currently routinely monitored.

Table 3-6

Monitoring wells downgradient of Cross Valley Dam, Rose Creek Tailings Facility.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Downgradient of Cross Valley Dam							
X16A	1981	6.0	3	6	1016.41	bi-annual	Alluvium
X16B	1981	34.0	20	34	1016.01	bi-annual	Alluvium
X17A	1981	6.2	4.5	6.2	1015.45	bi-annual	Alluvium
X17B	1981	25.0	17	25	1014.89	bi-annual	Alluvium
X18A	1981	10.6	8.8	10.6	1019.59	bi-annual	Alluvium
X18B	1981	22.8	16.6	22.8	1019.65	bi-annual	Alluvium
P01-01A	2001	21.4	19.8	21.36	1015.86	bi-annual	Alluvium
P01-01B	2001	35.3	33.78	35.3	1015.86	bi-annual	Alluvium

3.7.2 Review of Time Trends

Figures 3-22a/b show the water quality time trends in all wells screened downgradient of the Cross Valley Dam. The recent time trends can be summarized as follows:

North Side of Rose Creek Aquifer (P01-01A/B and X18A/B):

- Monitoring wells X18A/B and P01-01A show very similar time trends in groundwater quality, with a gradual increase in sulphate, magnesium and alkalinity; the highest concentrations were observed in the most recent survey (May 2007) with ~600 mg/L SO4, ~60 mg/L Mg, and ~260 mg/L CaCO3eq; metal concentrations have generally remained low and show no clear increasing trend except for manganese in P01-01A (~4.5 mg/L in May '07); time trends in zinc concentrations have been fairly erratic, at least in part due to problems with the high detection limits for zinc in recent years (see section 3.7.4);

- Monitoring well P01-01B (screened in deep alluvium) has not shown the same recent increases (since 2001) in sulphate and magnesium as observed elsewhere on the north side; note also that manganese concentrations have also remained very low (~0.1 mg/L) in P01-01B;

Central Portion of Rose Creek aquifer (X16A/B and X17A/B):

- The monitoring wells screened in the central portion of the Rose Creek aquifer (at X16A/B and X17A/B) generally show significantly less impact than on the north side, with all ARD products (SO4, Mg, Na and metals) at significantly lower concentrations; however the water quality time trends in those two sets of piezometers show some important differences:
    - Monitoring well X17B, screened in the deeper portion of the alluvial aquifer, has recently shown an increase in most major ions, including SO4, Mg, Na and alkalinity; in addition, iron and manganese concentrations have also shown a slight increase (again, zinc time trends could not be evaluated due to problems with the high MDL); note that the recent time trends also show a distinct seasonal trend, with higher concentrations typically observed during the spring/early summer;

- Monitoring wells X17A and X16A, both screened in the upper portion of the alluvial aquifer, and X16B (screened in the deeper portion of the aquifer) have not shown the same recent increases in major ions or metals, as observed at X17B;

In summary, the groundwater quality time trends observed in the Rose Creek aquifer further downgradient of the Cross Valley Dam mimic the trends observed along the toe of the Cross Valley Dam, with higher impacts observed on the northern side of the aquifer. The sulphate and magnesium concentrations currently observed further downgradient (at X18A/B and P01-01A) are similar to those observed several years earlier at the toe of the Cross Valley Dam (around 2002 in P01-11). This would suggest that the recent increases in sulphate and magnesium represent the "leading edge" of the contaminant plume observed in the northern portion of the aquifer (at the Cross Valley Dam and Intermediate Dam). In the author's opinion, sulphate and magnesium concentrations will likely continue to increase in wells located along the north side downgradient of the Cross Valley Dam. Further increases in sulphate and magnesium will likely precede any significant increases in zinc or other metals (Fe, Mn).

The recent increases in major ion and selected metal concentrations at X17B differ from that observed elsewhere in that (i) increases in sulphate and magnesium are also accompanied by significant increases in sodium and alkalinity, and (ii) the increases show significant seasonal variations. Elevated sodium and alkalinity levels have also been observed in the deep monitoring points at P03-09 and P05-01, which are screened in compact, basal till. It is therefore possible that the observed seasonal increases in major ions at X17B reflect increased contributions of deep groundwater upwelling from underlying bedrock and/or basal till, in particular during the spring runoff season.

The chemical composition and low ionic strength of the groundwater observed in the other wells (at X17A and X16A/B) is similar to that observed along the southern abutment of the Cross Valley Dam (P01-02A/B). As discussed earlier, leakage of very dilute surface water from the Rose Creek Diversion likely provides significant dilution to the groundwater in the Rose Creek aquifer in those areas.

3.7.3 Influence of Decommissioning of P01 Wells

All P01 wells installed in this reach were drilled through native materials (not tailings), hence there was no concern of leakage and decommissioning of these wells was not required.

3.7.4 Recommended Modifications to the Water Quality Monitoring Program

At present, six historic compliance wells (X16A/B, X17A/B and X18A/B) and one set of nested piezometers (P01-01A/B) are routinely monitored downgradient of the Cross Valley Dam. In the author's opinion, the current level of routine monitoring along this reach is justified considering the proximity to Rose Creek. Hence all monitoring wells in this reach should be retained in the routine monitoring program.

As discussed earlier, the high detection limits (MDL) for zinc analyses were frequently too high (as high as 0.03 mg/L) to allow a meaningful assessment of zinc time trends in this area. An attempt

should be made to reduce the MDL for zinc (to say <0.005 mg/L) by switching the method of analysis and/or the laboratory.

3.8 Implications for Closure Planning

The last comprehensive review of groundwater quality in the Rose Creek Tailings area was completed in 2004 (Robertson GeoConsultants Inc., 2006a). The water quality data available at that time (until mid 2004) were used to develop a load balance for the Rose Creek tailings area, including loading estimates from the different tailings reaches to the aquifer and predictions of contaminant loading to Rose Creek. This loading study had predicted significant increases in sulphate and zinc concentrations in the Rose Creek aquifer and ultimately loading to Rose Creek. This loading study also suggested that zinc must be attenuated along the flow path, either within the tailings profile and/or in the aquifer, likely in organic soils near the base of the tailings (Robertson GeoConsultants Inc., 2006a).

In this context, the following recent developments in groundwater quality in the Rose Creek aquifer and overlying tailings are of interest:

- Tailings pore water quality has generally deteriorated further over the last three years, as evidenced by significant increases in sulphate, magnesium and metals (in particular zinc, manganese and iron); in most cases these increases were accompanied by a significant decrease in pH and alkalinity; these changes were particularly evident in the Second Impoundment (e.g. at P03-01, P03-02, P03-03, P03-05) but may also be present in other parts of the facility (e.g. coarse tailings beaches in the Original Impoundment) where no such detailed monitoring is available;
- Groundwater quality in the underlying Rose Creek aquifer has also significantly deteriorated in the last three years in all reaches of the Rose Creek Tailings Facility, i.e. not only within the foot print area of the tailings impoundments but further downstream at the Intermediate Dam and the Cross Valley Dam. **Of particular concern are the significant increases in sulphate, magnesium and metal concentrations, including iron, zinc and manganese, at <u>greater depth</u> in the aquifer, in particular in the northern portion of the aquifer** (see for example P03-06, X21B, X24D). These recent time trends clearly indicate that the entire depth of the aquifer is affected by seepage from the tailings (and possibly the ETA area);
- Additional wells screened at shallow depth in the aquifer sediments underlying shallow tailings deposits (NA wells) show significantly elevated zinc concentrations (e.g. 22 mg/L at NA11) suggesting that the attenuation capacity of the tailings and/or organic soils underlying the tailings profile is slowly being exhausted; this process may explain the recent increases in zinc concentrations in many parts of the Rose Creek aquifer;

The implications of these recent findings for closure planning of the Rose Creek Tailings Facility are as follows:

- The recent increases in sulphate, magnesium and metal concentrations in both tailings pore water and groundwater in the underlying aquifer generally support earlier loading studies which predicted such increases. Specifically, the recent increases in zinc concentrations observed in the Rose Creek aquifer justify our earlier use of only limited (R=2) or no

retardation in the aquifer for zinc loading predictions (Robertson GeoConsultants Inc., 2006a). In other words, the zinc loading calculations completed in 2004 are still considered relevant for closure planning;

- The recent increases in contaminant concentrations throughout the tailings area also support our earlier contention, that groundwater interception at the Cross Valley Dam/Intermediate Dam and/or within the foot print area of the tailings will be required, even if all tailings were to be relocated in the very near future. Furthermore, projecting current time trends into the future, metal concentrations such as iron, zinc and manganese can be expected to increase further in the Rose Creek aquifer (possibly exponentially once the assimilative capacity of the system is exhausted), thus increasing the requirements for such “interim“ collection and treatment (collection efficiency, duration of pumping etc), **in other words, any further delay in relocating the tailings will further diminish the advantages of full or partial relocation of the tailings**;
- Recent monitoring has also clearly demonstrated that the contamination is occurring throughout the entire depth of the aquifer; this implies that any groundwater interception system (extraction wells, hydraulic barrier etc) will have to penetrate the entire depth of the aquifer) and possibly into the underlying competent till and/or bedrock (additional monitoring wells will have to be completed in bedrock to assess groundwater quality in those deeper units);
- Earlier loading calculations had indicated that the elevated contaminant concentrations along the north side may be caused by significant loading from the Faro Creek seepage (Robertson GeoConsultants Inc., 2006a) which until recently was diverted along the Second Impoundment and discharged into the Intermediate Impoundment. Recent monitoring has confirmed the presence of significantly higher contaminant concentrations, including metals such as zinc, iron and manganese on the northern side of the Rose Creek valley, in particular near the Faro Creek canyon (e.g. at P03-06). The recent breakthrough of these contaminants at depth (at P03-06) further supports this hypothesis. If correct, interception of this Faro Creek seepage is directly tied to closure of the Rose Creek Tailings Facility. Note that a significant portion of the Faro Creek seepage is now (since spring 2007) collected immediately downstream of the ETA area and pumped directly into the Intermediate Pond. The efficiency of this seasonal (interim) collection system and its influence on the groundwater quality in the Rose Creek aquifer should be assessed to assist in closure planning for the Rose Creek tailings facility;

4 GRUM & VANGORDA MINE SITE

4.1 Geographic Overview

Figure 4-1 shows the general layout of the Grum/Vangorda mine site, including the mine waste units and all available groundwater monitoring wells in the area. The Grum site comprises the Grum Pit, Grum rock dump (with suphide cell) and the Overburden stockpile. The Vangorda site comprises the Vangorda Pit (with in-pit rock dumps) and the Vangorda rock dump. Those monitoring wells routinely sampled as part of the ARMC groundwater quality monitoring program are shown in red. Monitoring wells no longer monitored are shown in yellow and abandoned/broken wells are shown in white.

Groundwater monitoring is generally concentrated in two specific geographic areas:

- Along the toe of the Grum rock dump; and
- Along the toe of the Vangorda rock dump.

In the following we review the recent time trends in groundwater water quality in these two geographic areas.

4.2 Downstream of Grum Rock Dump

4.2.1 Background

Figure 4-2 shows the locations of the monitoring wells located downgradient of the Grum rock dump and Table 4-1 lists pertinent information of those monitoring wells, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Historically, only one set of nested monitoring wells (P96-9A/B) was available for groundwater monitoring in this area (Robertson GeoConsultants Inc., 1996). However, several additional monitoring wells were completed along the toe of the Grum rock dump in 2004 and 2005 to assess local hydrogeologic conditions and to provide better spatial coverage for future groundwater monitoring (SRK Consulting, 2006a, 2007b).

The most recent review of groundwater quality time trends in the Grum area was completed in 2004, i.e. prior to installation of the recent monitoring wells (Robertson GeoConsultants Inc., 2004). The 2005 seepage investigation report also provided initial water quality results from the 2004 and selected 2005 monitoring wells (up to November 2005) (SRK Consulting, 2007a).

Table 4-1
Monitoring wells downgradient of Grum Rock Dump.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Grum WRD Area							
P96-9A	1996	9.5	4.96	9.45	~1098	bi-annual	Overburden
SRK04-5A	2004	23.7	22.7	23.7	1103.93	bi-annual	BR (weathered)
SRK04-5B	2004	14.7	13.7	14.7	1103.95	bi-annual	Overburden
BH05-9B-R	2005	18.6	15.5	18.6	1101.06	bi-annual	Overburden/BR
SRK05-05C	2005	3.2	1.5	3	1104.08	bi-annual	Overburden
SRK05-06 ("Moose Well 1")	2005	2.7	0.7	2.7	1073.83	bi-annual	Overburden
SRK05-07	2005	5.8	0.75	5.8	1107.30	bi-annual	Overburden/BR
SRK05-08	2005	7.6	2.1	7.6	1105.25	bi-annual	Overburden
SRK05-09 ("Moose Well 2")	2005	3.7	0.5	3.5	1072.82	bi-annual	Overburden

4.2.2 Review of Time Trends

Figure 4-2a/b shows selected water quality time trends for the monitoring wells located near Grum Creek and downgradient of the Moose Pond. Note that SRK-05-08 and 09 are also referred to as "Moose Well" 1 and 2, respectively. The following observations can be made:

Near Grum Creek (SRK04-5A/B; SRK05-05C):

- Monitoring well SRK05-05C, screened in shallow alluvial sediments, was only sampled once (in September 2006); groundwater in those shallow sediments showed slightly elevated sulphate (~400 mg/L), magnesium (57 mg/L), and alkalinity (240 mg/L CaCO3eq); metal concentrations were also slightly elevated metal concentrations (Fe ~1.2 mg/L, Mn ~4.0 mg/L and Zn ~0.02 mg/L) suggesting impact from waste rock seepage (Grum Dump);
- The two deeper, artesian monitoring wells (SRK04-5A/B), screened in coarse sediments and weathered bedrock, respectively, show very little, if any impact from waste rock seepage: groundwater in these deeper, confined layers has an alkaline pH (~8.0) and comparatively low concentrations of sulphate (~100 mg/L), magnesium (16 mg/L), and alkalinity (~140 mg/L); zinc concentrations are detectable but generally very low (<0.01 mg/L) (Note: the high zinc concentration (0.4 mg/L) reported for SRK-05-04 in June 2006 is likely in error);

Downstream of Moose Pond (SRK05-06; SRK05-09):

- Monitoring wells SRK05-06 (Moose Well 1) and SRK05-09 (Moose Well 2) are both screened in shallow colluvium, between "Moose Pond" and Vangorda Creek; groundwater in those shallow soils shows significant seasonal variation, for example, sulphate concentrations range from ~200-400 mg/L in the winter months to ~800 mg/L in the summer/fall; similar seasonal variations are observed for magnesium and alkalinity; in

contrast, metal concentrations have remained low throughout the year (Zn <0.01 mg/L; Fe <0.1 mg/L and Mn <0.01 mg/L) and do not show similar seasonal fluctuations[4];

The seasonal increases in ARD products (SO4, Mg, alkalinity) in SRK05-09 ("Moose Well 2") are likely a result of seepage from the Moose Pond (station V2A) which collects seepage from the Grum Rock Dump. The Grum Creek seepage entering the Moose Pond shows similar seasonal variations to those observed in the Moose Well 2, with sulphate values ranging from ~400 mg/L in the spring to 800-900 mg/L in the summer/fall. Note that the Grum Creek seepage shows elevated zinc concentrations (up to 1 mg/L). The lack of elevated zinc concentrations in SRK05-09 suggests that zinc is still being attenuated in these shallow sediments.

Figure 4-3a/b shows selected water quality time trends for the monitoring wells located downgradient of the Grum rock dump (west of Grum Creek). Note that the older well P96-9B was damaged (pinched) and was replaced in 2005 by the replacement well "BH05-9-BR". The time trends in those wells located west of Grum Creek can be summarized as follows:

- Monitoring well P96-9A, screened in shallow, alluvial sediments in a narrow side drainage, has shown a significant increase in ARD products (sulphate, magnesium, alkalinity) since about year 2000; at present, sulphate concentrations are around 1,600 mg/L, magnesium concentrations are ~300 mg/L and alkalinity is around 450-500 mg/L CaCO3eq; the observed increases are clear evidence of seepage from the Grum waste rock dump; note that metal concentrations have remained near or below the detection limit (Fe ~0.1 mg/L, Mn ~0.1 mg/L and Zn <0.1 mg/L) throughout the observation period indicating natural attenuation of these metals along the flow path;
- Monitoring well P96-9B (and more recently BH05-9B-R), screened in deeper till-like sediments and weathered bedrock, show very little, if any impact from waste rock seepage: groundwater in these deeper wells has virtually the same composition as observed in the deeper wells located further west at Grum Creek (see SRK04-05A/B discussed above);
- The two monitoring wells located further east (SRK05-07 and SRK05-08) are screened in shallow phyllite bedrock; groundwater in those shallow wells also shows elevated concentrations of ARD products (SO4, Mg and alkalinity) and trace concentrations of metals as observed further west at P96-09A and indicative of neutralized waste rock dump seepage; note that both of these shallow wells showed significant variations in the first three sampling events which may be related to the poor yield of these shallow bedrock wells; further monitoring will be required before an analysis of significant time trends will be possible.

4.2.3 Implications for Closure Planning

The more recent groundwater monitoring data confirm earlier interpretations for this area which had suggested that seepage from the Grum rock dump is responsible for the gradual increase in ARD

[4] Note that zinc concentrations for "Moose Well 2" are consistently lower by about an order of magnitude compared to zinc concentrations observed in SRK05-09 (i.e. the same well sampled/analysed by different programs); this discrepancy suggests significant systematic errors in one of the two programs and should be investigated

products (SO4, Mg and Zn) in shallow groundwater draining towards Vangorda Creek. The more recent monitoring data also support earlier conclusions that metal concentrations (in particular zinc) are (still) attenuated along the flow path. It can therefore be concluded that seepage interception along the toe of the Grum rock dump is not yet required but will likely be required in the future (when the attenuation capacity is exhausted).

The new deeper monitoring wells drilled in 2004 near Grum Creek and in 2005 at P96-9B also confirmed that seepage from the Grum rock dump appears to be limited to fairly shallow depth. In other words, a shallow seepage interception system may be adequate for the Grum rock dump area, at least until such time that a breakthrough of waste rock seepage is also observed in the deeper sediment/bedrock units.

The two new monitoring wells completed to the east of P96-9 into shallow bedrock indicate that waste rock seepage is not limited to the distinct drainage lines of Grum Creek and P96-9 but likely occurs along much of the toe of Grum rock dump. Unfortunately, the SONIC rig was not suitable for drilling and hydraulic testing at greater depth in bedrock. Drilling observations suggest that the shallow bedrock has a low permeability and does not transmit significant groundwater flow. This would suggest that seepage interception further east, where soils are either very shallow or completely absent, may not be required. However, additional hydraulic testing of the shallow bedrock in this area will be required to further assess the requirements for seepage interception in the shallow bedrock to the east of P96-9.

4.2.4 Recommended Modifications to the Water Quality Monitoring Program

The following recommendations are provided for modifications to the groundwater quality monitoring program downgradient of the Grum Rock Dump:

- Monitoring wells SRK05-04A/B are difficult to sample due to artesian conditions (which require a Margo plug) and may potentially be compromised due to problems during installation (difficulties with sealing the bore annulus); furthermore, groundwater quality in those wells is very similar to that observed at near-by BH05-9B-R. These wells should therefore no longer be sampled as part of the routine groundwater quality monitoring program; Note, however, that these wells should **NOT** be decommissioned to allow future sampling for targeted investigations, if required.
- Monitoring well SRK05-06 (“Moose Well #1”) is also considered redundant (providing the same information as near-by SRK-05-09 (“Moose Well #2”) and should therefore also no longer be sampled as part of the routine groundwater quality monitoring program. Note, however, that this well should **NOT** be decommissioned to allow future sampling for targeted investigations, if required.

In addition, the following monitoring data are missing in the current version of the Faro water quality data base and should be added;

- The results of the initial rounds of groundwater quality sampling at SRK-04-05A/B completed in September 2004 and May 2005 and reported in SRK Consulting (2006a, 7b);
- The results of the initial round of groundwater quality sampling at SRK-05-05C completed in November 2005 and reported in SRK Consulting (2007b);

Finally, as observed in other areas, detection limits (MDL) for zinc analyses were oftentimes too high (as high as 0.025 mg/L) to allow a meaningful assessment of zinc time trends in this area. An attempt should be made to reduce the MDL for zinc (to <0.005 mg/L) by switching the method of analysis and/or the laboratory.

4.3 Vangorda WRD area

4.3.1 Background

Figure 4-4 shows the locations of the monitoring wells located downgradient of the Vangorda Rock Dump and Table 4-2 lists pertinent information of those monitoring wells, including year of construction, installation details (total depth, screening interval) and status of monitoring.

Table 4-2
Monitoring wells downgradient of Vangorda Rock Dump.

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Vangorda WRD Area							
V34	1994	12.5	n/a	n/a	1117.45	bi-annual	BR
V35	1994	15.5	n/a	n/a	1117.41	bi-annual	Alluvium
V36	1994	11.9	n/a	n/a	1118.43	bi-annual	Alluvium
V37	1994	14.1	n/a	n/a	1116.17	bi-annual	Alluvium
P2001-02A	2001	13.6	n/a	n/a	~1118	bi-annual	n/a
P2001-02B	2001	27.0	n/a	n/a	~1118	bi-annual	n/a
P2001-03	2001	n/a	n/a	n/a	~1121	bi-annual	n/a

Monitoring of groundwater quality at the Vangorda Rock Dump commenced in 1994 with the installation of four “GW-94” wells along the toe of the Vangirda Rock Dump (SRK-Robinson, 1994). In 2001, three additional piezometers were installed further downgradient towards Vangorda Creek (“P2001” wells).

The most recent review of groundwater quality time trends in the Vangorda area was completed in 2004 (Robertson GeoConsultants Inc., 2004).

4.3.2 Review of Time Trends

Figure 4-5a/b shows selected water quality time trends for the monitoring wells located downgradient of the Vangorda Rock Dump. The following observations can be made:

- Most monitoring wells located downgradient of the Vangorda Rock Dump show some increase in ARD products (primarily SO4 and Mg) suggesting impact from waste rock seepage; however, the degree of impact varies among the different wells:
    - Monitoring well V35 shows the highest impact with sulphate and magnesium concentrations recently (May 2007) reaching 1,700 mg/L SO4 and 300 mg/L Mg, respectively. alkalinity concentrations have also increased markedly in 2006/07 (600-700 mg/L CaCO3eq); zinc concentrations have also increased in recent years

reaching a high of 0.113 mg/L in September 2006; (note, however, that zinc was below the detection limit in May 2007);

- Monitoring well V36 has also shown a significant increase in sulphate, magnesium and zinc but peak concentrations are still well below those observed at V35 (SO4~ 700 mg/L; Mg ~160 mg/L, Zn ~0.05 mg/L);
- Monitoring well V34 and the "P01" wells all show a similar trend of only slightly increasing concentrations of sulphate and magnesium (reaching ~100-300 mg/L SO4 and ~85-100 mg/L Mg); however, metal concentrations (including zinc) have remained very low (e.g. Zn < 0.01 mg/L, Mn < 0.1 mg/L);
- Monitoring well V37 has not shown any increase in ARD products (SO4, Mg, metals) since start of monitoring in 1994;

The gradual increases of sulphate, magnesium and zinc (in particular in V35 and V36) in the Vangorda wells clearly demonstrate that ARD seepage from the Vangorda rock dump is gradually recharging the local groundwater in the underlying till. Note, however, that most of the monitoring wells, in particular those clearly impacted, are located in close proximity of the toe of the waste rock dump. Hence, while contaminant concentrations in some Vangorda wells are now of similar magnitude than those observed at the Grum rock dump, travel times are inferred to be significantly slower than at Grum. This observation is consistent with the presence of thick deposits of low permeability tills at Vangorda compared to more permeable alluvial sediments, at least in some drainage channels, at Grum.

4.3.3 Implications for Closure Planning

The more recent groundwater monitoring data confirm earlier interpretations for this area which had suggested that seepage from the Vangorda rock dump is gradually impacting the groundwater residing in the till deposits underlying the Vangorda rock dump and draining towards Vangorda Creek. The more recent monitoring data also support earlier conclusions that groundwater impacts are generally more delayed at Vangorda, compared to anywhere else at the Anvil Range Mining Complex, due to the low permeability of the local till deposits. It can therefore be concluded that seepage interception along the toe of the Vangorda rock dump is not yet required and generally has a lower priority than elsewhere on the site.

Nevertheless, the recent increases of contaminants of concern (COCs) in at least two monitoring well (V35 and V36) at Vangorda raise the possibility that seepage interception in the local groundwater system may be required at some time in the future. At present, the closure options for Vangorda include a set of groundwater interception wells ("contingency wells") for the in-situ closure option (SRK, 2006). To the best of the author's knowledge, no hydrogeologic investigations have yet been completed in the Vangorda area to support the design of a seepage interception system. Considering the recent increases in contaminant concentrations at the toe of the Vangorda rock dump, a preliminary design study should be completed to assess the options for seepage interception for the Vangorda rock dump in more detail. Initially, a desktop study should be compiled to re-evaluate the existing hydrogeologic information (local lithology, hydraulic properties) for the area. If required, additional field work (drilling and/or hydraulic testing) should be carried out to fill any data gaps.

Based on these results, a conceptual design of a seepage interception system for the Vangorda rock dump area should be completed.

4.3.4 Recommended Modifications to the Water Quality Monitoring Program

At present, seven monitoring wells are routinely monitored downgradient of the Vangorda waste rock dump. In the author's opinion, all monitoring wells in this reach should be retained in the routine monitoring program.

5 REVIEW OF GROUNDWATER QUALITY MONITORING PROGRAM

One objective of this study was to provide an independent review of the current scope of groundwater quality monitoring and to recommend changes, if required. In the following we will provide recommendations for future routine monitoring at the Anvil Range Mining Complex (ARMC), including the number of wells routinely sampled, the sampling frequency and the suite of parameters to be analysed. It should be noted that these recommendations are based on technical merit only (as judged by the author) and do not take into account any regulatory requirements for sampling (as part of the current water licence and/or AMP procedures). A review of those legal requirements and any reconciliation between legal requirements and our recommendations was beyond the scope of this review.

5.1 Proposed Scope of Routine Groundwater Monitoring

5.1.1 Proposed "Routine" Monitoring Wells

As outlined in earlier sections, the number of monitoring wells currently monitored is very high and some rationalization is justified. Recommendations for monitoring wells to be retained in the routine monitoring program have already been provided in the context of the respective reaches of the ARMC.

Tables 5-1 to 5-3 summarize the selected monitoring wells, listed by reach, which are proposed for future routine groundwater monitoring at the Anvil Range Mining Complex. The proposed list includes 38 monitoring wells at the Faro mine site, 29 monitoring wells (including 7 multilevel wells) at the Rose Creek Tailings site and 13 at the Grum/Vangorda site.

Note that several monitoring wells routinely monitored at present (including several multilevel wells located within the Rose Creek Tailings Facility) have not been selected for future routine monitoring. As outlined earlier, those wells should **NOT** be decommissioned to allow future sampling for targeted investigations, if required.

5.1.2 Proposed Monitoring Frequency

Tables 5-1 to 5-3 also show the proposed frequency of groundwater monitoring for each monitoring well. We propose to introduce two different sampling regimes:

- Bi-Annual Sampling (Spring and Fall); and
- Annual Sampling (Fall only)

We propose to continue bi-annual sampling (once in May/June and once in September/October) in all wells listed as part of the existing water licence and in other selected monitoring wells located at strategic locations where there is a specific concern of groundwater impact to a near-by creek. The monitoring requirements for those wells are generally more stringent (higher frequency, more extensive suite of analytes) to ensure protection of the downstream surface water resource (creeks).

Monitoring wells selected for annual sampling represent those wells which, in the author's opinion, still require routine monitoring. However, these wells are located at less critical locations (typically upgradient of other compliance wells and/or at greater distance from a creek) so that the monitoring

requirements can be relaxed. Note that annual sampling is proposed for all (retained) multi-level wells located within the foot print area of the tailings impoundments. In the author's opinion, this is adequate considering the presence of additional monitoring wells located further downgradient (i.e. at the Intermediate and Cross Valley Dam).

Table 5.1.

Proposed List of Monitoring Wells for Faro Mine Site

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Faro Mine Site					
P96-8B	ETA Area	6913898	583328	bi-annual	Full
SRK04-3A	ETA Area	6913824	582977	Annual	Reduced
SRK05-ETA-BR1	ETA Area	6913846	582972	Annual	Reduced
SRK05-ETA-BR2	ETA Area	6913825	582987	Annual	Reduced
S1A	S-cluster Area	6912942	584539	bi-annual	Full
S1B	S-cluster Area	6912942	584539	bi-annual	Full
S2A	S-cluster Area	6912944	584577	bi-annual	Full
S2B	S-cluster Area	6912944	584577	bi-annual	Full
S3	S-cluster Area	6912918	584585	bi-annual	Full
P96-7	S-cluster Area	6913105	584225	bi-annual	Full
SRK05-SP-1A	S-cluster Area	6912901	584727	Annual	Reduced
SRK05-SP-1B	S-cluster Area	6912901	584726	Annual	Reduced
SRK05-SP-2	S-cluster Area	6912861	584791	Annual	Reduced
SRK05-SP-3A	S-cluster Area	6912924	584651	Annual	Reduced
SRK05-SP-3B	S-cluster Area	6912924	584652	Annual	Reduced
SRK05-SP-4A	S-cluster Area	6912939	584612	bi-annual	Full
SRK05-SP-4B	S-cluster Area	6912939	584611	bi-annual	Full
SRK05-SP-5	S-cluster Area	6912956	584576	bi-annual	Full
SRK05-SP-6	S-cluster Area	6912975	584492	Annual	Reduced
BH1	Zone 2 Outwash	6913532	585267	bi-annual	Full
BH2	Zone 2 Outwash	6913523	585206	bi-annual	Full
BH4	Zone 2 Outwash	6913467	585247	bi-annual	Full
BH5	Zone 2 Outwash	6913377	585194	bi-annual	Full
BH6	Zone 2 Outwash	6913466	585198	bi-annual	Full
BH8	Zone 2 Outwash	6913599	585253	Annual	Full
BH10A	Zone 2 Outwash	6913533	585190	Annual	Full
BH10B	Zone 2 Outwash	6913533	585191	Annual	Full
P05-04	Zone 2 Outwash	6913475	585224	bi-annual	Full
Zone 2 Pumping Well (X26)	Zone 2 pit	6913770	584868	bi-annual	Full
BH12A	NE Dumps	6914068	585871	Annual	Full
BH12B	NE Dumps	6914068	585871	Annual	Full
BH13A	NE Dumps	6914339	585844	Annual	Full
BH13B	NE Dumps	6914339	585844	Annual	Full
BH14A	NE Dumps	6913826	585676	bi-annual	Full
BH14B	NE Dumps	6913826	585676	bi-annual	Full
P96-6	Intermediate Dump (NFRC)	6913133	584999	bi-annual	Full

Table 5.2

Proposed List of Monitoring Wells for Rose Creek Tailings Facility.

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Rose Creek Tailings Facility					
TH86-17	upgradient	6912489	583943	Annual	Full
P03-01 (all ports)	Second Impoundment	6912580	583301	Annual	Reduced
P03-03 (all ports)	Second Impoundment	6912698	583068	Annual	Reduced
P03-04 (all ports)	Second Impoundment	6913186	582085	Annual	Reduced
P03-06 (all ports)	Second Impoundment	6913309	582573	Annual	Reduced
X21A-96	Intermediate Impoundment	6913417	581989	Bi-annual	Full
X21B-96	Intermediate Impoundment	6913417	581989	Bi-annual	Full
P03-08 (all ports)	Intermediate Impoundment	6913514	580980	Annual	Reduced
X24D-96	Intermediate Dam	6914124	580655	Bi-annual	Full
X25A-96	Intermediate Dam	6913945	580519	Bi-annual	Full
X25B-96	Intermediate Dam	6913945	580519	Bi-annual	Full
P01-03	Intermediate Dam	6914071	580639	Bi-annual	Full
P01-04A	Intermediate Dam	6913893	580496	Bi-annual	Full
P01-04B	Intermediate Dam	6913893	580496	Bi-annual	Full
P01-02A	Cross Valley Dam	6914044	580051	Bi-annual	Full
P01-02B	Cross Valley Dam	6914044	580051	Bi-annual	Full
P01-11	Cross Valley Dam	6914306	580214	Bi-annual	Full
P03-09 (all ports)	Cross Valley Dam	6914229	580065	Bi-annual	Full
P05-01 (all ports)	Cross Valley Dam	6914335	580165	Annual	Full
P05-02	Cross Valley Dam	6914265	580144	Bi-annual	Full
P05-03	Cross Valley Dam	6914171	580088	Bi-annual	Full
X16A	Downgradient of CVD	6914672	579574	Bi-annual	Full
X16B	Downgradient of CVD	6914672	579574	Bi-annual	Full
X17A	Downgradient of CVD	6914475	579874	Bi-annual	Full
X17B	Downgradient of CVD	6914475	579874	Bi-annual	Full
X18A	Downgradient of CVD	6914539	580105	Bi-annual	Full
X18B	Downgradient of CVD	6914539	580105	Bi-annual	Full
P01-01A	Downgradient of CVD	6914675	579819	Bi-annual	Full
P01-01B	Downgradient of CVD	6914675	579819	Bi-annual	Full

Table 5.3

Proposed List of Monitoring Wells for Grum/Vangorda Mine Site

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency	Proposed Analysis Scheme
Grum/Vangorda Mine Site					
P96-9A	Grum Rock Dump	6903165	592753	Bi-annual	Full
BH05-9B-R	Grum Rock Dump	6903172	592747	Bi-annual	Full
SRK05-05C	Grum Rock Dump	6903208	592873	Bi-annual	Full
SRK05-07	Grum Rock Dump	6903011	592477	Bi-annual	Full
SRK05-08	Grum Rock Dump	6903063	592690	Bi-annual	Full
SRK05-09 ("Moose Well 2")	Grum Rock Dump	6902986	593058	Bi-annual	Full
V34	Vangorda Rock Dump	6902295	593553	Bi-annual	Full
V35	Vangorda Rock Dump	6902371	593293	Bi-annual	Full
V36	Vangorda Rock Dump	6902733	593243	Bi-annual	Full
V37	Vangorda Rock Dump	6902913	593420	Bi-annual	Full
P2001-02A	Vangorda Rock Dump	6902880	593098	Bi-annual	Full
P2001-02B	Vangorda Rock Dump	6902880	593098	Bi-annual	Full
P2001-03	Vangorda Rock Dump	6902865	593131	Bi-annual	Full

5.1.3 Proposed Suite of Analytes

At present all groundwater samples are analysed for a large suite of parameters, including physical tests (EC, pH, hardness), all major cations (Ca, Mg, Na, K) and major anions (SO4, alkalinity, Br), and an exhaustive list of dissolved metals (Ag, Al, As, B, Ba, Cr, Co, Cu, Fe, Pb, Li, Mn, Mo, Ni, Sb, Se, Sn, Tl, Ti, U, V and Zn).

A review of the existing groundwater quality database suggests that some of the dissolved metals currently analysed are either at or below the detection limit in nearly all monitoring wells (e.g. Hg, Sn, Ti) and/or occur at much lower concentrations than applicable standards (e.g. B, Ba, Mo). Hence, there is an opportunity to reduce the list of dissolved metal that should be routinely analysed. It is the author's understanding that applicable standards for the Anvil Range Mining Complex are currently being developed by others. We recommend, that the list of dissolved metals be reviewed (with the view to eliminate those trace metals which do not pose a risk of contamination at the Anvil Range Mining Complex) once water quality standards for the site have been finalized.

In the interim, we propose two different analysis schemes for the selected monitoring wells (c. Tables 5-1 to 5-3):

- A "full" scheme consisting of the same suite of parameters as currently analysed for all wells to be sampled bi-annually; and
- A "reduced" scheme consisting of the following parameters: lab-EC, lab-pH, Ca, Mg, Na, K, SO4, alkalinity, Fe, Mn, and Zn in most wells to be sampled annually.

The reduced scheme includes the main indicator parameters for both waste rock and tailings seepage (SO4, Mg, alkalinity) as well as the main metals of concern with high mobility in the groundwater environment (Fe, Mn, Zn). The analysis of other major ions is required to allow the performance of a charge balance analysis for QA/QC purposes (see above). Note that the anions chloride and nitrate only occur in trace concentrations (typically < 5 mg/L) in the groundwater at the Anvil Range Mining Complex and their analysis is therefore not required for the charge balance analysis and/or routine groundwater monitoring.

5.1.4 Detection Limits

As outlined earlier in this report, some groundwater samples of monitoring wells completed in the Rose Creek aquifer had elevated detection limits (MDL) for certain metals (in particular zinc). In the author's opinion, this is problematic as zinc is a key contaminant of concern and an early detection of increasing zinc concentrations (e.g. at the Cross Valley Dam) is a key objective of the groundwater monitoring program.

Discussions with a laboratory representative (Mr. Can Dang from ALS, Vancouver) indicated that the higher MDLs are a result of matrix interference (in particular Ca) with some metals (including zinc) if the ICPMS method is used. To avoid such interference, the laboratory routinely dilutes the samples prior to ICPMS analysis thus raising the MDL of the analysis. This interference is not an issue with the ICPOES method.

In the future, the laboratory should always use the method which provides the lowest MDLs for the metals of concern, in particular zinc, iron, and manganese. The use of the most appropriate analysis method should be checked as part of the QAQC procedures (see section 5.2 below).

5.2 QA/QC Procedures & Reporting

5.2.1 QA/QC Procedures

A detailed review of the QA/QC procedures and the "quality" of the existing database was beyond the scope of this review. Nevertheless, a few shortcomings were noted during data processing and plotting for this report:

- A significant number of samples show very high charge balance errors (CBE), often exceeding 50%; inspection of the time trends suggested that this high CBE is commonly a result of erroneous sulphate concentrations (likely reported too low by a factor of 10 as inferred from time trend checks); these errors were corrected in our time trend plots but should also be corrected in the Faro water quality database;
- Significant (up to 10-fold discrepancies were reported between field EC and lab EC measurements;
- Some samples show significant discrepancies between field pH and lab pH; while some discrepancy can be expected (e.g. decrease in pH during transport to the laboratory due to iron oxidation in reduced samples) some field pH readings are clearly in error (e.g. SRK-05-SP1A in June 06);

In order to avoid the future entry of erroneous data into the database the author recommends that the following additional QA/QC procedures be implemented:

- The charge balance error (CBE) of any given analysis should always be computed prior to entry of this analysis into the ACCESS data base; this analysis should always be performed within the holding time of the sample so that re-analysis can be requested in case of a poor CBE (>25%);
- For each analysis, the field EC readings should be compared to the laboratory EC readings; discrepancies of greater than 15% should be investigated and flagged in the database;
- For each analysis, the field pH readings should be compared to the laboratory pH readings; discrepancies of greater than one pH unit should be investigated and flagged in the database;
- For each analysis, the MDLs of the dissolved metal analyses of concern (in particular Zn, Fe and Mn) should be checked to ensure that the most appropriate analysis method was reported by the laboratory.

To the extent possible, these QA/QC procedures should be automated and integrated in the process of electronic data entry into the ACCESS database. For example, the charge balance analysis can easily be programmed into ACCESS so that only those analyses with an acceptable charge balance (say CBE<25%) will be accepted into the database. Those samples not meeting this criterion should be rejected and flagged for further manual checking.

The current QA/QC practices of field filtration/preservation (for dissolved metal analysis), duplicate sampling (field replicate and splits), and lab QA/QC samples are appropriate and should be retained in the future groundwater monitoring program.

5.2.2 Reporting

The results of the groundwater monitoring program should be reviewed each year by a qualified hydrogeologist/hydrogeochemist familiar with local site conditions. This annual report should include the results of the QA/QC analysis and a discussion of important trends in groundwater quality. For this purpose, time trend plots of all major contaminants of concern (including but not limited to SO4, Mg, Zn, Fe and Mn) should also be presented in the annual report.

6 CONCLUSIONS & RECOMMENDATIONS

Recent time trends in groundwater quality were reviewed in different reaches of the Anvil Range Mining Complex to re-assess the extent of groundwater impacts and implications for on-going closure planning. The following sections summarize the main conclusions and recommendations of this review (by reach), with emphasis on any recent changes in groundwater quality.

6.1 Faro Mine Site

The main conclusions of the groundwater quality review at the Faro Mine Site are as follows:

- The groundwater quality data collected in the Emergency Tailings Area (ETA) are generally consistent with the results of the Faro Creek seepage surveys which had concluded that the ETA area represents a major source of contaminant loading, both by surface and subsurface pathways. These findings support earlier conclusions that the ETA area should be a priority for seepage interception.
- The groundwater quality in the S-cluster area has deteriorated dramatically over the last five years. Of particular concern is the rapid increase in dissolved zinc concentrations which have increased by as much as 100 mg/L in the last 20 months (Sep 2005 to June 2007) in selected wells (e.g. S1A, S2B, S3). These recent time trends emphasize the need for seepage interception. Note that the affected monitoring wells are all in close proximity of the North Fork of Rose Creek and, hence there is a potential for significant increase in zinc concentrations in NFRC along this reach of NFRC. We therefore recommend that the impact of contaminated groundwater discharge into NFRC be re-assessed and that an action plan be developed on how to manage potential future increases in zinc concentrations in local groundwater in this area.
- Recent seepage investigations in the Zone 2 Outwash Area (completed in 2005) had indicated the presence of moderately impacted groundwater (primarily elevated zinc concentrations) in the permeable alluvial sediments of the NFRC valley. Monitoring over the last two years has confirmed this assessment implying that earlier estimates of zinc loading and the resulting requirement for seepage interception in this area have not changed.
- Groundwater quality downgradient of the Northeastern Dump (at BH14A/B) has shown recent increases in zinc concentrations, with peak concentrations around 0.4 to 0.5 mg/L zinc (observed in 2006). The observed increases in zinc concentrations were preceded by a systematic and substantial increase in sulphate, magnesium and alkalinity. Geochemical characterization work has identified sulphide-rich waste rock in this portion of the Northeast Dumps and it is possible that groundwater quality will continue to deteriorate in this area with sulphate and eventually zinc concentrations reaching similar concentrations as currentl.

6.2 Rose Creek Tailings Facility

The main conclusions of the groundwater quality review at the Rose Creek Tailings facility are as follows:

- Tailings pore water quality (in the tailings) has generally deteriorated further over the last three years, as evidenced by significant increases in sulphate, magnesium and metals (in particular zinc, manganese and iron). In most cases these increases were accompanied by a significant decrease in pH and alkalinity. These changes were particularly evident in the Second Impoundment (e.g. at P03-01, P03-02, P03-03, P03-05) but may also be present in other parts of the facility (e.g. coarse tailings beaches in the Original Impoundment) where no such detailed monitoring is available.
- Groundwater quality in the underlying Rose Creek aquifer has also significantly deteriorated in the last three years in all reaches of the Rose Creek Tailings Facility, i.e. not only within the foot print area of the tailings impoundments but also further downstream at the Intermediate Dam and the Cross Valley Dam. Of particular concern are the significant increases in sulphate, magnesium and metal concentrations (including iron, zinc and manganese) at greater depth in the aquifer, in particular in the northern portion of the aquifer (see for example P03-06, X21B, X24D). These recent time trends clearly indicate that the entire depth of the aquifer is affected by seepage from the tailings (and possibly the ETA area).
- The recent increases in oxidation products and metal concentrations in the northern portion of the Rose Creek aquifer are significant and their cause should be further investigated. The most likely sources of ARD seepage include (i) coarse tailings beaches located in the northern portion of the Intermediate, Second or Original Impoundments and/or seepage from the Faro Creek canyon/diversion channel. We recommend that a more detailed hydrogeologic and geochemical analysis be carried out, including assessment of hydraulic gradients and geochemical fingerprinting, to determine the cause for the recent deterioration in groundwater quality in this portion of the Rose Creek aquifer.
- Additional wells screened at shallow depth in the aquifer sediments underlying shallow tailings deposits (NA wells) show significantly elevated zinc concentrations (e.g. 22 mg/L at NA11) suggesting that the attenuation capacity of the tailings and/or organic soils underlying the tailings profile is slowly being exhausted; this process may explain the recent increases in zinc concentrations in many parts of the Rose Creek aquifer;
- Recent monitoring in multilevel well P03-03, located about 140m downgradient of the “leaky wells” P01-09A/B/C/D has shown a significant decrease in zinc concentrations at depth in the aquifer (P03-03-02, -03 and -04) in May 2007. This recent decrease may have been caused by decommissioning (sealing) of the “leaky wells” P01-09A/B/C/D in October 2005. However, additional monitoring will be required to confirm this initial assessment.

6.3 Grum/Vangorda Mine Site

The main conclusions of the groundwater quality review at the Grum/Vangorda mine site are as follows:

- Recent groundwater quality time trends observed in wells located downgradient of the Grum Rock Dump confirm earlier interpretations which had suggested that seepage from the Grum rock dump is responsible for the gradual increase in ARD products (SO4, Mg, and to a lesser extent Zn) in shallow groundwater draining towards Vangorda Creek. The more recent monitoring data also support earlier conclusions that metal concentrations (in particular zinc) are (still) attenuated along the flow path. It can therefore be concluded that seepage interception along the toe of the Grum rock dump is not yet required but will likely be required in the future (when the attenuation capacity is exhausted).
- The new deeper monitoring wells drilled in 2004 near Grum Creek and in 2005 at P96-9B also confirmed that seepage from the Grum rock dump appears to be limited to fairly shallow depth. In other words, a shallow seepage interception system may be adequate for the Grum rock dump area, at least until such time that a breakthrough of waste rock seepage is also observed in the deeper sediment/bedrock units.
- Recent monitoring of groundwater quality in wells located downgradient of the Vangorda Rock Dump supports earlier conclusions that groundwater quality impacts are generally more delayed at Vangorda, compared to anywhere else at the Anvil Range Mining Complex, due to the low permeability of the local till deposits. Nevertheless, one monitoring well (V35) has shown a recent increase in some contaminants of concern (SO4, Mg, Zn) raising the possibility that some seepage interception may also be required downgradient of the Vangorda Rock Dump at some time in the future. We therefore recommend that a preliminary design study be completed to assess the options for seepage interception downgradient of the Vangorda Rock Dump.

6.4 Recommendations for Future Groundwater Monitoring

One objective of this study was to provide an independent review of the current scope of groundwater quality monitoring and to provide recommendations for future groundwater monitoring, including the number of wells routinely sampled, the sampling frequency and the suite of parameters to be analysed.

Tables 5-1 to 5-3 summarize the selected monitoring wells, listed by reach, which are proposed for future routine groundwater monitoring at the Anvil Range Mining Complex. The proposed list includes 38 monitoring wells at the Faro mine site, 29 monitoring wells (including 7 multilevel wells) at the Rose Creek Tailings site and 13 at the Grum/Vangorda site.

We propose to introduce two different sampling and analysis regimes:

(i) Bi-Annual Sampling (with a “full suite” of analytes) in all wells listed as part of the existing water licence and in other selected monitoring wells located at strategic locations where there is a specific concern of groundwater impact to a near-by creek and

(ii) Annual sampling (with a “reduced suite” of analytes) in selected wells which are located at strategically less critical locations (typically upgradient of other compliance wells and/or at greater distance from a creek).

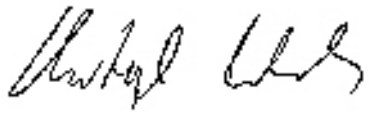
Additional recommendations for improved QA/QC procedures and reporting are provided in section 5.2 of this report.

7 CLOSURE

This report was prepared by Robertson GeoConsultants Inc., for Deloitte & Touche Inc. in its capacity as Interim Receiver of Anvil Range Mining Corporation. No third-party engineer or consultant shall rely on any of the information, conclusions, opinions, or any other material contained in this report without the express written consent of Deloitte & Touche Inc. and RGC.

We trust that the information provided in this report meets your requirements at this time. Should you have any questions or if we can be of further assistance, please do not hesitate to contact the undersigned.

Respectfully Submitted



Christoph Wels, Ph.D., M.Sc.
Principal & Senior Hydrogeologist

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582500 584000 585500 587000

6915000

6913500

Faro Valley Rock Dump

Northwest Rock Dump

Faro Pit

Faro Creek Diversion

Northeast Rock Dump

Guardhouse Creek

Mill Site

Main Rock Dump

Zone II (backfilled)

Intermediate Rock Dump

North Fork Rose Creek

1350 1280 1310 1360 1190 1280 1250 1240 1170 1120 1110 1090 1210 1200 1140 1110 1180 1130 1240 1190 1150 1120 1140

LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)
- Abandoned Well
- Drive Point
- Zone II Pit Outline

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2M

N W E S

Layout of Faro Mine Site

Anvil Range Mining Complex

SCALE

0 380 760 1,140 1,520 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Groundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

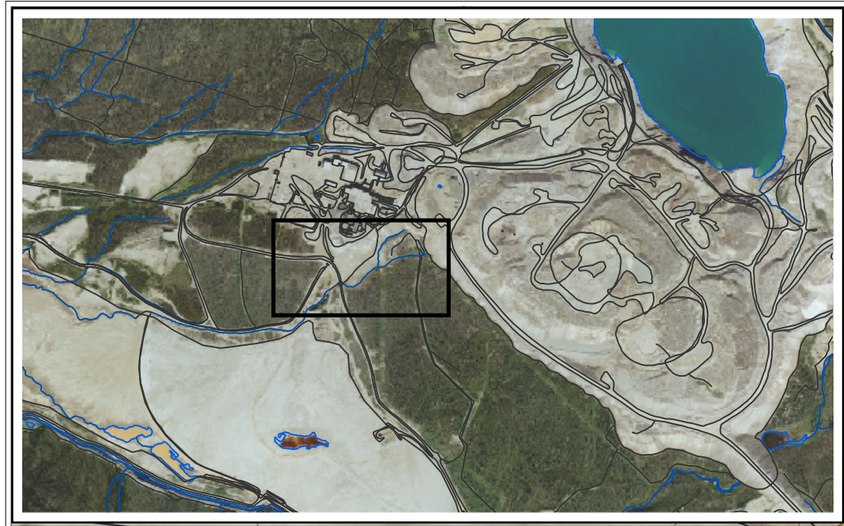
FIGURE: 2-1

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582800 583000 583200 583400

6914000

6913800



Mill Site

Main Rock Dump

Emergency Tailing Area (ETA)

ETA-05-1
ETA-05-5
ETA-05-2
ETA-05-4
SRK05-ETA-BR1
SRK04-4
SRK04-3B
SRK04-3A
SRK05-ETA-BR2
ETA-05-3

P96-8A
P96-8B

Faro Creek Canyon

1090 1100 1110 1120 1130 1140 1150 1160

LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

N W E S

Groundwater Monitoring Wells
ETA Area
Faro Mine Site

SCALE

0 25 50 100 150 200 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Goundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 2-2

DATE: Nov - 07
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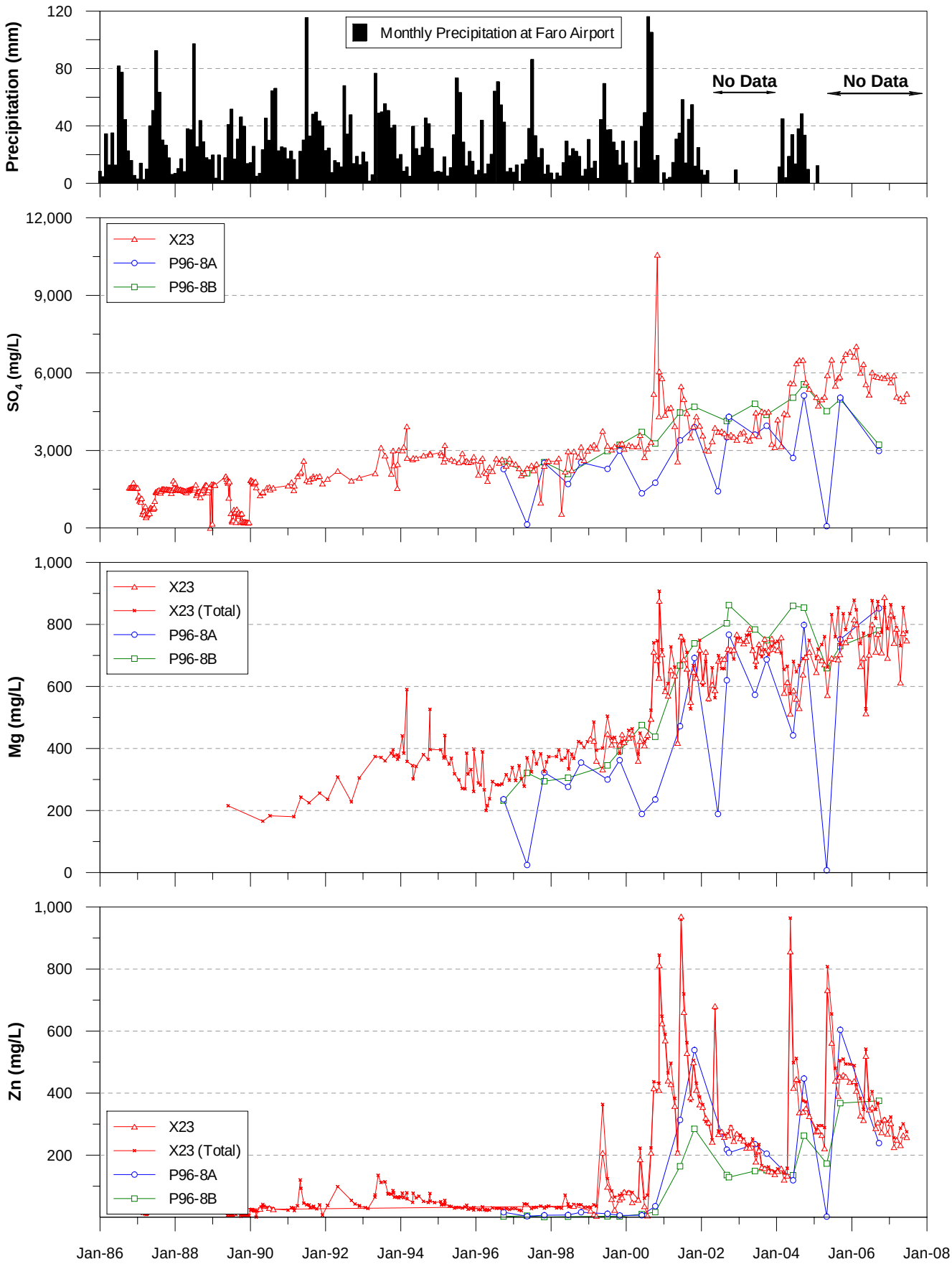


Figure 2-3a. Precipitation and water quality (SO_4, Mg and Zn) in X23 and P96-8A/B.

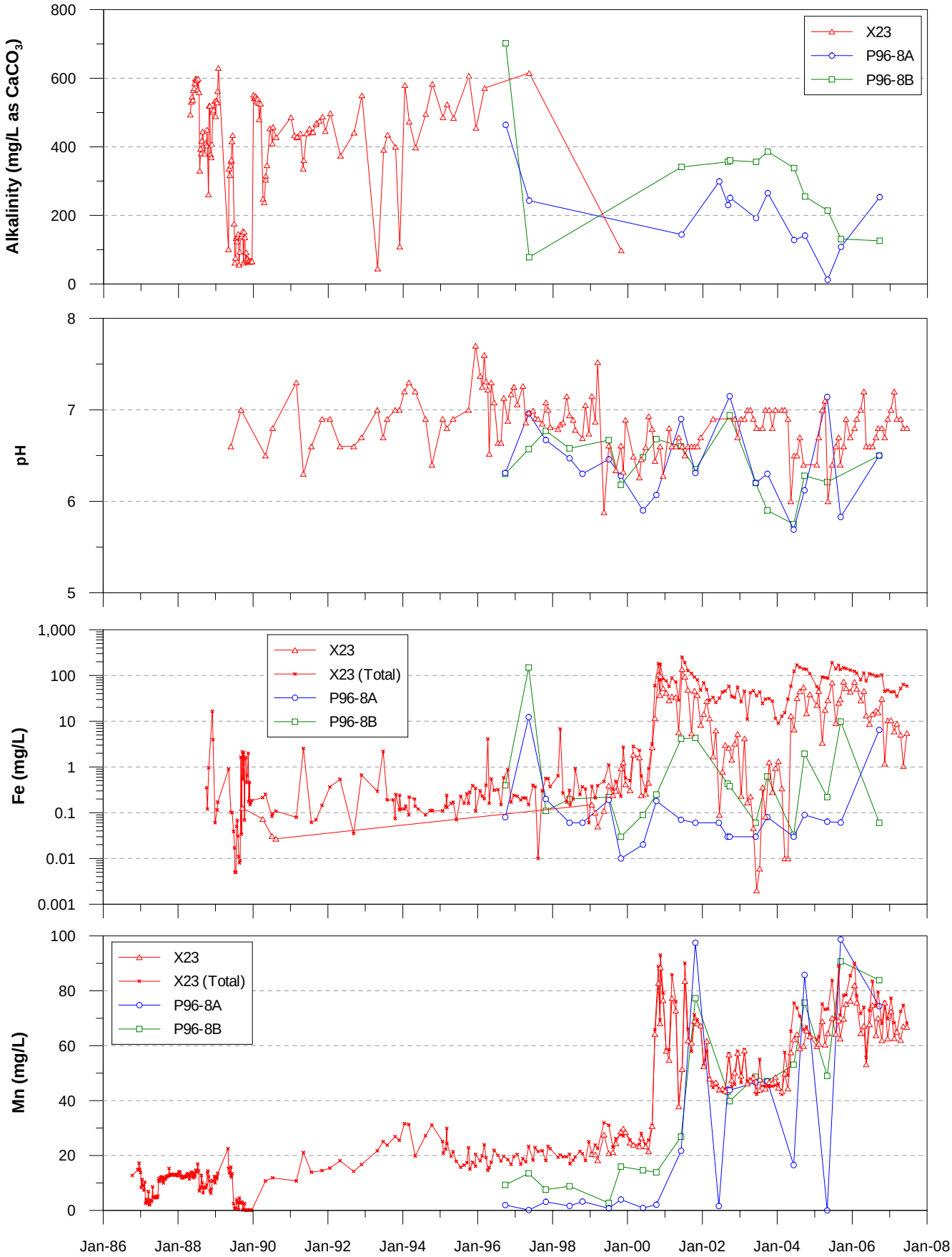


Figure 2-3b. Water quality (alkalinity, pH, Fe and Mn) in X23 and P96-8A/B.

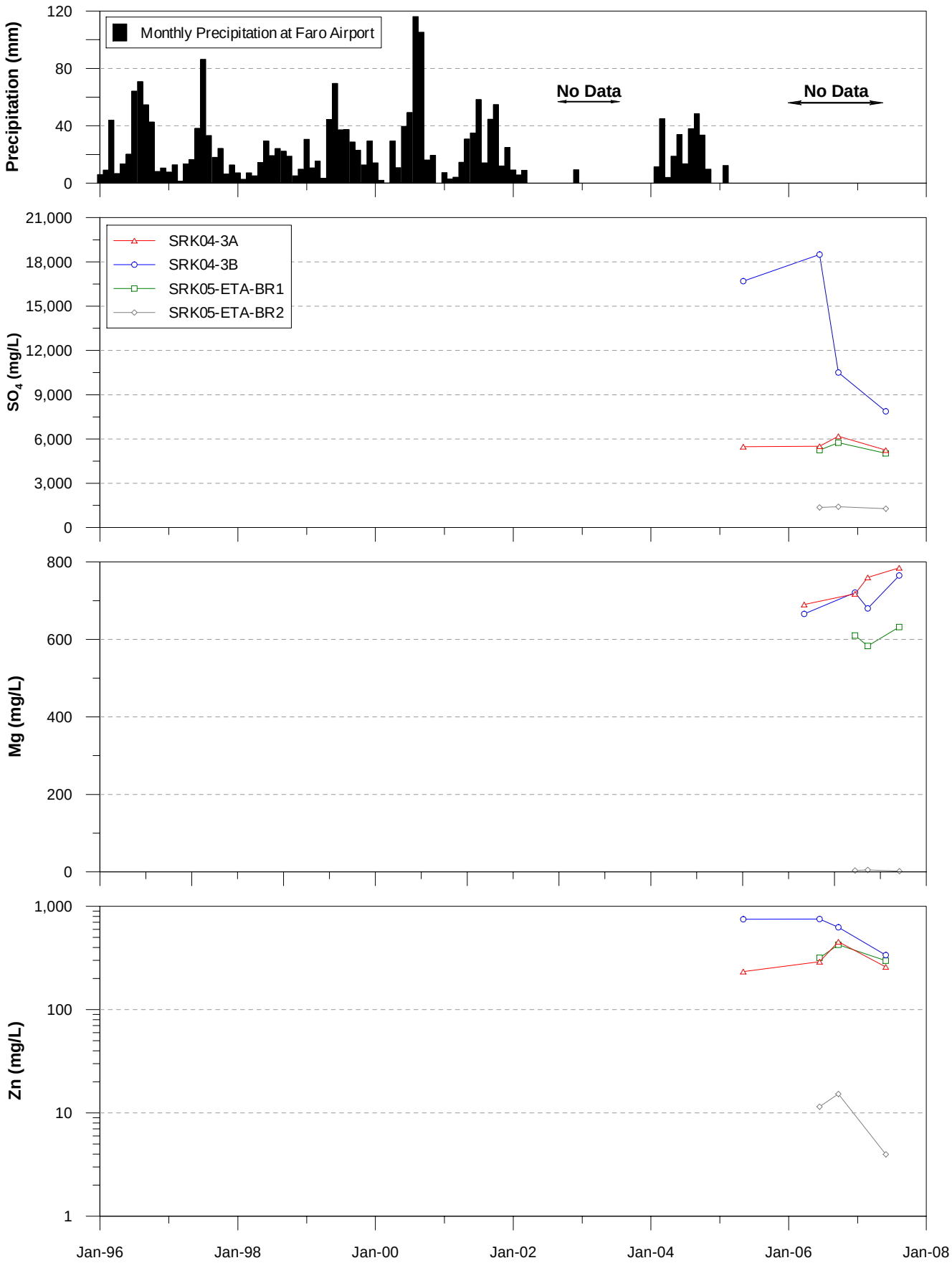


Figure 2-4a. Precipitation and water quality (SO_4, Mg and Zn) in SRK wells in ETA area.

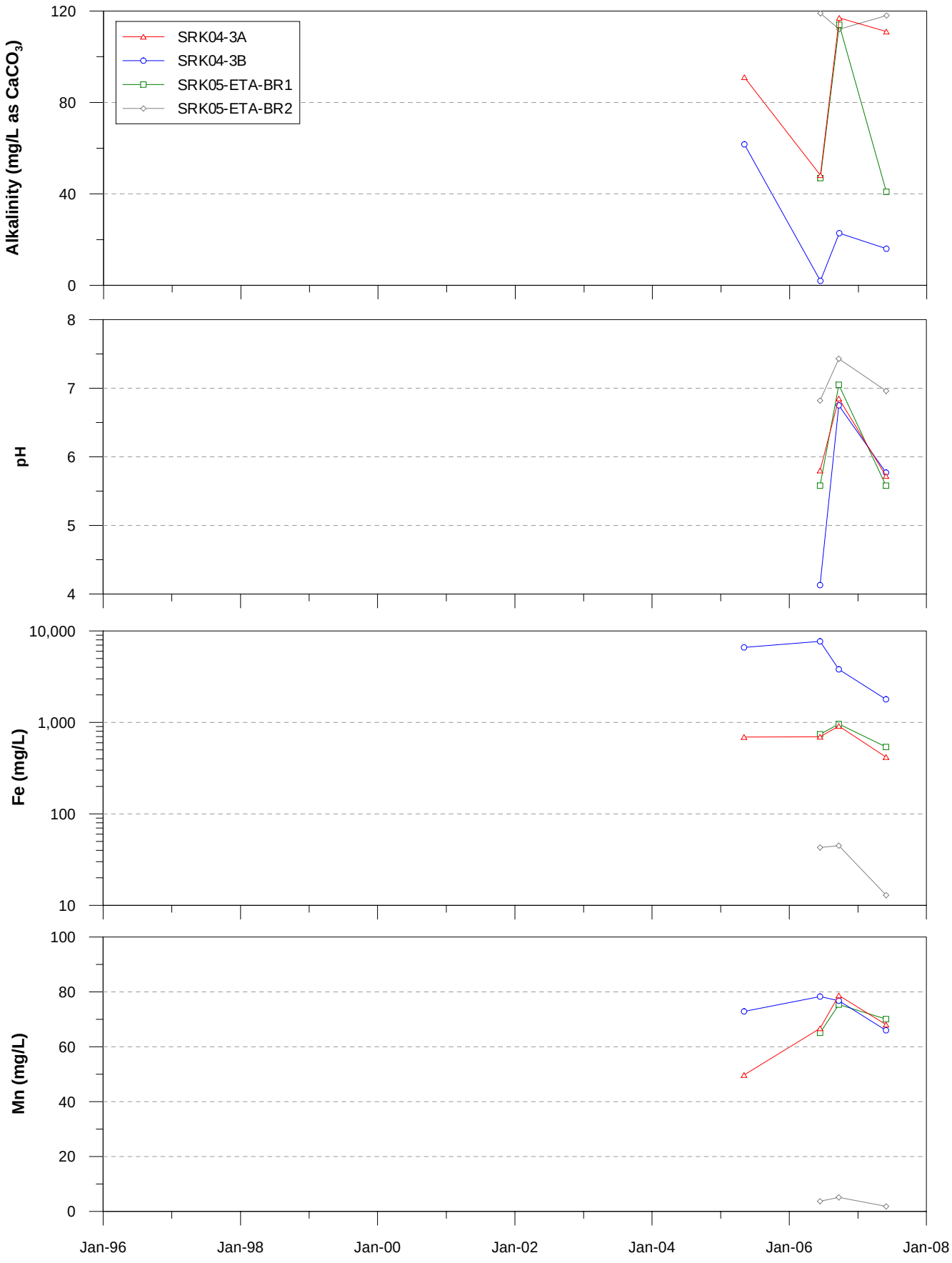


Figure 2-4b. Water quality (alkalinity, pH, Fe and Mn) in SRK wells in ETA area.

584200 584400 584600 584800

6913000

6912800

Intermediate Rock Dump

Outer Haul Road Rock Dump

Haul Road

P96-7

SRK05-SP-6

SRK05-SP-5

SRK05-SP-4B

SRK05-SP-4A

SRK05-SP-3B

SRK05-SP-3A

SRK05-SP-1B

SRK05-SP-1A

SRK05-SP-2

S1A

S1B

S2A

S2B

S3

DP4

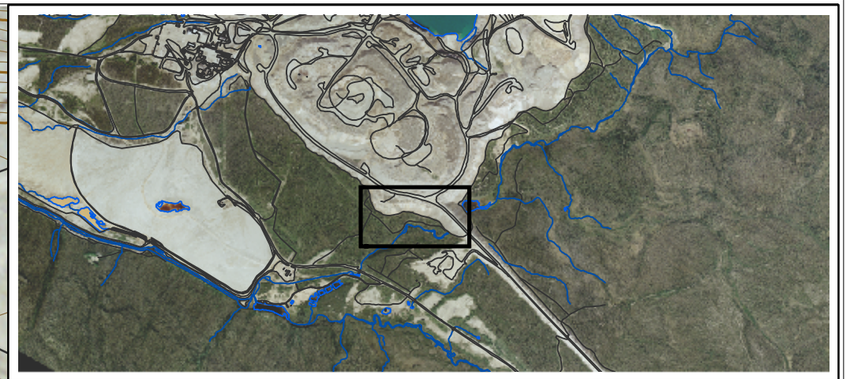
DP2

DP3

DP1

SRK04-2

1170 1150 1140 1120 1100 1090 1080



LEGEND

- Monitoring Well
- Abandoned Well
- Drive Point

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

N W E S

Groundwater Monitoring Wells
S - Cluster Area
Faro Mine Site

SCALE

0 25 50 100 150 200 Meters

Deloitte & Touche

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Groundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FIGURE: 2-5

DATE: Nov - 07
DRAWN BY: OM
FILE: Faro_S_Cluster.mxd

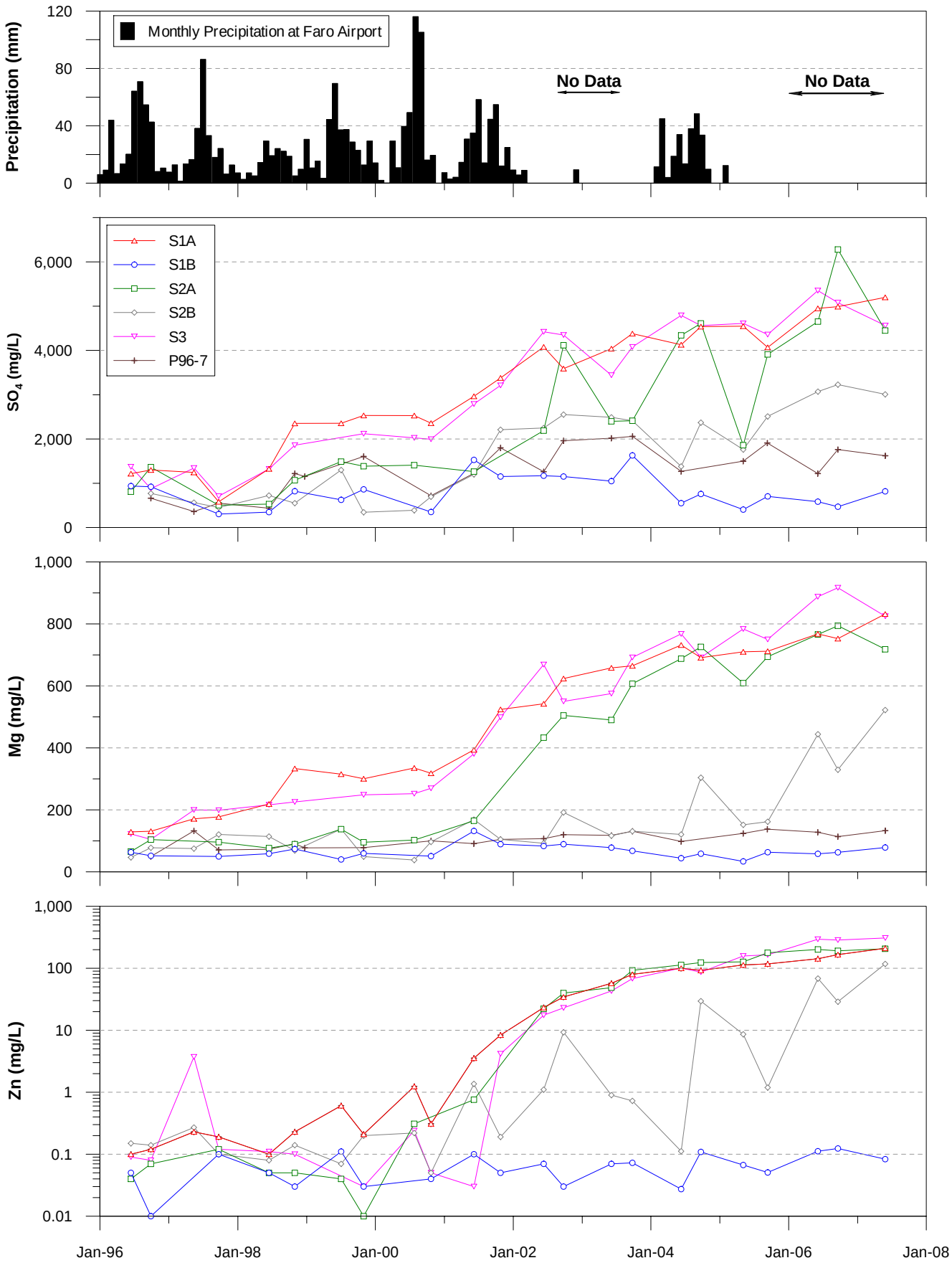


Figure 2-6a. Precipitation and water quality (SO_4, Mg and Zn) in S-Cluster Wells.

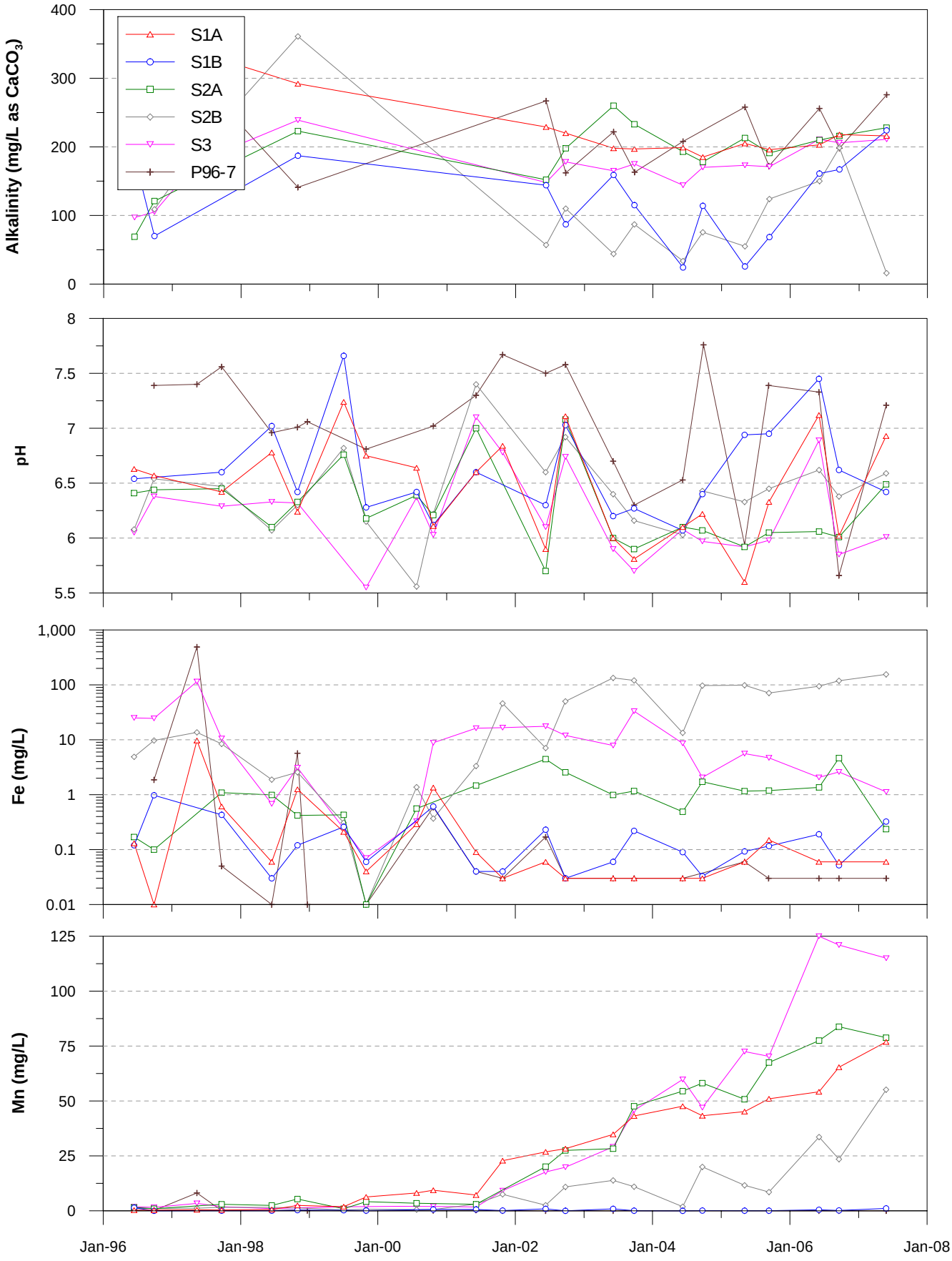


Figure 2-6b. Water quality (alkalinity, pH, Fe and Mn) in S-Cluster Wells.

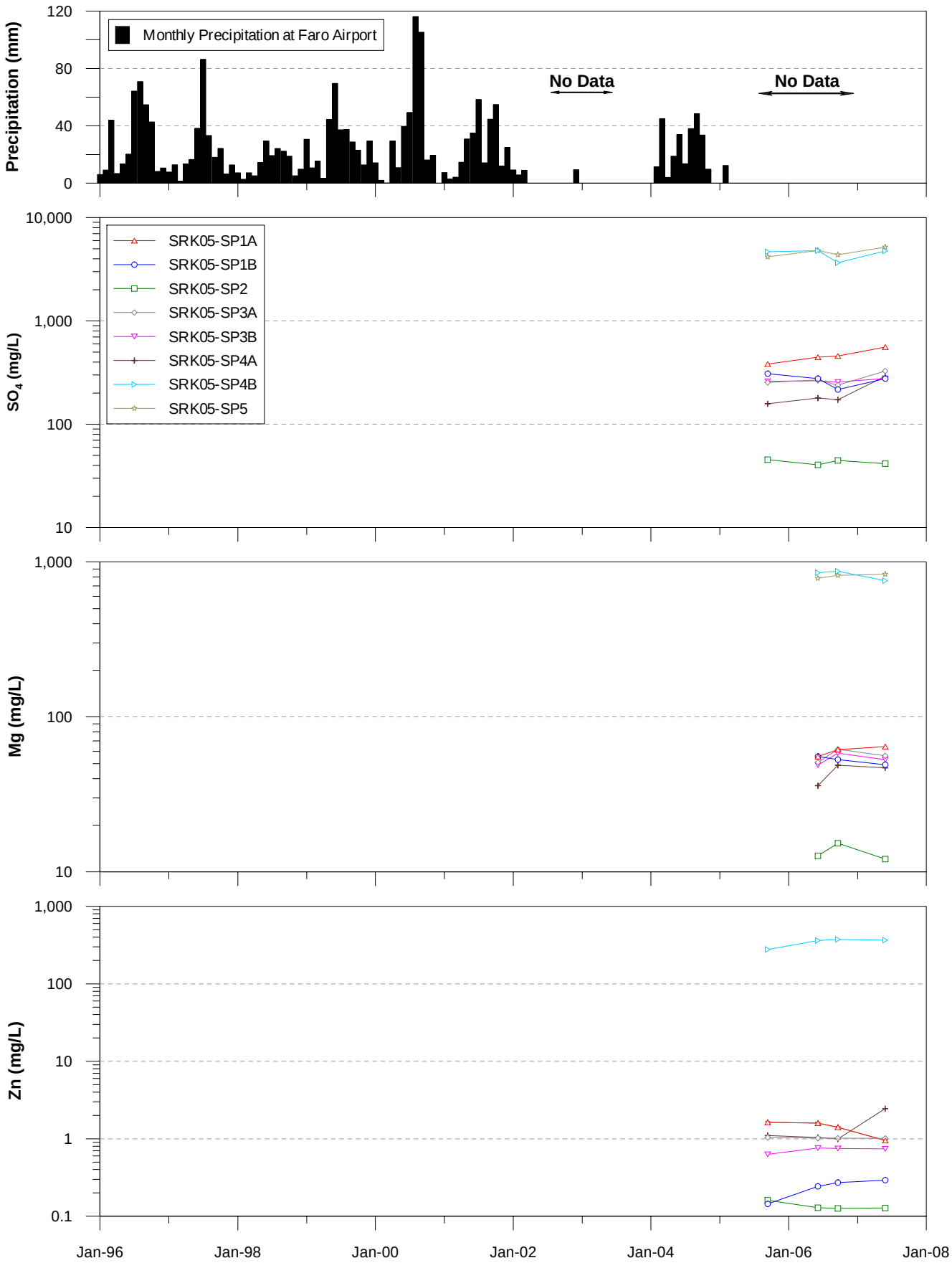


Figure 2-7a. Precipitation and water quality (SO_4, Mg and Zn) in SRK Wells in S-Cluster Area.

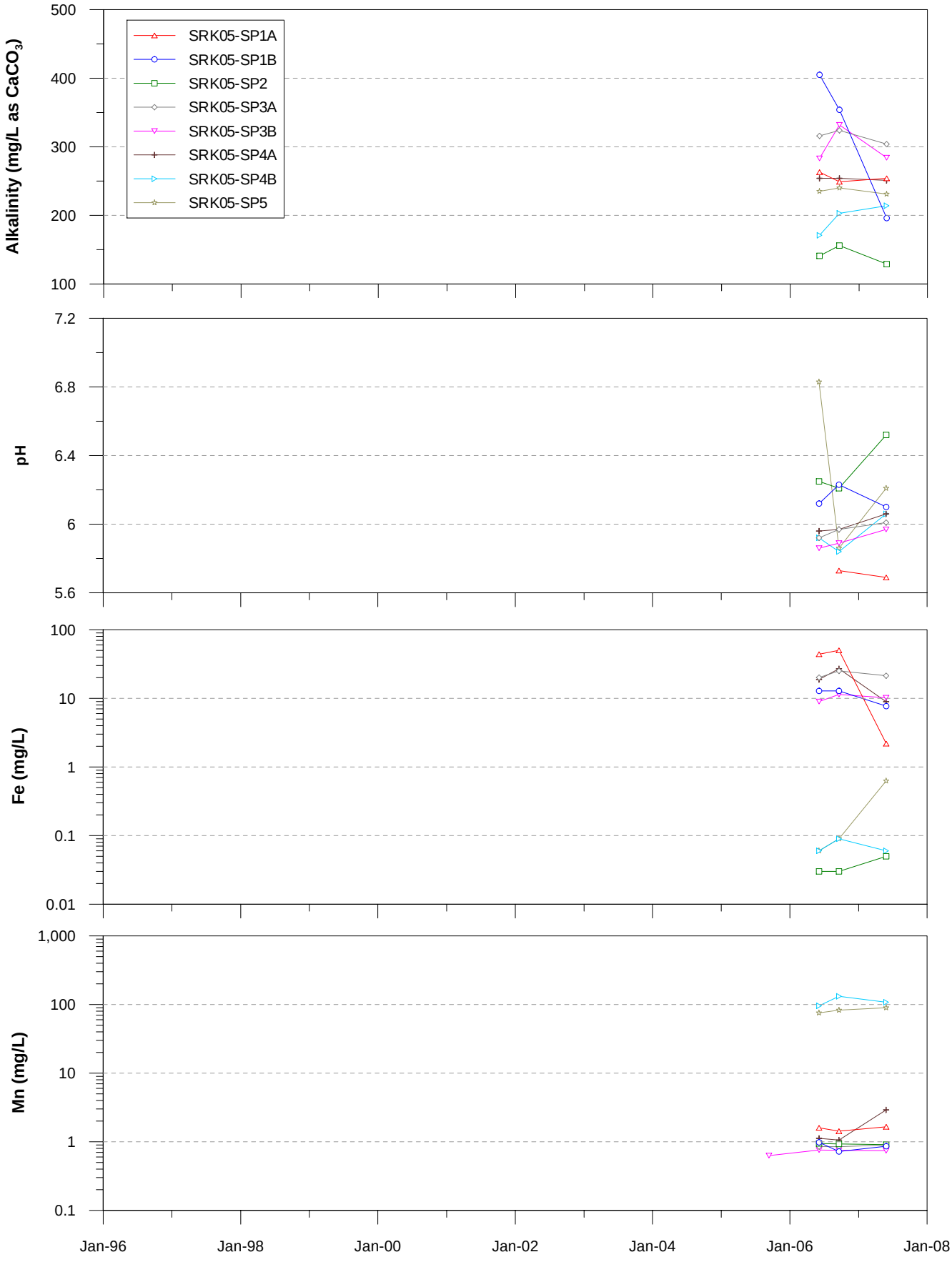
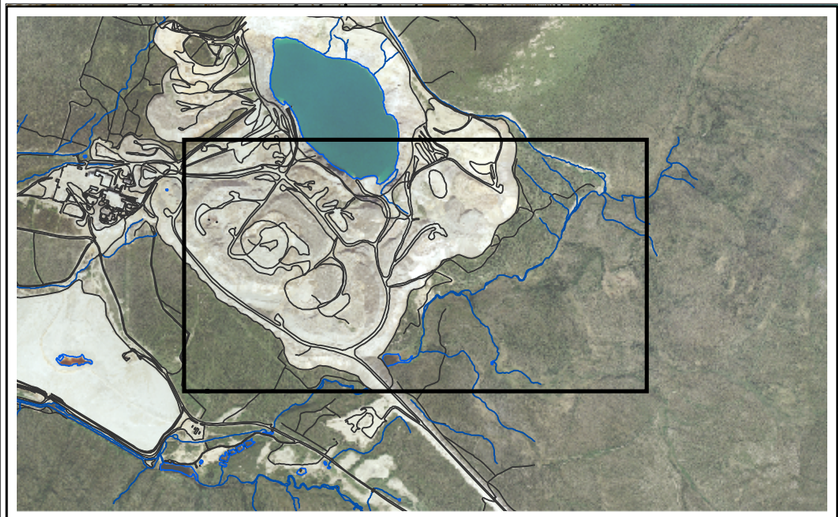


Figure 2-7b. Water quality (alkalinity, pH, Fe and Mn) in SRK Wells in S-Cluster Area.

584000 585000 586000

6914000

6913000



Northeast Rock Dump

Zone II Pit (backfilled with waste rock)

Intermediate Rock Dump

Haul Road

North Fork Rose Creek

Zone 2 Pumping Well (X26)

BH13A BH13B

BH12A BH12B

BH14A BH14B

BH9 BH8 BH7D(A) BH7S(B) BH2 BH10A BH10B BH1 P05-04 BH05-01 RGC-PW3 BH6 BH4 DP5 BH5 DP6

P96-6

1240 1220 1200 1180 1160 1150 1140 1130 1120 1110 1100 1090 1230 1210 1190 1170

LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)
- Abandoned Well
- Drive Point
- Zone II Pit Outline

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

N W E S

Groundwater Monitoring Wells
North Fork Rose Creek Area
Faro Mine Site

SCALE

0 75 150 300 450 600 Meters

Deloitte & Touche

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Groundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FIGURE: 2-8

DATE: Nov - 07
DRAWN BY: OM
FILE: Faro_RoseCreek.mxd

584800 585000 585200 585400

6913600

6913400

Zone 2 Pumping Well (X26)

Zone II Pit
(backfilled with waste rock)

1180

1160

BH9

BH8

BH7D (A)
BH7S (B)

BH10A/B

BH1

BH2

BH05-01

North Fork Rose Creek

P05-04

RGC-PW3

BH4

BH6

DP5

BH5

DP6

LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)
- Abandoned Well
- Drive Point
- Zone II Pit Outline

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

N
W E
S

Groundwater Monitoring Wells
Zone II Pit Outwash Area
Faro Mine Site

SCALE

0 25 50 100 150 200 Meters

Deloitte & Touche

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Groundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FIGURE: 2-9

DATE: Nov - 07
DRAWN BY: OM
FILE: Faro_Zone2_area.mxd

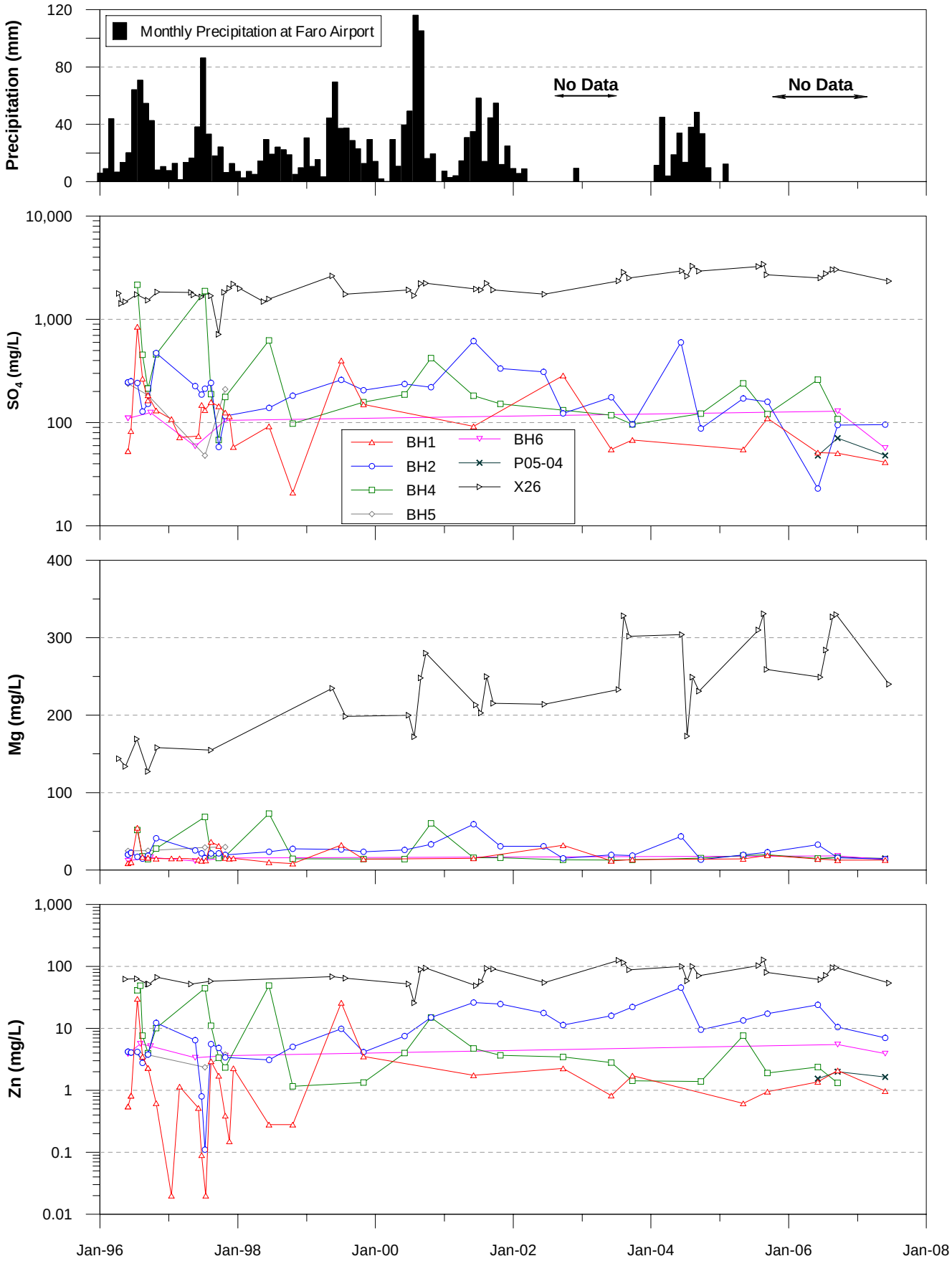


Figure 2-10a. Precipitation and water quality (SO_4, Mg and Zn) in Zone 2 Outwash Area.

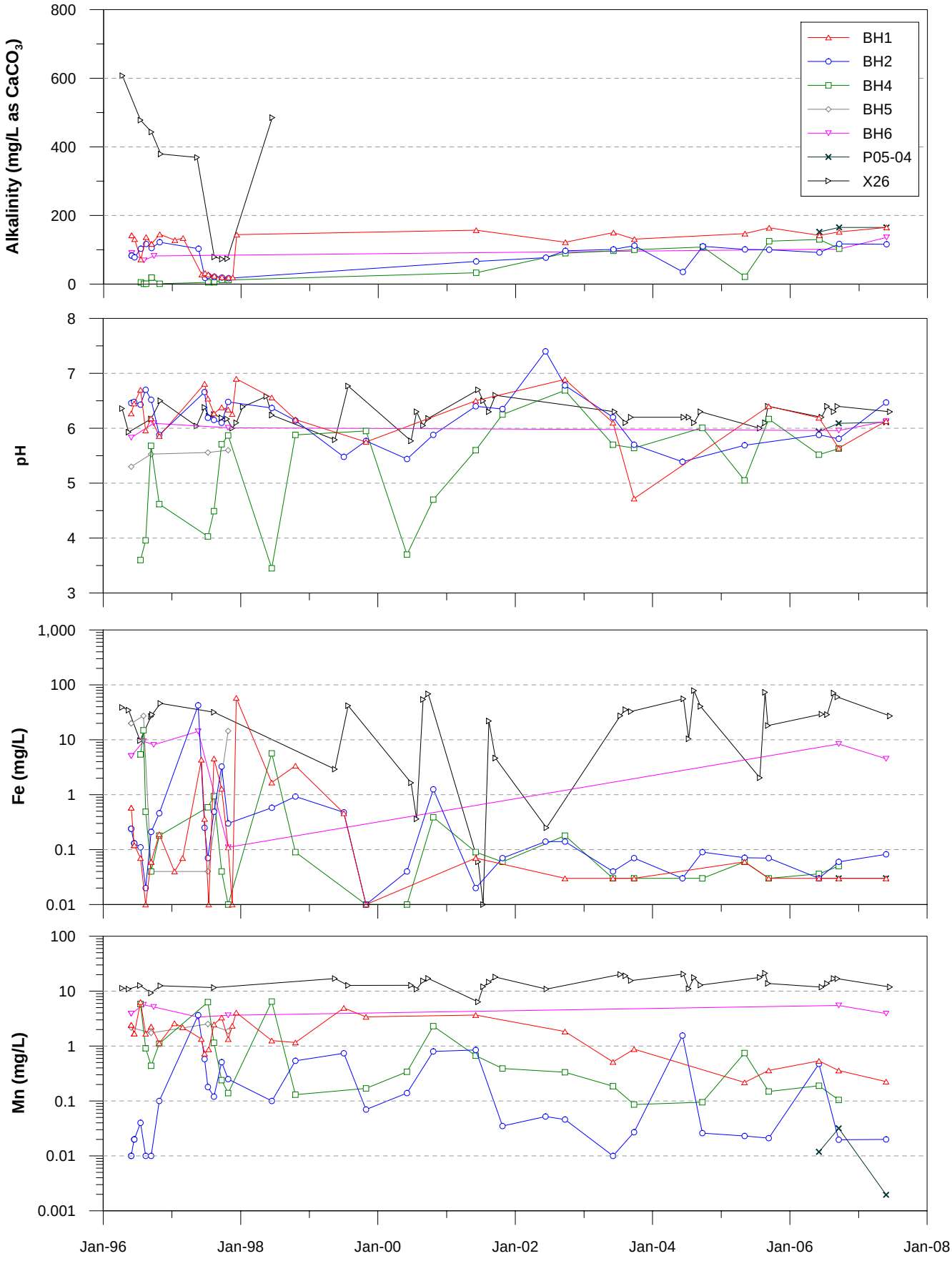


Figure 2-10b. Water quality (alkalinity, pH, Fe and Mn) in Zone 2 Outwash Area.

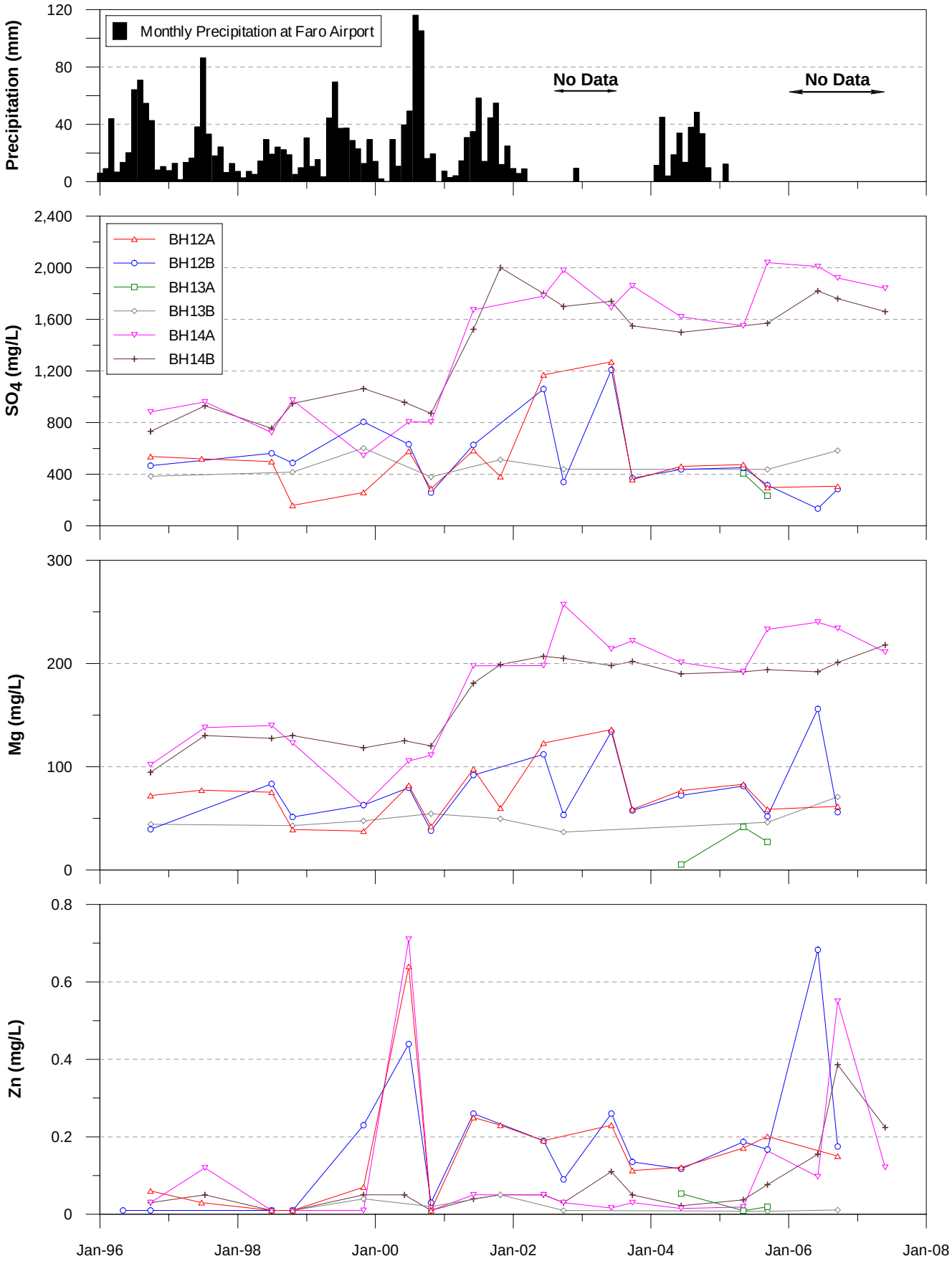


Figure 2-11a. Precipitation and water quality (SO_4, Mg and Zn) at toe of Northeast Dumps.

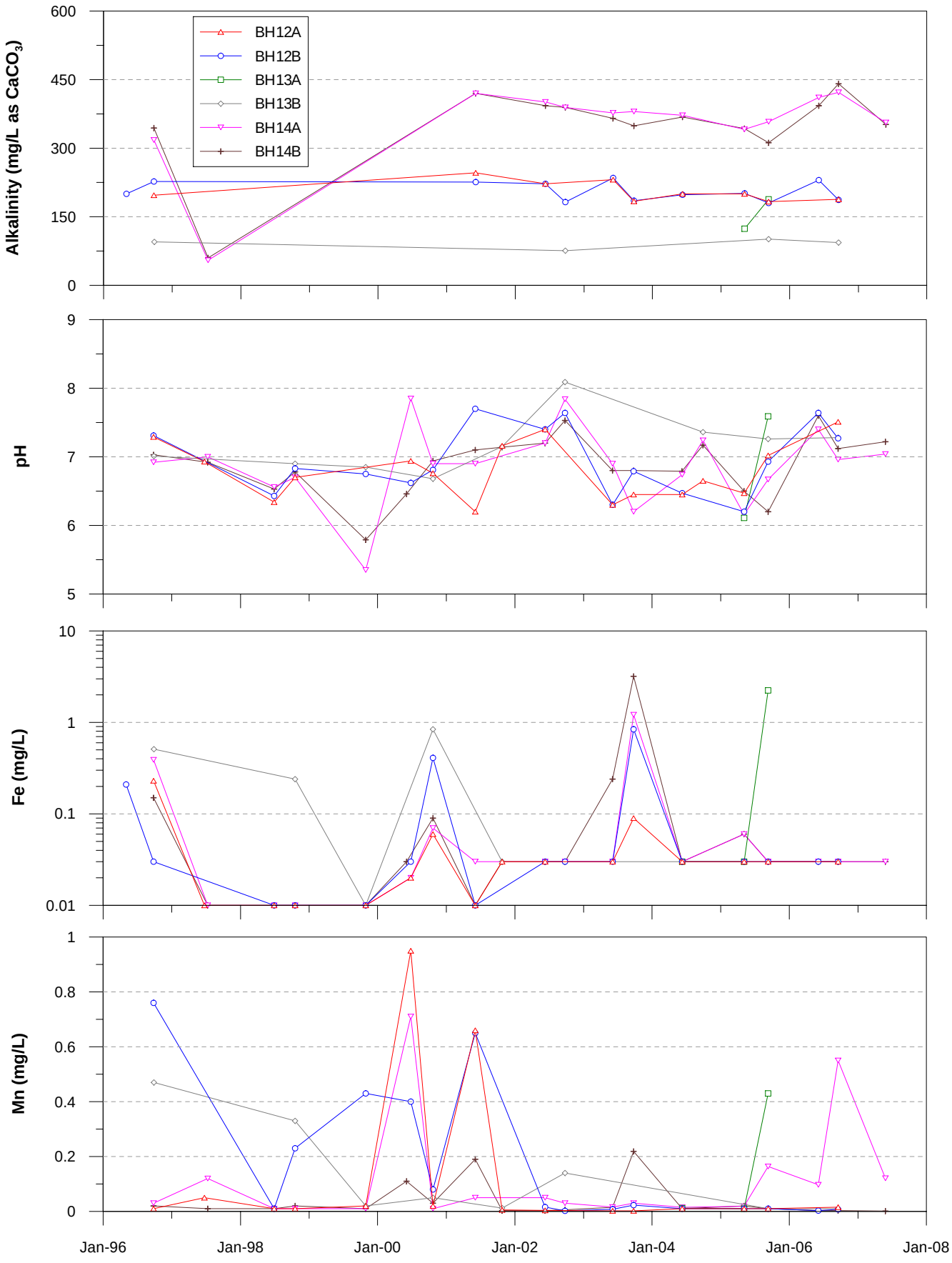


Figure 2-11b. Water quality (alkalinity, pH, Fe and Mn) at toe of Northeast Dumps.

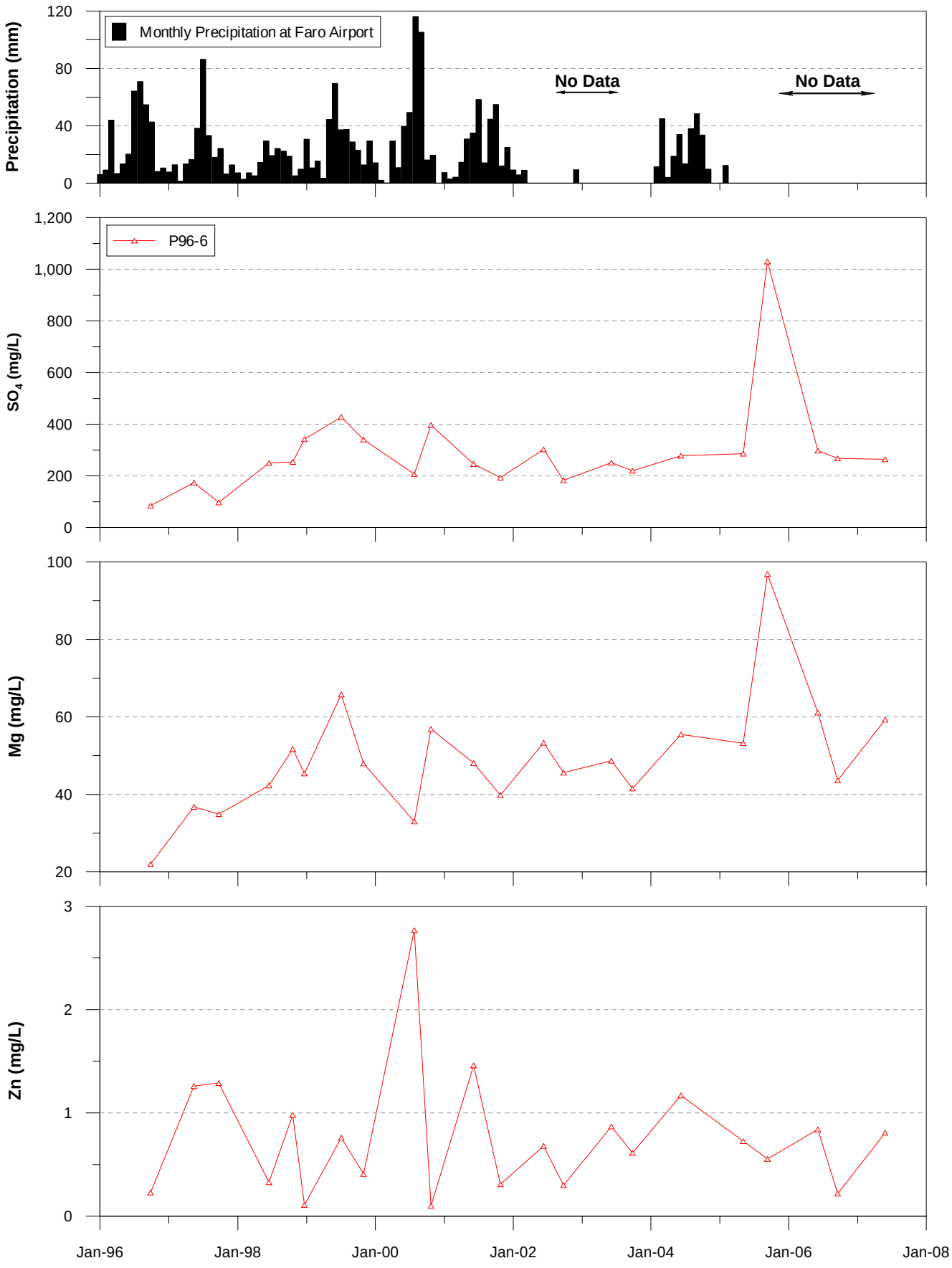


Figure2-12a. Precipitation and water quality (SO_4, Mg and Zn) at toe of Intermediate Dump (P96-6).

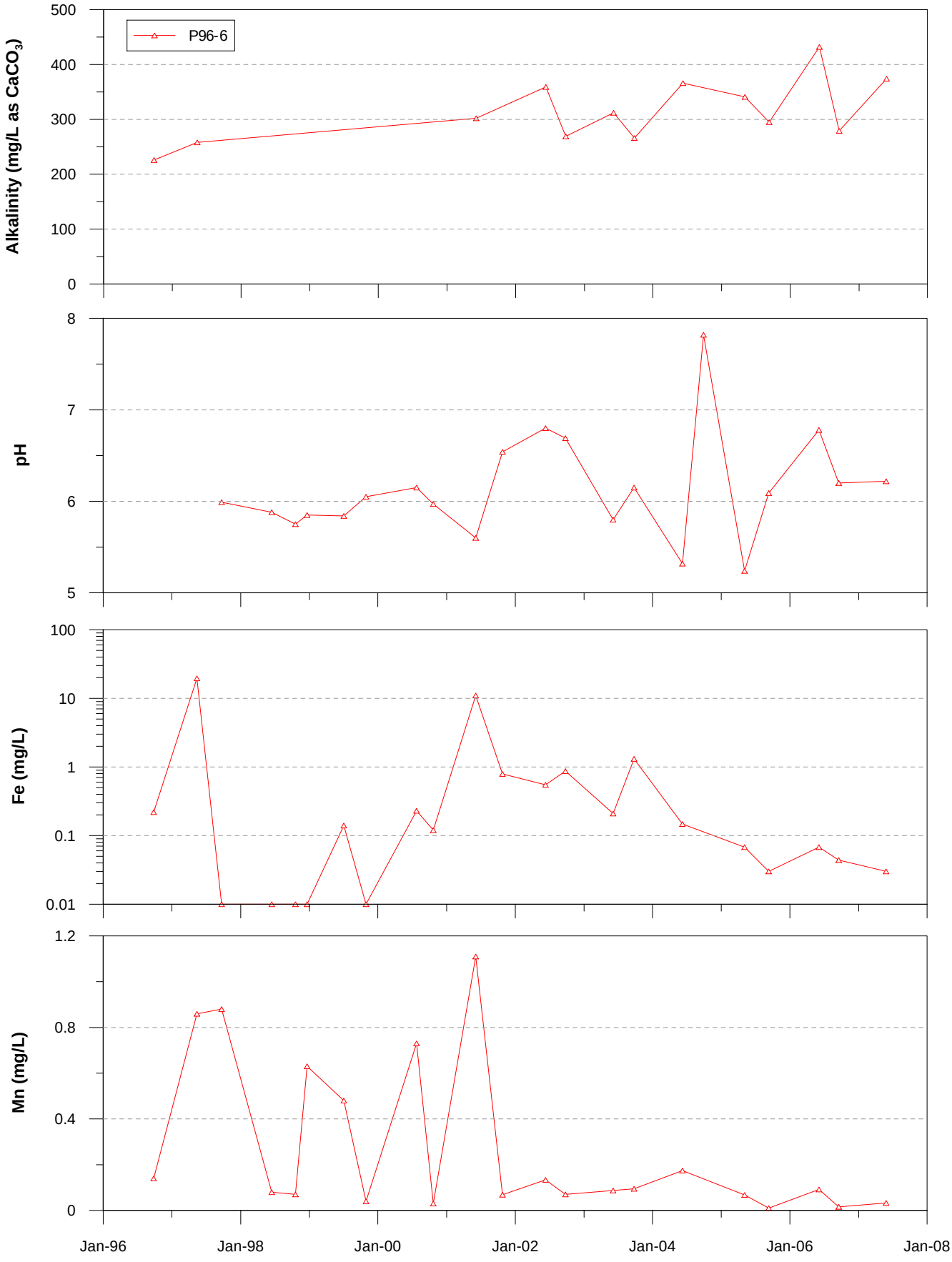


Figure 2-12b. Water quality (alkalinity, pH, Fe and Mn) at toe of Intermediate Dump (P96-6).

580000 581000 582000 583000 584000

6915000 6914000 6913000

Cross Valley Dam

Intermediate Dam

X16A/B
P01-01A/B
X18A/B
X17A/B
RGC-PW1
MW1
P05-01
P05-02
P01-11
P03-09
MW2
P05-03
RGC-PW2
X24A/B/C/D-96
P01-03
P01-02A/B
X25A/B-96
P01-04A/B

Polishing Pond

Intermediate Pond

Intermediate Impoundment

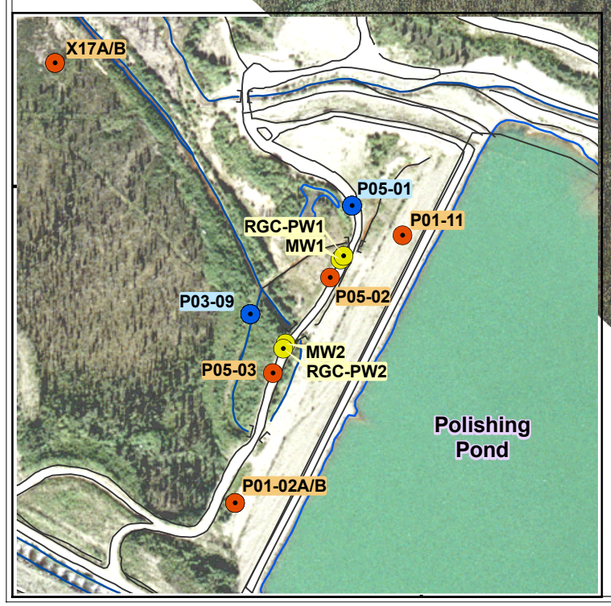
P03-08
NA05-2D
NA05-2S
P01-06
X21A/B/C-96
P01-05A
P01-05B
P03-04
P01-7A/B/C/D/E
P03-06
P03-07
P01-8A/B/C
P03-05

Second Impoundment

Original Impoundment

P01-10A/B
NA05-11A
P03-03
P01-9A/B/C/D
NA05-9S
NA05-9D
P03-01
P03-02
TH86-17

1230 1170 1150 1120 1200 1230 1170 1090 1050 1120 1100 1080 1230 1230 1140 1130 1120 1110 1070 1100 1070 1090



LEGEND

- Monitoring Well
- Multilevel Monitoring Well
- Other Well (not Monitored Routinely)
- Decommissioned Well

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2M

N W E S

Groundwater Monitoring Wells
Rose Creek Tailings Facility
Anvil Range Mining Complex

SCALE

0 205 410 820 1,230 1,640 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Groundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 3-1

DATE: Feb - 08
DRAWN BY: OM
FILE: Faro_Tailing_area.mxd

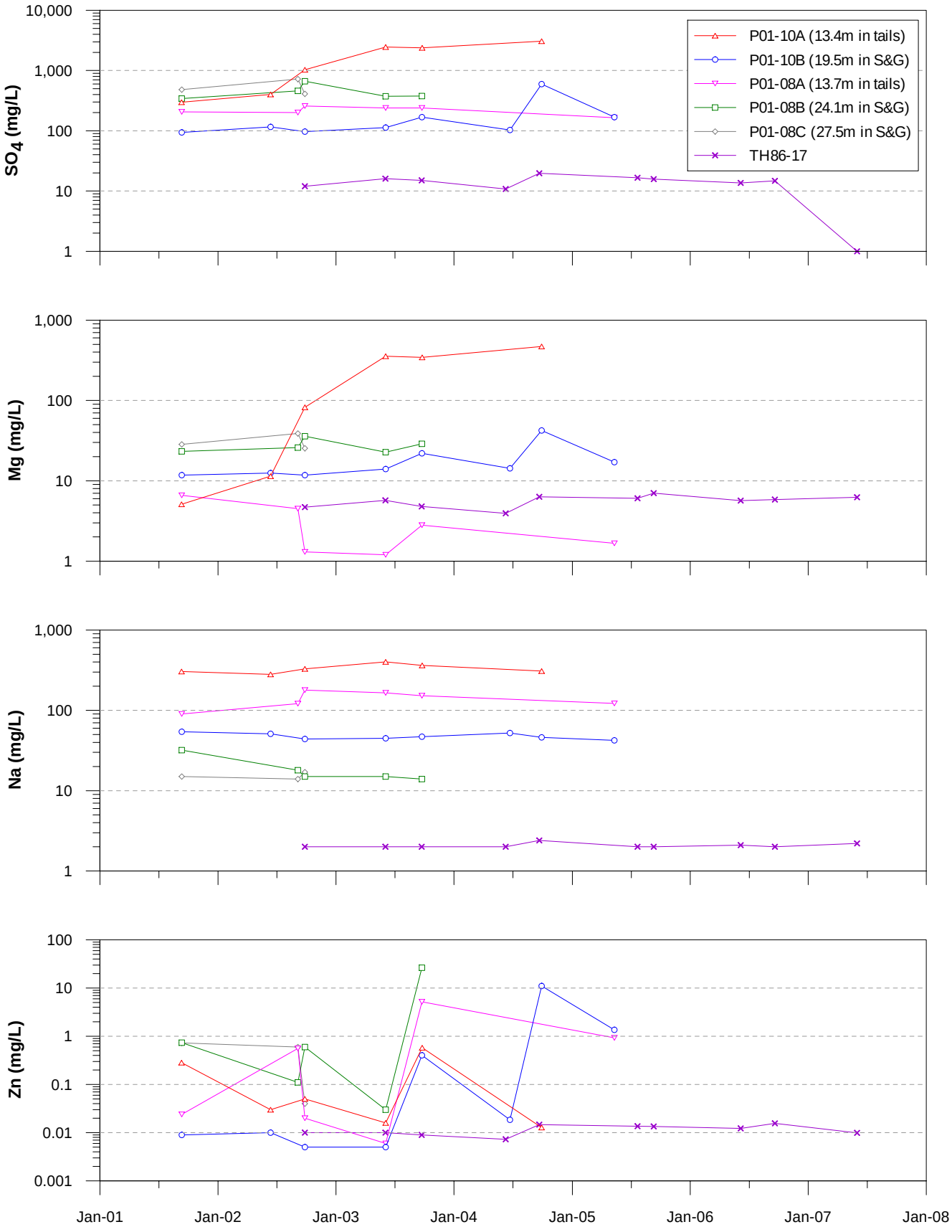


Figure 3-2a. Water quality (SO_4, Mg, Na and Zn) in P01-10, P01-08 and TH86-17 (Original Impoundment).

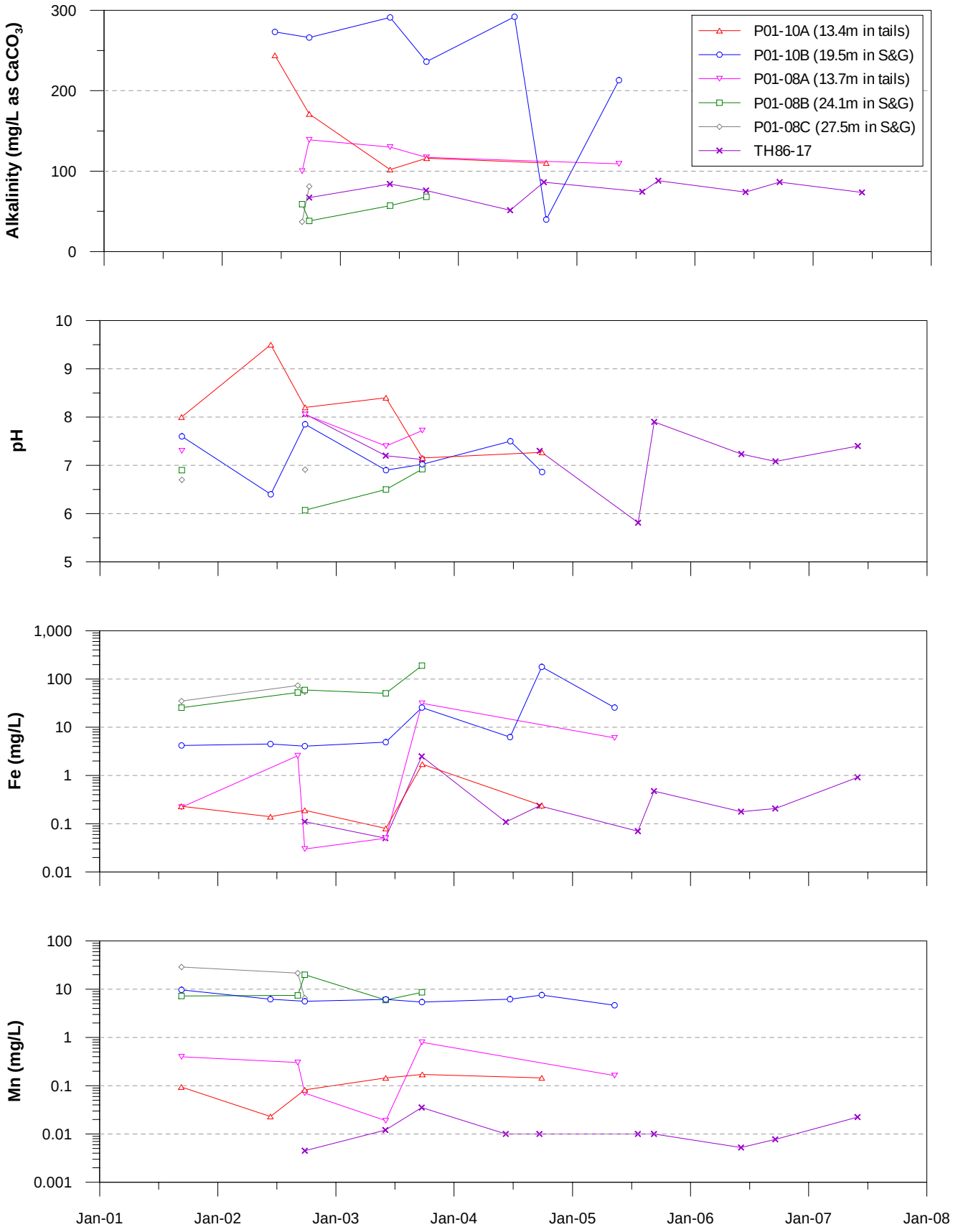


Figure 3-2b. Water quality (alkalinity, pH, Fe and Mn) in P01-10, P01-08 and TH86-17 (Original Impoundment).

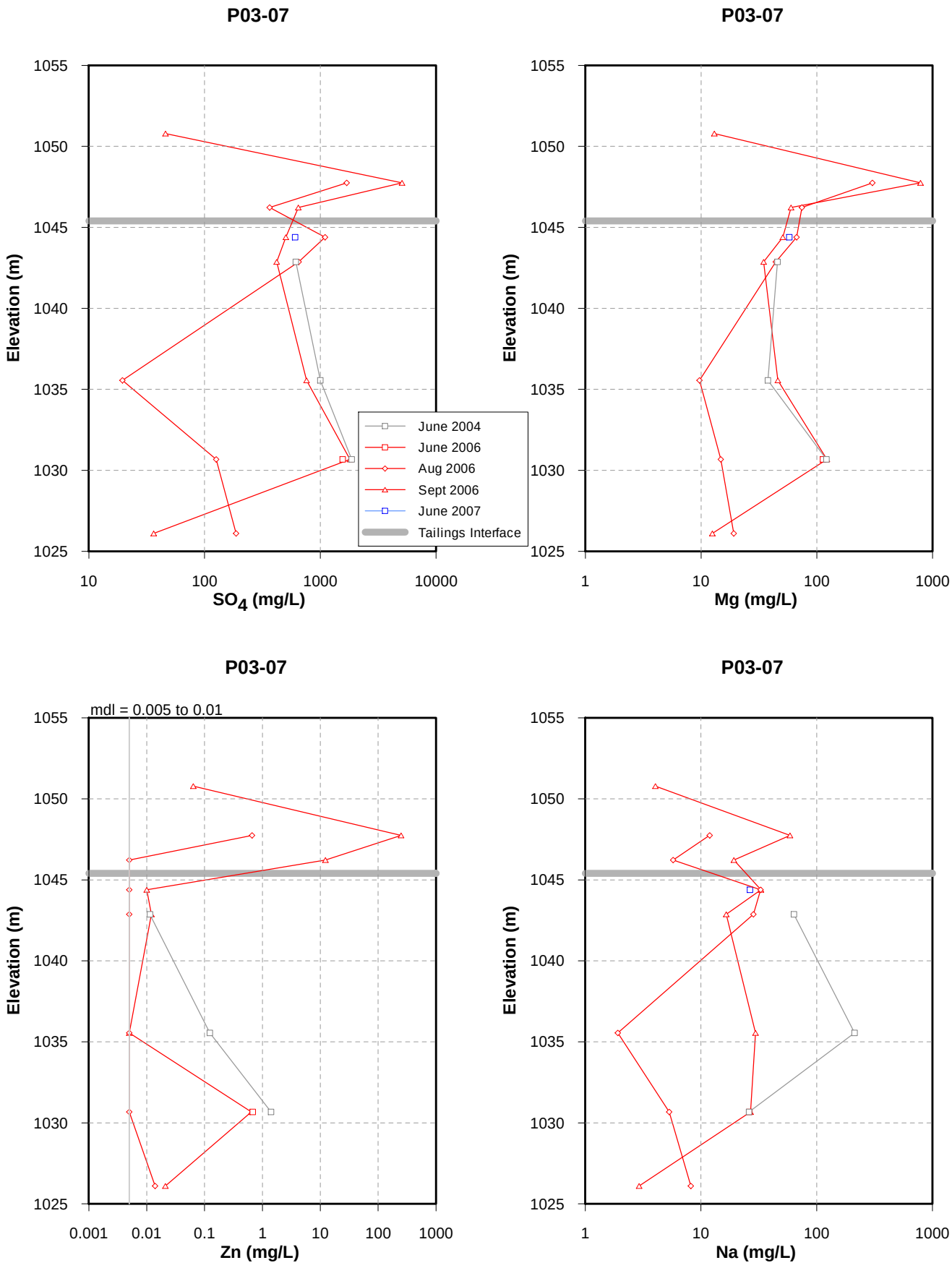


Figure 3-3a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-07 (Original Impoundment).

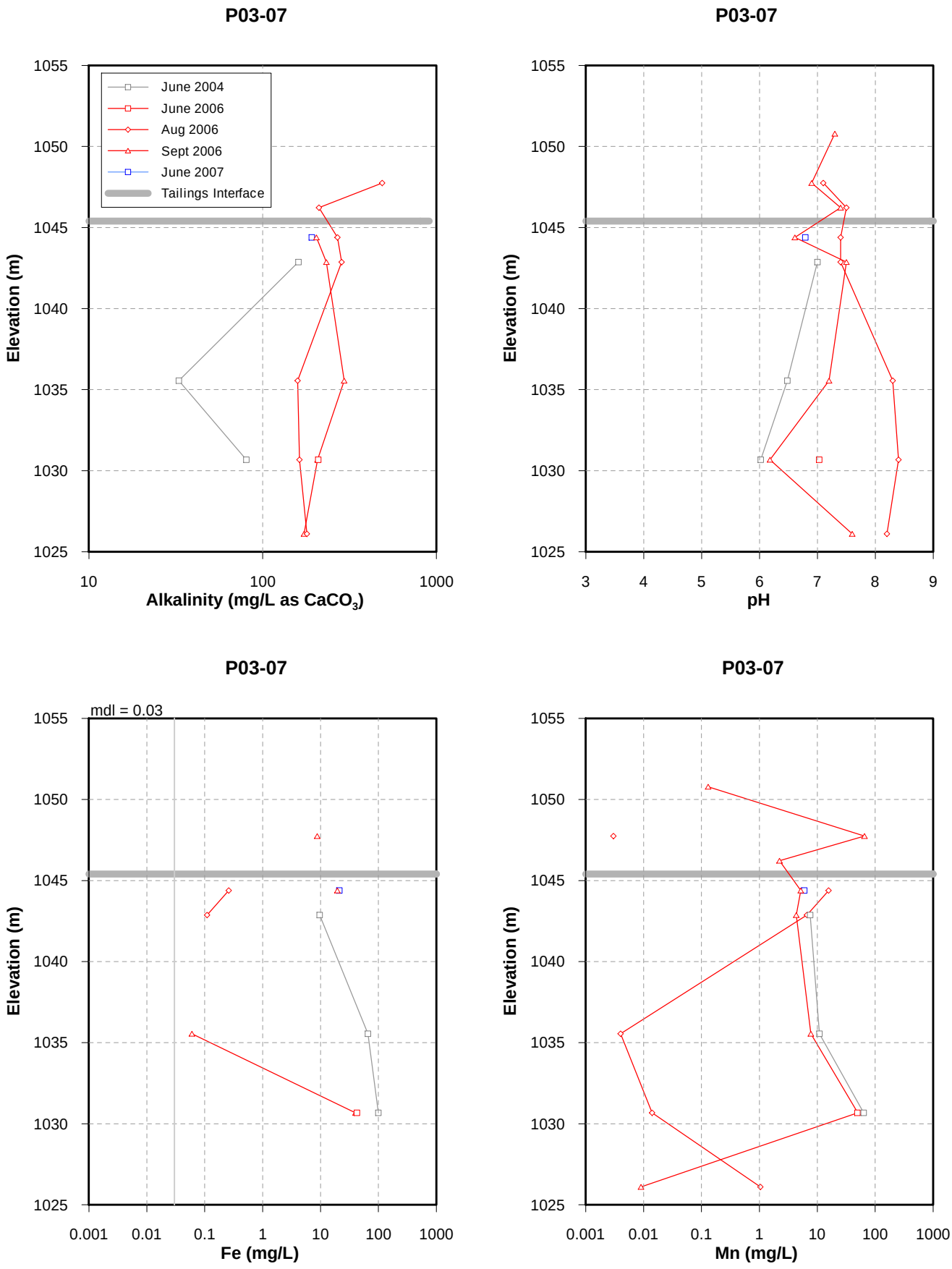


Figure 3-3b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-07 (Original Impoundment).

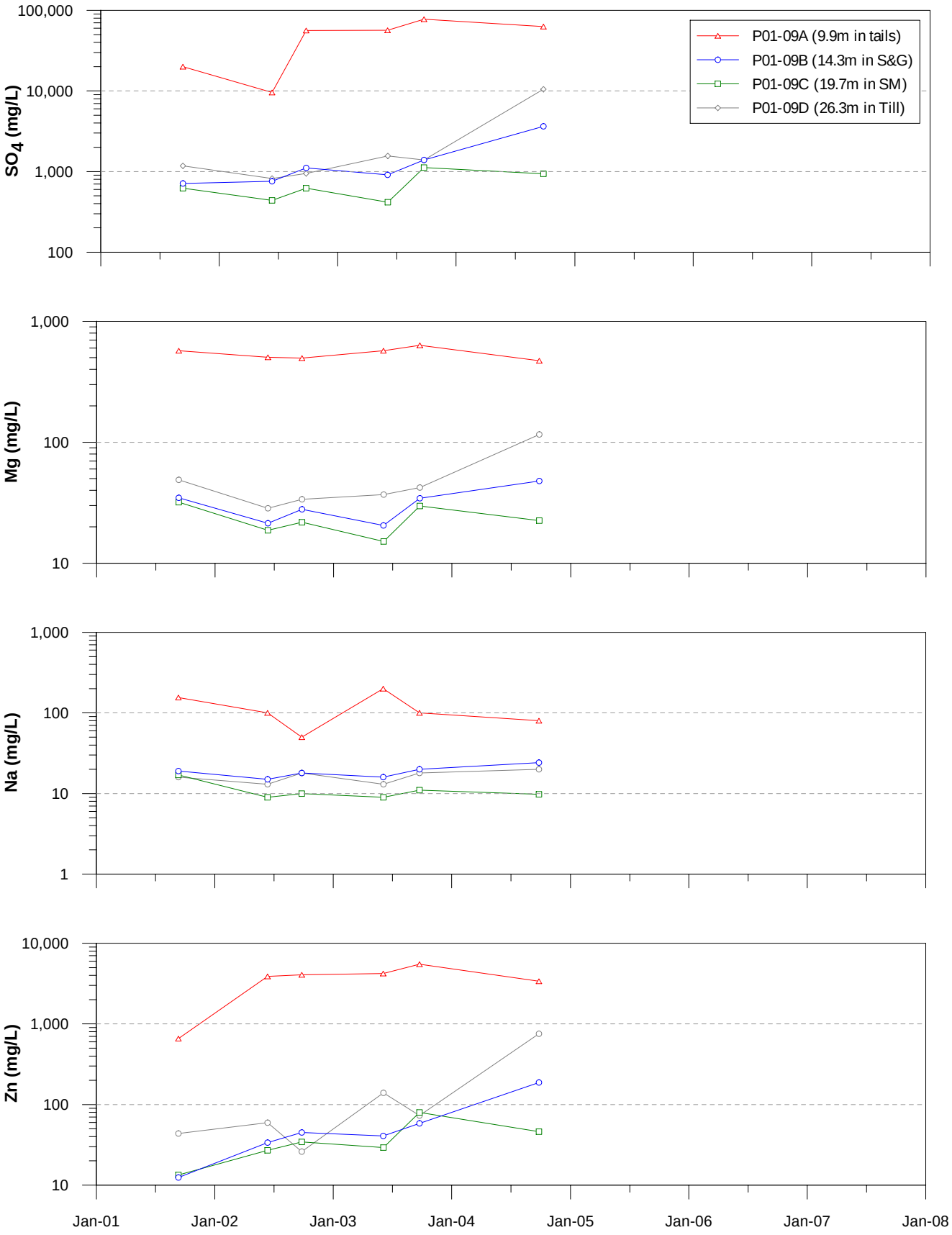


Figure 3-4a. Water quality (SO_4, Mg, Na and Zn) in P01-09 (Second Impoundment).

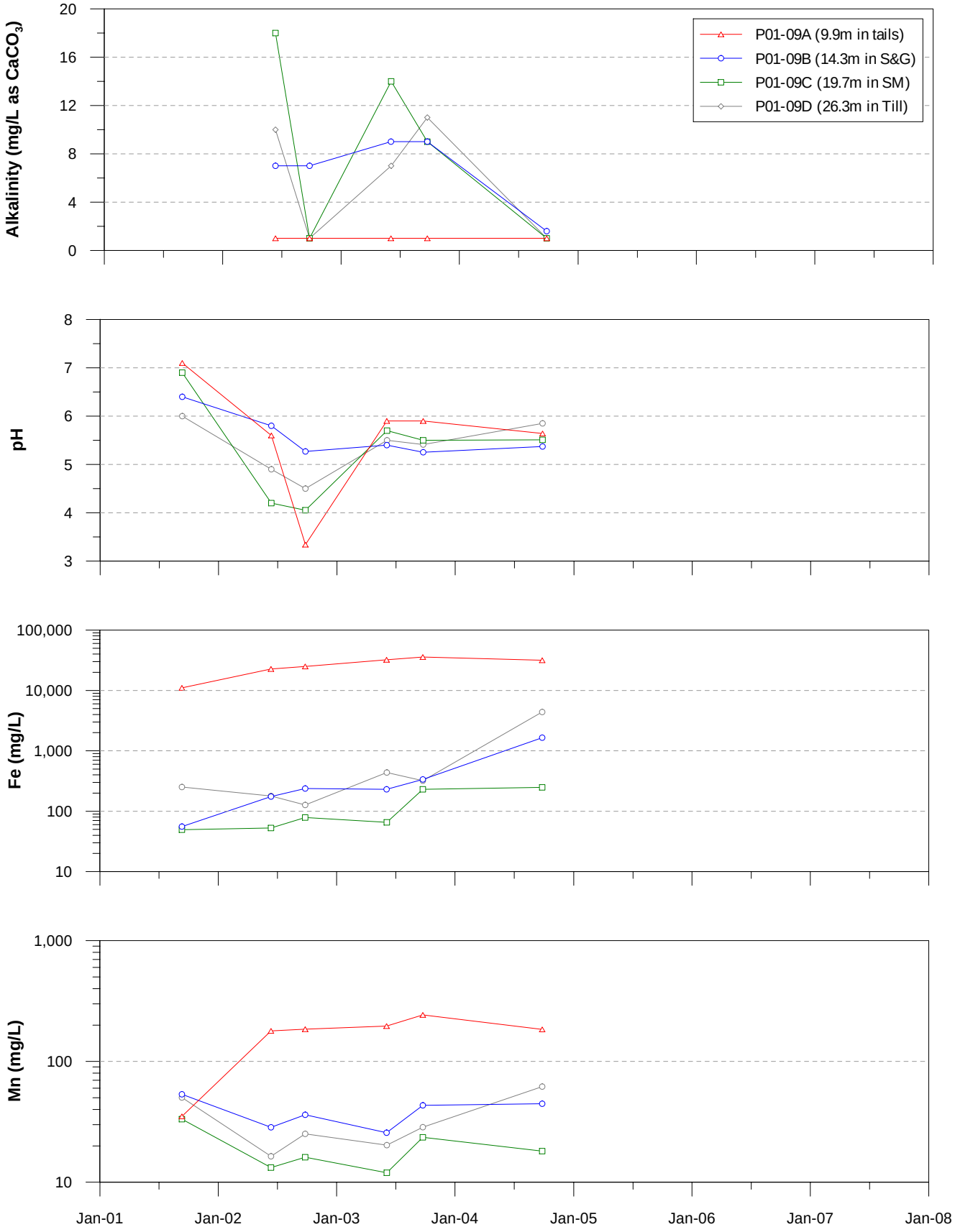


Figure 3-4b. Water quality (alkalinity, pH, Fe and Mn) in P01-09 (Second Impoundment).

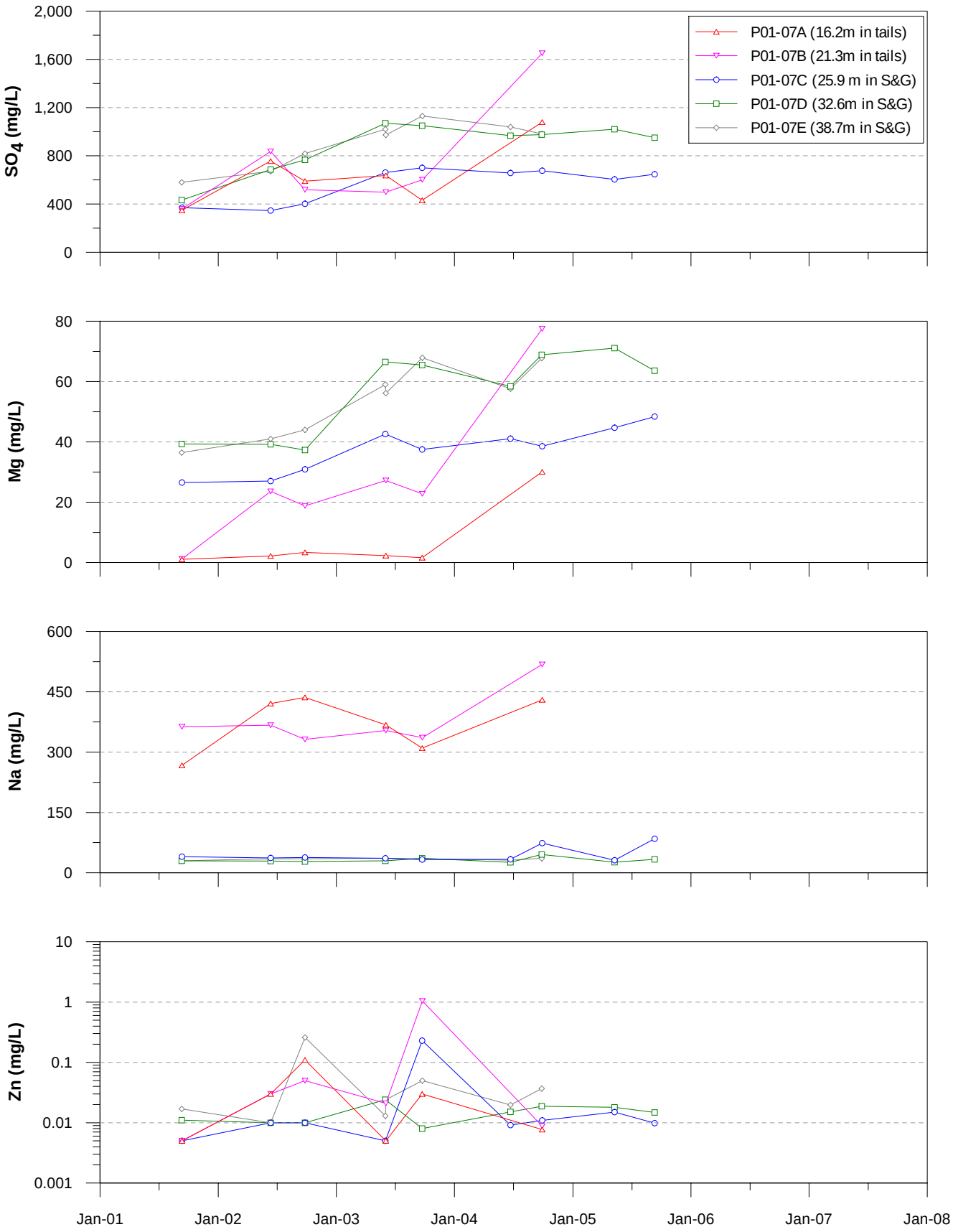


Figure 3-5a. Water quality (SO_4, Mg, Na and Zn) in P01-07 (Second Impoundment).

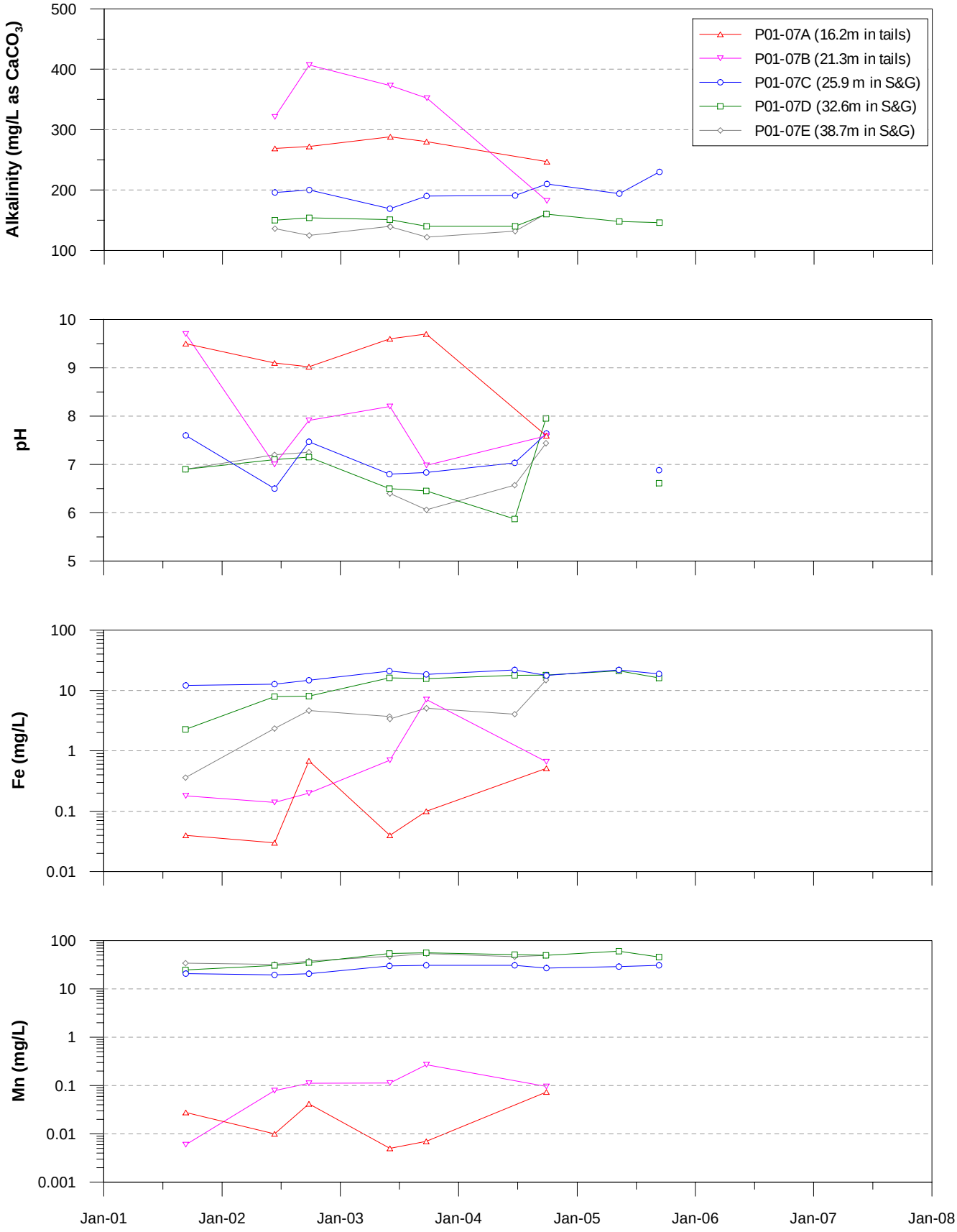


Figure 3-5b. Water quality (alkalinity, pH, Fe and Mn) in P01-07 (Second Impoundment).

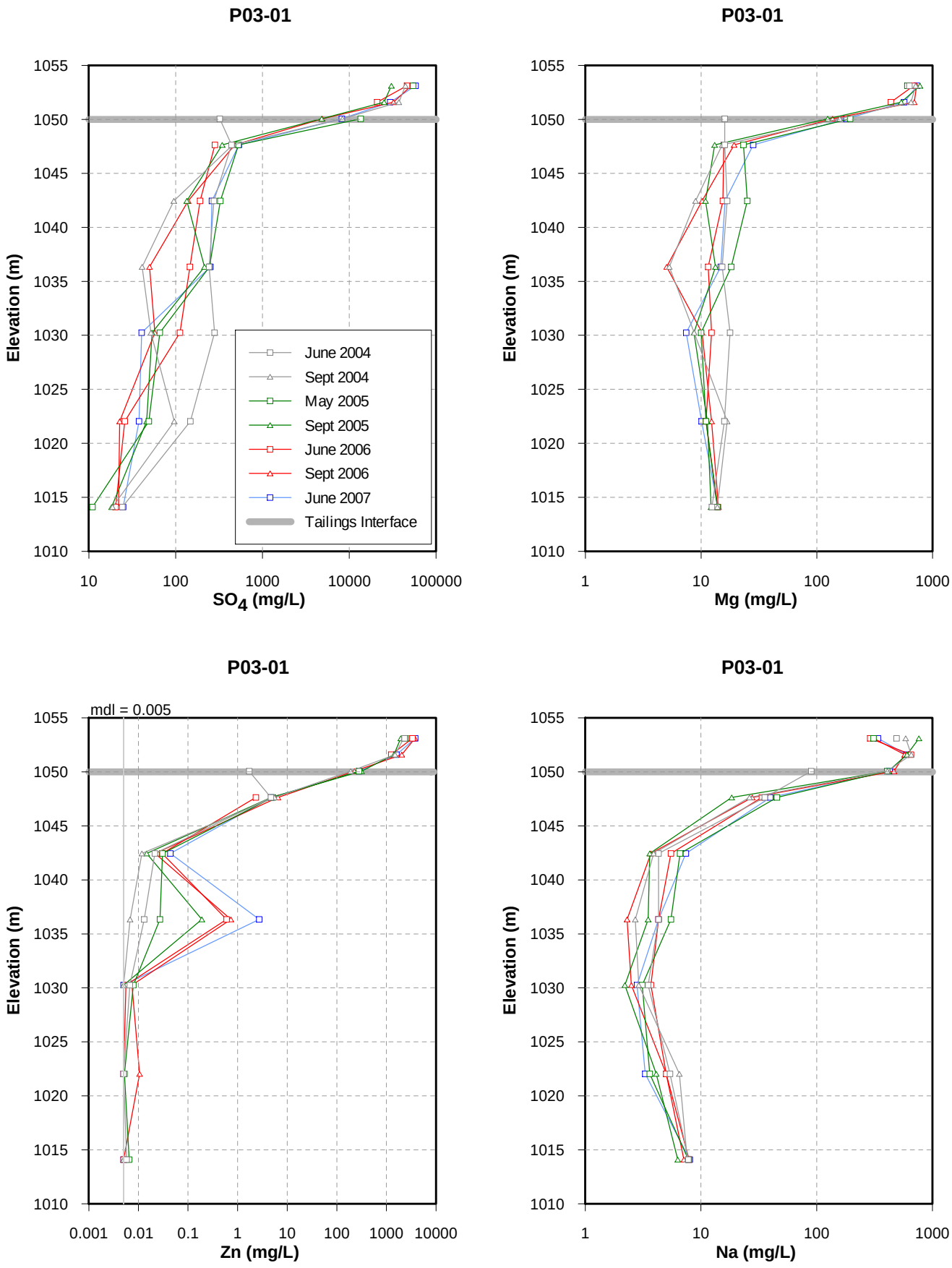


Figure 3-6a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-01 (Second Impoundment).

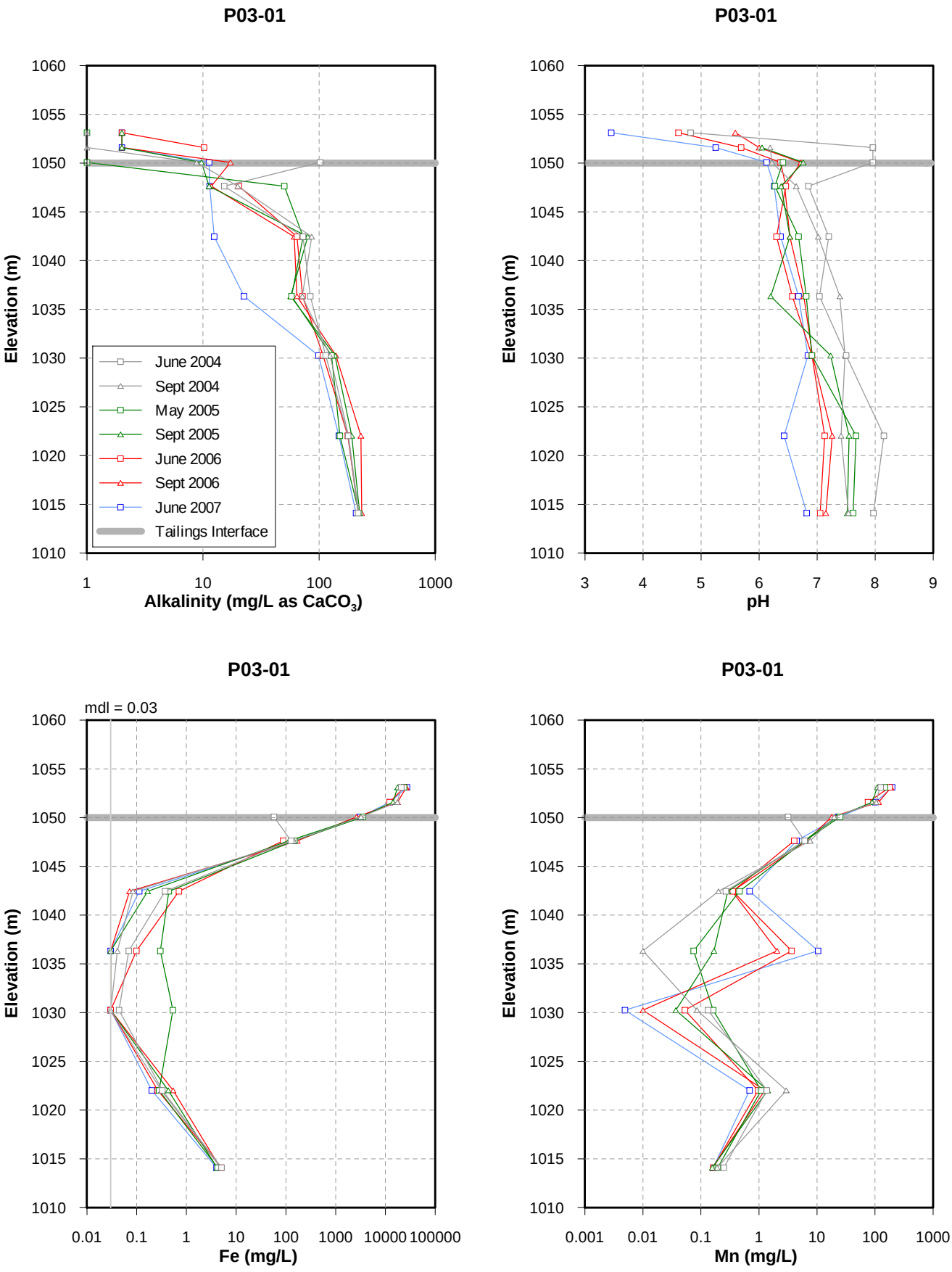


Figure 3-6b. Water quality depth profiles of Alkalintiy, pH, Fe and Mn in P03-01 (Second Impoundment).

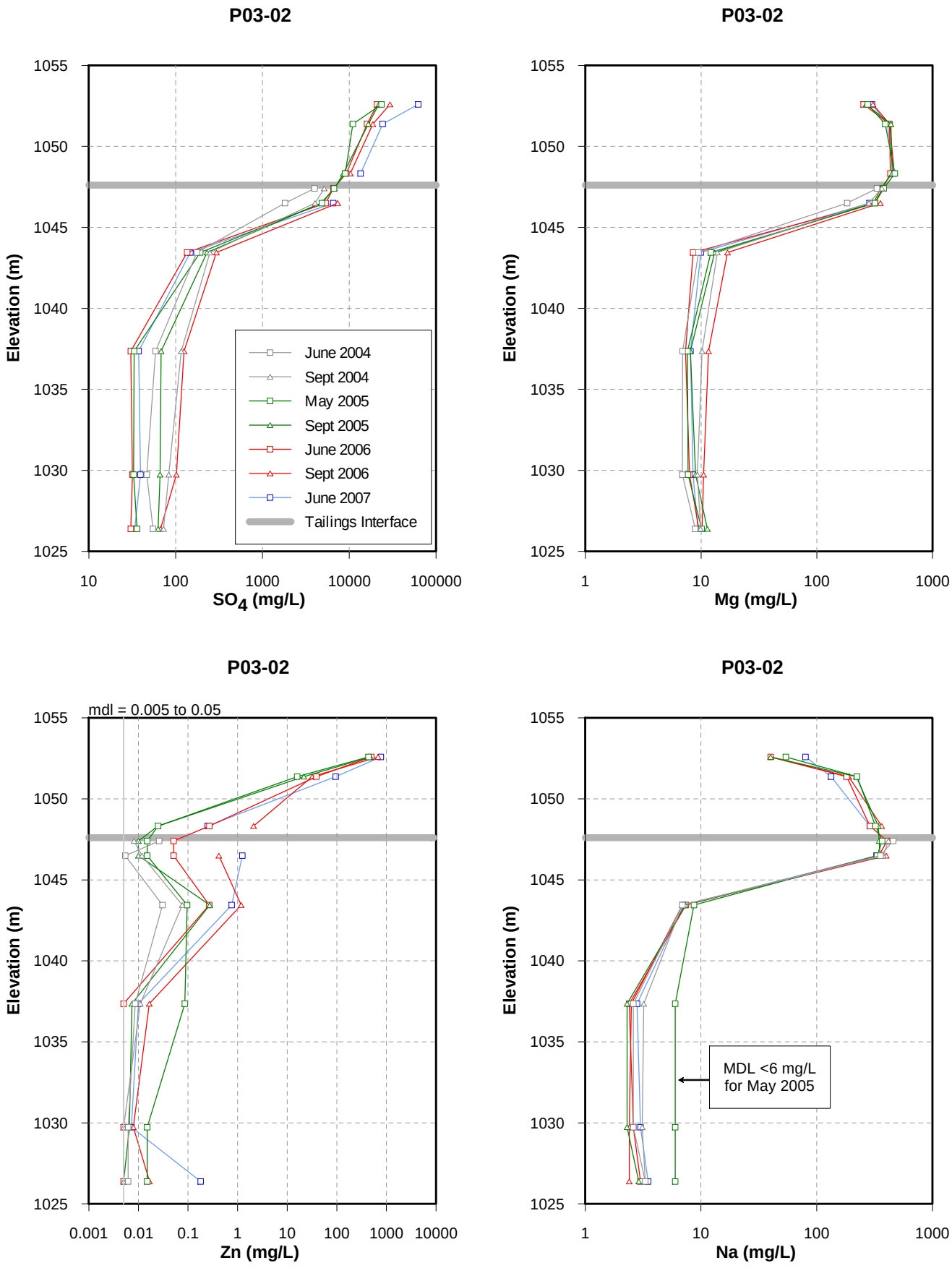


Figure 3-7a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-02 (Second Impoundment).

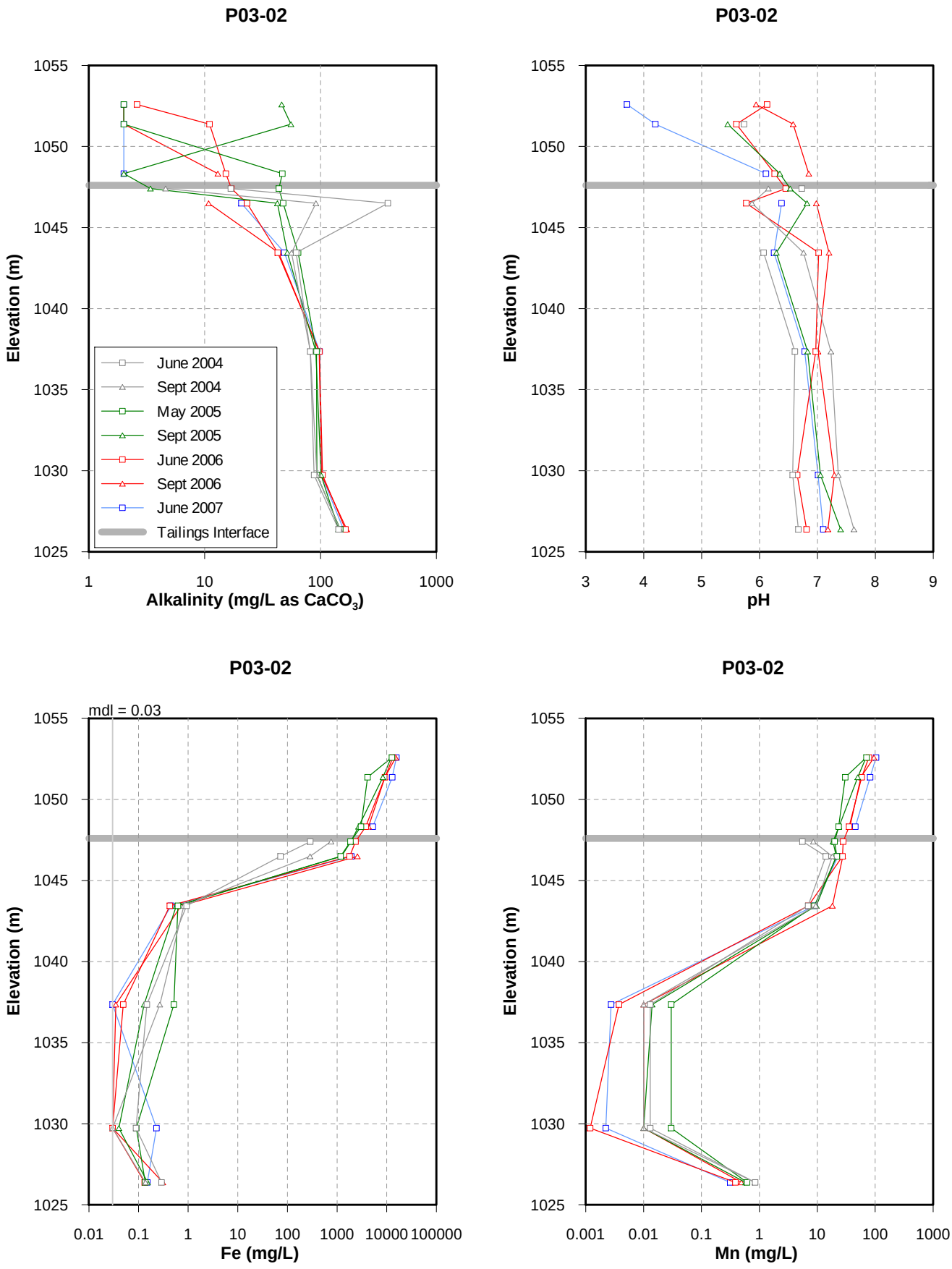


Figure 3-7b. Water quality depth profiles of Alkalinity, pH, Fe and Mn in P03-02 (Second Impoundment).

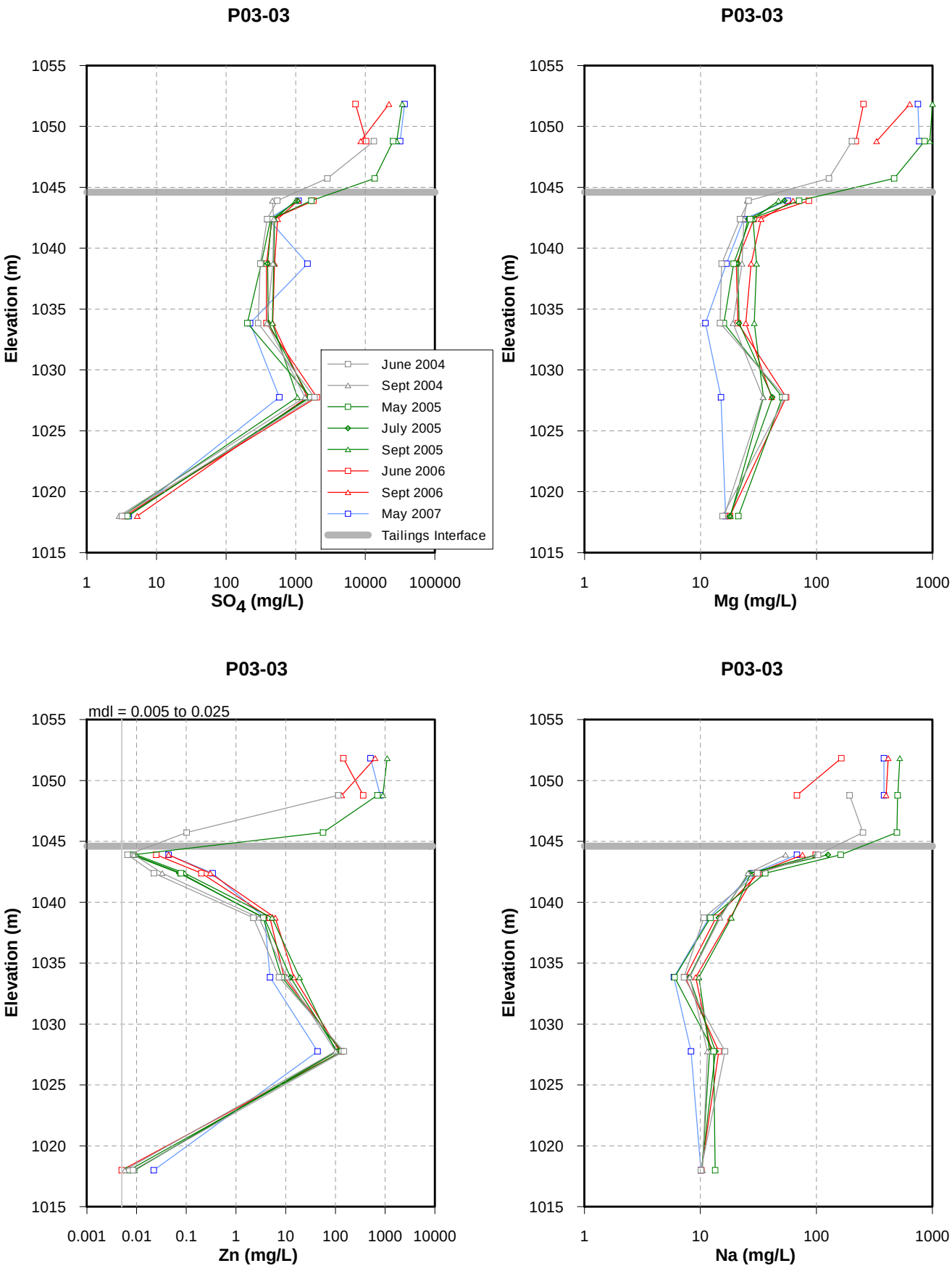


Figure 3-8a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-03 (Second Impoundment).

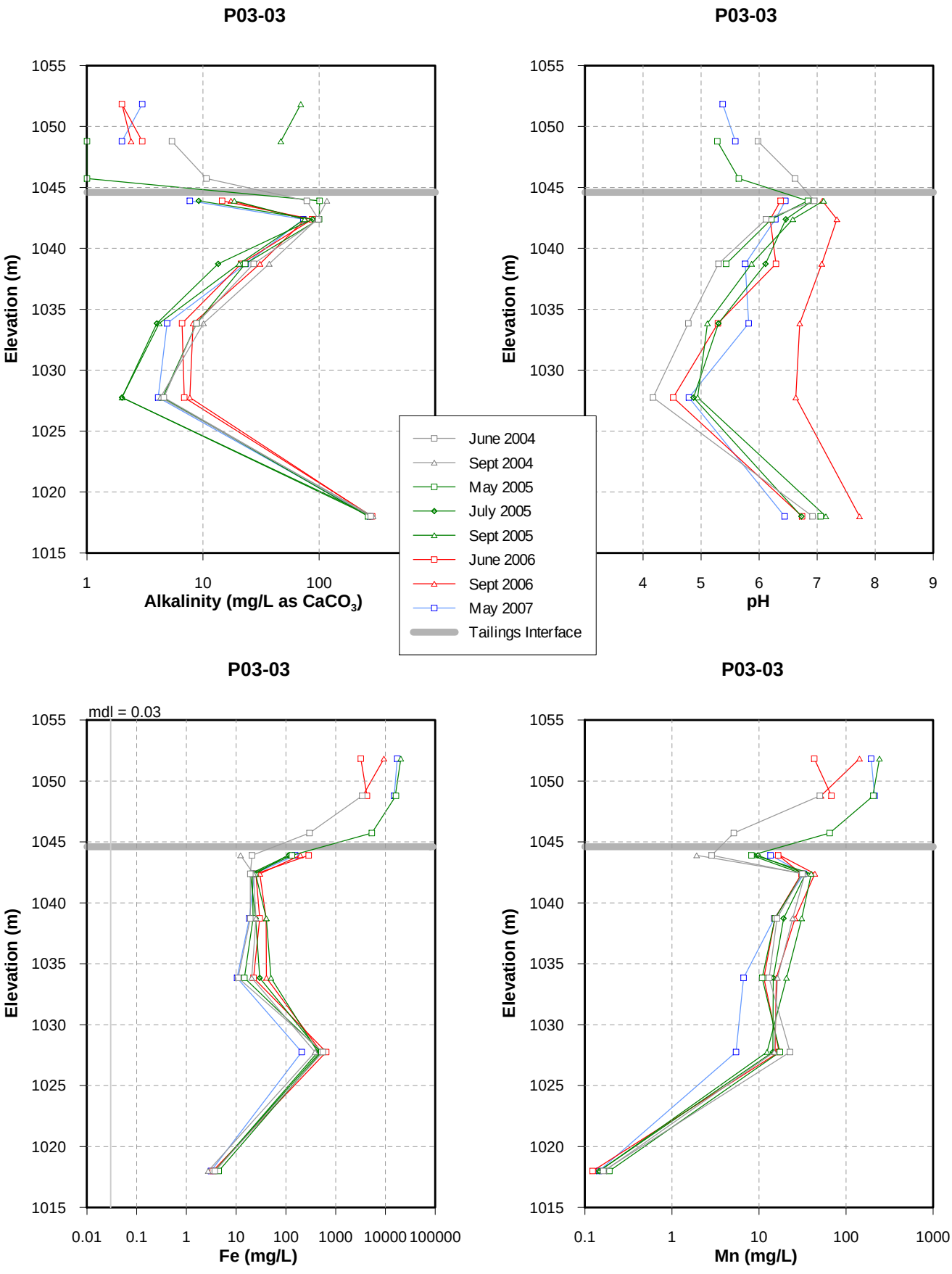


Figure 3-8b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-03 (Second Impoundment).

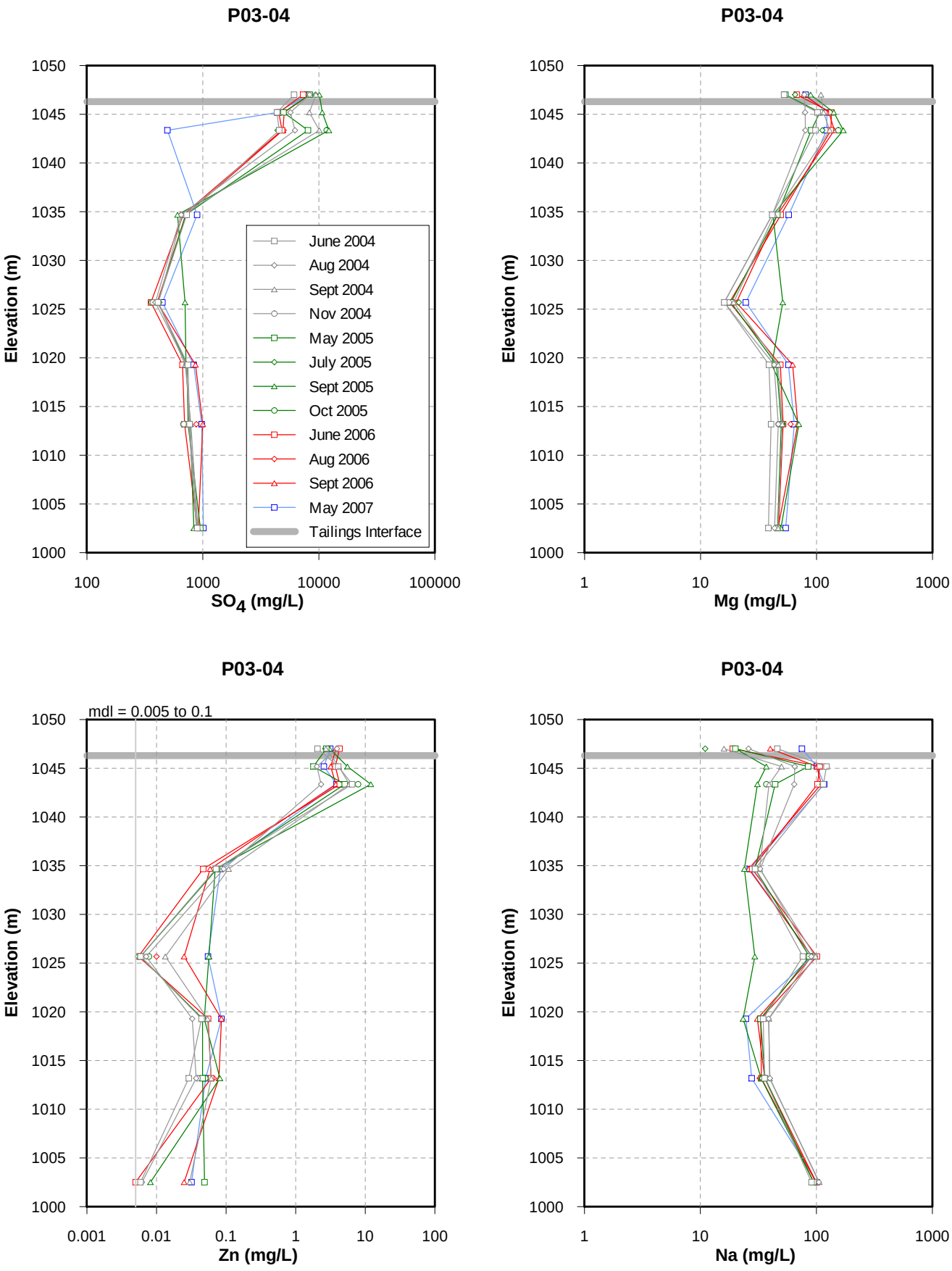


Figure 3-9a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-04 (Second Impoundment).

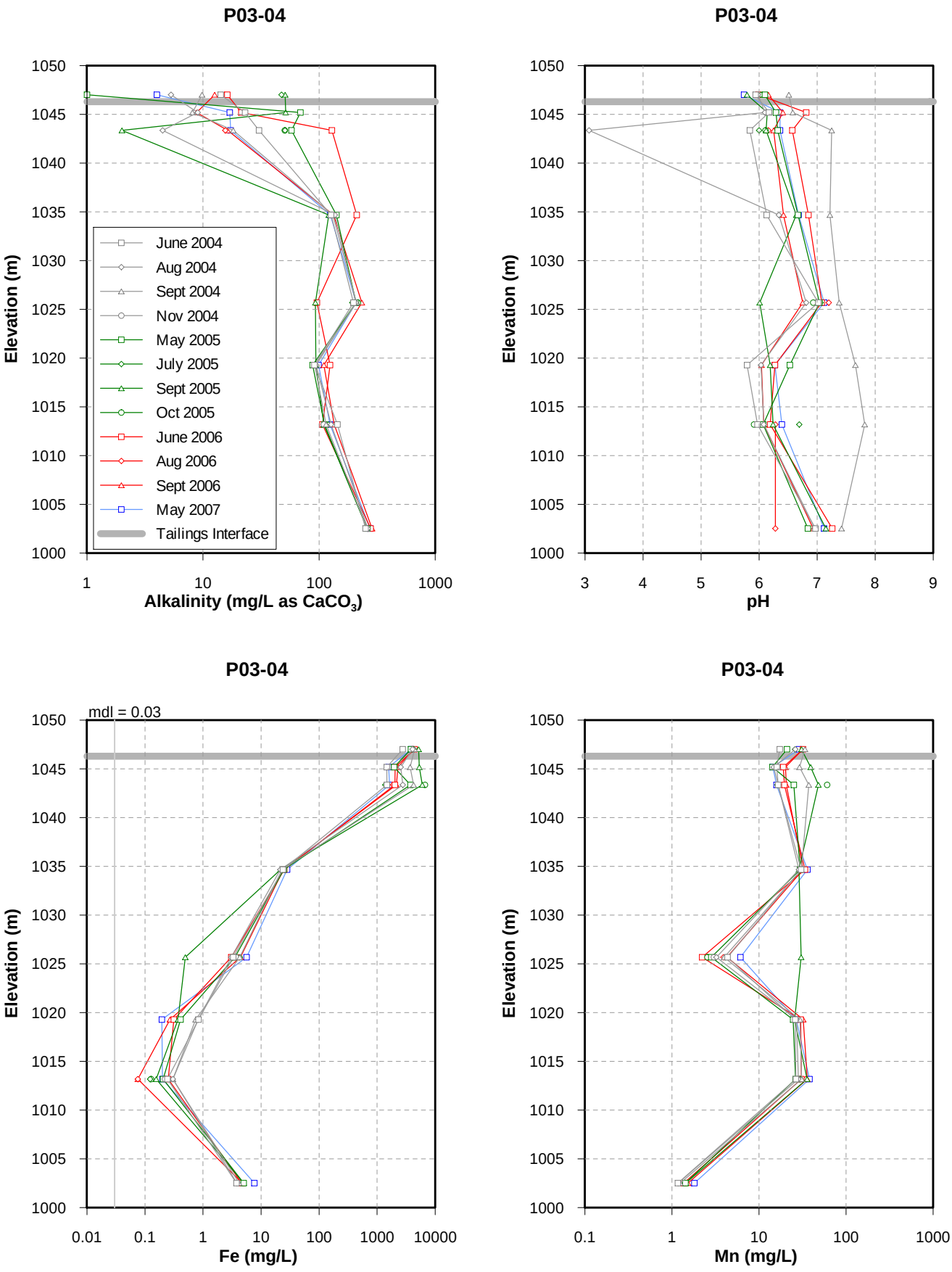


Figure 3-9b. Water quality depth profiles of Alkalinity, pH, Fe and Mn in P03-04 (Second Impoundment).

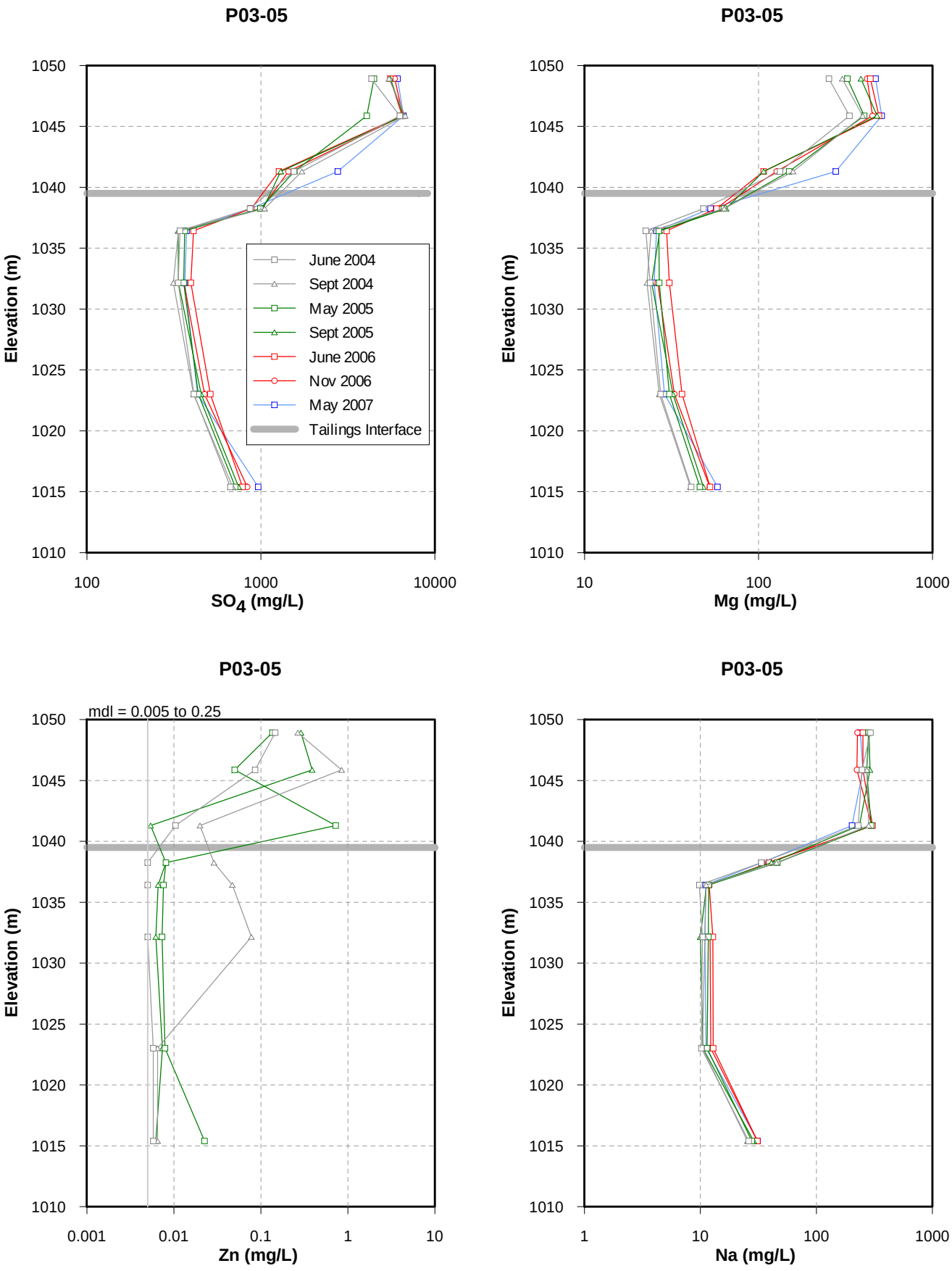


Figure 3-10a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-05 (Second Impoundment).

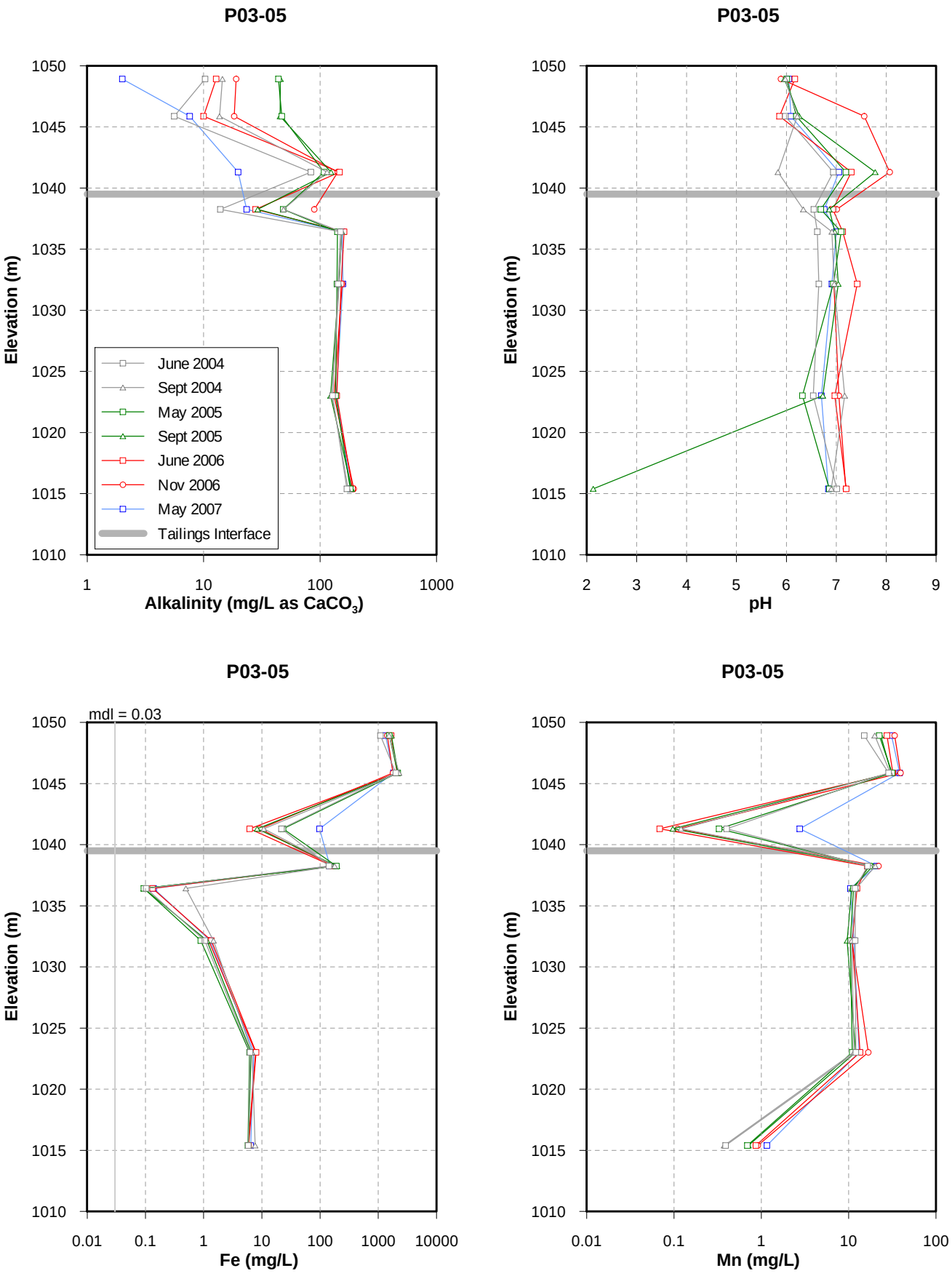


Figure 3-10b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-05 (Second Impoundment).

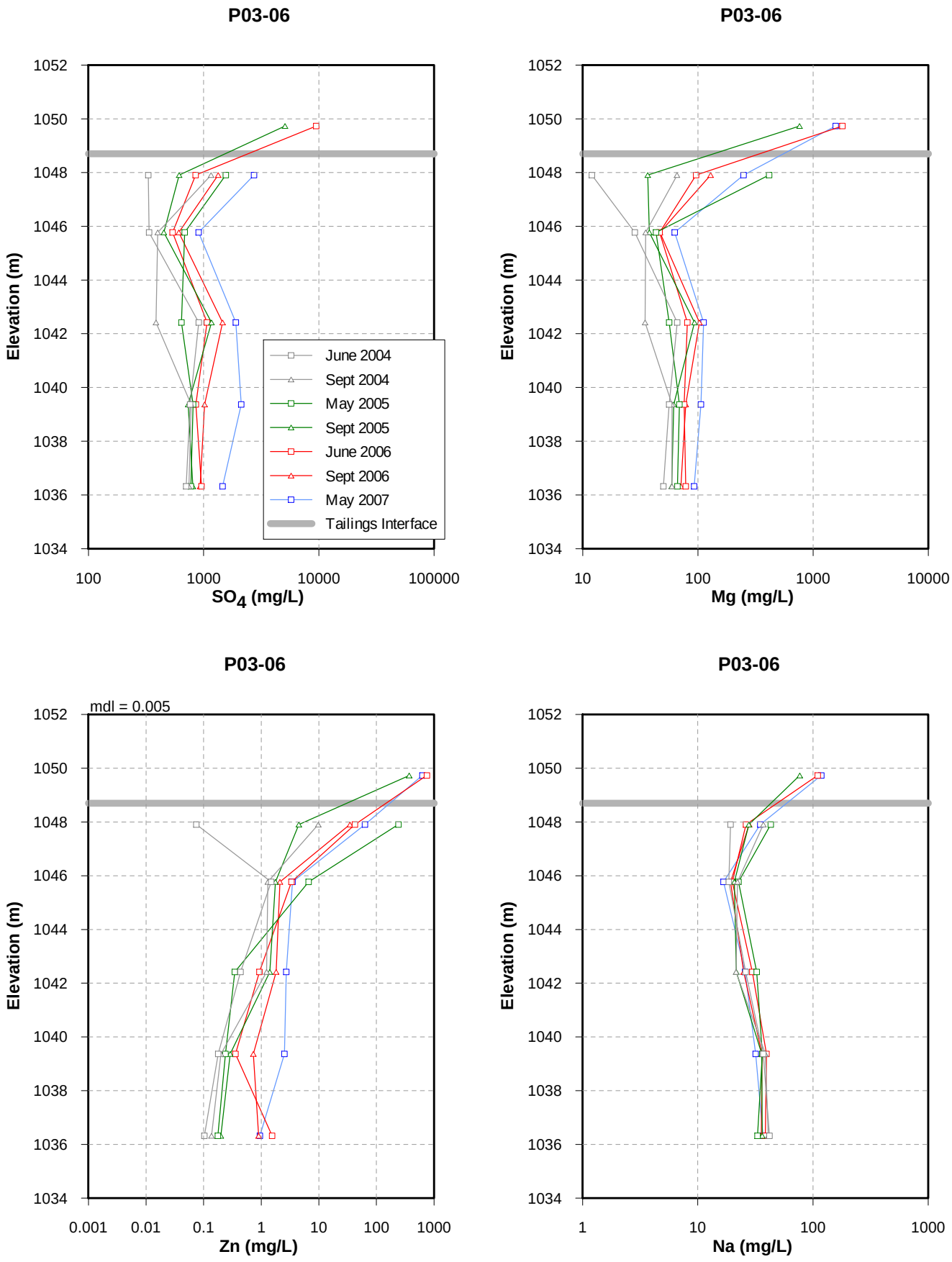


Figure 3-11a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-06 (Second Impoundment).

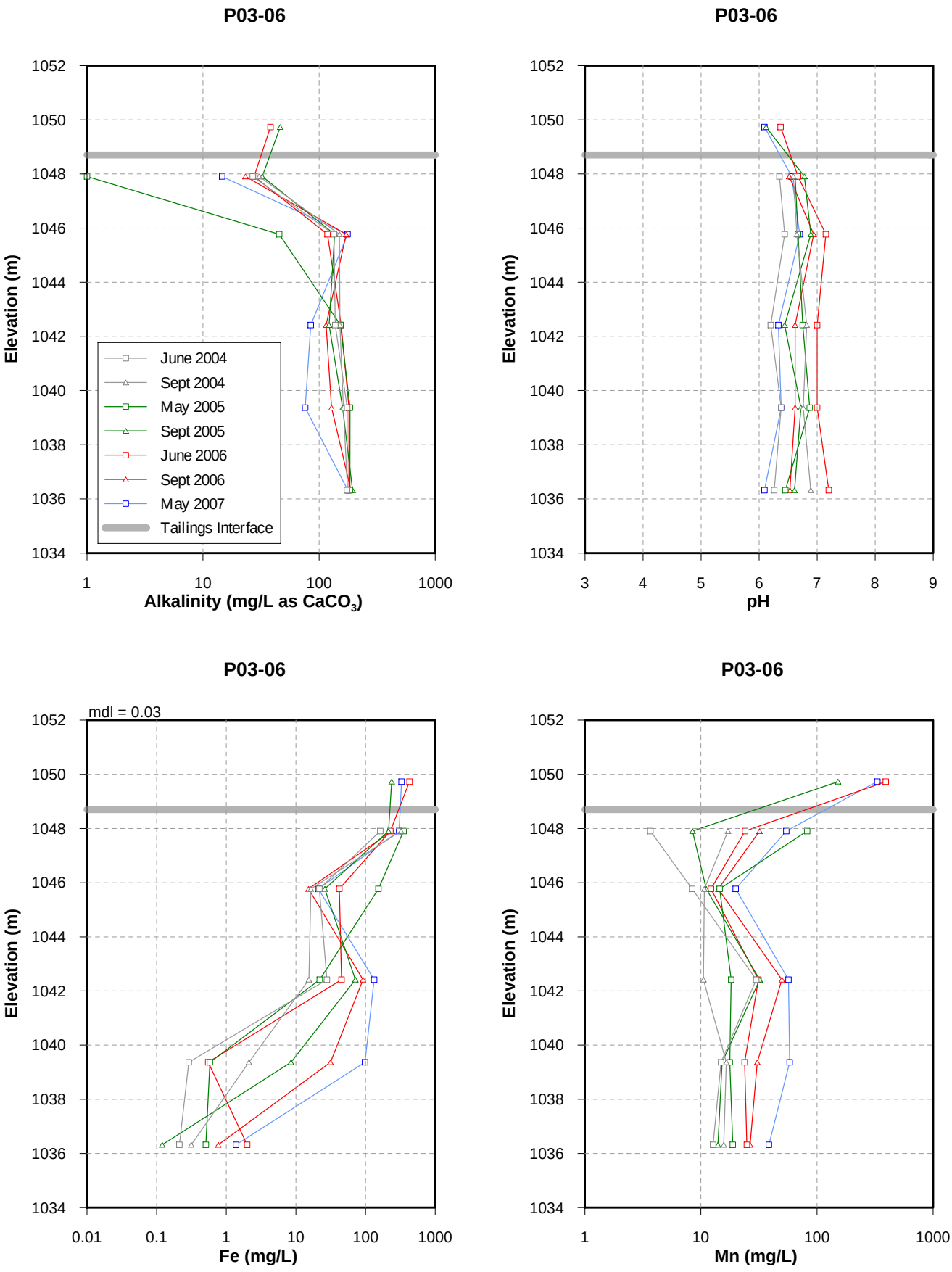


Figure 3-11b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-06 (Second Impoundment).

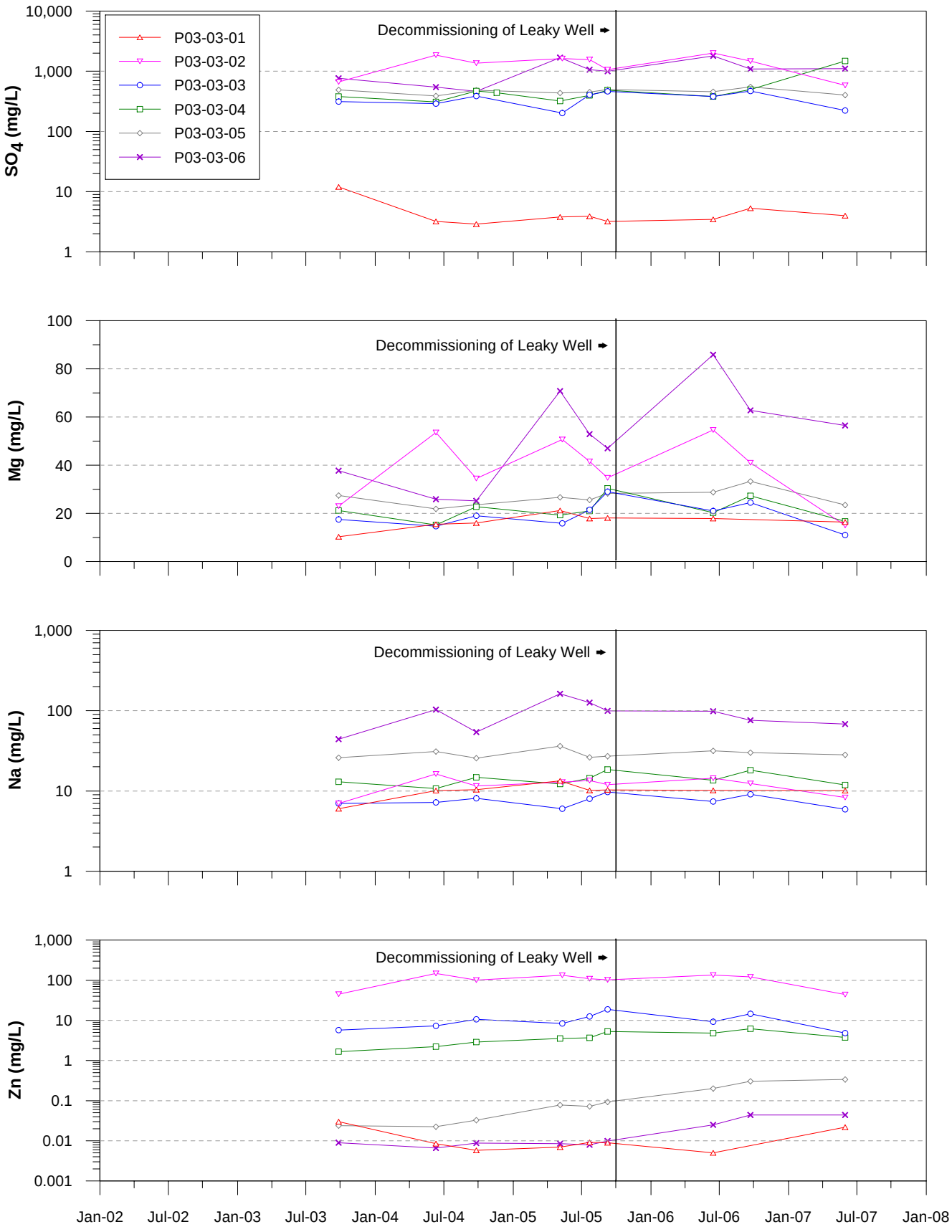


Figure 3-12a. Water quality (SO_4, Mg, Na and Zn) in P03-03 (aquifer only).

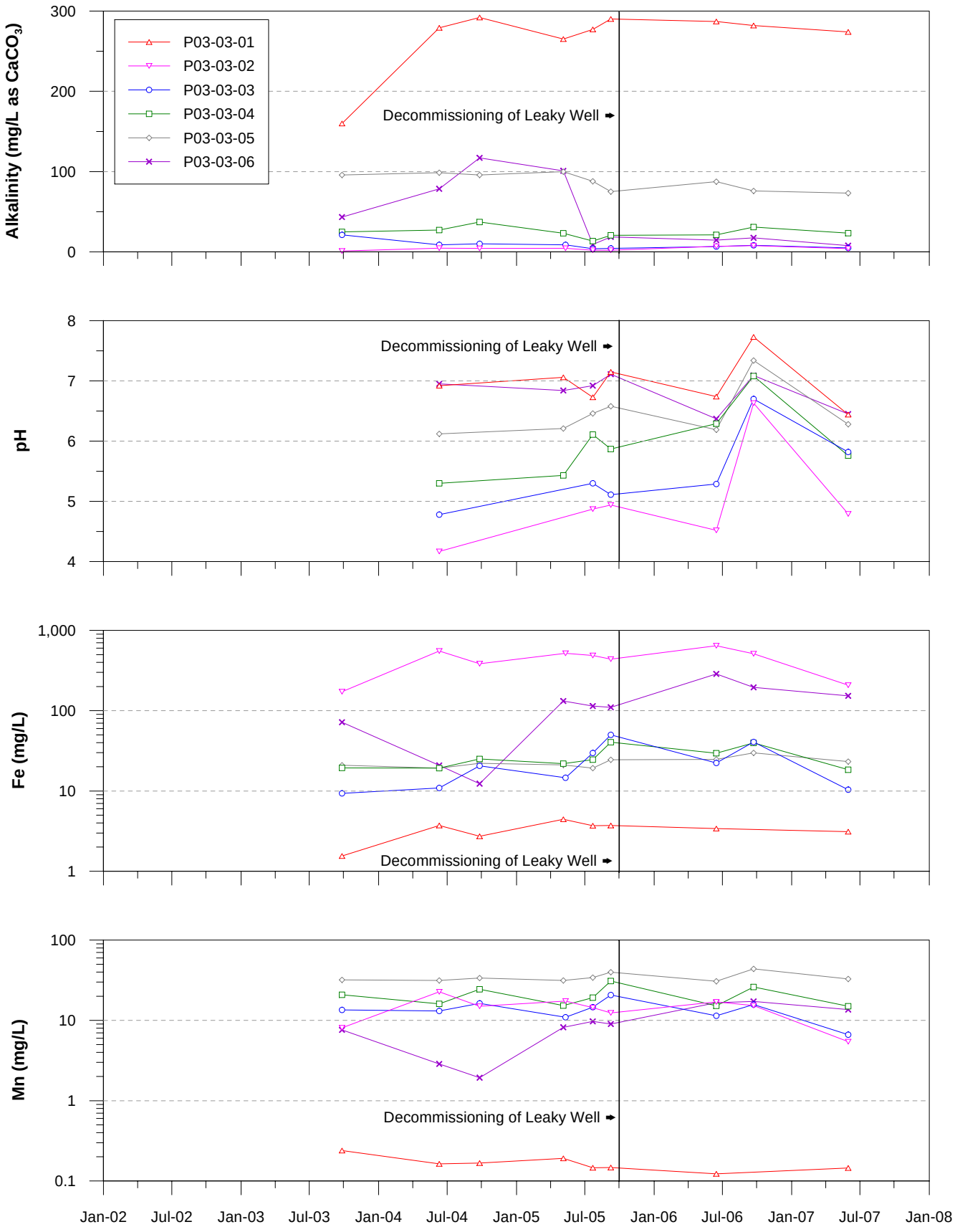


Figure 3-12b. Water quality (alkalinity, pH, Fe and Mn) in P03-03 (aquifer only).

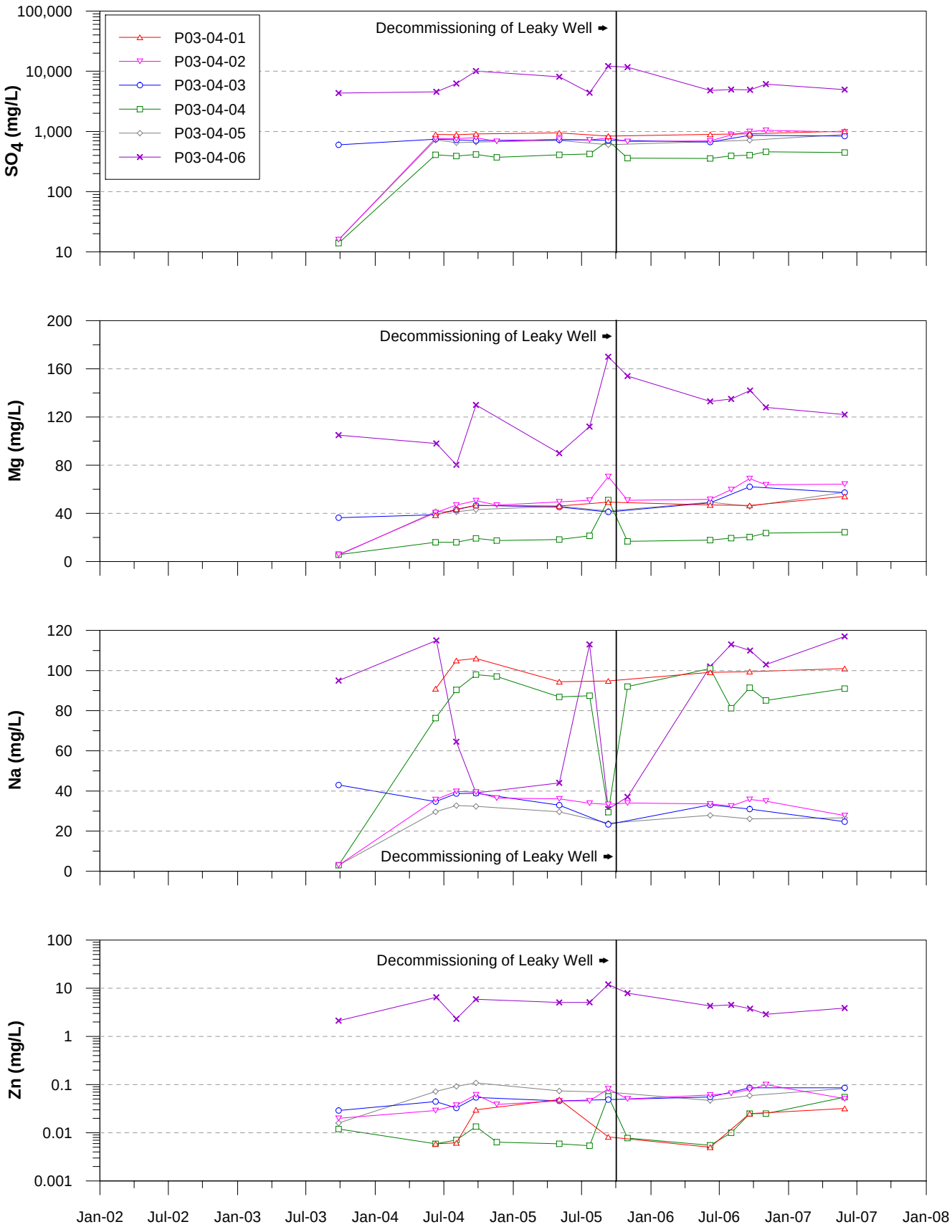


Figure 3-13a. Water quality (SO_4, Mg, Na and Zn) in P03-04 (aquifer only).

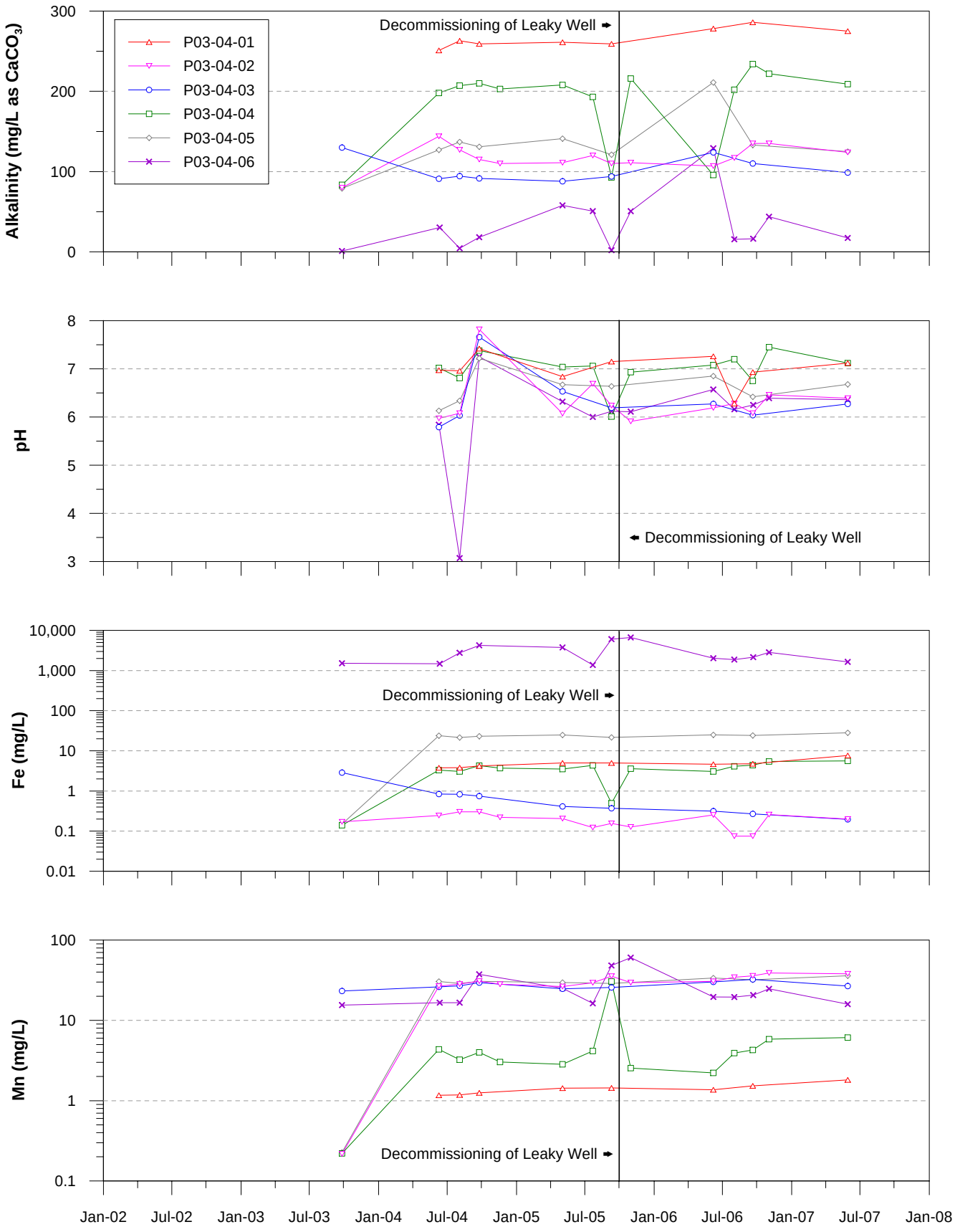


Figure 3-13b. Water quality (alkalinity, pH, Fe and Mn) in P03-04 (aquifer only).

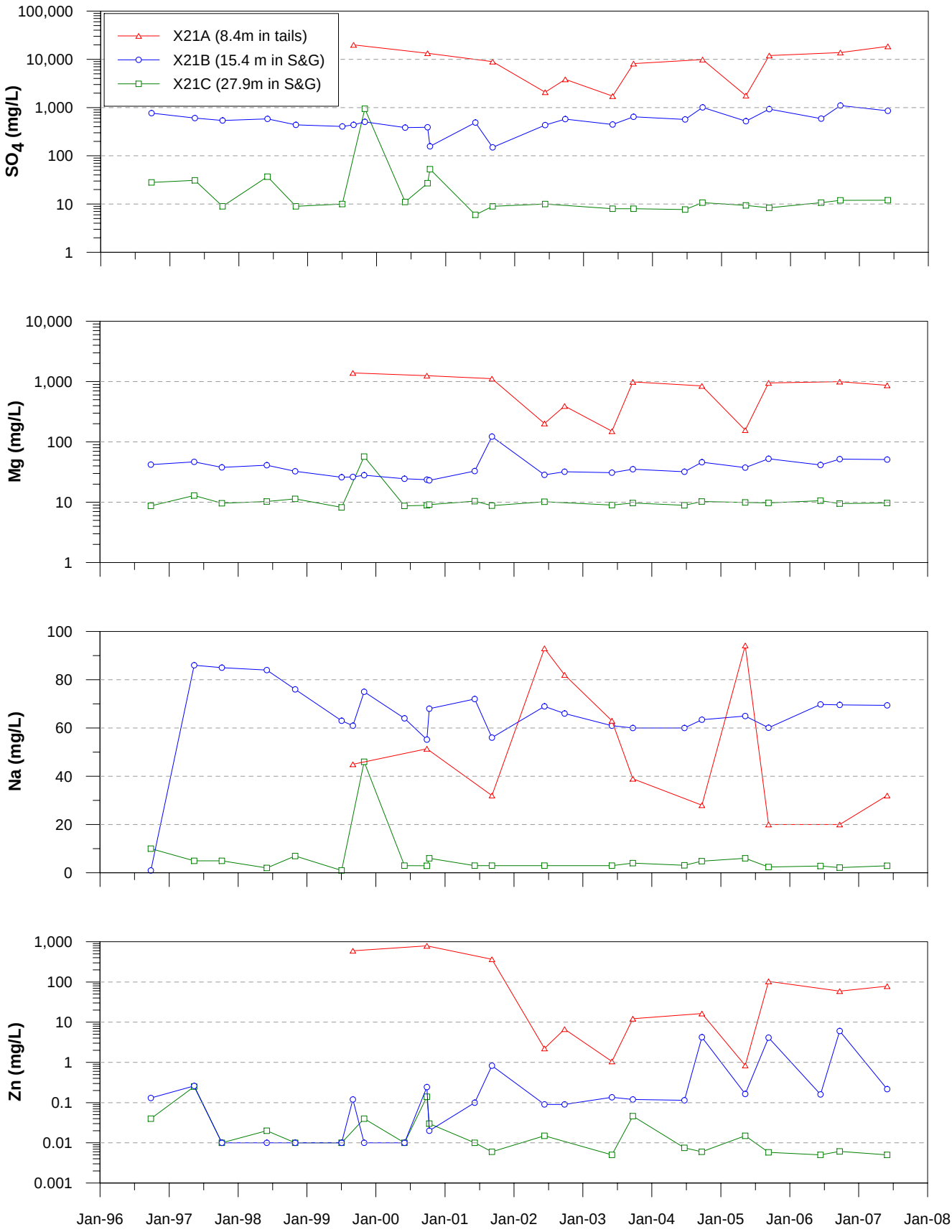


Figure 3-14a. Water quality (SO_4, Mg, Na and Zn) in X21(96) (Intermediate Impoundment).

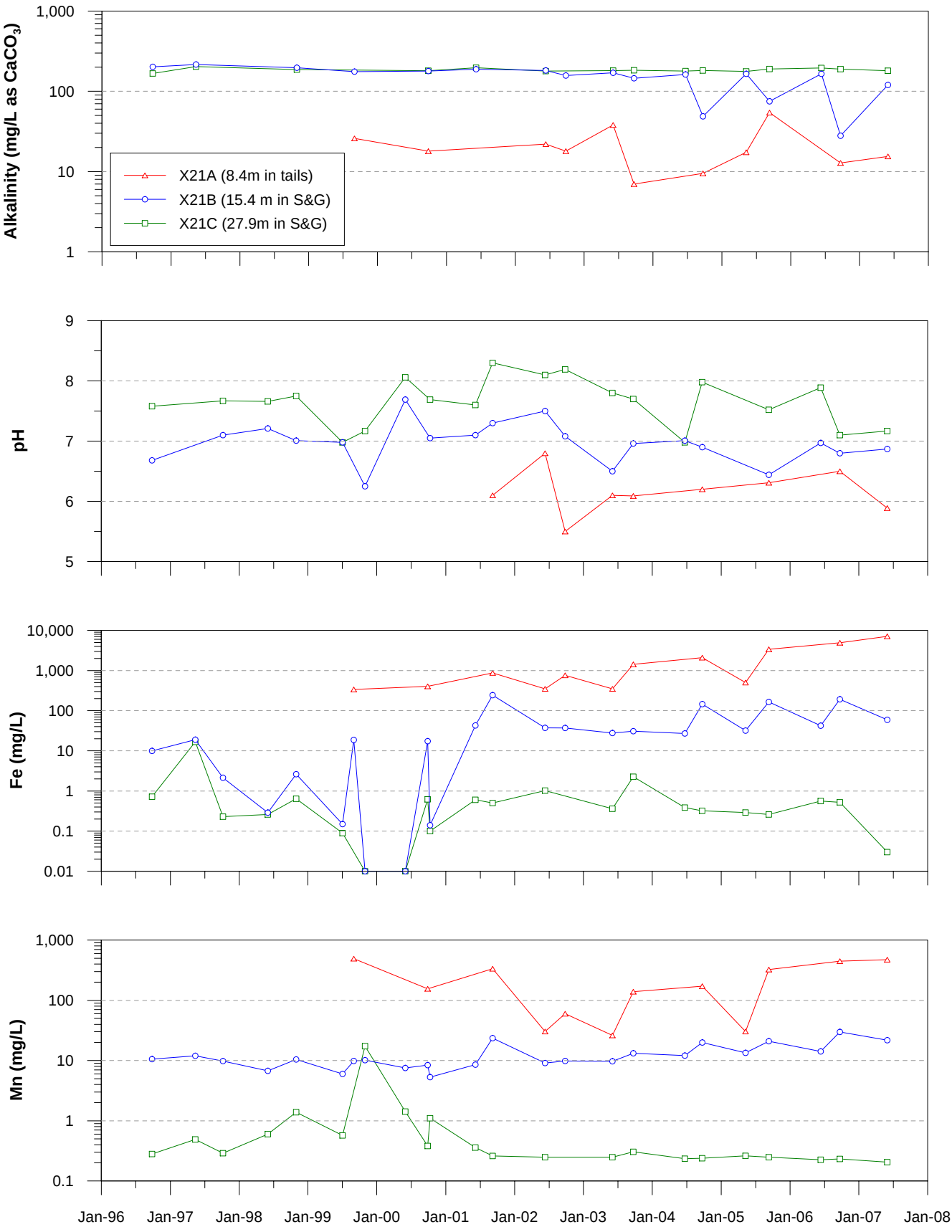


Figure 3-14b. Water quality (Alkalinity, pH, Fe and Mn) in X21(96) (Intermediate Impoundment).

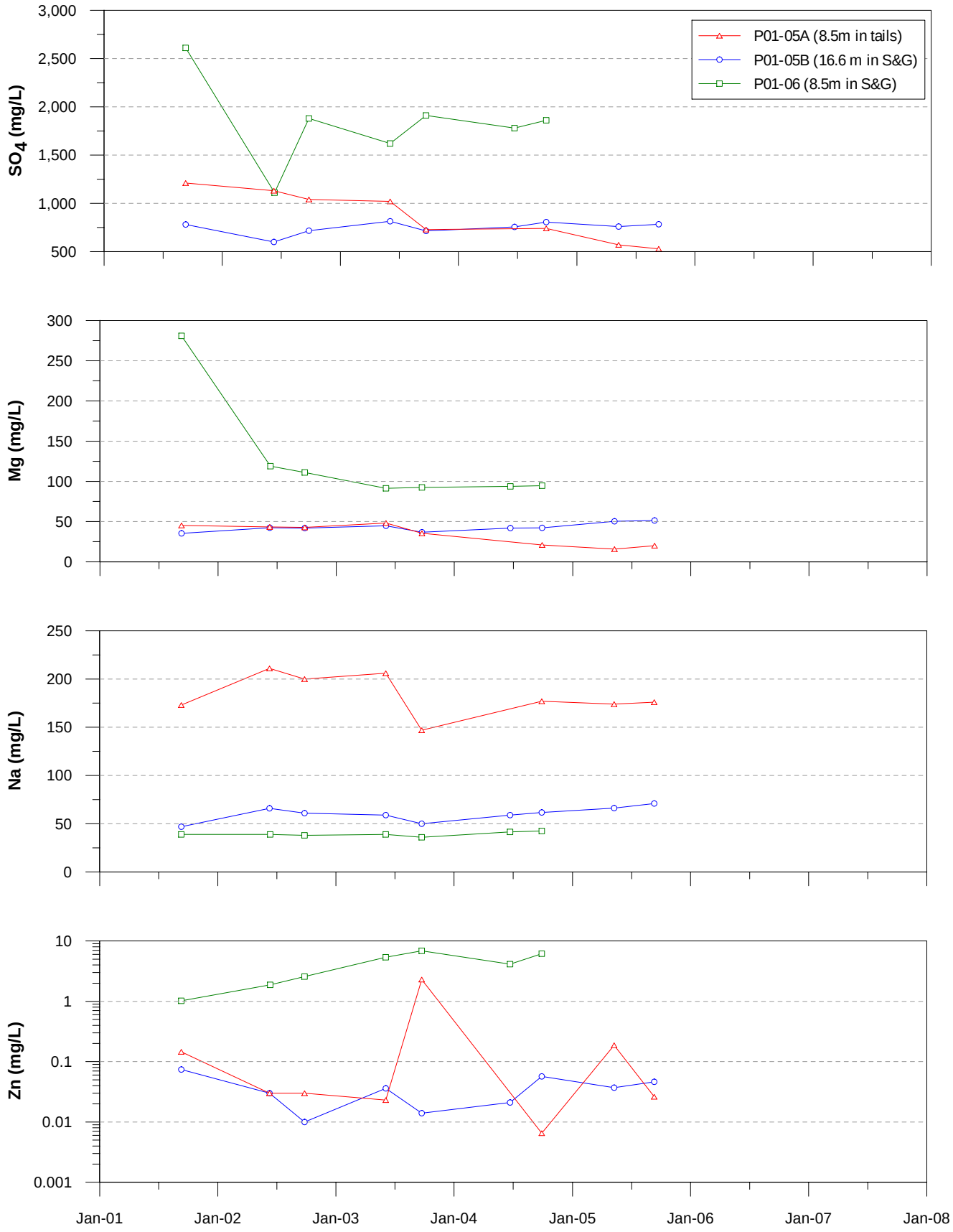


Figure 3-15a. Water quality (SO_4, Mg, Na and Zn) in P01-05 and P01-06 (Intermediate Impoundment).

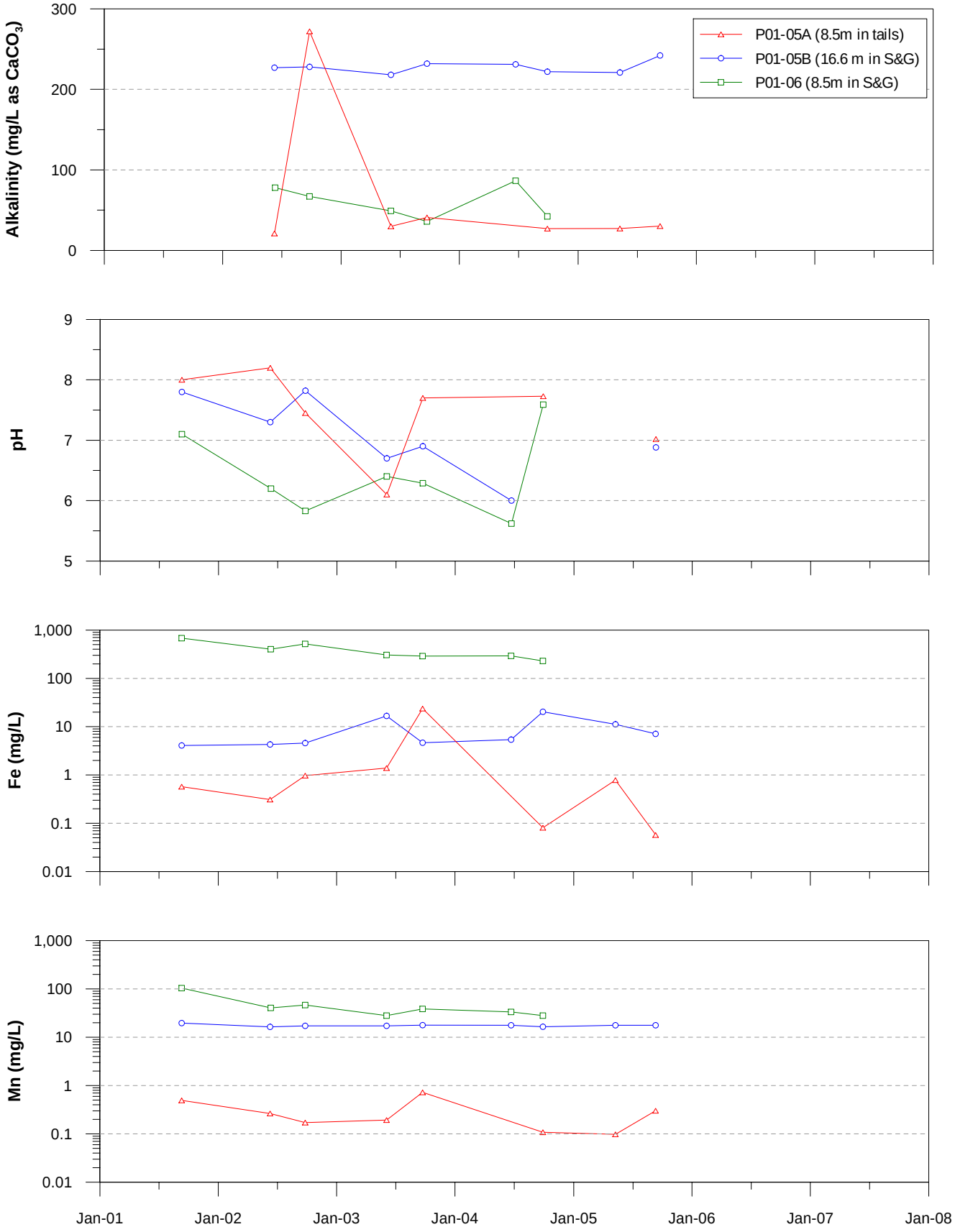


Figure 3-15b. Water quality (alkalinity, pH, Fe and Mn) in P01-05 and P01-06 (Intermediate Impoundment).

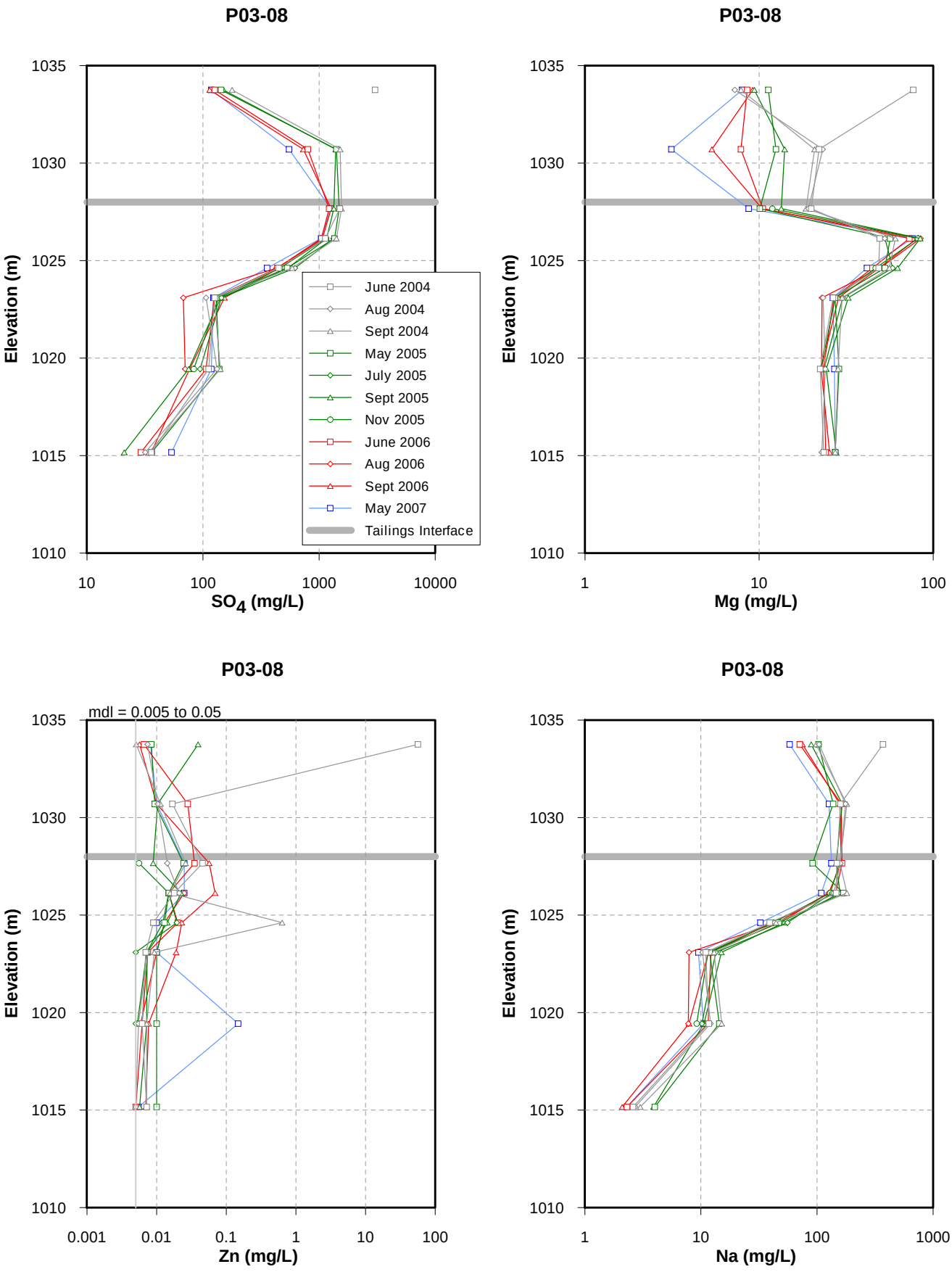


Figure 3-16a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-08 (Intermediate Impoundment).

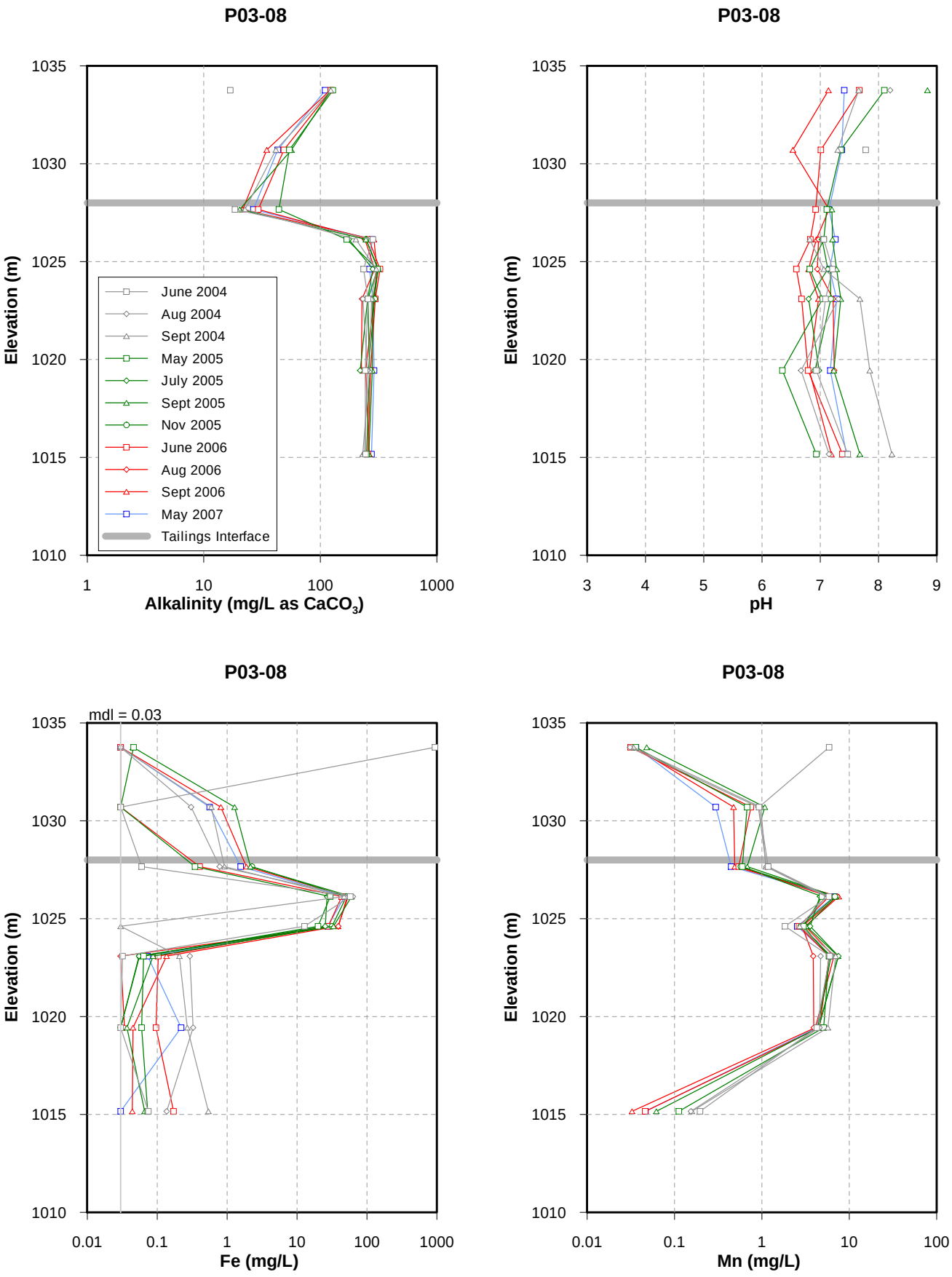


Figure 3-16b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-08 (Intermediate Impoundment).

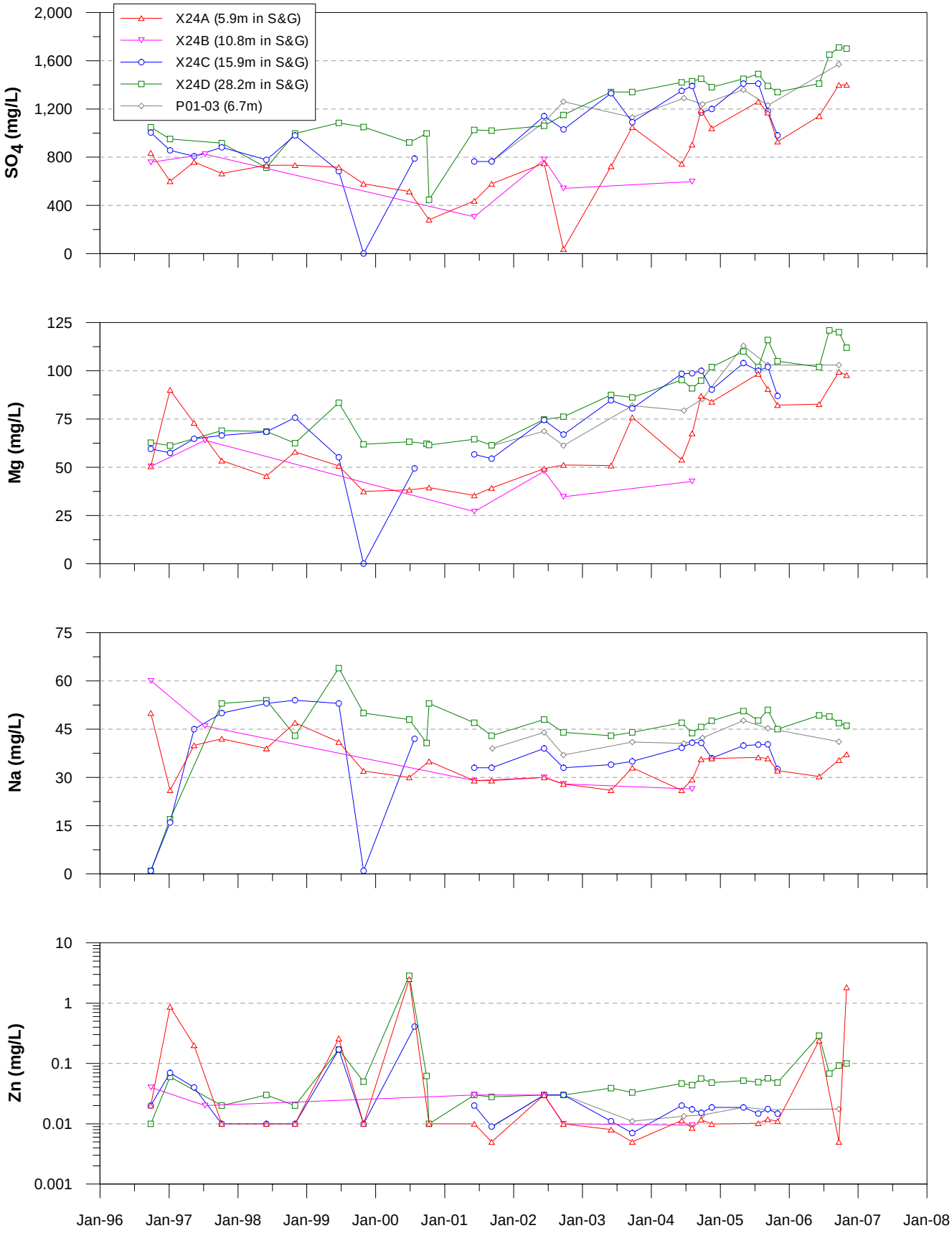


Figure 3-17a. Water quality (SO_4, Mg, Na and Zn) in X24(96) and P01-03 (north side of Intermediate Dam).

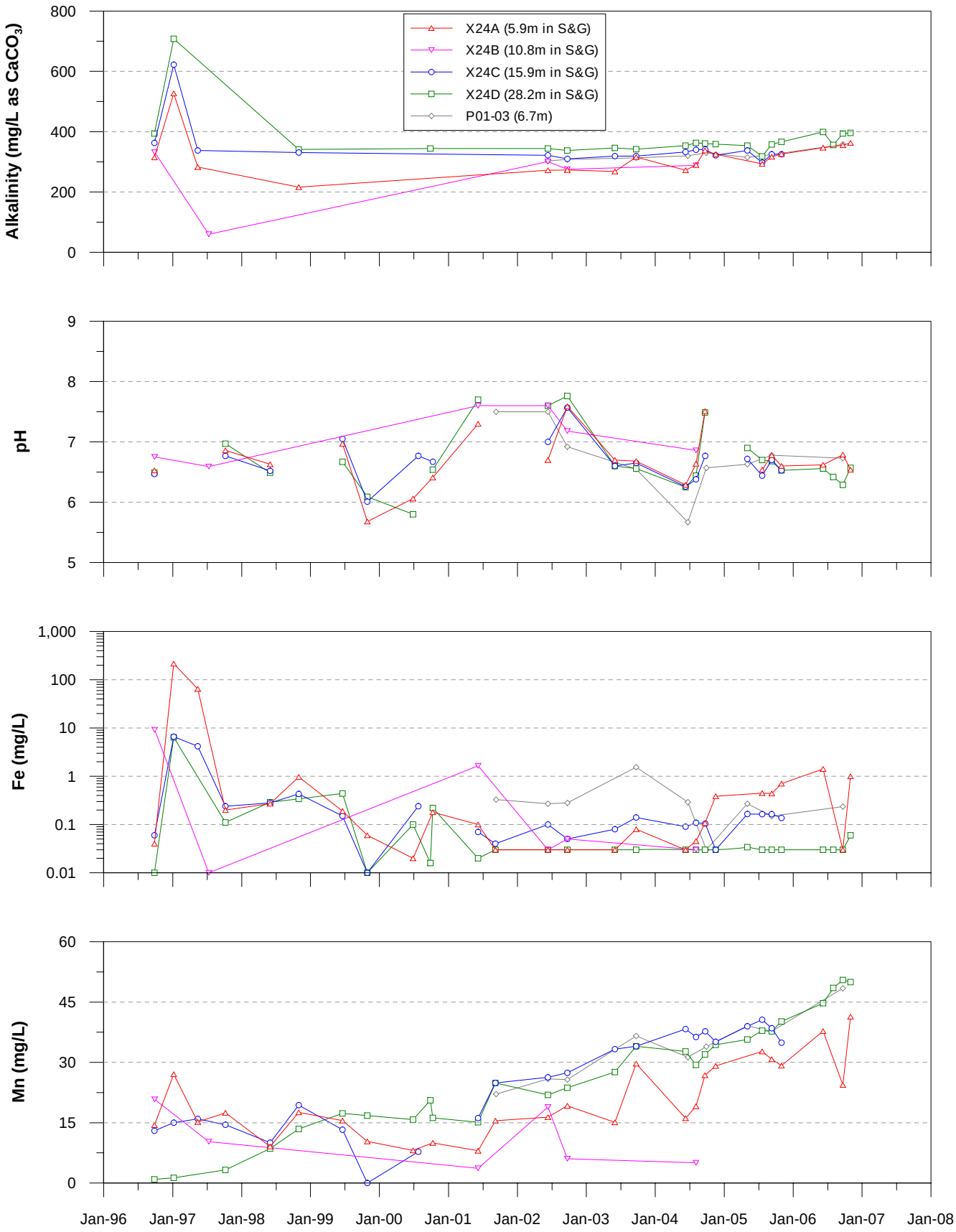


Figure 3-17b. Water quality (alkalinity, pH, Fe and Mn) in X24(96) and P01-03 (north side of Intermediate Dam).

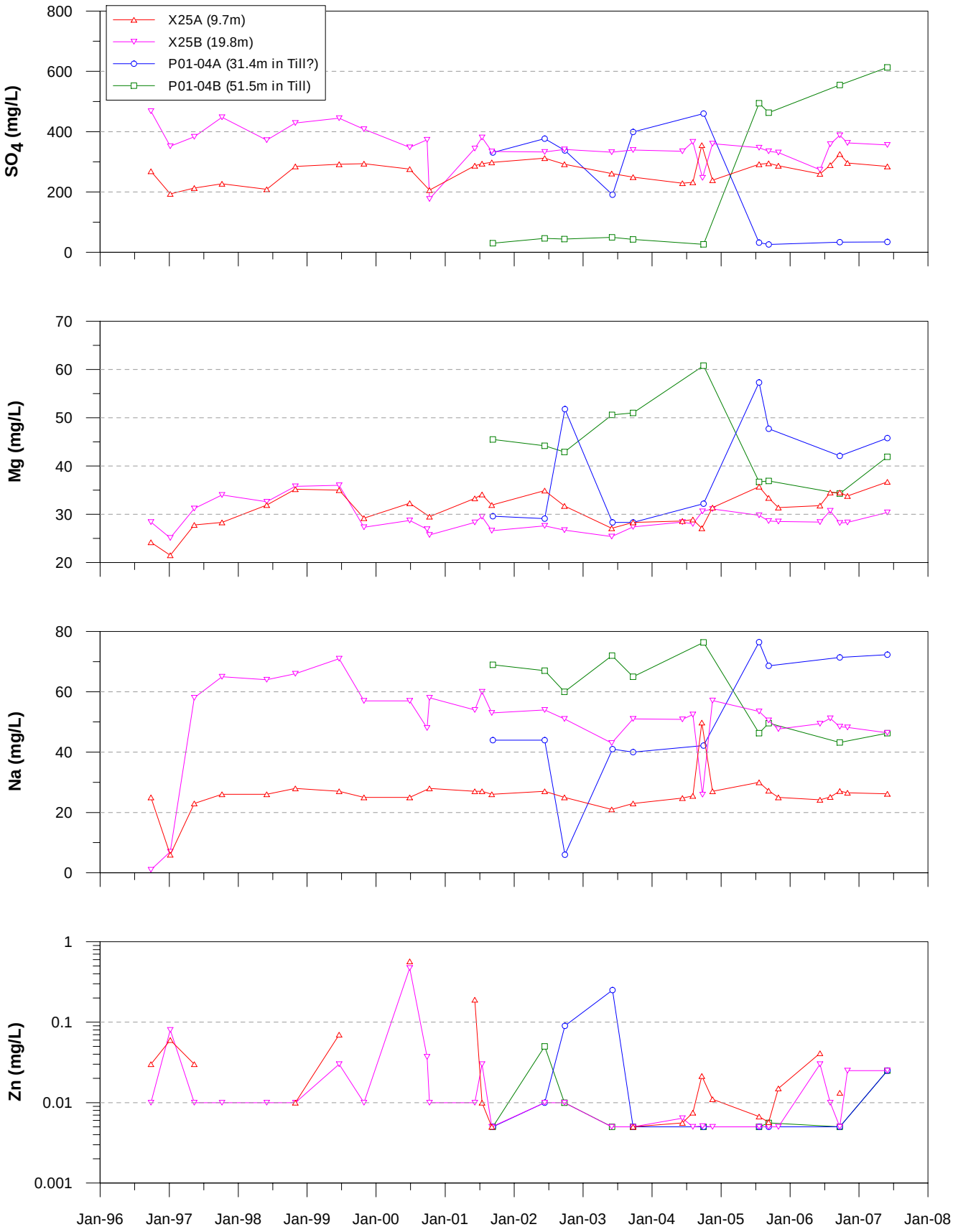


Figure 3-18a. Water quality (SO_4, Mg, Na and Zn) in X25(96) and P01-04 (south side of Intermediate Dam).

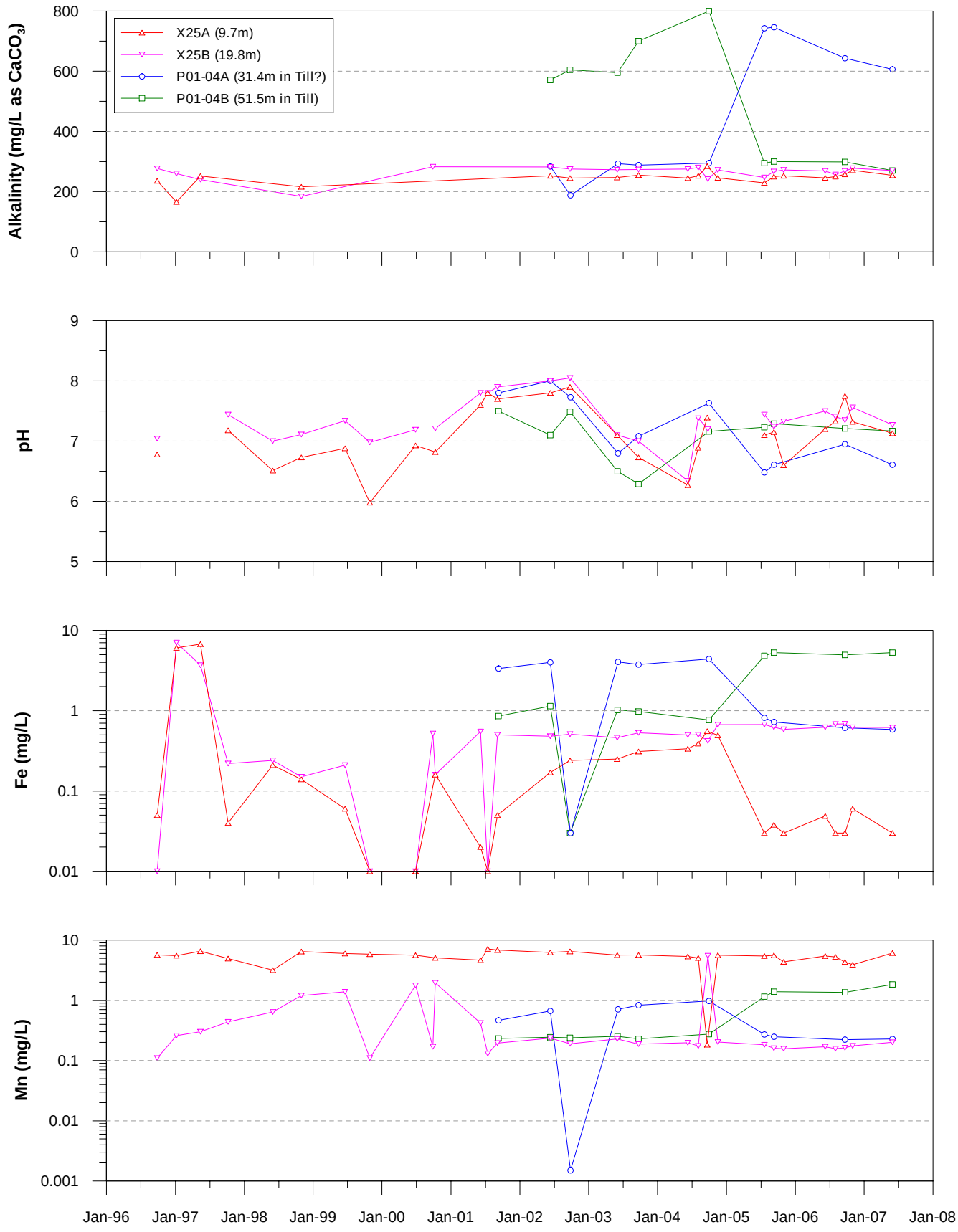


Figure 3-18b. Water quality (alkalinity, pH, Fe and Mn) in X25(96) and P01-04 (south side of Intermediate Dam).

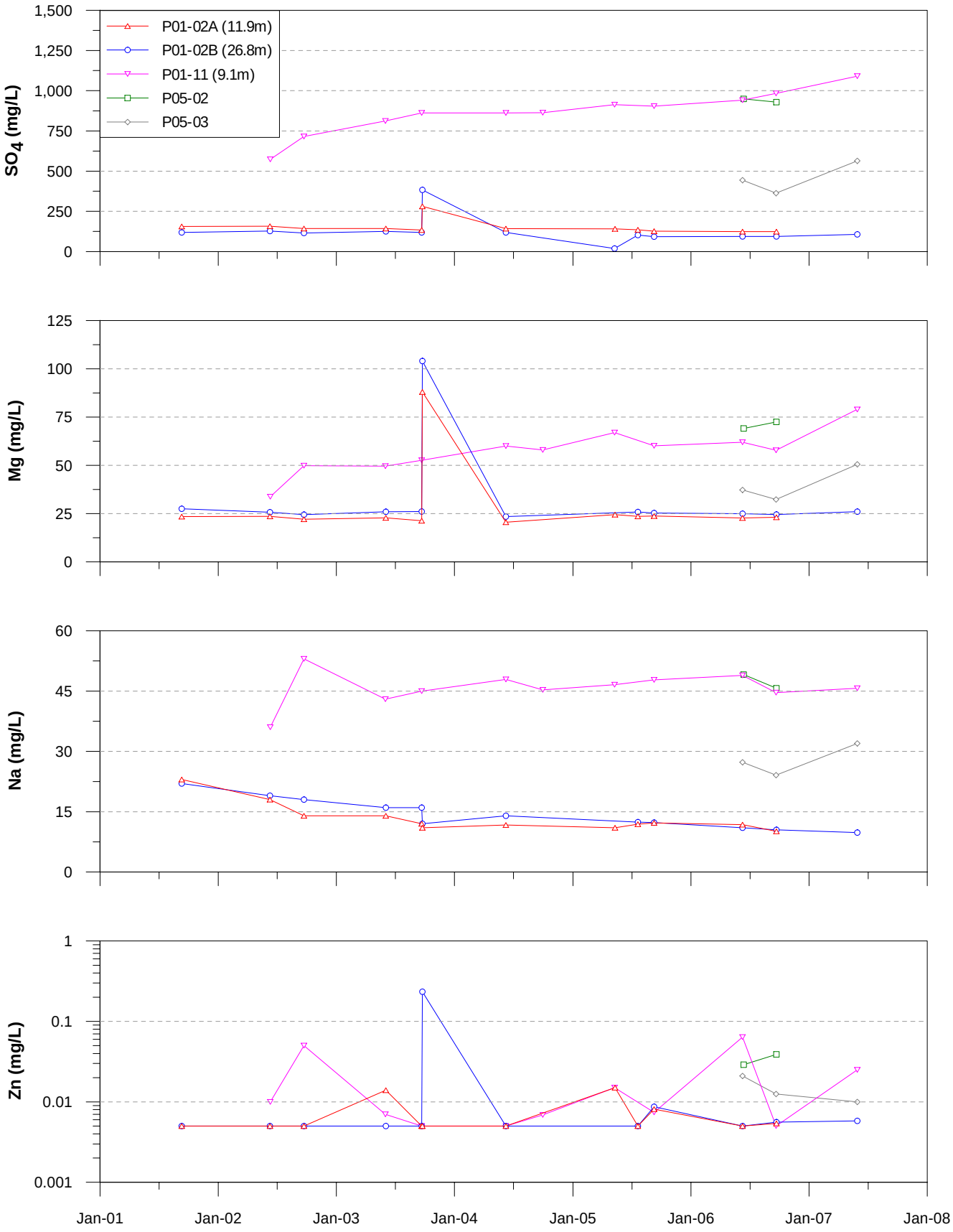


Figure 3-19a. Water quality (SO_4, Mg, Na and Zn) in wells along toe of Cross Valley Dam.

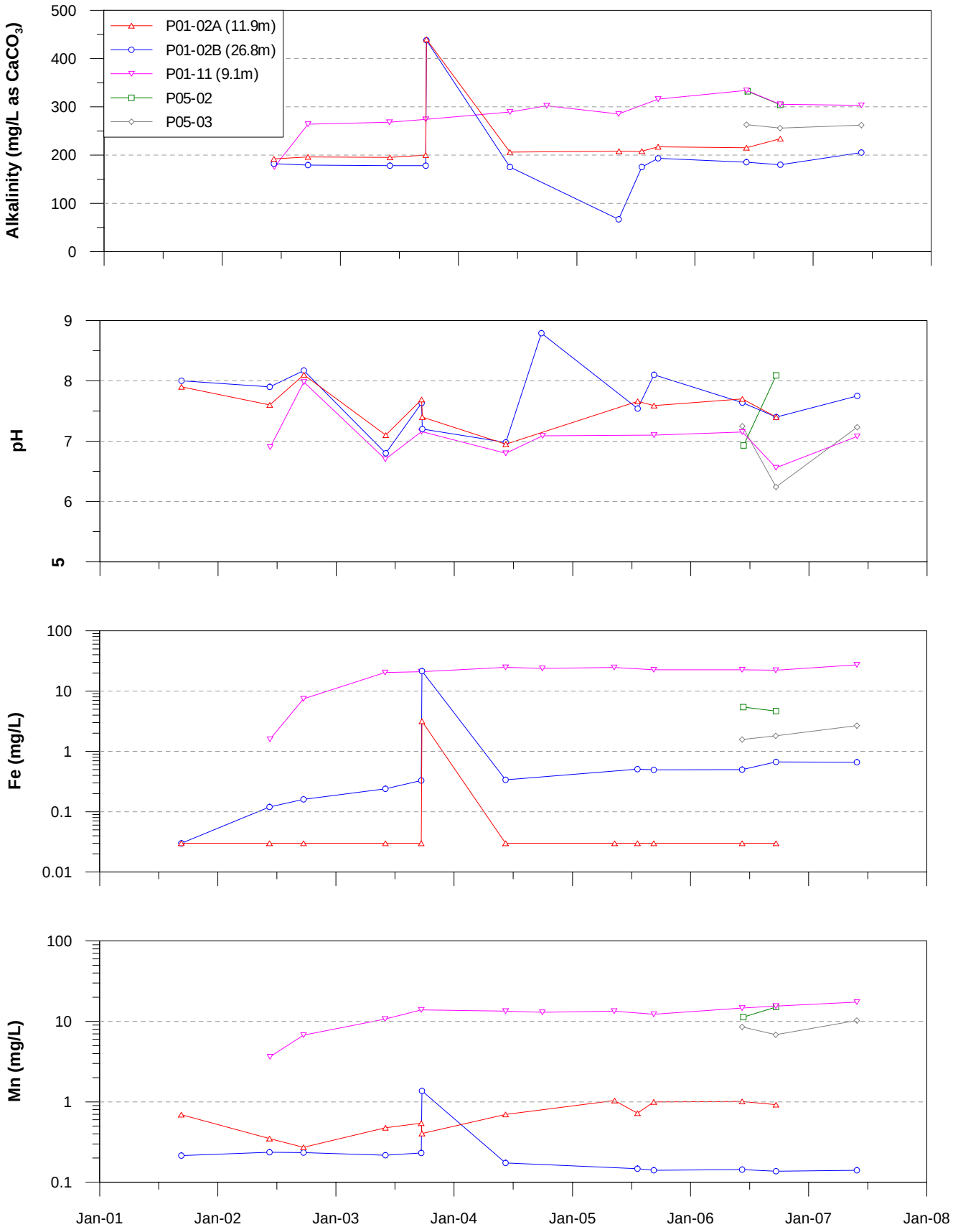


Figure 3-19b. Water quality (alkalinity, pH, Fe and Mn) in wells along toe of Cross Valley Dam.

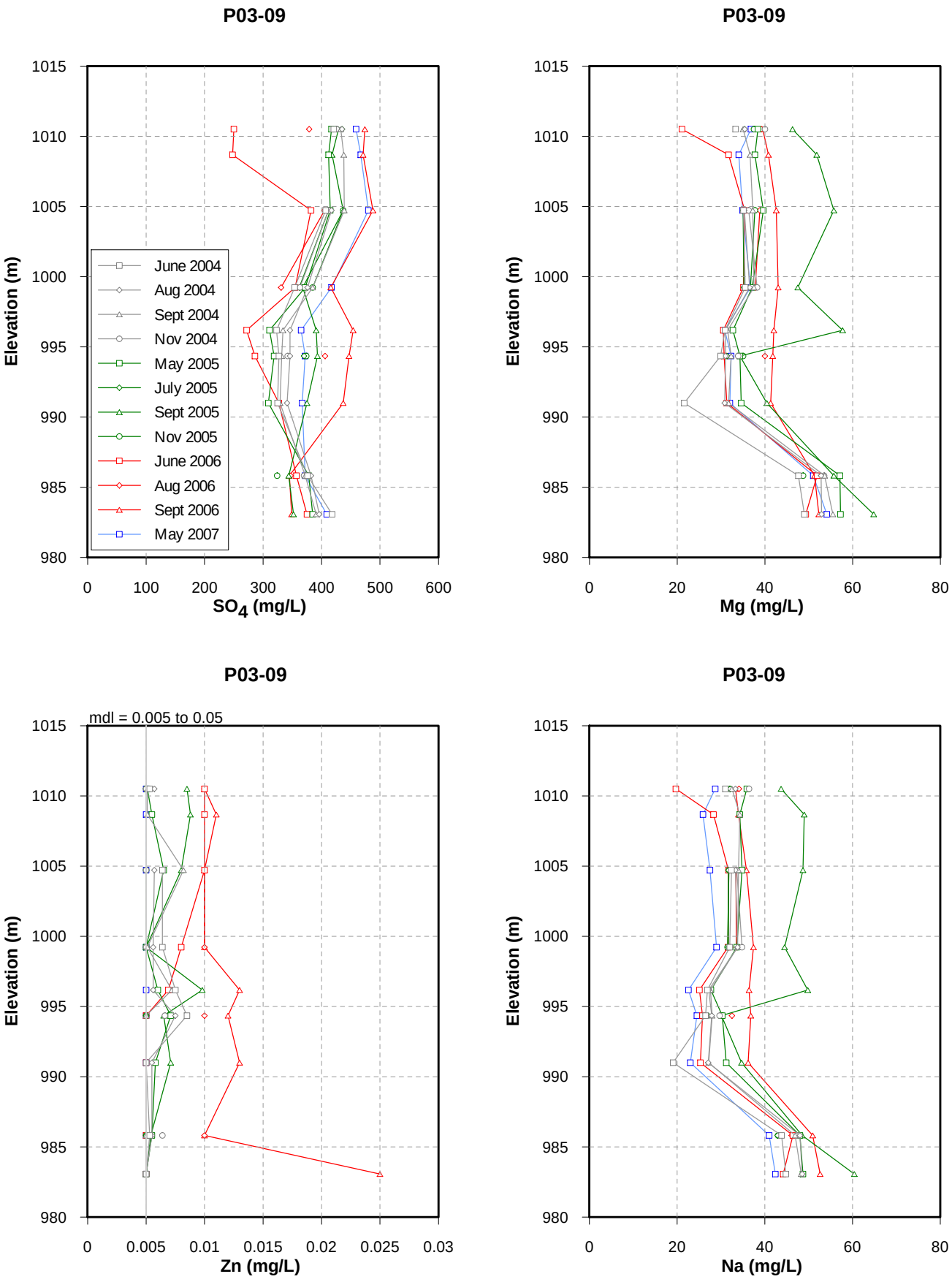


Figure 3-20a. Water quality depth profiles of SO_4, Mg, Zn and Na in P03-09 (at Cross Valley Dam).

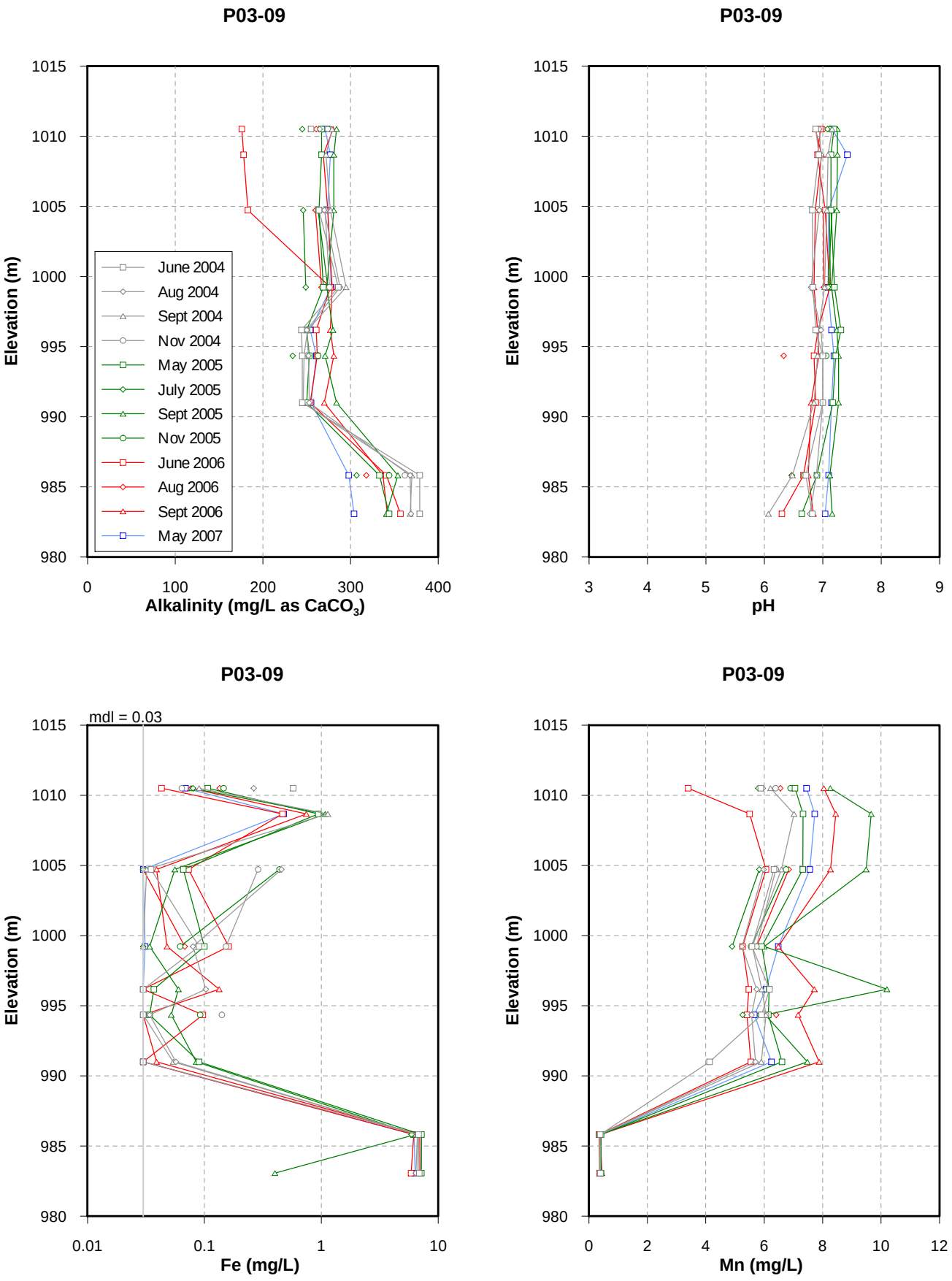


Figure 3-20b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P03-09 (at Cross Valley Dam).

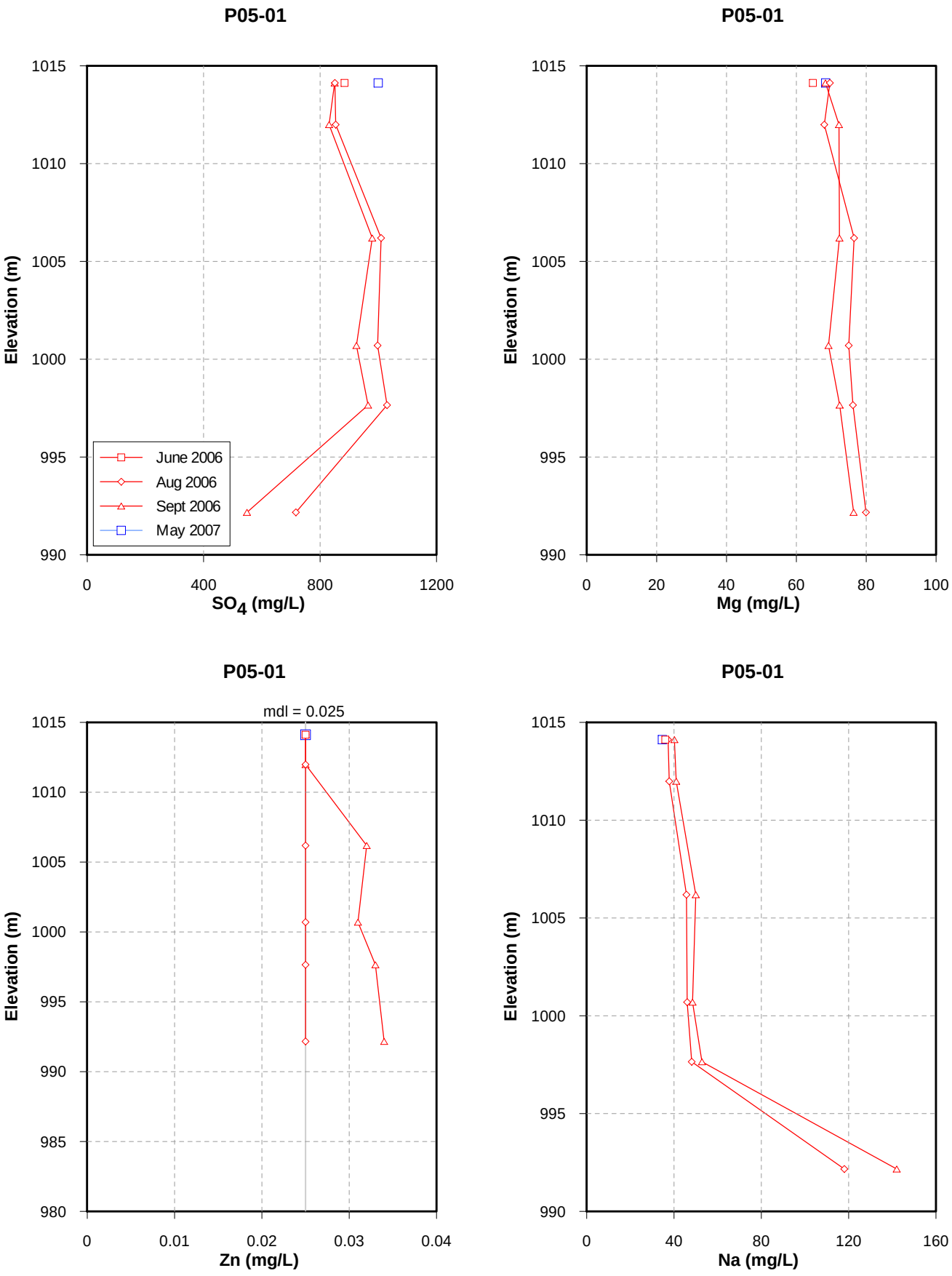


Figure 3-21a. Water quality depth profiles of SO_4, Mg, Zn and Na in P05-01 (at Cross Valley Dam).

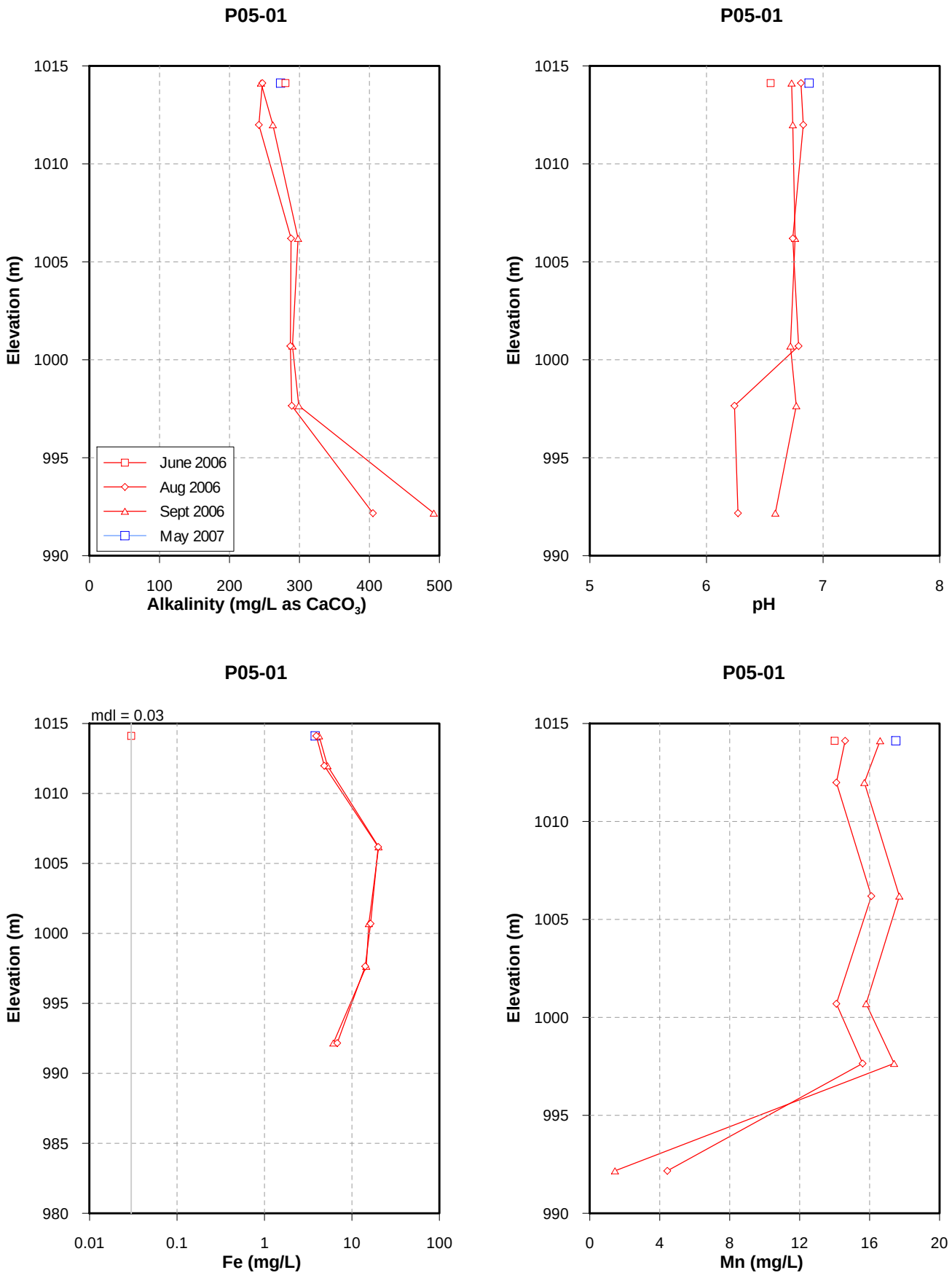


Figure 3-21b. Water quality depth profiles of alkalinity, pH, Fe and Mn in P05-01 (at Cross Valley Dam).

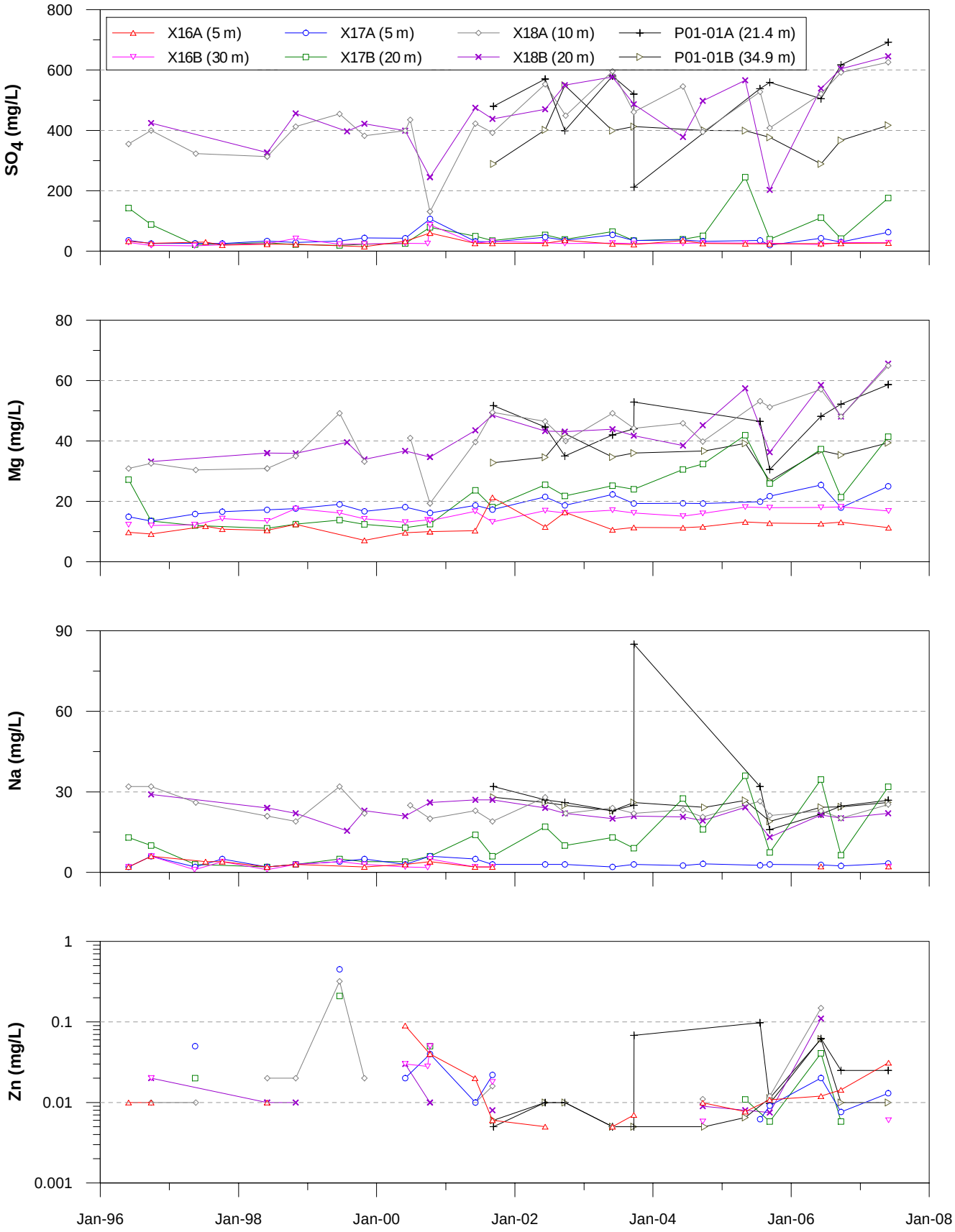


Figure 3-22a. Water quality (SO_4, Mg, Na and Zn) in wells downgradient of Cross Valley Dam.

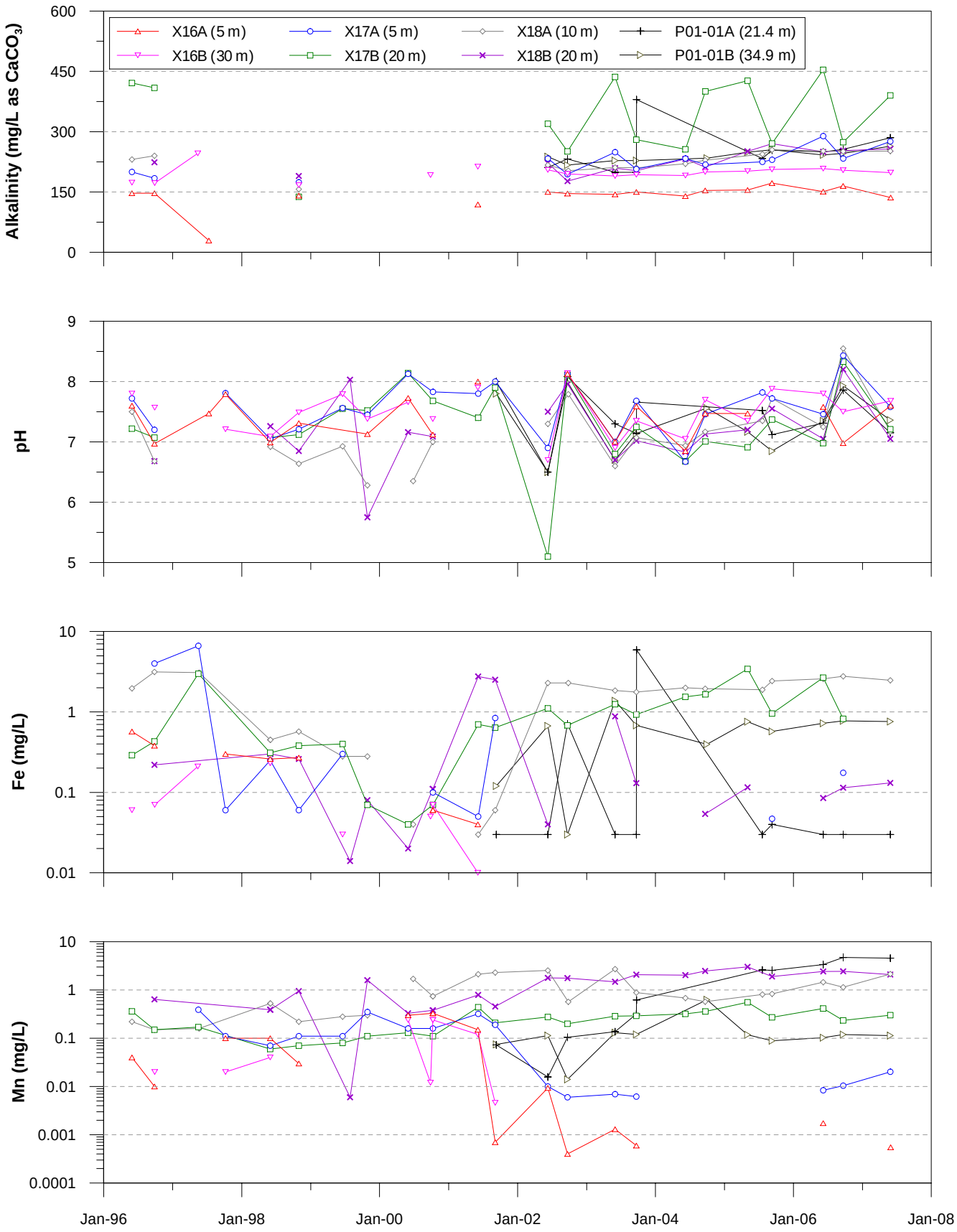


Figure 3-22b. Water quality (alkalinity, pH, Fe and Mn) in wells downgradient of Cross Valley Dam.

590000 592000 594000 596000

6904000

Grum Pit

Overburden Dump

Grum Rock Dump

Grum Creek

Vangorda Pit

Vangorda Rock Dump

Vangorda Creek

SRK04-5A/B
SRK05-05C
BH05-9B-R
P96-9A
SRK05-08
SRK05-09
SRK05-07
SRK05-06
V37
V36
P2001-02A/B
P2001-03
V35
V34

1320 1310 1290 1270 1240 1200 1310 1300 1290 1270 1250 1290 1240 1320 1270 1220 1200 1160 1180 1150 1110 1170

LEGEND

Monitoring Well

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

N W E S

Layout of Grum & Vangorda Mine Site

Anvil Range Mining Complex

SCALE

0 200 400 800 1,200 1,600 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Groundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 4-1

DATE: Nov - 07
DRAWN BY: OM
FILE: Faro_GrumVangorda.mxd

592500
593000
6904000
6903500
6903000

Overburden Dump

Grum

Rock Dump

1290
1260
1220
1190
1150
1130
1090
1250
1110

Grum Creek

Vangorda Creek

Moose Pond

SRK04-5A/B
BH05-9B-R
SRK05-05C
P96-9A
SRK05-08
SRK05-07
SRK05-06
SRK05-09

N
W
E
S

LEGEND

Monitoring Well

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

Groundwater Monitoring Wells
Grum Rock Dump Area
Grum & Vangorda Mine Site

SCALE

0 25 50 100 150 200 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Groundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 4-2

DATE: Nov - 07 DRAWN BY: OM FILE: Faro_Grum.mxd

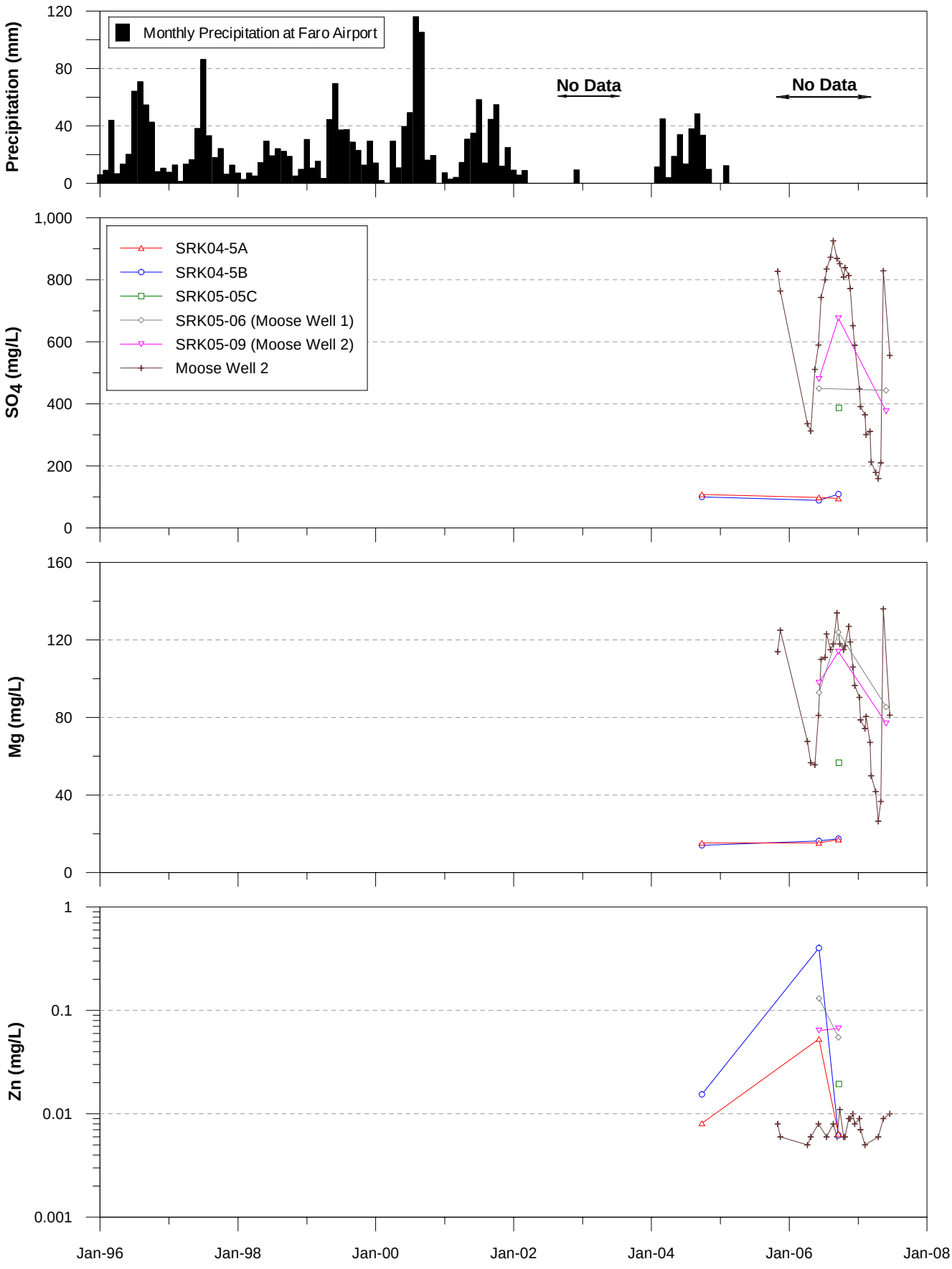


Figure 4-3a. Precipitation and water quality (SO_4, Mg and Zn) in wells in Grum Creek drainage.

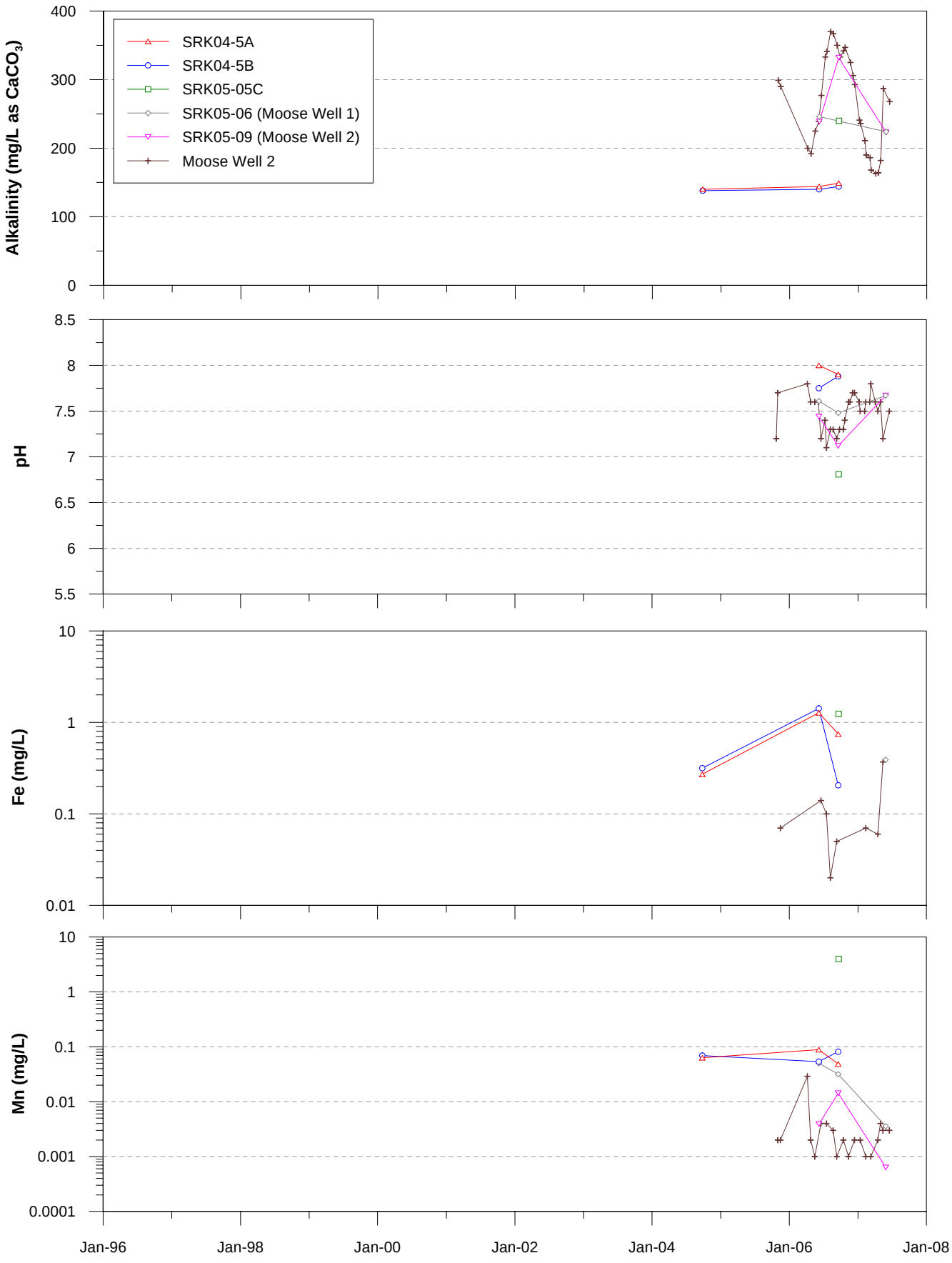


Figure 4-3b. Water quality (alkalinity, pH, Fe and Mn) in wells in Grum Creek drainage.

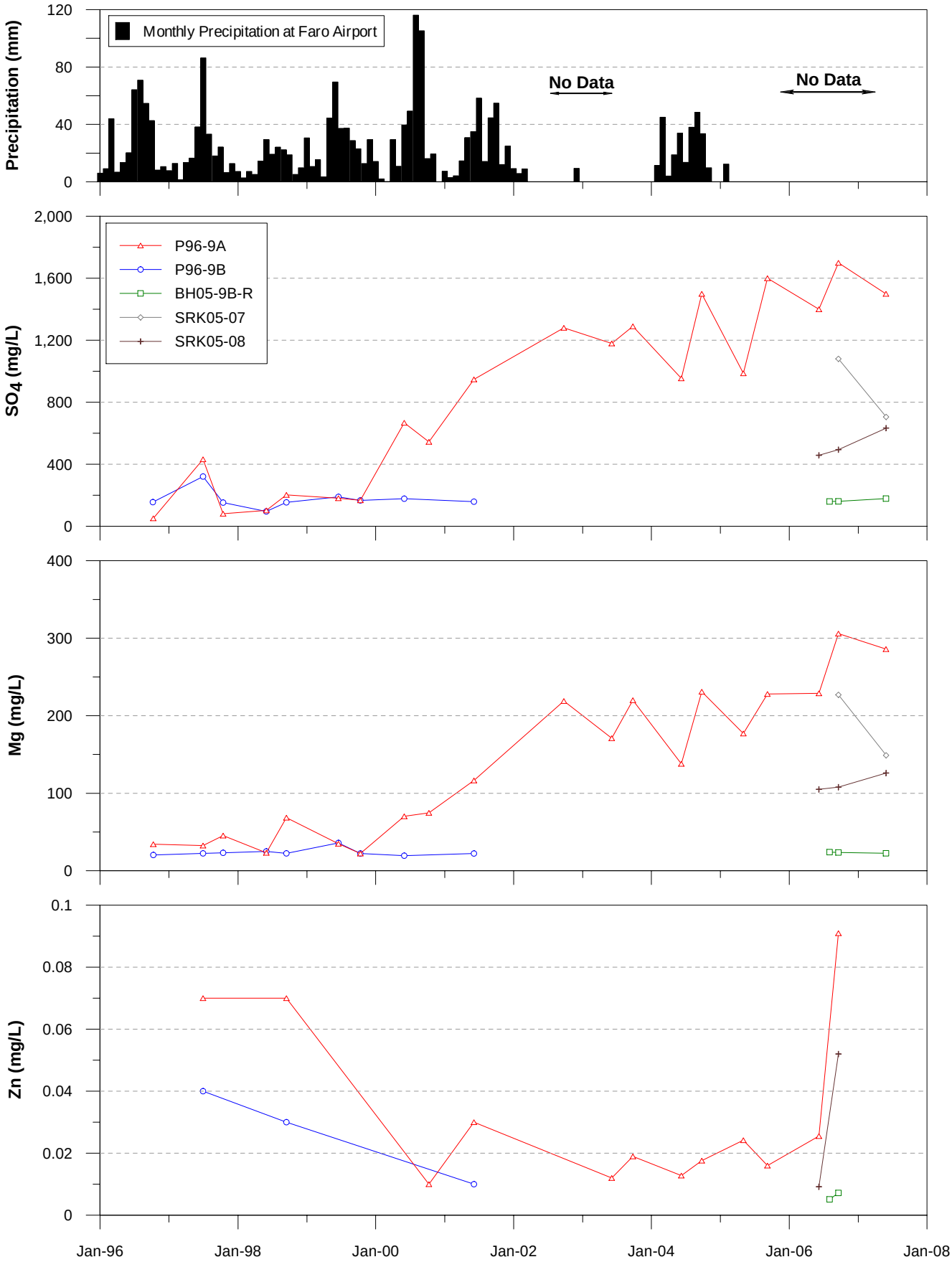


Figure 4-4a. Precipitation and water quality (SO_4, Mg and Zn) in wells located west of Grum Creek.

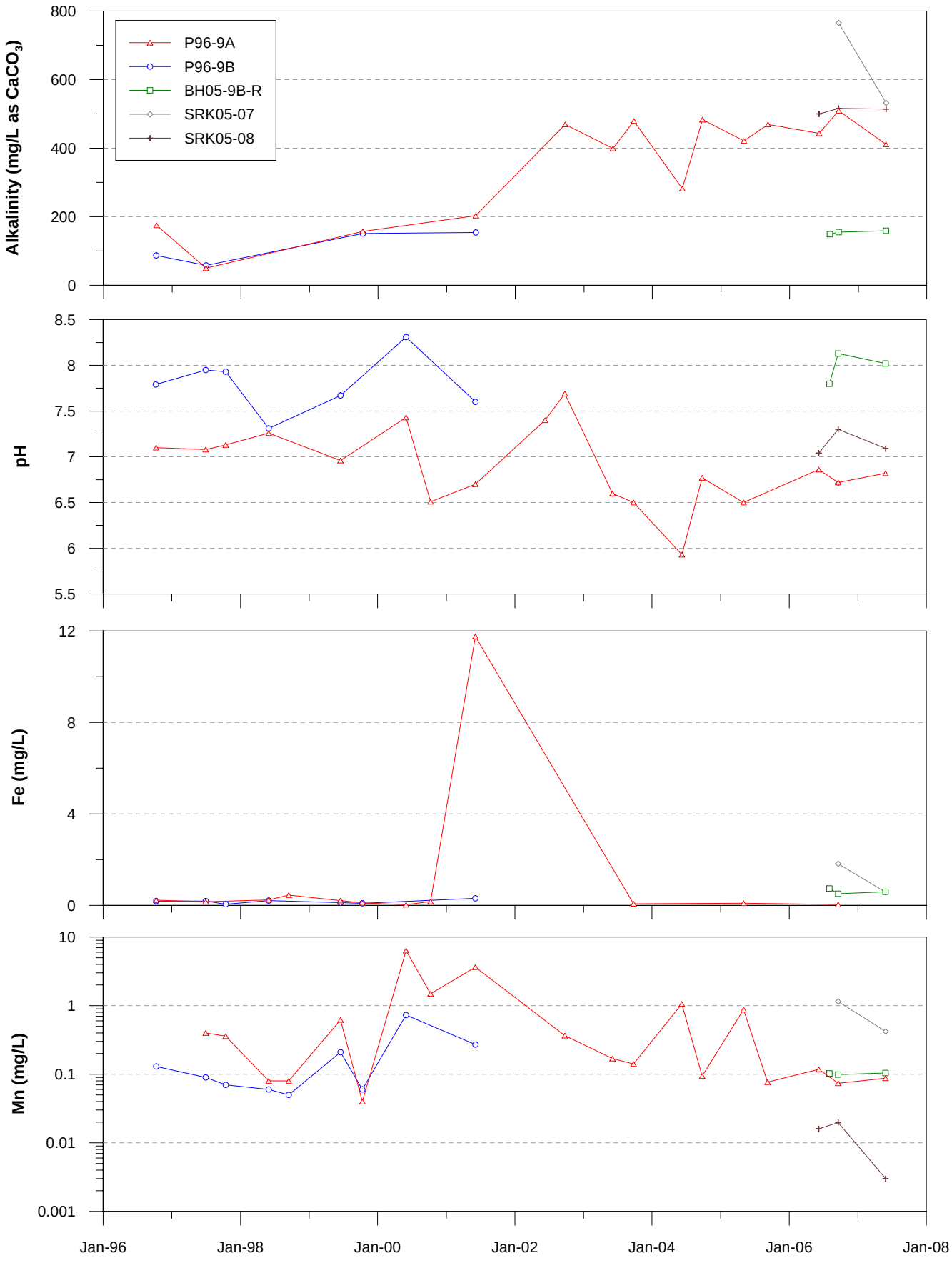
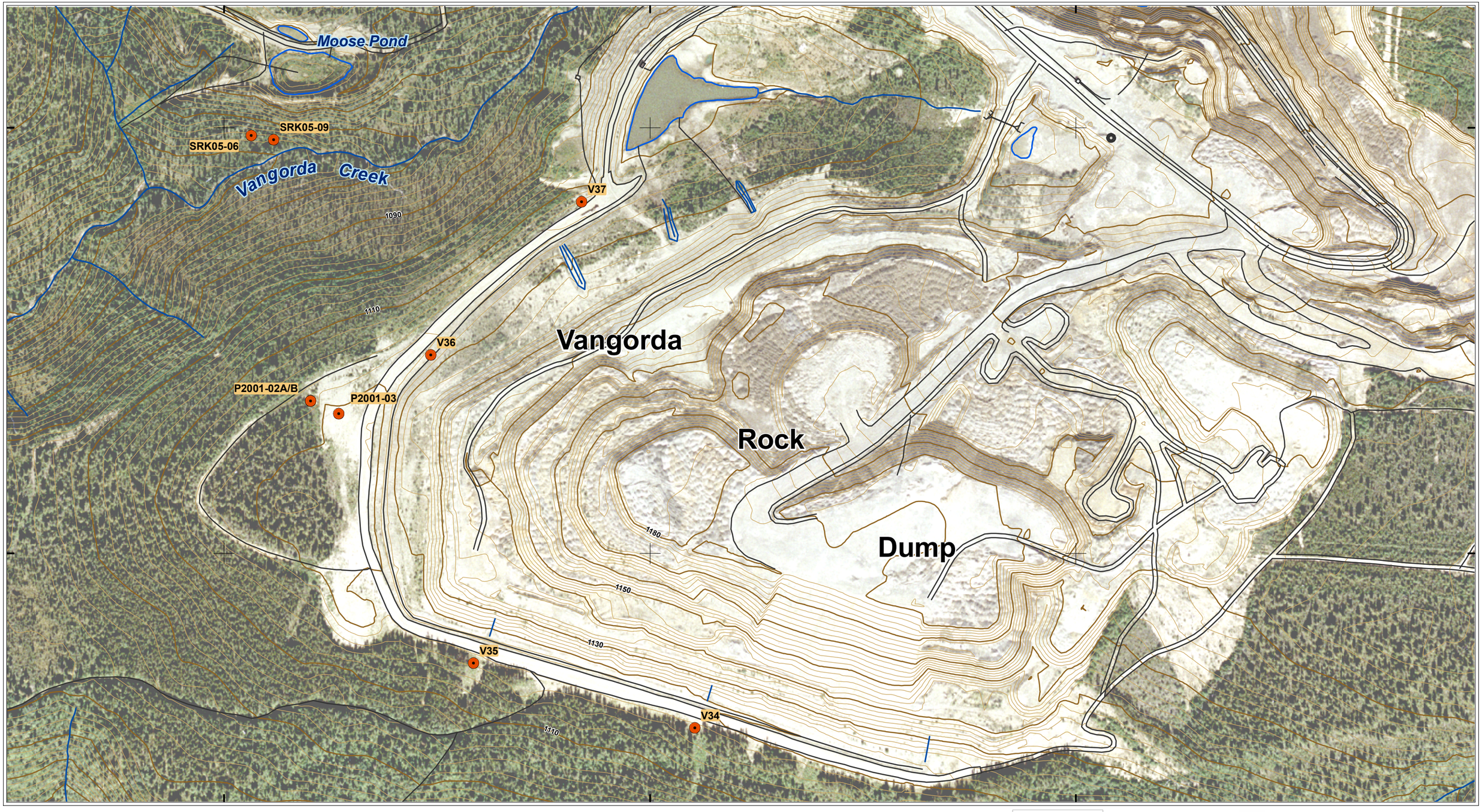


Figure 4-4b. Water quality (alkalinity, pH, Fe and Mn) in wells located west of Grum Creek.



Groundwater Monitoring Wells
Vangorda Rock Dump Area

Grum & Vangorda Mine Site

LEGEND

- Monitoring Well

PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

N
W E
S

SCALE

0 50 100 200 300 400 Meters

Deloitte & Touche

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Deloitte & Touche Inc.
PROJECT: 2007 Groundwater Review
REPORT: RGC 118012
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 4-5

DATE: Nov - 07
DRAWN BY: OM
FILE: Faro_Vangorda.mxd

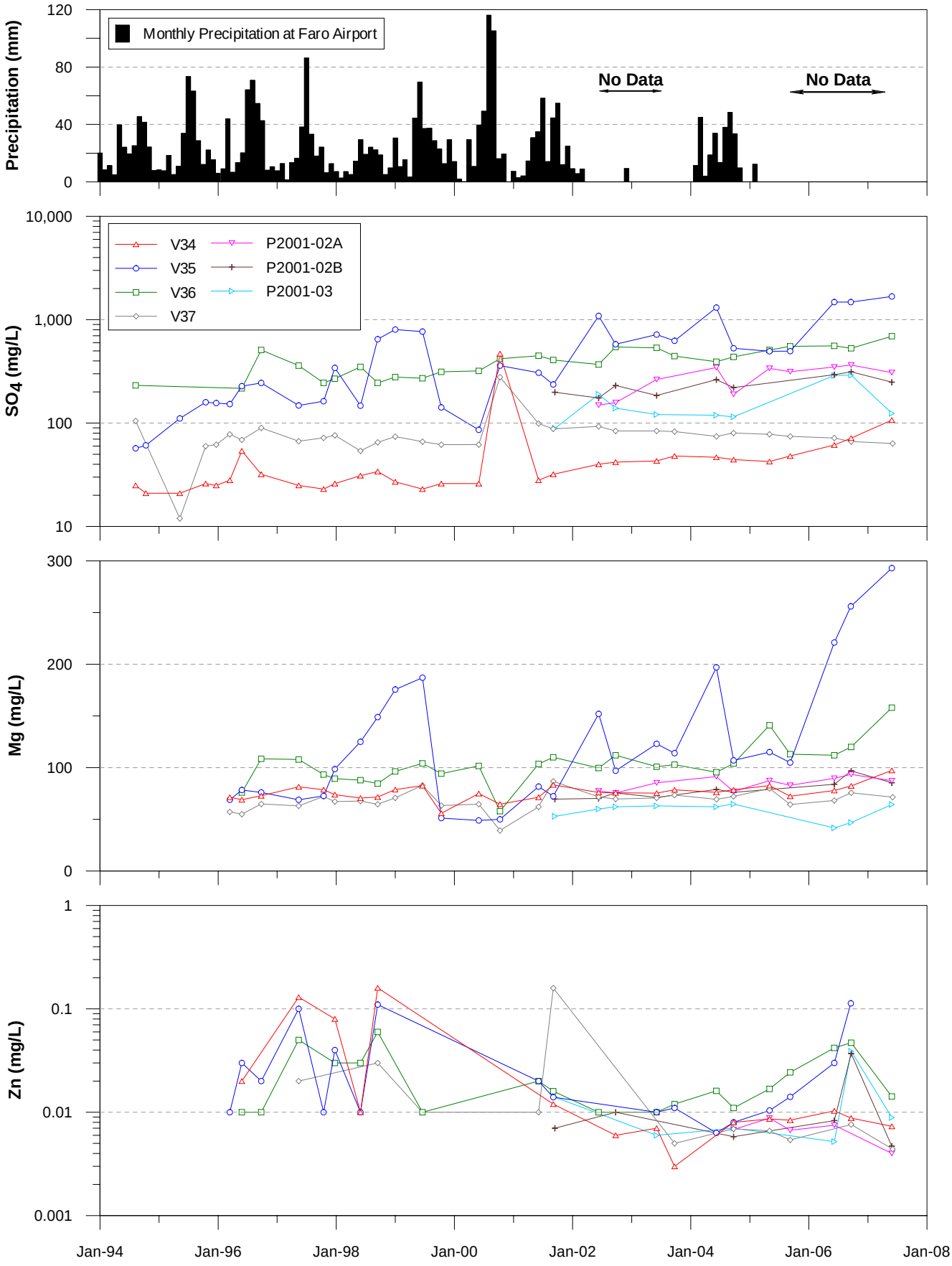


Figure 4-6a. Precipitation and water quality (SO_4, Mg and Zn) in wells downgradient of Vangorda Rock Dump.

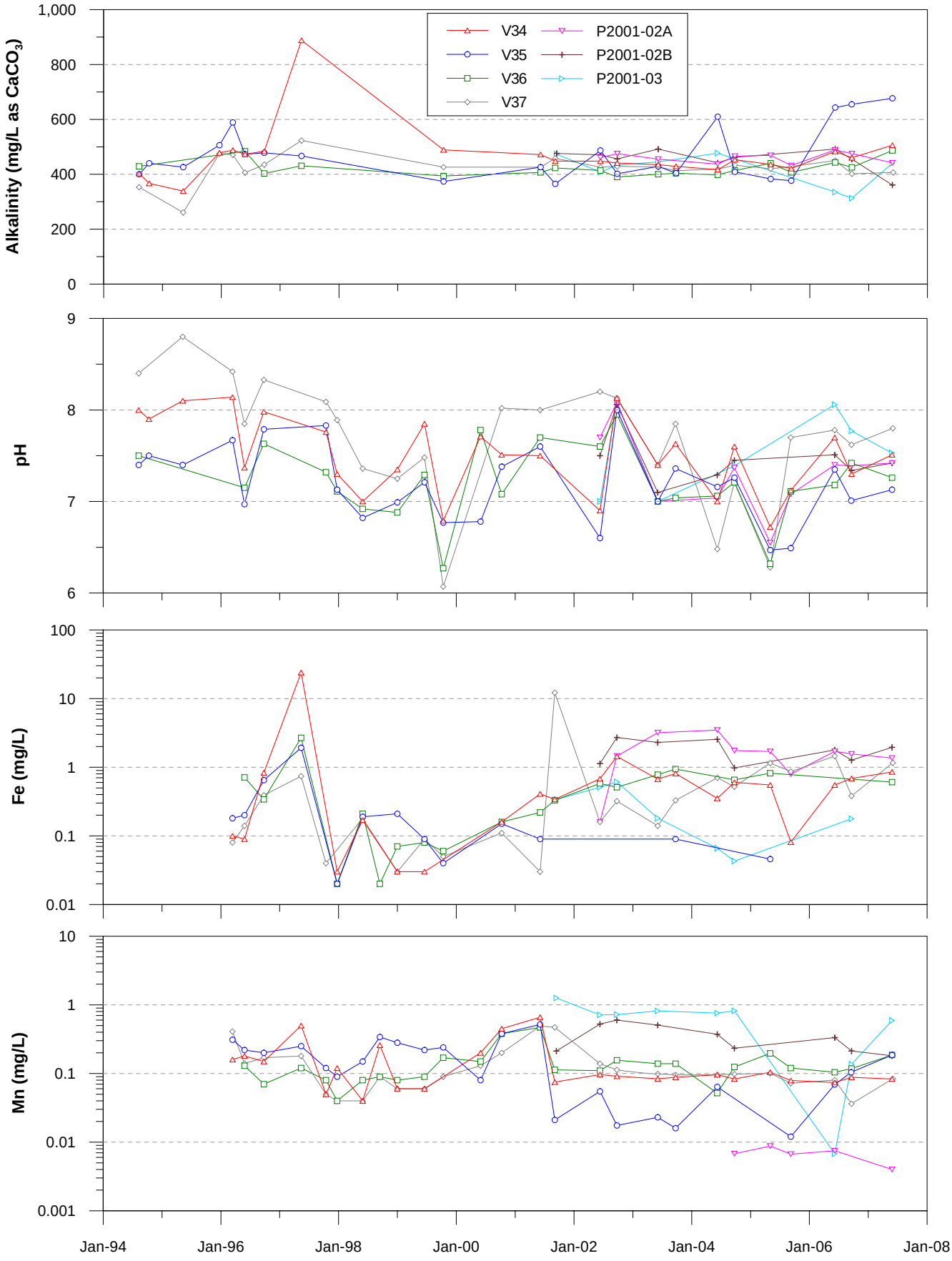


Figure 4-6b. Water quality (alkalinity, pH, Fe and Mn) in wells downgradient of Vangorda Rock Dump.