
Report No. 118022/1

**2011 GROUNDWATER QUALITY REVIEW
ANVIL RANGE MINING COMPLEX, YUKON TERRITORY**



Prepared for:



Assessment and Abandoned Mines

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EXECUTIVE SUMMARY

Recent trends in groundwater quality in different reaches of the Anvil Range Mining Complex (ARMC) were reviewed in order to identify changes in the condition of groundwater quality that occurred in 2011. The main conclusions of this review are summarized as follows:

Faro Mine Site

Seepage water quality from the Main WRD (at X23) continued to deteriorate in 2011 as SO₄, Mg, and dissolved metals established new (and higher) plateaus and highly-acidic conditions (pH<3) were observed more frequently. Groundwater immediately downgradient of the Main WRD has become appreciably more acidic in recent years and SO₄, Mg, and dissolved metal concentrations in groundwater continued to increase in 2011 due to higher loads from the Main WRD. More acidic conditions in groundwater reflect a further reduction in the buffering capacity of alluvial soils and/or waste rock within the Main WRD and are expected to precede further increases in contaminant levels in the coming years.

In the ETA area upgradient of the mine access road, shallow groundwater in the sediments and overlying tailings has shown a gradual increase in concentrations of SO₄, Mg, Zn and other metals of interest due to higher contaminant loading from the Main Dump. Groundwater quality conditions in deep bedrock beneath the channel and near the mouth of the Faro Creek canyon remained less impacted than shallow groundwater and did not change appreciably during the current monitoring period.

Operation of the ETA SIS has not (to date) resulted in any notable improvement in water quality in the shallow groundwater at the mouth of the Faro Creek Canyon, possibly due to year-round seepage by-pass and seasonal shutdown during the winter months.

In the Mill Site area, groundwater remains impacted by conservatively-transported species (like SO₄ and Mg) but metals concentrations remain low and there were no changes in water quality during the current monitoring period.

In the S-cluster area, groundwater quality conditions in the bedrock aquifer continued to improve as a result of seepage recovery upgradient. There is, however, no definitive evidence that groundwater quality conditions in shallow overburden are improving as a result of the interceptor trench in this area. Potential explanations include the limited lateral extent of the trench, inadequate hydraulic control, and/or insufficient capacity during high flow periods. A detailed performance review is recommended to identify potential issues and determine how the system could be improved (or if it should be re-built).

Near the Northeast WRD, the long-term trend towards increasing SO₄, Mg, and dissolved metals concentrations in groundwater near the toe of the dump (at wells BH14A/B) continued in 2011. Increasing concentrations are likely due to an incremental contaminant load from the Northeast WRD that is also thought to affect groundwater quality in the NFRC alluvial aquifer further downgradient. Of particular interest are elevated concentrations of Zn (~10 mg/L) that have persisted in groundwater at well BH14A since 2008 and suggest continued breakthrough of highly-impacted waste rock seepage in this area.

In the Zone 2 Pit outwash area, SO₄ and Mg concentrations in water pumped from the backfilled pit (via X26) have become more variable in recent years (possibly due to more aggressive pumping) but

there is no clear trend towards higher concentrations. Groundwater in this area remains impacted by waste rock seepage from the backfilled Zone 2 pit but groundwater quality conditions appear to be relatively stable.

Rose Creek valley

Groundwater upgradient of the RCTF remains unimpacted by mine waste seepage from either the Main or Intermediate WRDs. In the Original and Second Impoundments, recent trends towards higher contaminant levels continued during the current monitoring period. Of particular interest are increases in SO_4 , Mg, and metals of concern (Zn, Mn) throughout the alluvial aquifer at P03-06, which suggest loads from FCS and and/or coarse tailings beaches in the Original Impoundment continue to affect groundwater quality in this area. Significant increases in sulphate and metal concentrations (including zinc) were also observed in the southern portion of the alluvial aquifer (at P03-03 and P03-05) due to tailings seepage from the Second Impoundment.

Near the northern abutment of the Intermediate Dam, concentrations of SO_4 , Mg, and metals of interest in groundwater continued to increase in 2011. Results are consistent with a long-term trend observed over the last 10 to 12 years. Gradual increases in Zn concentrations in this area suggest that the attenuation capacity of the RCAA is gradually becoming exhausted and concentrations of Zn and other metals of interest are expected to increase further as a result. Groundwater near the southern abutment of the Intermediate Dam is still less impacted than groundwater to the north but groundwater quality conditions are deteriorating (as the leading edge of a TDS front appears to have reached this area).

In the Cross Valley Dam reach, groundwater along the southern side of the Rose Creek valley remains only modestly-impacted by mine waste seepage but groundwater quality to the north is affected the ongoing transport of a TDS plume from the Faro Creek canyon and/or the Original Impoundment along the north side of Rose Creek valley. In bedrock near the toe of the Cross Valley Dam, impacted groundwater is observed towards the northern side of the valley and suggests that the mine waste seepage that affects groundwater quality in the RCAA also affects groundwater in the underlying bedrock.

Downgradient of the Cross Valley Dam, groundwater quality at wells located near the northern side of the valley continued to deteriorate during the current monitoring period but contamination remains limited to major ions. These data support the assertion from previous reports/studies that a TDS plume is present in this area but that the leading edge of a metals front still resides upgradient.

Grum/Vangorda Mine Site

Shallow groundwater in soils downgradient of the Moose Pond remains impacted by seepage from the Moose Pond (which is used as an infiltration pond for seepage from the Grum WRD). SO_4 and Mg concentrations in this area decreased over the current monitoring period after reaching all-time highs in 2010. Zn concentrations remain low but there is some indication that the sorption capacity of the local soils is gradually being depleted in this area and that Zn concentrations may begin to increase in the coming years.

Groundwater in the shallow overburden soils to the south, southwest and west of the Grum Sulphide Cell continues to gradually deteriorate as it has for nearly ten years. Contamination is, however, thus

far limited to conservatively-transported species and deeper groundwater near the bedrock-overburden interface in this area remained unimpacted by waste rock seepage.

Immediately downgradient of the Vangorda WRD, groundwater quality deteriorated as a result of the breakthrough of a TDS front in this area. Zn concentrations remain low in most of the wells in this area but have increased near the northwestern toe of the Vangorda WRD.

Groundwater in the Vangorda Creek drainage immediately downgradient of the Vangorda Pit continued to show no signs of impact by seepage from the Vangorda Pit. Groundwater quality immediately downgradient of Little Creek Dam shows some signs of impact but concentrations did not increase significantly in 2011.

Recommendations

No changes to the ARMC's routine groundwater monitoring program are recommended at this time.

We recommend, however, that additional monitoring wells be installed (using the SONIC drill rig currently on site) to better characterize waste rock seepage and its impact on groundwater and surface water at the following locations:

- 2 wells along the toe of NE dumps (replacement for BH12 and BH13)
- 1 well in the NFRC valley (upgradient of SRK08-P12)
- 1-2 wells at the toe of the NW dump (upstream of mill site and GH Creek)
- 2 wells along the southern toe of the Vangorda waste rock dump

In light of significant deterioration of groundwater quality at P03-06 (including high metal concentrations) we also recommend installation of two monitoring wells below the coarse tailings beach of the Original Impoundment (screened in alluvium), between the Faro Creek Canyon and P03-06 to investigate the source of the recent deterioration of groundwater quality at P03-06 (i.e. FCS seepage versus tailings seepage).

It is also recommended that additional monitoring wells be installed in bedrock immediately downgradient of the Cross Valley Dam in order to establish the extent of groundwater impacts in the weathered and/or fractured bedrock underlying the RCAA.

Finally, it is recommended that a detailed performance review of the S-Cluster SIS be completed in order to establish why the shallow interceptor trench in this area is not working as intended and what improvements to the system would be necessary to protect water quality in the North Fork of Rose Creek.

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ANVIL RANGE MINING COMPLEX, YUKON TERRITORY

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1 INTRODUCTION

1.1 Terms of Reference

Routine groundwater monitoring at the Anvil Range Mine Complex (ARMC) has been conducted since 1997 and hence a detailed record of historic trends in groundwater quality exists for the site. In 2004, Robertson GeoConsultants Inc. (RGC) completed an initial review of the groundwater quality monitoring data collected near the Faro and Grum/Vangorda rock dumps in order to assist in the design of additional field programs and develop water and contaminant load balances for the Rose Creek Tailings Facility (see RGC, 2006a).

In 2007, RGC was commissioned to carry out a more comprehensive review of groundwater quality across the ARMC that included the description of conditions in the Rose Creek Tailings Facility, the Zone 2 Pit outwash area, and the areas surrounding the Grum and Vangorda waste rock dumps (RGC, 2008). RGC has since conducted annual reviews of groundwater quality data in order to track any changes in groundwater quality conditions over time and recommend changes to the ARMC's routine monitoring program accordingly (RGC, 2009b; 2010b; 2011).

1.2 Study Objectives

The objectives of this report are to:

- Review groundwater quality data collected from November 2010 to October 2011 across the ARMC and identify any changes in groundwater quality during that period; and
- Evaluate the ARMC's routine groundwater monitoring program in terms of the frequency of water quality sampling and the number of wells monitored.

1.3 Scope of Work

Groundwater quality data were collected from monitoring wells in the following geographic areas of the ARMC:

- Faro Mine Site
- Rose Creek valley
- Grum and Vangorda Mine Sites

For ease of reference, these areas are discussed separately in Sections 2, 3, and 4 of this report.

Groundwater quality data reviewed in this report were downloaded from the Faro database (“emLine”) on May 28, 2012. A complete QA/QC check of the data was beyond the scope of this review so time trends were based on the raw data that was downloaded. These data are considered reliable though and any minor errors are not expected to affect the interpretation of water quality time trends.

2 FARO MINE SITE

2.1 Geographic Overview

The Faro Mine Site consists of the Faro Pit, the surrounding waste rock dumps (WRDs), the Mill Site area, and the Emergency Tailings Area (ETA). The general layout of the mine site and the locations of groundwater monitoring wells installed since 2007 are illustrated in Figure 2-1.

Groundwater monitoring wells have generally been constructed in areas where an impact from mine waste seepage has been identified at ground surface. These areas are considered “priority areas” and include:

- the Emergency Tailings Area (ETA) & Mill Site;
- the S-Cluster Area; and
- the Zone 2 Pit Outwash Area.

Groundwater quality data in each of these areas are discussed separately in the sections below.

2.2 Emergency Tailings Area (ETA) and Mill Site

2.2.1 Background & Well Locations

Figure 2-2 shows the general layout of the ETA and the groundwater monitoring network in this area. Table 2-1 summarizes pertinent information related to the groundwater monitoring wells located in the ETA, including year of construction, installation details (i.e. total depth, screening interval), and the current status of monitoring.

2.2.2 Review of Time Trends

Time trends for pH, alkalinity, and the concentrations of selected major ions and metals of interest in seepage from the Main WRD (at the V-notch weir at X23) and in groundwater from wells P96-8A/B are shown in Figure 2-3a/b. Wells P96-8A/B are screened in alluvium near the toe of the Main WRD approximately 15 m southwest of the V-notch weir at X23 (i.e. station ‘FCS-1’ in RGC, 2010c).

SO₄, Mg, and Zn concentrations in seepage at X23 are lower than they were in 2009/2010 after a particularly large ‘flush’ of contaminants occurred in 2009 (see Figure 2-3a/b). Water quality results are, however, consistent with a long-term trend towards higher contaminant concentrations that has been observed over the last 15 years. Seepage from the Main WRD has also become noticeably more acidic over the last 2 to 3 years and alkalinity levels have decrease substantially over this period. Higher contaminant concentrations, lower pH conditions, and decreasing alkalinity levels suggest the ongoing ‘breakthrough’ of ARD products at X23 and a decline in the buffering capacity of waste rock within the Main WRD.

Table 2-1.

Monitoring wells in the Emergency Tailings Area (ETA) and Mill Site, 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	annual	Tailings/All
SRK04-3B	2004	7.1	5.50	7.00	1104.63	no longer sampled	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	annual	Alluvium
SRK05-ETA-BR2	2005	18.4	14.6	18.9	1103.75	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
P09-ETA1	2009	29.8	26.9	29.8	1074.66	annual	Bedrock
P09-ETA2	2009	17.7	16.15	17.7	1074.46	annual	OB/BR Contact
Main Dump/Mill Site							
SRK08-P9	2008	6.1	3.05	6.1	1144.208	not routinely monitored	Weathered BR
SRK08-P10A	2008	13.1	10.06	13.11	1112.896	annual	Weathered BR
SRK08-P10B	2008	7.6	4.57	7.62	1112.775	not routinely monitored	Overburden
SRK08-P11A	2008	12.2	9.14	12.19	1137.082	bi-annual	Weathered BR
SRK08-P11B	2008	6.1	3.05	6.1	1137.226	bi-annual	Overburden

Groundwater immediately downgradient of the Main WRD (at wells P96-8A/B) continues to become more acidic and characterized by lower alkalinity levels over time (see Figure 2-3a,b). Contaminant concentrations in groundwater also continue to mimic changes in seepage water quality at X23 (meaning that concentrations of SO₄, Mg, and metals are gradually increasing over time).

More acidic conditions in groundwater at P96-8A/B suggest a significant reduction in the buffering capacity of alluvial soils in this area due to increasing contaminant loads from the Main WRD. Higher concentrations of SO₄, Mg, and dissolved metals in groundwater are expected in the coming years as a result.

Key findings in the ETA area upstream of the mill access road near the Faro Creek canyon are summarized as follows:

- Groundwater from wells screened in the alluvial sediments and overlying tailings of the Faro Creek channel (at wells SRK04-3A and SRK05-ETA-BR1) is generally more acidic and characterized by higher concentrations of SO₄, Mg, and metals of concern (i.e. Zn, Fe, and Mn) than groundwater that resides in bedrock beneath the alluvium (at well SRK05-ETA-BR2). These differences indicate that groundwater in deep bedrock within the ETA is much less affected by mine waste seepage than the overlying alluvial channel.
- Seepage in the alluvial channel of the ETA area continues to show a gradual decrease in pH and an increase in SO₄, Mg, Zn and other metals (e.g. Mn) which is consistent with the time

trends observed further upgradient (at P96-8A/B). These data suggest that groundwater in the ETA area is continually deteriorating in response to higher contaminant loading from the Main Dump (X23).

- Iron concentrations show a significant increase in shallow groundwater across the ETA area suggesting that the residual tailings stored in the ETA area leach significant quantities of iron to the shallow groundwater system.

Since 2007, the surface seepage from the ETA area is collected during the ice free season using a cut-off trench. The ETA collection system was historically operated through the summer with all of the collected water being discharged into the Intermediate Pond. In 2011, this water was pumped directly to the Faro Mill Treatment System during the treatment season, from mid-May to mid-September (DES, 2012). The total volume of seepage intercepted in 2011 was estimated to be about 76,000 m³ which is more than twice the volume collected during 2010 (DES, 2012).

Groundwater quality downstream of the ETA SIS is monitored in a pair of nested wells (P09-ETA-01 and -02) located at the mouth of Faro Creek. Seasonal operation of the ETA SIS has not improved groundwater quality in those two wells thus far. Groundwater near the overburden/bedrock contact (at well P09-ETA-02), continues to be highly-impacted by seepage from the ETA area. Groundwater in deep bedrock (at well P09-ETA-01) continues to show negligible impact by mine waste seepage.

Previous reviews have indicated that the ETA SIS captures only about 50% of total seepage due to winter shutdown (RGC, 2010, 2011b). Year-round operation of the ETA SIS would likely be required to significantly improve groundwater quality in the shallow sediments/weathered bedrock in the reach downgradient of Faro Creek Canyon.

Groundwater quality conditions in the Mill Site area are summarized as follows:

- Groundwater at wells SRK08-P11A/B (near Guardhouse Creek) is characterized by elevated SO₄ and Mg concentrations at wells but relatively low concentrations of Zn (and other metals of interest) (see Figure 2-3c/d); these data, high alkalinity levels, and near-neutral pH conditions suggest that groundwater in this area is only modestly-affected by seepage from the Main WRD and water quality conditions did not change during the current monitoring period;
- Downgradient near the ETA area, groundwater at SRK08-P10A is more impacted by seepage from the Mill Site and/or WRDs than groundwater near Guardhouse Creek but contamination is limited to SO₄ and Mg (i.e. no metals); groundwater quality conditions in this area appear to be relatively stable as there were no appreciable changes in 2011;
- Near the toe of the Main WRD (southeast of the mill), groundwater at well SRK08-P09 is characterized by elevated SO₄ and Mg concentrations but metals of interest are low;

groundwater quality in this area has not deteriorated in recent years as alkalinity levels remain high and there is no trend towards higher concentrations of SO_4 or Mg.

2.3 S-Cluster Area

2.3.1 Background & Well Locations

Figure 2-5 shows the general layout of the S-Cluster area and the monitoring/pumping wells in this area. Most wells in this area are located between the southern toe of the Intermediate WRD and the North Fork of Rose Creek (NFRC) near the S-Cluster SIS. Table 2-2 summarizes pertinent information related to wells in the S-Cluster area, including year of construction, installation details, and the current monitoring status.

The S-Cluster SIS was constructed in 2009 to intercept Zn loads from the Intermediate WRD before they reached the nearby NFRC (SRK, 2009, 2010). The SIS consists of two groundwater components:

- A shallow rock-filled interceptor trench that cross-cuts the shallow (overburden) aquifer in this area and incorporates a 2.1 m diameter central sump (i.e. pumping well SRK08-PW3); and
- Two pumping wells (SRK08-SPW1 and SRK08-SPW2) screened in the deeper bedrock aquifer.

Water pumped from the bedrock aquifer is directed to the sump and then pumped to the Faro Pit with groundwater collected by the interceptor trench. The surface water component of the S-Cluster SIS consists of a rock drain that intercepts surface seepage from the toe of the Intermediate WRD and diverts it to the interceptor trench (see SRK, 2009).

In 2009, the following modifications to the S-Cluster SIS were made (SRK, 2010):

- The interceptor trench was extended eastward by 25 m;
- Well SRK08-SPW3 was deepened by 2.0 m; and
- The capacity of the system was increased to accommodate flows during the spring freshet.

According to SRK (2011a), these modifications have not allowed the minimum water level in the trench to be maintained below the level of the NFRC (or below groundwater levels downgradient of the SIS) due to physical limitations. These limitations were recognized during the design process so the objective of modifying the SIS was to lower the water level in the shallow aquifer as much as possible to reduce hydraulic gradients towards the NFRC.

The performance of the S-Cluster SIS immediately after the modifications to the SIS were made was evaluated in SRK (2010) and additional monitoring data (up to May 2011) was reviewed in SRK (2011a). In those reports, the hydraulic performance of the S-Cluster SIS and associated changes in

groundwater quality and Zn loads in the area were evaluated. Such a review is beyond the scope of this report but groundwater quality time trends in the S-Cluster area are described below and some context regarding SIS performance is provided.

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 (masl)	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	no longer sampled	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	annual	Till
S3	1989	4.8	2.6	5.6	1085.53	no longer sampled	Till
P96-7	1996	9.2	6.26	9.24	~1127	bi-annual	Overburden/BR
SRK04-2B	2004					no longer sampled	Alluvium
SRK04-2A	2004					no longer sampled	Alluvium
SRK05-SP-1A	2005	19.2	13.7	19.2	1091.99	annual	Overburden/BR
SRK05-SP-1B	2005	12.3	9	12.3	1091.94	annual	Overburden
SRK05-SP-2	2005	11.0	7.9	11	1086.70	annual	Alluvium/BR
SRK05-SP-3A	2005	22.9	17.4	21.9	1088.50	annual	Overburden
SRK05-SP-3B	2005	12.3	8.3	11.4	1088.41	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	not routinely monitored	Overburden
SRK05-SP-5	2005	14.0	9.4	12.5	1087.53	annual	Overburden/BR
SRK05-SP-6	2005	11.0	3.1	11	1097.73	no longer sampled	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
SRK08-SP7A	2008	17.75	14.02	17.07	~ 1081.74	quarterly	BR (weath)
SRK08-SP7B	2008	8.49	4.88	7.92	~ 1081.73	quarterly	Overburden
SRK08-SP8A	2008	11.59	7.62	10.67	~ 1077.74	annual	BR (weath)
SRK08-SP8B	2008	7.04	3.05	6.10	~ 1077.78	annual	Overburden
SRK08-SBR1	2008	n/a	27.74	33.83	~ 1087.80	not routinely monitored	BR (weath)
SRK08-SBR2	2008	18.33	12.19	18.29	~ 1087.50	annual	Overburden
SRK08-SBR3	2008	13.22	6.10	12.19	~ 1096.60	annual	BR (weath)
SRK08-SBR4	2008	n/a	15.09	21.49	~ 1087.70	annual	BR (weath)
P09-SIS1	2009	6.3	4.8	6.3	1087.59	bi-annual	Overburden
P09-SIS2	2009	5.5	4.6	5.5	1087.39	quarterly	Overburden
P09-SIS3	2009	3.7	2.2	3.7	1087.36	quarterly	Overburden
P09-SIS4	2009	3.7	2.8	3.7	1087.55	not routinely monitored	Overburden
P09-SIS5	2009	3.7	2.8	3.7	1087.49	not routinely monitored	Overburden
P09-SIS6	2009	4.6	4.6	5.5	1087.39	not routinely monitored	Overburden

2.3.2 Review of Time Trends

Figures 2-6a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest in groundwater from the historic 'S' wells and well P96-7. Similar time trend plots for the 'SRK05-SP' and 'P09-SIS' well series are shown in Figure 2-7a/b and Figure 2-7c/d, respectively.

Time trends for the recently-installed bedrock wells in the S-Cluster area ('SBR' series) and wells further downgradient of the SIS (wells SRK08-SP7A/B and SRK08-SP8A/B) are shown in Figure 2-8a/b and Figure 2-8c/d, respectively.

Groundwater quality in the S-Cluster area has previously been classified into three broad categories:

- Highly-impacted groundwater (wells S1A, S2A/B, S3, SRK05-SP4B, SRK05-SP5, P09-SIS1, P09-SIS2, P09-SIS3, and P09-SIS4);
- Moderately-impacted groundwater (wells SRK05-SP1A, SRK05-SP3A, SRK05-SP3B, P09-SIS5 and P09-SIS6, and SRK05-SP4A, SRK08-SP7B, SRK08-SP8A, SRK08-SBR4);
- Slightly-impacted groundwater (wells S1B, SRK05-SP1B, SRK05-SP2, SRK08-SP7A, SRK08-SP8B, SRK08-SBR1, SRK08-SBR2, and SRK08-SBR3).

Concentrations of SO₄, Mg, and metals of interest in 'moderately-impacted' and 'slightly-impacted' groundwater have been relatively stable for several years and this trend generally continued during the current monitoring period. Groundwater quality along the southern toe of the Intermediate WRD (at wells SRK05-SP1A/B and SRK05-SP2) does, however, continue to deteriorate gradually and conditions are expected to deteriorate further (as seepage is not intercepted in this area).

Key findings identified from groundwater quality time trends are summarized as follows:

- Operation of the seepage recovery well SRK08-SPW2 (screened in bedrock) has significantly reduced contaminant levels in 'highly-impacted' groundwater in the bedrock aquifer at wells S1A and S2A (see Figure 2-6a/b); SO₄, Mg, and Zn concentrations in groundwater from these wells are now more characteristic of 'moderately-impacted' groundwater (i.e. less than 250 mg/L SO₄ and 1 to 3 mg/L Zn); groundwater quality conditions in the bedrock aquifer have also improved at well SRK08-SBR4 (see Figure 2-8a/b), suggesting that well SRK08-SPW2 is drawing water from at least 75 m away (and has caused a cone of depression to develop); however, pumping in bedrock (at SPW2) has not improved groundwater quality in the overlying sediments (see SRK05-SP5)
- Groundwater quality conditions at well S2B continued to deteriorate in 2011 (see Figure 2-6a/b); this well is screened in till (and hence not affected by seepage recovery via well SRK05-SPW2) and is located west of the shallow interceptor trench; SO₄ concentrations in well S2B now exceed 6,000 mg/L (and Zn concentrations reached 400 mg/L in June 2011); these concentrations suggest substantial bypass towards the NFRC via the shallow overburden soils west of the interceptor trench;
- Groundwater quality conditions in shallow overburden immediately downgradient of the interception trench (at wells P09-SIS1, -SIS2, and -SIS3 and SRK05-SP4B) remain

- comparable to those observed in 2009 (see Figure 2-7c); hence there is no definitive evidence that the interceptor trench is working as intended;
- Further downgradient of the SIS near the NFRC, groundwater quality conditions at wells SRK08-SP7A/B have improved significantly in recent years and contaminant levels remained low during the current monitoring period (see Figure 2-8c/d); the pronounced improvement in groundwater quality conditions in shallow overburden (at well SRK08-SP7B) is clearly caused by operation of the S cluster SIS; the relatively abrupt decrease in contaminant concentrations at SP7B would suggest that this area is fed by deeper groundwater which is now intercepted effectively by SPW2 (located 200m upgradient); groundwater in the deeper bedrock well SP7A shows a more gradual recovery suggesting poorer hydraulic connection to contaminated groundwater intercepted at SPW2¹.

This review of water quality time trends suggests that groundwater quality in the bedrock aquifer of the S-Cluster area is improving as a result of seepage recovery from the bedrock (at SRK08-SPW2) but that the interceptor trench has not led to any significant improvement in shallow groundwater quality in this area. The implication is that groundwater-borne contaminants may continue to reach the NFRC via shallow overburden and adversely affect surface water quality conditions in the creek. Possible explanations for the apparent lack of water quality improvement in the shallow aquifer include (i) the limited lateral extent of the seepage trench, (ii) inadequate hydraulic control, and/or (iii) insufficient capacity during high flow periods (see SRK, 2011a).

The 2011 Environmental Monitoring and Activities Report (DES, 2012) reported that the S-cluster SIS was operated “continuously throughout the year (with minor interruptions) with variable pumping rate. The flow totalizer indicates that approximately 73,000 m³ of water was pumped to Faro Pit”. This total volume represents a mean annual flow rate of about 2.2 L/s and is essentially the same amount reportedly intercepted in 2010 (DES, 2012). No further information on S-cluster SIS performance was included in the 2011 Environmental Monitoring Report.

We recommend that a detailed performance review of the S-Cluster SIS be completed (which was beyond the scope of this review) to determine how the system could be improved or if replacement would be necessary to ensure water quality in the NFRC is not affected by loads from the Intermediate WRD (see recommendations).

¹ The recovery patterns observed in the nested wells SP7A/B are inconsistent with the time trends observed further upslope (which consistently show faster recovery in bedrock wells); the depth of these two monitoring wells should be checked to verify that these two wells are correctly labeled

2.4 North Fork of Rose Creek Reach

2.4.1 Background & Well Locations

Figure 2-9 shows the general layout of the North Fork of Rose Creek (NFRC) reach upstream of the rock drain. The NFRC reach can be subdivided as follows:

- NFRC upgradient of the Faro Mine
- Northeast WRD Reach
- Zone 2 Pit outwash area
- Intermediate WRD Reach

Most of the monitoring wells in the NFRC reach are located in the Zone 2 Pit outwash area (see Figure 2-10). Groundwater monitoring wells upgradient and downgradient of the Zone 2 Pit outwash area are shown in Figure 2-9. Pertinent information related to groundwater monitoring wells in the NFRC reach is provided in Table 2-3.

2.4.2 Review of Time Trends

Groundwater quality in the four reaches mentioned above described separately in the following subsections.

2.4.2.1 NFRC Upgradient of Faro Mine

Water quality data for the 'P09-UN' wells series and wells SRK08-P12A/B are shown in Figure 2-11a/b.

The 'P09-UN' wells are screened in the NFRC alluvial aquifer about 50 m downstream of the confluence between the NFRC and the Faro Creek diversion channel. These wells were not sampled during the current monitoring period but groundwater quality in each is known to reflect background conditions for the ARMC.

Groundwater from wells SRK08-P12A/B is characterized by SO_4 concentrations of less than 200 mg/L and Zn concentrations up to 1 mg/L (at well SRK08-P12A). These wells are screened in permeable bedrock or alluvial sediments upgradient of the Zone 2 Pit outwash area so elevated Zn concentrations suggest a substantial Zn load to the NFRC valley from the Northeast WRD. No changes in groundwater quality conditions in this area were evident during the current monitoring period.

Table 2-3.
Monitoring wells in the Zone 2 Pit 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				Not routinely monitored	n/a
BH2	1992	4.8			1099.70	Not routinely monitored	n/a
BH4	1992	2.5			1097.02	Not routinely monitored	n/a
BH5	1994	7.6	6.01	7.62	1095.57	Annual	Alluvium
BH6	1994	6.3	4.72	6.25	1097.84	Annual	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	Annual	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	Annual	BR (Biotite-schist)
BH10B	1994	54.9	53.34	54.84	1101.72	Annual	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	Not routinely monitored	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					bi-annual	waste rock (?)
SRK08-P13A	2008		7.32	10.36		Not routinely monitored	Weathered BR
SRK08-P13B	2008		3.05	6.1		Not routinely monitored	Overburden
Toe of Northeast Dumps (NFRC)							
BH12A	1994	3.1	1.53	3.05	1157.39	Not routinely monitored	BR (weath)
BH12B	1994	8.2	6.1	8.23	1157.50	Not routinely monitored	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
Near NFRC							
SRK08-P12A	2008	12.19	9.14	12.19	12.19	Annual	BR
SRK08-P12B	2008	7.62	4.57	7.62	7.62	Annual	BR
P09-UN1	2009	5.2	3.7	5.2	1114.21	Not routinely monitored	Overburden
P09-UN2	2009	6.7	5.2	6.7	1114.72	Not routinely monitored	Overburden
P09-UN3	2009	8.8	7.3	8.8	1115.26	Not routinely monitored	Overburden

2.4.2.2 Northeast WRD Reach

Time trends for pH, alkalinity, selected major ions, and metals of interest in groundwater from wells BH12A/B, BH13A/B, and BH14A/B are shown in Figure 2-12a/b. Each of these wells is located along the toe of the Northeast WRD (see Figure 2-9).

Groundwater quality conditions at wells BH14A/B have deteriorated significantly over the last 10 years and data for the current monitoring period are consistent with a long-term trend towards higher concentrations. Of particular interest are high Zn concentrations (~10 mg/L) in groundwater from well BH14A (screened in weathered bedrock) that have persisted since 2008. These high concentrations suggest the breakthrough of more highly-impacted seepage from the Northeast WRD continues in this area and that a condition of steady-state has not yet been reached. Note that Zn concentrations

in this area are much lower than in the S-Cluster area but water quality conditions in the NFRC could eventually be affected (as seepage is not intercepted in this area).

Trends towards higher contaminant concentrations in groundwater from wells BH14A/B are indicative of seepage from sulphide-rich waste rock that has been identified in the Northeast WRD (see RGC, 2008). Seepage from this sulphide-rich waste rock does not (yet) appear to have affected groundwater quality to the northeast at wells BH12A/B and BH13A/B, as contaminant concentrations in this area are relatively low and not increasing (see Figure 2-12a,b). Note, however, that monitoring wells BH12A/B and BH13A are no longer monitored (broken or frozen). Installation of additional monitoring wells at the toe of the Northeast WRD is recommended to improve monitoring of seepage from the NE dump and potential loading to the NFRC alluvial aquifer.

As mentioned, contaminant loads from the Northeast WRD likely explain the elevated Zn and SO₄ concentrations in wells SRK08-P12A/B. Both of these wells are screened in the permeable NFRC aquifer just upgradient of the Zone area outwash area so Zn concentrations of ~1 mg/L suggest a substantial load from the Northeast WRD to this area. Further monitoring (and additional monitoring wells) is needed to affirm this scenario and evaluate the future effect of these loads on water quality in the NFRC.

2.4.2.3 Zone 2 Pit outwash area

Time trends for pH, alkalinity, selected major ions, and metals of interest in water pumped from the backfilled Zone 2 Pit (via X26) and in wells located near the toe of the pit are shown in Figure 2-13a/b. Time trends for wells located further downgradient in the Zone 2 Pit outwash area are shown in Figure 2-14a/b.

Samples from X26 reflect the condition of water that accumulates in the backfilled Zone 2 Pit. Water from X26 is typically characterized by SO₄ concentrations of ~3,000 mg/L but SO₄ (and Mg) concentrations have been more variable since 2008 (possibly due to more aggressive pumping from X26 over this time period).

Contaminant concentrations at X26 tend to be lower during periods of high recharge in the spring but water quality conditions (Zn in particular) have remained relatively stable over the last ten years. This trend continued during the current monitoring period as no appreciable increase in the concentrations of SO₄ or metals of interest was evident. Similarly, no appreciable changes in groundwater quality in the Zone 2 Pit outwash area or downgradient were evident during the current monitoring period as data was generally consistent with historic time trends (see Figure 2-13a/b and 2-14a/b).

2.4.2.4 Intermediate WRD Reach

Figure 2-15a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest in groundwater from well P96-6. This well is located along the toe of the Intermediate WRD and is used to monitor the condition of groundwater flowing from this area towards the NFRC.

Groundwater in this area is moderately-impacted by waste rock seepage and concentrations of SO₄ and Mg have increased gradually over the last decade or so. Zn concentrations are, however, typically less than 1 mg/L and not increasing over time. Elevated contaminant levels at P96-6 are thought to reflect a small seepage load from the Intermediate WRD but no recent changes in the intensity of this load have occurred that would cause a substantive change in groundwater quality.

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3 ROSE CREEK VALLEY

3.1 Geographic Overview

Figure 3-1 shows the general layout of the Rose Creek valley and major units/features of the Rose Creek Tailings Facility (RCTF). The RCTF consists of three historic tailings disposal areas (the Original, Second, and Intermediate Impoundments), the Intermediate Pond (w/ Intermediate Dam), and the Polishing Pond (w/ Cross Valley Dam).

The groundwater monitoring network in the Rose Creek valley is extensive and most of the wells are screened in the highly-permeable Rose Creek alluvial aquifer (RCAA) that runs the entire length of the valley. Several wells have also been completed in the less permeable bedrock that underlies the RCAA to monitor potential contaminant transport via deep groundwater.

For the purpose of this report, the Rose Creek valley is sub-divided into the following geographic areas:

- Upgradient of RCTF
- Original Impoundment
- Second Impoundment
- Intermediate Impoundment
- Toe of Intermediate Dam
- Toe of Cross Valley Dam
- Downstream of Cross Valley Dam

Groundwater quality in each of these areas is discussed separately in the sub-sections below.

3.2 Upgradient of Rose Creek Tailings Facility

3.2.1 Background & Well Locations

Groundwater quality upgradient of the RCTF is routinely monitored via well TH86-17 and several other 'background wells' nearby (see Figure 3-1). Some pertinent information related to the construction of TH86-17 is provided in Table 3-1.

Table 3-1.
Monitoring wells upgradient of and within the Original Impoundment, RCTF

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	Annual	n/a
P03-07-01	2003	38.4	38.10	38.40	1064.98	Not routinely monitored	Alluvium
P03-07-02	2003	33.8	33.53	33.83	1064.98	Not routinely monitored	Alluvium
P03-07-03	2003	29.0	28.65	28.96	1064.98	Not routinely monitored	Alluvium
P03-07-04	2003	21.6	21.34	21.64	1064.98	Not routinely monitored	Alluvium
P03-07-05	2003	20.1	19.81	20.12	1064.98	Not routinely monitored	Alluvium
P03-07-06	2003	18.3	17.98	18.29	1064.98	Not routinely monitored	Tailings
P03-07-07	2003	16.8	16.46	16.76	1064.98	Not routinely monitored	Tailings
P03-07-08	2003	13.7	13.41	13.72	1064.98	Not routinely monitored	Tailings
NA05-11A	2005	14.3	12.8	14.3	1068.35	Not routinely monitored	Alluvium

3.2.2 Review of Time Trends

Figure 3-2a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest in groundwater from well TH86-17 and nearby wells.

Groundwater from these wells is characterized by very low concentrations of SO₄, Mg, and metals of interest that reflect 'background' conditions in the RCAA. Concentrations remained low during the current monitoring period and hence there is no indication that mine waste seepage from the Main or Intermediate WRDs (nor the NFRC aquifer) has impacted groundwater upgradient of the Original Impoundment.

3.3 Original Impoundment

3.3.1 Background

The locations of monitoring wells in the Original Impoundment are shown in Figure 3-1. Pertinent information related to the construction of the nested piezometers at P03-07 and well NA05-11A is summarized in Table 3-1.

3.3.2 Review of Time Trends

None of the wells in the Original Impoundment are routinely sampled so no additional groundwater quality data were available for the current monitoring period.

3.4 Second Impoundment

3.4.1 Background & Well Locations

Groundwater monitoring wells located in the Second Impoundment are shown in Figure 3-1. Pertinent information related to construction of these monitoring wells is provided in Table 3-2.

3.4.2 Review of Time Trends & Water Quality Depth Profiles

Water quality depth profiles for multi-level piezometers within the footprint area of the Second Impoundment are shown in Figures 3-3a/b to 3-8a/b.

Water quality data for the current monitoring period defined depth profiles that are similar to those observed historically. In accordance with previous findings, the highest levels of SO_4 and metals of interest are observed in tailings porewater in the southeastern (at P03-01 and P03-03) and northwestern (at P03-06) sections of the Second Impoundment. Also, concentrations of selected major ions and metals of interest are typically highest in piezometers that are screened near the interface between the sand and gravel aquifer and the overlying tailings. The lowest levels of ARD products are observed in the southwestern section (at P03-05).

Water quality profiles for multi-level piezometers P03-03 and P03-06 differ from the typical profile for the Second Impoundment. At P03-03, SO_4 concentrations are elevated throughout the aquifer and Zn concentrations actually increase at greater depths (see Figure 3-5a). At P03-06, SO_4 and Zn concentrations are elevated throughout the aquifer (Figure 3-8a). These depth profiles suggest a contribution of SO_4 and Zn from the overlying tailings profile and from an additional source located upgradient (see RGC, 2006a; RGC, 2008).

This upgradient source was previously thought to be seepage from the 'leaky wells' P01-09 (and P01-07) but no improvement in groundwater quality at P03-03 has occurred since these wells were decommissioned in October 2005. Instead, SO_4 and Mg concentrations have remained relatively consistent or actually increased at P03-03-06 (see Figure 3-9a/b). These results suggest that seepage from the highly-oxidized tailings in the coarse tailings beaches of the Second Impoundment (e.g. near well P03-01) is a more likely upgradient source of contaminants to the alluvial aquifer near P03-03.

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

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							
P03-01-01	2003	46.8	46.48	46.79	1061.11	Not routinely monitored	Alluvium
P03-01-02	2003	38.9	38.56	38.86	1061.11	Annual	Alluvium
P03-01-03	2003	30.6	30.33	30.63	1061.11	Not routinely monitored	Alluvium
P03-01-04	2003	24.5	24.23	24.54	1061.11	Annual	Alluvium
P03-01-05	2003	18.4	18.14	18.44	1061.11	Not routinely monitored	Alluvium
P03-01-06	2003	13.3	12.95	13.26	1061.11	Annual	Alluvium
P03-01-07	2003	10.8	10.52	10.82	1061.11	Not routinely monitored	Alluvium
P03-01-08	2003	9.3	8.99	9.30	1061.11	Annual	Tailings
P03-01-09	2003	7.8	7.47	7.77	1061.11	Annual	Tailings
P03-02-01	2003	33.8	33.53	33.83	1060.60	Not routinely monitored	Alluvium
P03-02-02	2003	30.5	30.18	30.48	1060.60	Not routinely monitored	Alluvium
P03-02-03	2003	22.9	22.56	22.86	1060.60	not routinely monitored	Alluvium
P03-02-04	2003	16.8	16.46	16.76	1060.60	not routinely monitored	Alluvium
P03-02-05	2003	13.7	13.41	13.72	1060.60	not routinely monitored	Alluvium
P03-02-06	2003	12.8	12.50	12.80	1060.60	not routinely monitored	Alluvium
P03-02-07	2003	11.9	11.58	11.89	1060.60	Not routinely monitored	Tailings
P03-02-08	2003	8.8	8.53	8.84	1060.60	not routinely monitored	Tailings
P03-02-09	2003	7.6	7.32	7.62	1060.60	Not routinely monitored	Tailings
P03-03-01	2003	43.0	42.67	42.98	1061.49	Not routinely monitored	Alluvium
P03-03-02	2003	33.2	32.92	33.22	1061.49	Annual	Alluvium
P03-03-03	2003	27.1	26.82	27.13	1061.49	Not routinely monitored	Alluvium
P03-03-04	2003	22.3	21.95	22.25	1061.49	Annual	Alluvium
P03-03-05	2003	18.6	18.29	18.59	1061.49	Not routinely monitored	Alluvium
P03-03-06	2003	17.1	16.76	17.07	1061.49	Annual	Alluvium
P03-03-07	2003	15.2	14.94	15.24	1061.49	Not routinely monitored	Tailings
P03-03-08	2003	12.2	11.89	12.19	1061.49	Annual	Tailings
P03-03-09	2003	9.1	8.84	9.14	1061.49	Annual	Tailings
P03-04-01	2003	58.2	57.91	58.22	1061.21	Not routinely monitored	Alluvium
P03-04-02	2003	47.5	47.24	47.55	1061.21	Annual plus AMP	Alluvium
P03-04-03	2003	41.5	41.15	41.45	1061.21	Not routinely monitored	Alluvium
P03-04-04	2003	35.1	34.75	35.05	1061.21	Annual plus AMP	Alluvium
P03-04-05	2003	26.1	25.76	26.06	1061.21	Not routinely monitored	Alluvium
P03-04-06	2003	17.4	17.07	17.37	1061.21	Annual plus AMP	Alluvium
P03-04-07	2003	15.5	15.24	15.54	1061.21	Not routinely monitored	Alluvium
P03-04-08	2003	13.7	13.41	13.72	1061.21	Annual plus AMP	Tailings
P03-04-09	2003	12.8	12.50	12.80	1061.21	Not routinely monitored	Tailings
P03-05-01	2003	44.5	44.20	44.50	1060.43	Not routinely monitored	Alluvium
P03-05-02	2003	36.9	36.58	36.88	1060.43	Annual	Alluvium
P03-05-03	2003	27.7	27.43	27.74	1060.43	Not routinely monitored	Alluvium
P03-05-04	2003	23.5	23.16	23.47	1060.43	Annual	Alluvium
P03-05-05	2003	21.6	21.34	21.64	1060.43	Not routinely monitored	Alluvium
P03-05-06	2003	18.6	18.29	18.59	1060.43	Annual	Tailings
P03-05-07	2003	14.0	13.72	14.02	1060.43	Not routinely monitored	Tailings
P03-05-08	2003	11.0	10.67	10.97	1060.43	Annual	Tailings
P03-06-01	2003	25.9	25.60	25.91	1062.79	Bi-annual	Alluvium
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

Other key findings pertaining to groundwater quality conditions in the Second Impoundment are summarized as follows (see additional time trend plots shown in Figures 3-10a to 3-10f):

- At P03-05, SO₄ and Zn concentrations continued to increase during the current monitoring period and thereby continued a trend that has been observed for several years (see Figure 3-10e/f); the 'breakthrough' of SO₄, Mg, and some metals of interest suggests that the leading edge of the contaminant plume observed at similar depths at well P03-03 has reached well P03-05 (i.e. 500 m downgradient).
- At P03-04 (located ~140 m downgradient of the "leaky well" P01-07 and roughly cross-gradient of P03-06), groundwater quality in this area has remained unchanged since well P01-07 was decommissioned (see Figure 3-10c/d); groundwater in this area therefore remains moderately-impacted by ARD.
- At P03-06 (located near the mouth of Faro Creek canyon), substantial increases in the concentrations of SO₄ and metals of interest (including Zn, Fe, Mn) have occurred since 2005 and groundwater has become considerably more acidic over this period; previous reports have emphasized that most of the deterioration in water quality has occurred at greater depth in the aquifer at P03-06; ground water quality in this part of the alluvial aquifer has continued to deteriorate significantly in 2011 (Figure 3-10a/b) despite seasonal operation of the ETA SIS.

The recent increase in metal concentrations in P03-06 (screened in the alluvial aquifer) is of some concern and warrants further study. Earlier geochemical analysis had suggested that groundwater in this area is primarily caused by seepage from the ETA area (based on geochemical signature) but the recent increases in Fe and particularly Mn suggest that seepage from the coarse tailings beach of the Original Impoundment may also be a contributing contaminant source. Consideration should therefore be given to installing additional monitoring wells in this area to allow an assessment of the groundwater flow field and likely sources of contamination in this area (ETA versus tailings seepage) (see recommendations).

3.5 Intermediate Impoundment

3.5.1 Background & Well Locations

Groundwater monitoring wells located in the Second Impoundment are shown in Figure 3-1. Table 3-3 summarizes pertinent information related to the groundwater monitoring wells located in the Intermediate Impoundment.

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

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	Not routinely monitored	Alluvium
P03-08-01	2003	32.6	32.31	32.61	1048.35	Not routinely monitored	Alluvium
P03-08-02	2003	28.3	28.04	28.35	1048.35	Annual	Alluvium
P03-08-03	2003	24.7	24.38	24.69	1048.35	Not routinely monitored	Alluvium
P03-08-04	2003	23.2	22.86	23.16	1048.35	Annual	Alluvium
P03-08-05	2003	21.6	21.34	21.64	1048.35	Not routinely monitored	Alluvium
P03-08-06	2003	20.1	19.81	20.12	1048.35	Annual	Tailings
P03-08-07	2003	17.1	16.76	17.07	1048.35	Annual	Tailings
P03-08-08	2003	14.0	13.72	14.02	1048.35	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

3.5.2 Review of Time Trends

Time trends for pH, alkalinity, selected major ions, and metals of interest for the 'X21' well series are shown in Figures 3-11a/b. Key findings are summarized as follows:

- Shallow tailings porewater (at X21A) is highly-impacted by ARD; concentrations of SO₄ and metals of interest (Zn, Fe, Mn) are highly elevated but have remained relatively consistent over the last 10 years or so; in contrast, alkalinity (and pH) have decreased rather abruptly in 2009 and have remained low in October 2011 suggesting the breakthrough of an acid front in the tailings;
- Contaminant concentrations in the RCAA at X21B continued to gradually increase in 2011 as they have since 2000 yet groundwater remains much less impacted than shallow tailings porewater (at X21A); the gradual deterioration in water quality at X21B is likely related to seepage from the coarse, permeable tailings beach of the Intermediate Impoundment (and FCS) and concentrations are expected to increase further until they resemble those observed in groundwater upgradient in the Second Impoundment (e.g. P03-06).

Depth profiles for pH, alkalinity, selected major ions, and metals of interest at P03-08 are shown in Figure 3-12a/b. This multi-level piezometer is located along the southern side of the Rose Creek valley near the Intermediate Pond and is the furthest downgradient in the Intermediate Impoundment. Depth profiles for the current monitoring period at P03-08 showed no appreciable changes in groundwater quality at this location.

3.6 Toe of Intermediate Dam

3.6.1 Background & Well Locations

Groundwater monitoring wells located in the Second Impoundment are shown in Figure 3-1. Table 3-4 summarizes pertinent information related to the groundwater monitoring wells located at the toe of the Intermediate Dam.

Table 3-4.
Monitoring wells near the Intermediate Dam, RCTF

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	Not routinely monitored	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 plus AMP	Alluvium
X25A-96	1996	8.9	7.44	8.97	1032.08	Bi-annual plus AMP	Alluvium
X25B-96	1996	19.1	17.7	19.17	1032.03	Bi-annual plus AMP	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

3.6.2 Review of Time Trends

Time trends for pH, alkalinity, selected major ions, and metals of interest in wells located near the northern abutment of the Intermediate Dam are shown in Figure 3-13a/b.

Concentrations of SO₄, Mg, and metals of interest in this area have generally increased since 2001 due to seepage from the coarse tailings beaches along the northern edge of the Intermediate, Second or Original Impoundments and/or FCS delivered to the Second Impoundment from the Faro Creek canyon/diversion channel (RGC, 2008; 2010a). Only wells X24D and P01-03 were sampled during the current monitoring period. Well P01-03 is screened in the shallow RCAA (~6 m bgs) and well X24D screens the deep RCAA (see Table 3-4). Increases in SO₄, Mg, Mn, and Zn concentrations in both wells in 2011 and are consistent with a long-term trend observed over the last 10 to 12 years (see Figure 3-13a/b). These data indicate that the entire RCAA near the northern abutment of the Intermediate Dam remains affected by tailings seepage and/or FCS from upgradient and water quality conditions are expected to deteriorate further in the coming years.

Groundwater near the southern abutment of the Intermediate Dam (at X25A/B and P01-04A/B) is less impacted than groundwater to the north but groundwater quality conditions are deteriorating in this area (see Figure 3-14a/b). Specifically, SO₄ and Mg concentrations in wells X25A, X25B, and P01-04A have increased considerably since 2004. Fe and Mn concentrations are also gradually

increasing but Zn concentrations remain low. These data suggest that the leading edge of a TDS front has reached this area.

It is noteworthy that the highest SO₄ and Mg concentrations along the southern abutment are observed at significant depth in the RCAA (i.e. in P01-04A screened at 32m depth). This indicates that the full depth of the aquifer is impacted by tailings seepage from upgradient sources (Second Impoundment).

Lower concentrations of SO₄, Mg, and metals of interest in groundwater near the southern abutment of the Intermediate Dam compared to the northern abutment are consistent with the observed water quality further upgradient in the Intermediate Impoundment. This difference is attributed in part to the lack of FCS on the southern side of the valley (RGC, 2008, 2010b) and the long transport distances between the coarse tailings beaches in the Second Impoundment (near P03-01, P03-02 and P03-03) and the southern abutment of the Intermediate Dam. Based on current trends, however, groundwater in this area is expected to deteriorate further and may eventually be contaminated to a similar extent as groundwater near the northern abutment of the Intermediate Dam.

3.7 Toe of Cross Valley Dam

3.7.1 Background & Well Locations

Groundwater monitoring wells located in the Second Impoundment are shown in Figure 3-1. Table 3-5 summarizes pertinent information related to the groundwater monitoring wells located along the toe of the Cross Valley Dam.

3.7.2 Review of Time Trends

Time trends for pH, alkalinity, selected major ions, and metals of interest in groundwater near the toe of the Cross Valley Dam are shown in Figures 3-15a/b to 3-17a/b.

Groundwater along the southern side of the Rose Creek valley (at wells P01-02A/B) remains only modestly impacted by mine waste seepage. Groundwater quality near the middle of the Cross Valley Dam (at P05-03) appears to be more impacted but contaminant concentrations are still lower than in groundwater along the northern side of the Cross Valley Dam (at wells P01-11 and P05-02). This trend towards higher SO₄ and Mg concentrations likely reflects the ongoing transport of a TDS plume from the Faro Creek canyon and/or the Original Impoundment along the north side of Rose Creek valley (i.e. in the Second and Intermediate Impoundments and in the Intermediate Dam reach at X24).

Table 3-5.
Monitoring wells below the toe of the Cross Valley Dam, RCTF

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	Not routinely monitored	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	Not routinely monitored	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	Not routinely monitored	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	Not routinely monitored	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	Bi-annual	Till/BR
P05-01-02	2005	19.8	19.67	19.82	1018.00	Bi-annual	Alluvium
P05-01-03	2005	16.8	16.62	16.77	1018.00	Bi-annual	Alluvium
P05-01-04	2005	11.3	11.13	11.28	1018.00	Bi-annual	Alluvium
P05-01-05	2005	5.5	5.33	5.48	1018.00	Bi-annual	Alluvium
P05-01-06	2005	3.4	3.20	3.35	1018.00	Bi-annual	Alluvium
P05-02	2005	5.2	1.83	4.88	1016.67	Bi-annual	Alluvium
P05-03	2005	7.6	3.44	7.62	1019.79	Bi-annual	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
P09-C1	2009	34.0	32.6	34	1017.36	Bi-annual	Bedrock
P09-C2	2009	59.3	53.5	59.3	1016.58	Bi-annual	Bedrock
P09-C3	2009	48.7	45.8	48.7	1019.65	Bi-annual	Alluvium

Note that sulphate, magnesium and most metal concentrations (including Zn, Fe and Mn) continued to gradually increase in the shallow groundwater along the north side of the Cross Valley Dam (P01-11 and P05-2). Maximum zinc concentrations observed in the shallow alluvium during the 2011 monitoring period were about 0.05 mg/L (in P05-02).

Time trends for pH, alkalinity, selected major ions, and metals of interest in the multilevel wells P03-09 and P05-01 are shown in Figures 3-16a/b and 3-17a/b, respectively. Groundwater at P05-01 is more impacted by ARD than groundwater at P03- in part to the FCS load delivered to the RCAA along the northern side of the Rose Creek valley in the Intermediate Dam reach. Note that SO₄ and Mg concentrations in both sets of piezometers continued to increase during the current monitoring period (as they have since 2004) but metals of interest (in particular Zn) remain low.

Time trends for pH, alkalinity, selected major ions, and metals of interest for the 'P09-C' well series are shown in Figure 3-18a/b. Groundwater in deep bedrock near the northern abutment of the Cross Valley Dam (at well P09-C1) is characterized by SO₄, Mg, Fe and Mn concentrations that are comparable to those in the shallow RCAA above. In contrast, groundwater in deep bedrock in the

central portion of the valley (at P09-C3) showed very low sulphate and high Na and alkalinity suggesting no impact of mine waste seepage. No appreciable changes in groundwater quality conditions occurred during the current monitoring period in both bedrock wells.

These results suggest that groundwater in deep bedrock near the northern abutment of the Cross Valley Dam is impacted to a similar extent as the shallow RCAA in this area but that groundwater in bedrock in the central portion of the Rose Creek valley remains unaffected by mine waste seepage. Note that groundwater quality at bedrock well P09-C2 showed zinc concentrations of up to 0.02 mg/L which are inferred to represent natural background in deep bedrock (see RGC, 2010a).

The limited number of monitoring wells completed in bedrock to date suggest that the fractured bedrock is hydraulically connected to the overlying weathered bedrock and alluvial aquifer (at least on the north side but possible elsewhere) and may potentially be impacted by mine waste seepage in the future. It is recommended that additional monitoring wells be completed in weathered and fractured bedrock along the toe of the Cross Valley Dam to establish better baseline conditions and to assist in design of a groundwater interception system at this location.

3.8 Downgradient of the Cross Valley Dam

3.8.1 Background & Well Locations

Four nested piezometers (X16A/B, X17A/B, X18A/B, and P01-01A/B) located downgradient of the Cross Valley Dam are sampled bi-annually as part of the routine groundwater monitoring program (see Figure 3-1). Pertinent details regarding their construction are provided in Table 3-6.

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

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

3.8.2 *Review of Time Trends*

Figures 3-19a/b show time trends for pH, alkalinity, selected major ions, and metals of interest in wells X16A/B, X17A/B, X18A/B and P01-01A/B.

In wells X18A/B and P01-01A/B (both located on the northern side of Rose Creek valley), concentrations of SO_4 and Mg continued to increase in 2011 as they have in recent years but metal concentrations have remained low. The increase in SO_4 and Mg in this area is caused by the leading edge of a TDS front that has been identified upgradient along the northern side of the Cross Valley Dam (at wells P01-11 and P05-01) and in the Intermediate Dam reach (at well X24).

Groundwater in the center of the valley (at X17A/B) and further downgradient at X16A/B is less impacted (if impacted at all). The lack of any significant groundwater impact by mine waste seepage in this area is believed to be a combination of groundwater upwelling, the discharge of impacted groundwater at surface, and dilution by seepage from the Rose Creek diversion channel. Note that the slightly elevated Zn concentrations (~0.01 mg/L) observed in the shallow well X16A are believed to be a result of recharge from the Rose Creek diversion (which shows slightly elevated zinc concentrations) and/or leaching of historic tailings nearby but not the transport of impacted groundwater into the area from upgradient.

4 GRUM & VANGORDA MINE SITE

4.1 Geographic Overview

Figure 4-1 shows the general layout of the Grum and Vangorda Mine Site and the groundwater monitoring network in this area.

The Grum Mine Site consists of the Grum Pit, Grum WRD (w/ sulphide cell) and the overburden stockpile. The Vangorda Mine Site consists of the Vangorda Pit (w/ in-pit rock dumps) and the Vangorda WRD. Groundwater monitoring wells are located primarily along the toes of the WRDs in order to monitor potential seepage to groundwater.

Groundwater quality data for the Grum and Vangorda Mine Sites are discussed separately in the sections below.

4.2 Grum Mine Site

4.2.1 Background & Well Locations

Figure 4-2 shows the locations of the monitoring wells located downgradient of the Grum WRD and Table 4-1 lists pertinent information regarding the construction of these wells and their monitoring status.

Table 4-1.

Monitoring wells location near Grum Slot, west of Grum WRD, and near Little Creek Dam, Grum/Vangorda 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
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	not routinely monitored	Overburden
SRK05-07	2005	5.8	0.75	5.8	1107.30	not routinely monitored	Overburden/BR
SRK05-08	2005	7.6	2.1	7.6	1105.25	not routinely monitored	Overburden
SRK05-09 ("Moose Well 2")	2005	3.7	0.5	3.5	1072.82	not routinely monitored	Overburden
SRK05-09	2005	3.3	0.9	3.3	1060.64	not routinely monitored	Overburden/BR
SRK05-10	2005	2.2	0.7	2.2	1043.40	not routinely monitored	Overburden
SRK08-P14	2008	9.1	6.1	9.1	1234.17	annual	Weathered BR
SRK08-P15	2008	7.6	4.6	7.6	1184.62	annual	Bedrock
SRK08-P16	2008	9.1	6.1	9.1	1108.87	not routinely monitored	Bedrock
P09-GS1A	2009	29.6	23.5	29.6	1230.00	annual	Bedrock
P09-GS1B	2009	6.6	5.1	6.6	1229.98	annual	Overburden/BR
P09-GW1	2009	3.7	1.56	3.66	1280.01	not routinely monitored	Overburden
P09-GW3	2009	2.4	1.4	2.4	1279.80	not routinely monitored	Overburden

4.2.2 Review of Time Trends

Time trends for pH, alkalinity, selected major ions, and metals of interest for the monitoring wells located near Grum Creek and downgradient of the Moose Pond are shown in Figure 4-3a/b.

In the former Grum Creek drainage channel, shallow groundwater at well SRK05-05C remains only modestly-impacted by ARD and there was no appreciable change in groundwater quality conditions during the current monitoring period.

At well SRK05-09 ("Moose Well #2"), SO₄, Mg, and alkalinity concentrations decreased significantly in early 2011 due to spring recharge before recovering somewhat by mid-summer. The overall trend for the current monitoring period was, however, towards lower concentrations of major ions. Concentrations of Zn (and other metals of interest) at well SRK09-05 are generally quite variable but there is no trend towards higher concentrations (see Figure 4-3a). Water quality data therefore suggest the breakthrough of conservatively-transported ARD species has occurred but that the leading edge of a metals plume remains upgradient (due to sorption by soils).

In a nearby side channel from Grum Creek, deeper groundwater (at well BH05-9B-R) remains only modestly-impacted by waste rock seepage (see Figure 4-4a/b). In contrast, groundwater quality in shallow groundwater (at well P96-9A) continued to deteriorate during the current monitoring period suggesting increased flushing of ARD products from the Grum WRD. At present, SO₄ concentrations in groundwater from well P96-9A exceed 2,000 mg/L and Zn concentrations in this shallow occasionally exceed 0.05 mg/L (see Figure 4-4a).

In the ETA area of the Faro Mine, sulphate concentrations higher than 3,000 mg/L were typically followed by a breakthrough of metals (Zn in particular) within a few years. A more significant breakthrough of zinc in groundwater near the Grum WRD may therefore also occur in at the Grum WRD over the next few years. The potential breakthrough of metals in this area should be closely monitored in order to determine whether the deterioration in groundwater quality conditions near the Grump WRD will follow the pattern established in other areas of the ARMC.

Groundwater quality in wells SRK05-07 and SRK05-08, located further to the west and screened in shallow sediments and/or weathered bedrock, also showed a gradual increase in sulphate concentrations over time suggesting that the TDS plume from the Grum WRD extends beyond specific drainage channels.

Near the Grum Slot (west of the Grum WRD), groundwater at well P09-GS1A is characterized by moderately-elevated SO₄ concentrations (i.e. 400 to 600 mg/L) and low concentrations of Zn and other metals of interest. SO₄ concentrations at well P09-GS1B are similar in magnitude but Zn concentrations are approaching 10 mg/L (or about two orders of magnitude higher than in groundwater from well P09-GS1A). These high Zn concentrations were originally believed to be related to *in situ* leaching of mineralized waste rock observed in the drill cuttings of P09- and not the

transport of ARD products in groundwater from upgradient. However, the recent trends of increasing sulphate and zinc concentrations would suggest that this well may be influenced by an upgradient source (potentially seepage from the Grum WRD).

Wells P09-GW1 and P09-GW3 were not sampled during the current monitoring period due to insufficient water. Results from November 2009 suggest that groundwater in the vicinity of well P09-GW1 is moderately-impacted by ARD but that metals concentrations are relatively low. Groundwater along the western toe of the Grum WRD therefore appears to be impacted by a 'TDS front' but does not yet receive a substantial load of metals. Conditions are similar near the southwest toe of the Grump WRD (monitored by SRK08-P14 to -P16), as this area also features a gradual breakthrough of a TDS plume but the breakthrough of metals in groundwater has not yet occurred (see Figure 4-5c/d).

4.3 Vangorda Mine Site

4.3.1 Background & Well Locations

Figure 4-6 shows the locations of monitoring wells located downgradient of the Vangorda WRD and Table 4-2 summarizes pertinent information regarding the construction of these wells and their monitoring status.

Table 4-2.

Monitoring wells downgradient of Vangorda WRD and near Vangorda Creek, Grum/Vangorda 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
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
P09-VC1	2009	57.9	52.6	57.9	1113.28	Annual	Bedrock
P09-VC2	2009	21.3	18.25	21.3	1110.90	Annual	Overburden
P09-LCD1	2009	6.5	5.97	6.47	1097.53	Bi-annual	Overburden
P09-LCD2	2009	4.8	3.6	4.8	1097.69	Not routinely monitored	Overburden
P09-LCD3	2009	6.0	5.5	6	1093.71	Not routinely monitored	Overburden
P09-LCD4	2009	11.8	10.88	11.78	1093.68	Bi-annual	Overburden
P09-LCD6	2009	7.3	6.41	7.31	1096.21	Bi-annual	Overburden
P09-LCD7	2009	10.4	7.4	10.4	1101.68	Not routinely monitored	Overburden

4.3.2 Review of Time Trends

Time trends for pH, alkalinity, selected major ions, and metals of interest in wells along the toe of the Vangorda WRD are shown in Figure 4-7a/b.

SO₄ and Mg concentrations in most of the wells located in this area have increased over the last five years (see Figure 4-7a/b). Zn concentrations (and other metals of interest) have generally remained low during this period (except near the western toe of the dump at well V36), suggesting that only the breakthrough of a TDS plume has occurred. Hydraulic testing in these monitoring wells indicated that V36 is screened in permeable alluvial sediments which would explain the preferred breakthrough of sulphate (and zinc) at this location. It is inferred that seepage from the Vangorda waste rock dump may follow preferred flow paths in this generally low permeability environment.

Seepage water quality at DH1, DH2, and DH3 deteriorated during the current monitoring period (see Figure 4-8a/b). These recovery wells are screened in low-K till beneath the Vangorda WRD (see SRK, 2011b). High concentrations of SO₄, Mg, alkalinity and selected metals are thought to be characteristic of neutralized waste rock seepage and differences in seepage water quality are attributed to the presence of more 'mature' waste rock seepage in some areas of the Vangorda Dump (i.e. from the sulphide cell).

Time trends for pH, alkalinity, selected major ions, and metals of interest in monitoring wells located in the Little Creek Dam (LCD) area and near Vangorda Creek are shown in Figure 4-9a/b.

SO₄ and Mg concentrations in groundwater from the 'P09-VC' and 'P09-LCD' well series are generally lower than in the other wells near the Vangorda WRD and suggest only modest impact by waste rock seepage in this area. Groundwater quality in monitoring wells located immediately downgradient of Little Creek Dam (in the 'P09-LCD' wells) did not show any significant changes during the current monitoring period and data are generally consistent with groundwater that is only modestly impacted by seepage from the LCD (i.e. SO₄ <300 mg/L and low concentrations of metals).

Groundwater in the Vangorda Creek drainage immediately downgradient of the Vangorda Pit (at wells P09-VC1 and P09-VC2) continued to show very limited impact from mine waste seepage. Zn concentrations in well P09-VC2 showed some modest increase in 2011 (up to ~0.08 mg/L) but these concentrations are attributed to the localized leaching of mineralized waste rock used for road construction and not the transport of metals via groundwater into this area. These results suggest that there is no seepage from the Vangorda Pit in overburden and/or fractured bedrock in this area and there seems to be little risk of seepage from the Vangorda Pit entering Vangorda Creek if the water level in Vangorda Pit is maintained at or below its current elevation.

5 CONCLUSIONS & RECOMMENDATIONS

The main conclusions of this report are summarized below in sections 5.1 to 5.3 and recommendations regarding future groundwater monitoring are provided in section 5.4.

5.1 Faro Mine Site

- Water quality of waste rock seepage (at X23) continued to deteriorate in 2011 as SO₄, Mg, and dissolved metals established new (and higher) plateaus and highly-acidic conditions (pH<3) were observed more frequently; groundwater immediately downgradient of the Main WRD has become appreciably more acidic in recent years and SO₄, Mg, and dissolved metal concentrations in groundwater continued to increase in 2011 due to higher loads from the Main WRD; more acidic conditions in groundwater reflect a further reduction in the buffering capacity of alluvial soils and/or waste rock within the Main WRD and are expected to precede further increases in contaminant levels in the coming years.
- Seepage in the alluvial channel of the ETA area (upgradient of the mine access road) continues to show a gradual decrease in pH and an increase in SO₄, Mg, Zn and other metals (e.g. Mn) as a result of higher contaminant loading from the Main Dump (X23).
- Operation of the ETA SIS has not (to date) resulted in any notable improvement in water quality in the shallow groundwater at the mouth of the Faro Creek Canyon, possibly due to year-round seepage by-pass and seasonal shutdown during the winter months.
- Groundwater quality conditions in deep bedrock in the ETA area and near the mouth of the Faro Creek canyon is significantly less impacted than shallow groundwater and did not change appreciably during the current monitoring period;
- In the Mill Site area, groundwater remains impacted by conservatively-transported species (like SO₄ and Mg) but metals concentrations remain low and there were no changes in water quality during the current monitoring period;
- In the S-cluster area, groundwater quality conditions in the bedrock aquifer continued to improve as a result of seepage recovery upgradient; there is, however, no definitive evidence that groundwater quality conditions in shallow overburden are improving as a result of operation of the interceptor trench; potential explanations include (i) the limited lateral extent of the trench, (ii) inadequate hydraulic control, and/or (iii) insufficient capacity during high flow periods; however, a detailed performance review of the S-cluster SIS was beyond the scope of this report;
- Near the Northeast WRD, the long-term trend towards higher SO₄, Mg, and dissolved metals concentrations in groundwater near the toe of the dump (at BH14A/B) continued in 2011;

increasing concentrations are likely due to an incremental contaminant load from the Northeast WRD that is also thought to affect groundwater quality in the NFRC alluvial aquifer further downgradient; of particular interest are relatively high concentrations of Zn (~10 mg/L) that have persisted in groundwater at well BH14A since 2008 and suggest continued breakthrough of highly-impacted waste rock seepage in this area;

- In the Zone 2 Pit outwash area, SO₄ and Mg concentrations in water pumped from the backfilled pit (via X26) have become more variable in recent years (possibly due to more aggressive pumping) but there is no clear trend towards higher concentrations; groundwater in this area remains impacted by waste rock seepage from the backfilled pit but groundwater quality conditions appear to be relatively stable.

5.2 Rose Creek valley

Groundwater quality conditions in the Rose Creek valley are summarized as follows:

- Groundwater upgradient of the RCTF remains unimpacted by mine waste seepage from either the Main or Intermediate WRDs;
- In the Original and Second Impoundments, recent trends towards higher contaminant levels continued during the current monitoring period; of particular interest were increases in SO₄, Mg, and metals of concern (Zn, Mn) throughout the alluvial aquifer at P03-06, which suggest loads from FCS and and/or coarse tailings beaches in the Original Impoundment continue to affect groundwater quality in this area; significant increases in sulphate and metals (including zinc) were also observed in the southern portion of the alluvial aquifer (at P03-03 and P03-05) due to tailings seepage from the Second Impoundment;
- Near the northern abutment of the Intermediate Dam, concentrations of SO₄, Mg, and metals of interest in groundwater continued to increase in 2011; results are consistent with a long-term trend observed over the last 10 to 12 years; gradual increases in Zn concentrations in this area suggest that the attenuation capacity of the RCAA is gradually becoming exhausted and concentrations of Zn and other metals of interest are expected to increase further as a result; groundwater near the southern abutment of the Intermediate Dam is less impacted than groundwater to the north but groundwater quality conditions are deteriorating (as the leading edge of a TDS front appears to have reached this area);
- In the Cross Valley Dam reach, groundwater along the southern side of the Rose Creek valley remains only modestly-impacted by mine waste seepage but groundwater quality to the north is affected the ongoing transport of a TDS plume from the Faro Creek canyon and/or the Original Impoundment along the north side of Rose Creek valley. In bedrock near the toe of the Cross Valley Dam, impacted groundwater is observed towards the northern

side of the valley and suggests that the mine waste seepage that affects groundwater quality in the RCAA also affects groundwater in the underlying bedrock.

- Downgradient of the Cross Valley Dam, groundwater quality at wells located near the northern side of the valley continued to deteriorate during the current monitoring period but contamination remains limited to major ions; these data support the assertion from previous reports/studies that a TDS plume is present in this area but that the leading edge of a metals front still resides further upgradient.

5.3 Grum/Vangorda Mine Site

Groundwater quality conditions at the Grum and Vangorda Mine Sites are summarized as follows:

- Shallow groundwater in soils downgradient of the Moose Pond remains impacted by seepage from the Moose Pond (which is used as an infiltration pond for seepage from the Grum WRD); SO_4 and Mg concentrations in this area decreased over the current monitoring period after reaching all-time highs in 2010; Zn concentrations remain low but there is some indication that the sorption capacity of the local soils is gradually being depleted in this area and that Zn concentrations may begin to increase in the coming years;
- Groundwater quality in the shallow overburden soils to the south, southwest and west of the Grum Sulphide Cell continues to gradually deteriorate as it has for nearly ten years; contamination is, however, so far limited to conservatively-transported species (SO_4 , Mg) and deeper groundwater near the bedrock-overburden interface in this area remained unimpacted by waste rock seepage;
- Immediately downgradient of the Vangorda WRD, groundwater quality deteriorated as a result of the breakthrough of a TDS front in this area; Zn concentrations remain low in most of the wells in this area but have increased near the northwestern toe of the Vangorda WRD;
- Groundwater in the Vangorda Creek drainage immediately downgradient of the Vangorda Pit continued to show no signs of impact by seepage from the Vangorda Pit; groundwater quality immediately downgradient of Little Creek Dam shows some signs of impact but concentrations did not increase significantly in 2011.

5.4 Recommendations

No changes to the ARMC's routine monitoring program are recommended at this time. Wells to be sampled in 2012 are listed in Tables 5-1 to 5-3.

However, we recommend that consideration be given to installing additional monitoring wells (using the SONIC drill rig currently on site) to better characterize waste rock seepage and its impact on groundwater and surface water at the following locations:

- 2 wells along the toe of NE dumps (replacement for BH12 and BH13)
- 1 well in the NFRC valley (upgradient of SRK08-P12)
- 1-2 wells at the toe of the NW dump (upstream of mill site and GH Creek)
- 2 wells along the southern toe of the Vangorda waste rock dump

In light of recent increases of metal concentrations in the RCAA at P03-06 (up to 10 mg/L Zn, 150 mg/L Mn and ~1,000 mg/L Fe) we also recommend installing two new monitoring wells below the coarse tailings beach of the Original Impoundment (screened in alluvium), between the Faro Creek Canyon and P03-06 to investigate the source of the recent deterioration of groundwater quality at P03-06 (i.e. ETA seepage versus tailings seepage).

It is also recommended that additional monitoring wells be completed in weathered and fractured bedrock along the toe of the Cross Valley Dam to better delineate the groundwater impacts in bedrock and to assist in design of a groundwater interception system at this location. As part of this program, the inclined borehole C-3 should be redrilled to intersect and screen the highly-permeable fracture intersected at greater depth in fresh bedrock (see RGC, 2010a).

Finally, a detailed performance review of the S-Cluster SIS is recommended in order to clearly establish why the shallow interceptor trench in this area is not working as intended. This review should include a detailed interpretation of pumping rates, groundwater levels, and water quality conditions in the S-Cluster area and the effect of SIS operation on stream water quality in the NFRC (at X2). This review should be used to determine how the SIS could be improved.

Table 5.1.
Recommended Scope of Groundwater Monitoring in 2011, Faro Mine Site

Well ID	Region	Northing UTM z8 NAD27	East ing UTM z8 NAD27	Proposed Frequency
Faro Mine Site				
P96-8A	ETA Area	6913898	583328	Bi-annual
P96-8B	ETA Area	6913898	583328	Bi-annual
SRK04-3A	ETA Area	6913824	582977	Annual
SRK05-ETA-BR1	ETA Area	6913846	582972	Annual
SRK05-ETA-BR2	ETA Area	6913825	582987	Annual
P09-ETA1	ETA Area	6913635	582807	Annual
P09-ETA2	ETA Area	6913633	582832	Bi-annual
S1A	S-cluster Area	6912942	584539	Bi-annual
S1B	S-cluster Area	6912942	584539	Bi-annual
S2A	S-cluster Area	6912944	584577	Bi-annual
S2B	S-cluster Area	6912944	584577	Bi-annual
P96-7	S-cluster Area	6913105	584225	Bi-annual
SRK05-SP-1A	S-cluster Area	6912901	584727	Annual
SRK05-SP-1B	S-cluster Area	6912901	584726	Annual
SRK05-SP-2	S-cluster Area	6912861	584791	Annual
SRK05-SP-3A	S-cluster Area	6912924	584651	Annual
SRK05-SP-3B	S-cluster Area	6912924	584652	Annual
SRK05-SP-4A	S-cluster Area	6912939	584612	Bi-annual
SRK05-SP-4B	S-cluster Area	6912939	584611	Bi-annual
SRK05-SP-5	S-cluster Area	6912956	584576	Bi-annual
SRK05-SP-6	S-cluster Area	6912975	584492	Annual
SRK08-SP7A	S-cluster Area			Quarterly
SRK08-SP7B	S-cluster Area			Quarterly
SRK08-SBR2	S-cluster Area			Annual
SRK08-SBR3	S-cluster Area			Annual
SRK08-SBR4	S-cluster Area			Annual
P09-SIS1	S-cluster Area	6912954	584585	Quarterly
P09-SIS2	S-cluster Area	6912950	584594	Quarterly
P09-SIS3	S-cluster Area	6912944	584602	Quarterly
P09-SIS4	S-cluster Area	6912936	584617	Quarterly
P09-SIS6	S-cluster Area	6912934	584625	Bi-annual
SRK08-P9	Toe Main Dump	6913440	583804	Bi-annual
SRK08-P10A	Mill Site	6914055	582720	Bi-annual
SRK08-P11A	Mill Site	6914573	582585	Bi-annual
SRK08-P11B	Mill Site	6914574	582584	Bi-annual
BH5	Zone 2 Outwash	6913377	585194	Annual
BH6	Zone 2 Outwash	6913466	585198	Annual
BH8	Zone 2 Outwash	6913599	585253	Annual
BH10A	Zone 2 Outwash	6913533	585190	Annual
BH10B	Zone 2 Outwash	6913533	585191	Annual
P05-04	Zone 2 Outwash	6913475	585224	Annual
SRK08-P12A	Zone 2 Outwash	6913506	585348	Annual
SRK08-P12B	Zone 2 Outwash	6913509	585345	Annual
Zone 2 Pumping Well (X26)	Zone 2 pit	6913770	584868	Bi-annual
BH13B	NE Dumps	6914339	585844	Bi-annual
BH14A	NE Dumps	6913826	585676	Bi-annual
BH14B	NE Dumps	6913826	585676	Bi-annual
P96-6	Intermediate Dump (NFRC)	6913133	584999	Bi-annual

Table 5.2

Recommended Scope of Groundwater Monitoring for 2011, Rose Creek Tailings Facility

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency
Rose Creek Tailings Facility				
TH86-2	upgradient	?	?	Annual
TH86-5	upgradient	?	?	Annual
TH86-17	upgradient	6912489	583943	Annual
P03-01 (-02,-04,-06,-08,-09)	Second Impoundment	6912580	583301	Annual
P03-03 (-02,-04,-06,-08,-09)	Second Impoundment	6912698	583068	Annual
P03-04 (-02,-04,-06,-08)	Second Impoundment	6913186	582085	Annual
P03-05 (-02,-04,-06,-08)	Second Impoundment	6912934	582605	Annual
P03-06 (all ports)	Second Impoundment	6913309	582573	Bi-annual
X21A-96	Intermediate Impoundment	6913417	581989	Bi-annual
X21B-96	Intermediate Impoundment	6913417	581989	Bi-annual
P03-08 (-02,-04,-06,-07,-08)	Intermediate Impoundment	6913514	580980	Annual
X24D-96	Intermediate Dam	6914124	580655	Bi-annual
X25A-96	Intermediate Dam	6913945	580519	Bi-annual
X25B-96	Intermediate Dam	6913945	580519	Bi-annual
P01-03	Intermediate Dam	6914071	580639	Bi-annual
P01-04A	Intermediate Dam	6913893	580496	Bi-annual
P01-04B	Intermediate Dam	6913893	580496	Bi-annual
P01-02A	Cross Valley Dam	6914044	580051	Bi-annual
P01-02B	Cross Valley Dam	6914044	580051	Bi-annual
P01-11	Cross Valley Dam	6914306	580214	Bi-annual
P03-09 (-02,-04,-06,-08,-09)	Cross Valley Dam	6914229	580065	Bi-annual
P05-01 (all ports)	Cross Valley Dam	6914335	580165	Bi-annual
P05-02	Cross Valley Dam	6914265	580144	Bi-annual
P05-03	Cross Valley Dam	6914171	580088	Bi-annual
P09-C1	Cross Valley Dam	6914314	580171	Bi-annual
P09-C2	Cross Valley Dam	6914228	580119	Bi-annual
P09-C3	Cross Valley Dam	6914143	580078	Bi-annual
X16A	Downgradient of CVD	6914672	579574	Bi-annual
X16B	Downgradient of CVD	6914672	579574	Bi-annual
X17A	Downgradient of CVD	6914475	579874	Bi-annual
X17B	Downgradient of CVD	6914475	579874	Bi-annual
X18A	Downgradient of CVD	6914539	580105	Bi-annual
X18B	Downgradient of CVD	6914539	580105	Bi-annual
P01-01A	Downgradient of CVD	6914675	579819	Bi-annual
P01-01B	Downgradient of CVD	6914675	579819	Bi-annual

Table 5.3

Recommended Scope of Groundwater Monitoring for 2011, Grum/Vangorda Mine Site

Well ID	Region	Northing UTM z8 NAD27	Easting UTM z8 NAD27	Proposed Frequency
Grum/Vangorda Mine Site				
P96-9A	Grum Rock Dump	6903165	592753	Bi-annual
BH05-9B-R	Grum Rock Dump	6903172	592747	Bi-annual
SRK05-05C	Grum Rock Dump	6903208	592873	Bi-annual
SRK05-07	Grum Rock Dump	6903011	592477	Bi-annual
SRK05-08	Grum Rock Dump	6903063	592690	Bi-annual
SRK05-09 ("Moose Well 2")	Grum Rock Dump	6902986	593058	Bi-annual
SRK08-P14	Grum Dump Southwest	6903706	591761	Annual
SRK08-P15	Grum Dump Southwest	6903534	591961	Annual
SRK08-P16	Grum Dump Southwest	6902964	592322	Annual
P09-GW1	Grum Dump West			Annual (Spring)
P09-GW3	Grum Dump West			Annual (Spring)
P09-GS1A	Grum Slot Area	6904658	592593	Bi-annual
P09-GS1B	Grum Slot Area	6904657	592601	Bi-annual
V34	Vangorda Rock Dump	6902295	593553	Bi-annual
V35	Vangorda Rock Dump	6902371	593293	Bi-annual
V36	Vangorda Rock Dump	6902733	593243	Bi-annual
V37	Vangorda Rock Dump	6902913	593420	Bi-annual
P2001-02A	Vangorda Rock Dump	6902880	593098	Bi-annual
P2001-02B	Vangorda Rock Dump	6902880	593098	Bi-annual
P2001-03	Vangorda Rock Dump	6902865	593131	Bi-annual
DH1	Vangorda Rock Dump	6903022	593577	Bi-annual
DH2	Vangorda Rock Dump	6902814	593212	Bi-annual
DH3	Vangorda Rock Dump	6902669	593221	Bi-annual
DH4	Vangorda Rock Dump	6902508	593738	Bi-annual
DH5	Vangorda Rock Dump	6902681	593561	Bi-annual
P09-LCD1	Little Creek Dam	6903138	593468	Bi-annual
P09-LCD4	Little Creek Dam	6903097	593436	Bi-annual
P09-LCD6	Little Creek Dam	6903073	593421	Bi-annual
P09-VC1	Vangorda Creek	6903244	593627	Bi-annual
P09-VC2	Vangorda Creek	6903259	593623	Bi-annual

6 CLOSURE

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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.

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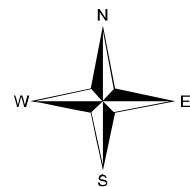


LEGEND

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

PROJECTION: UTM
 ZONE: 8
 DATUM: NAD 83
 UNITS: Meters

CONTOUR INTERVAL: 2M



Layout of Faro Mine Site
Anvil Range Mining Complex



CLIENT: Yukon Government
 PROJECT: 2010 ARMC Groundwater Review
 REPORT: RGC 118018
 LOCATION: Anvil Range Mining Complex, YT, Canada



FIGURE: 2-1

DATE: 032411
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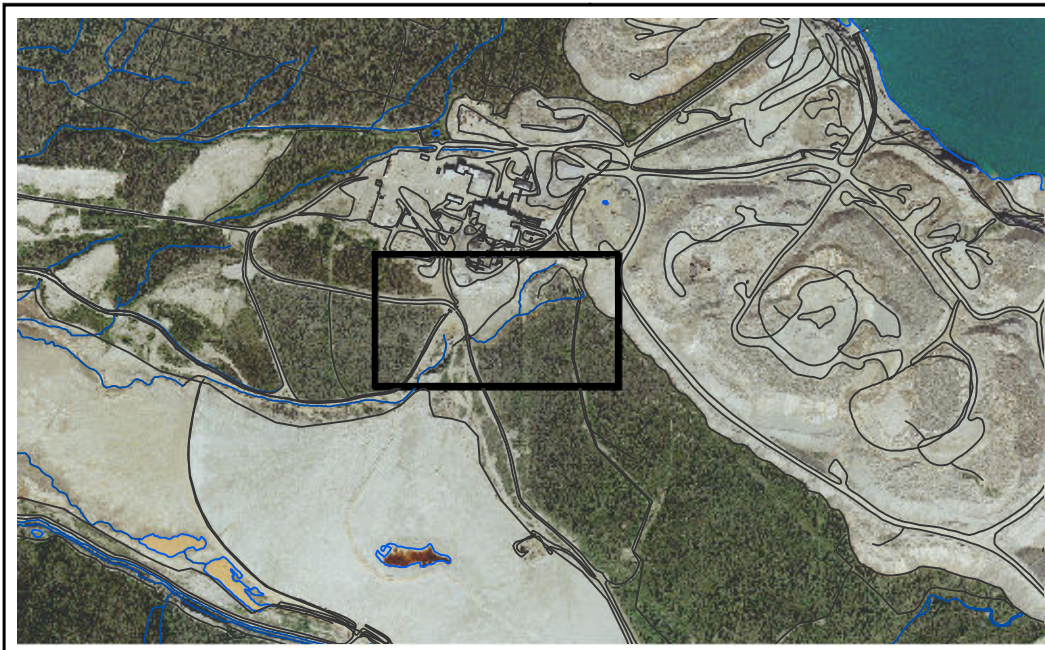
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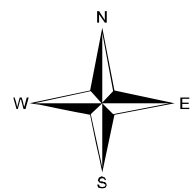
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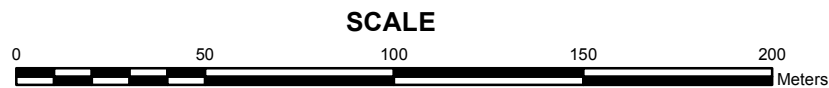
LEGEND

- Monitoring Well
- Other Well (not Monitored Routinely)
- Seep Monitoring Station

PROJECTION: UTM
 ZONE: 8
 DATUM: NAD 83
 UNITS: Meters
 CONTOUR INTERVAL: 2m



Groundwater Monitoring Wells
ETA Area
 Faro Mine Site



CLIENT: Yukon Government
 PROJECT: 2010 ARMC Groundwater Review
 REPORT: RGC 118018
 LOCATION: Anvil Range Mining Complex, YT, Canada



FIGURE: 2-2

DATE: 032411
 DRAWN BY: OM
 FILE: Faro_ETA_area_11.mxd

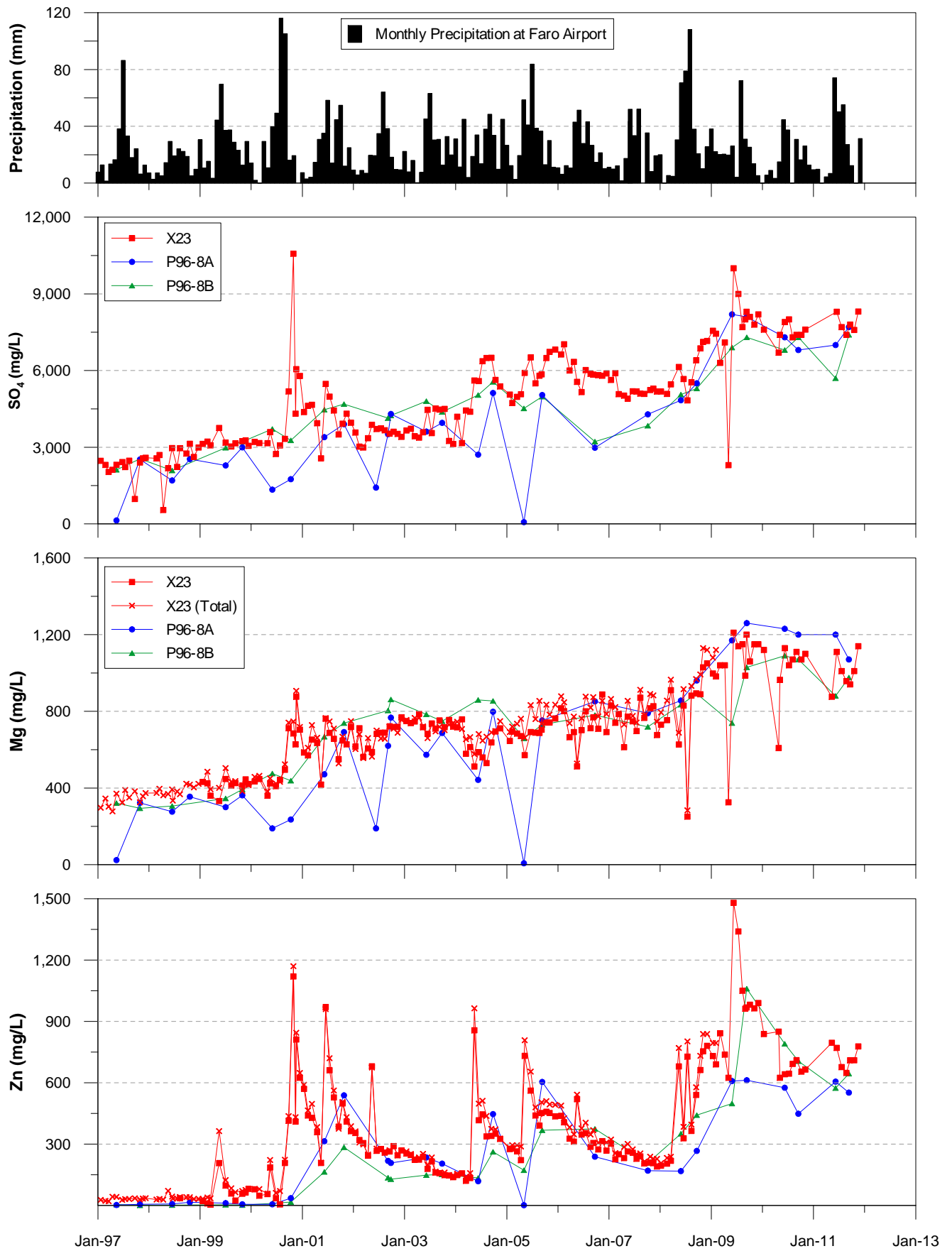


Figure 2-3a. Time trends for SO₄, Mg and Zn at X23 and P96-8A/B

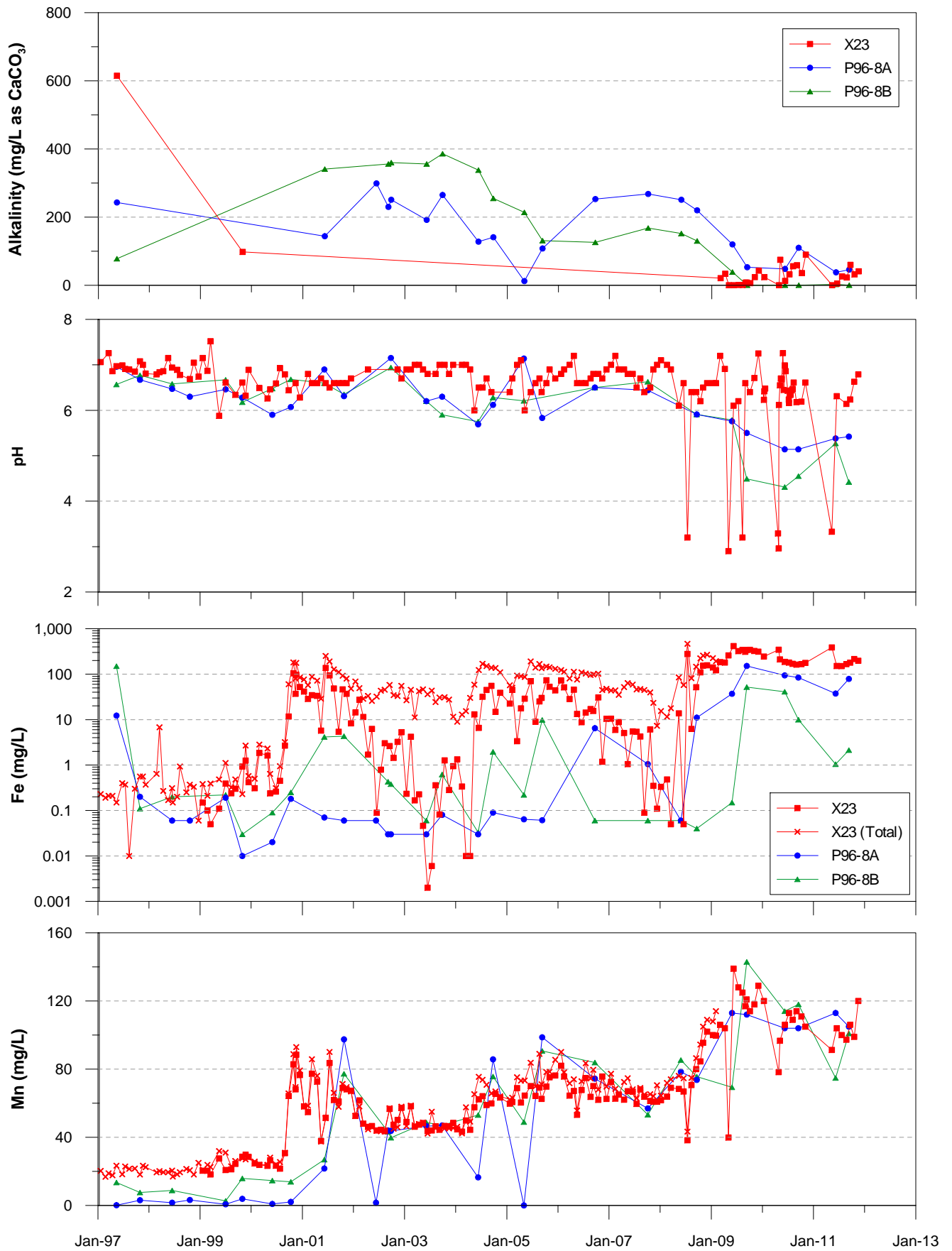


Figure 2-3b. Time trends for alkalinity, pH, Fe and Mn at X23 and P96-8A/B

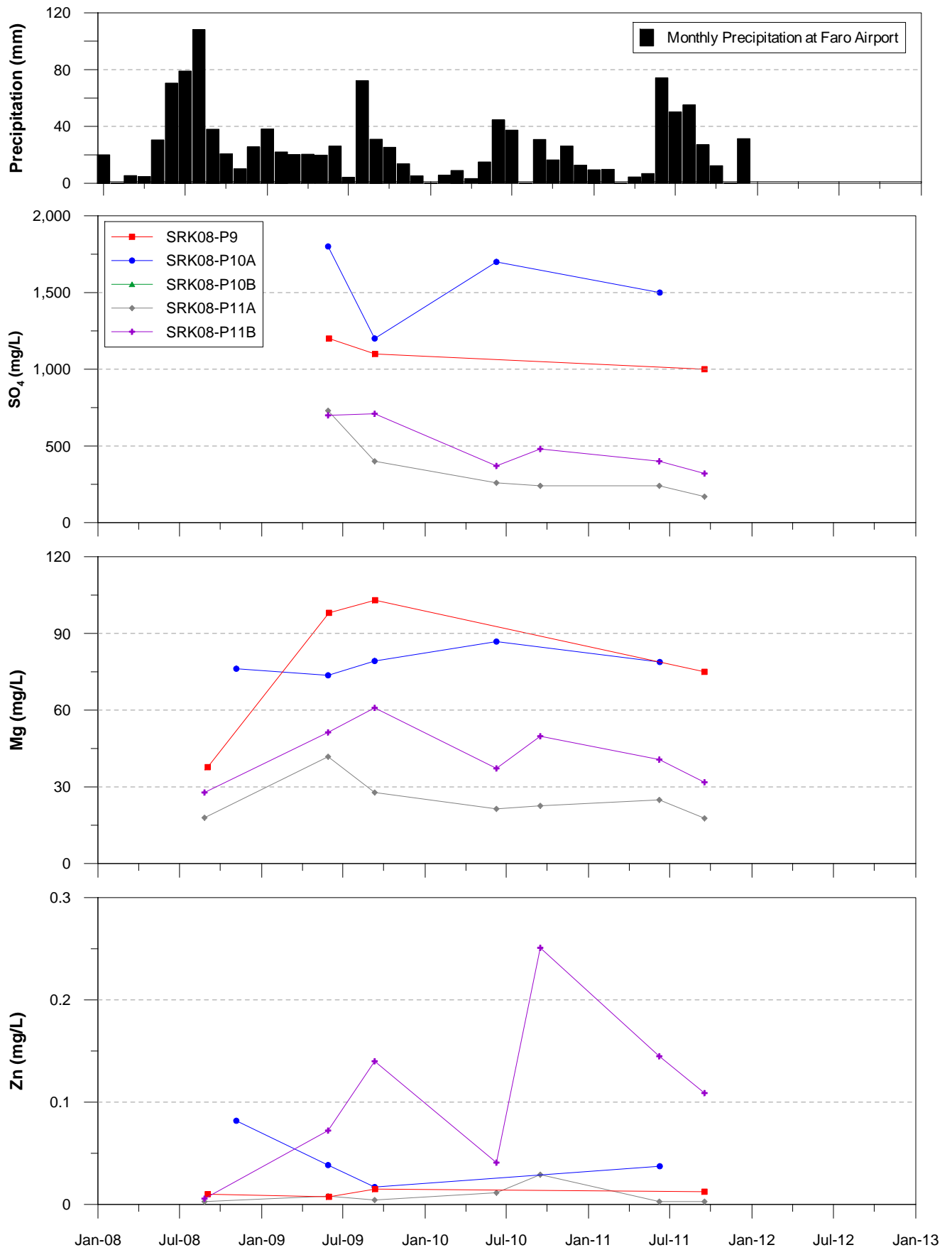


Figure 2-3c. Time trends for SO₄, Mg and Zn in SRK08 wells located in Main Rock Dump and Mill Site areas

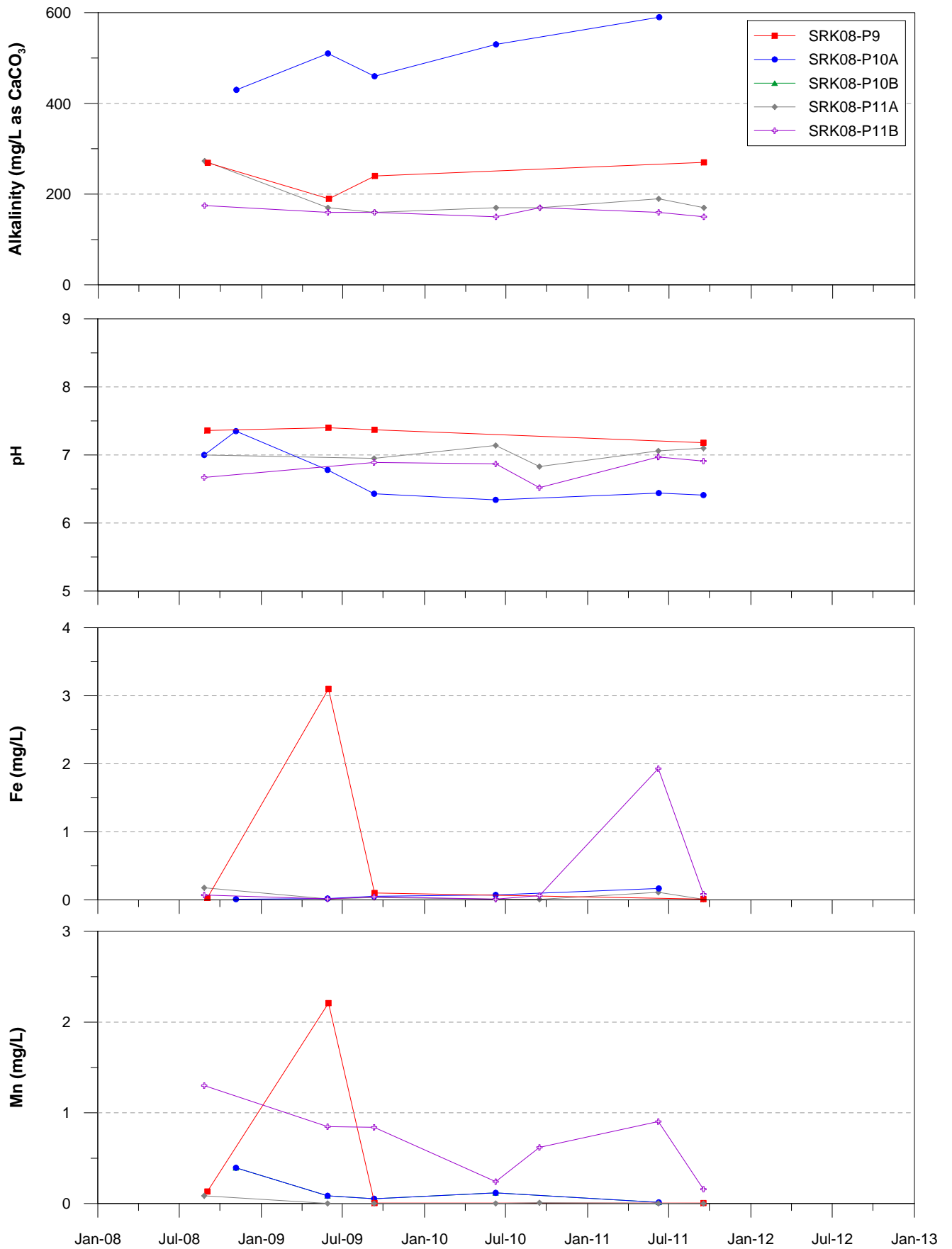


Figure 2-3d. Time trends for alkalinity, pH, Fe and Mn in SRK08 wells located in Main Rock Dump and Mill Site areas

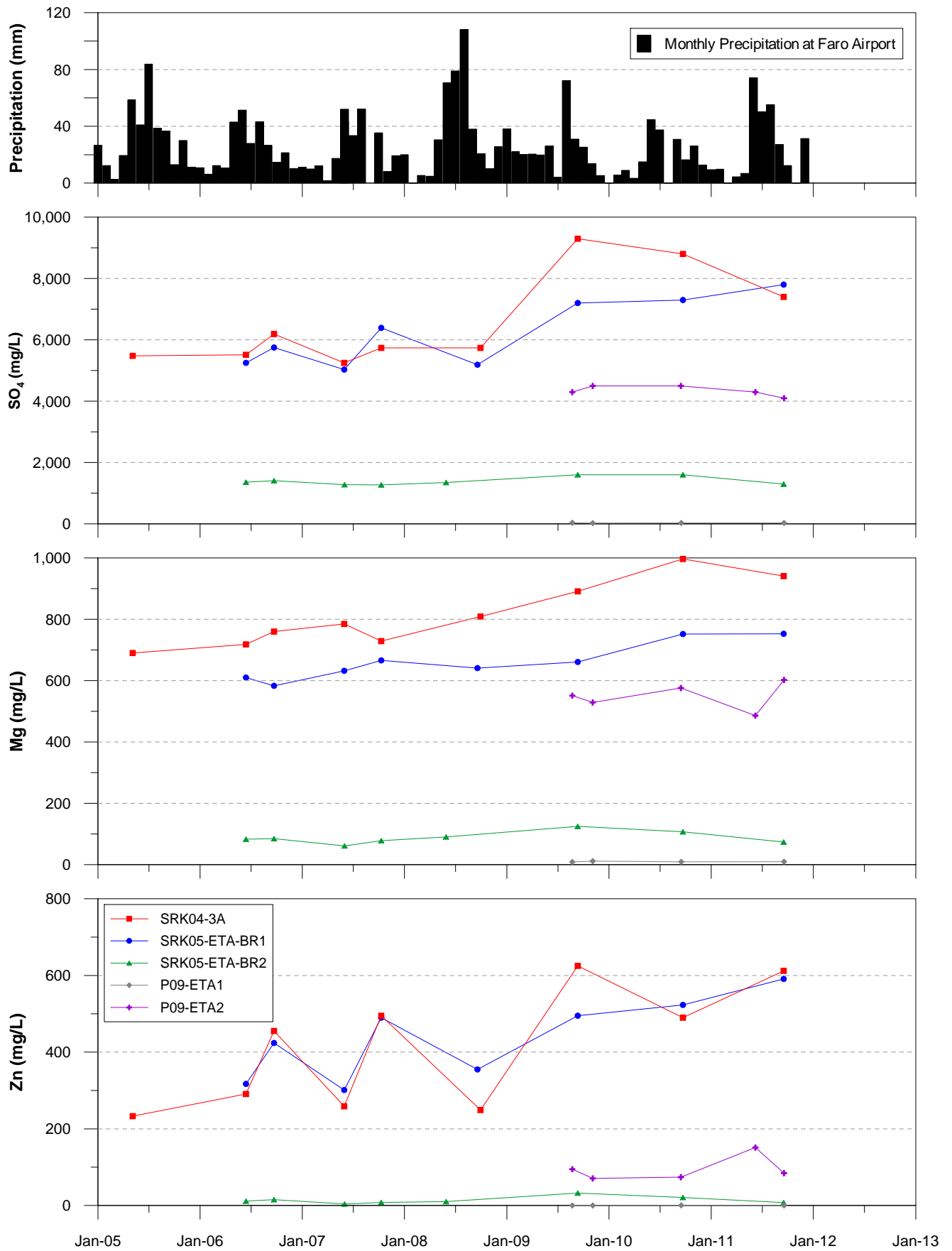


Figure 2-4a. Time trends for SO_4 , Mg and Zn in SRK wells in the ETA

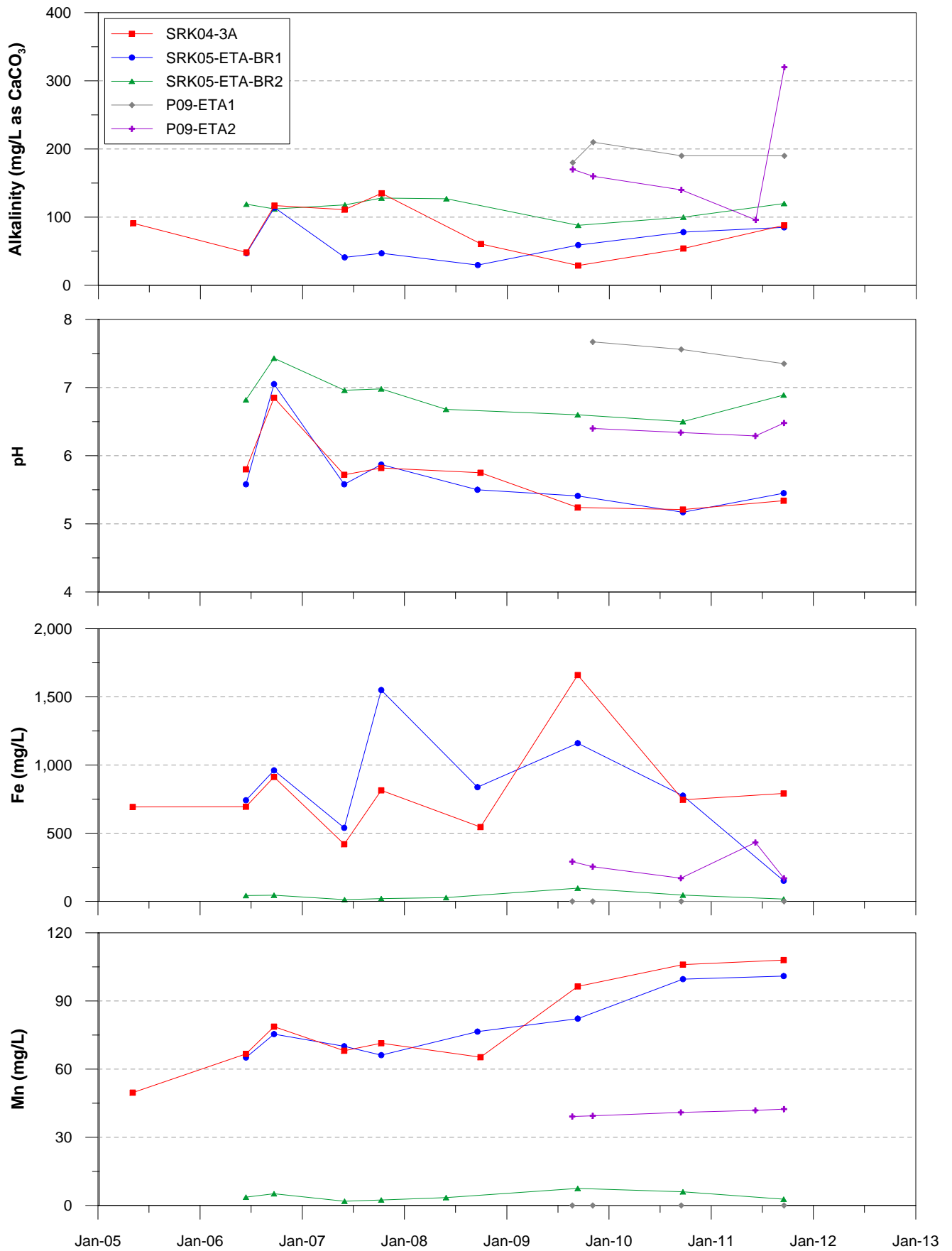


Figure 2-4b. Time trends for alkalinity, pH, Fe and Mn in SRK wells in the ETA

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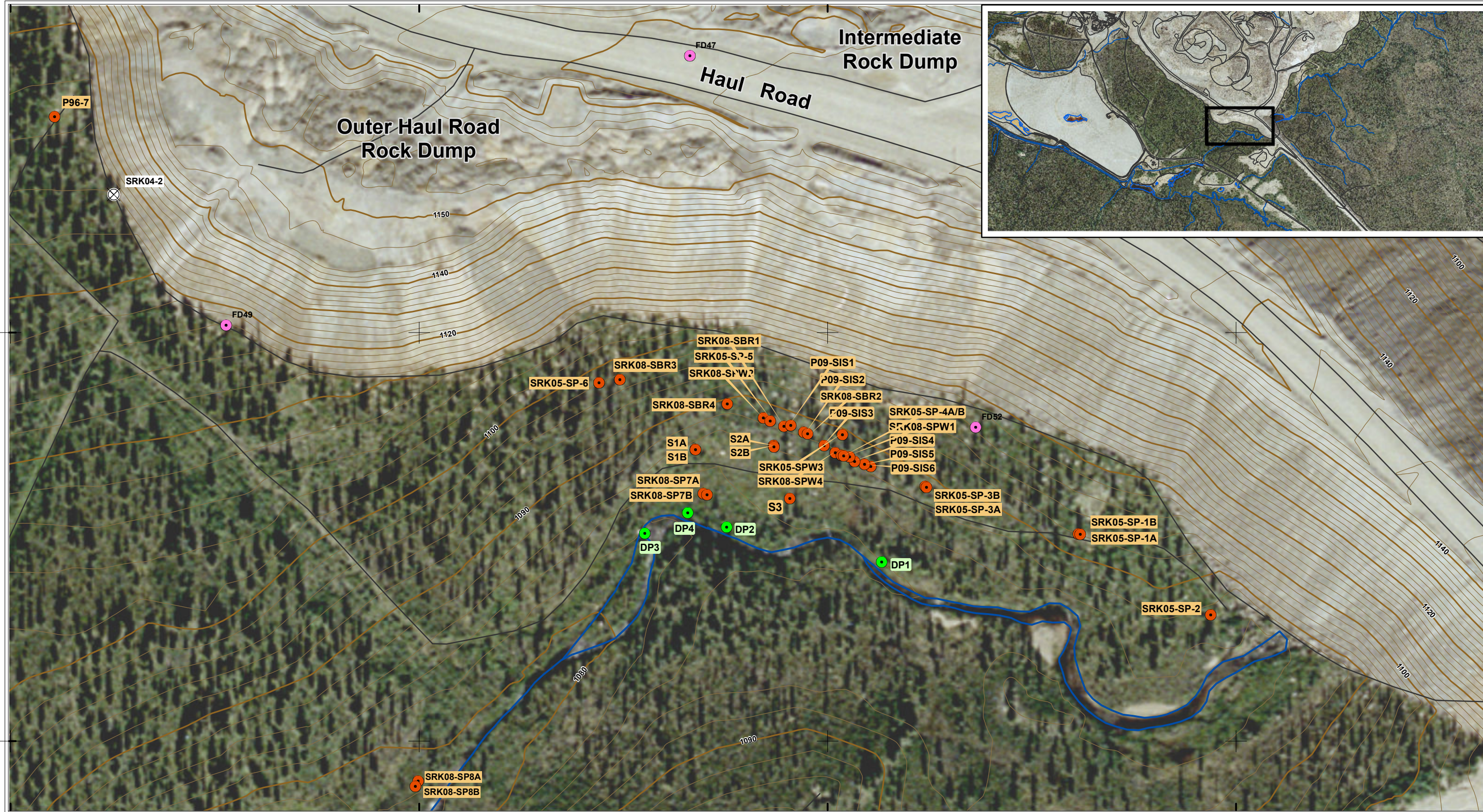
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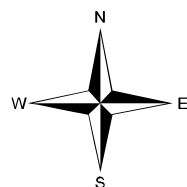
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LEGEND

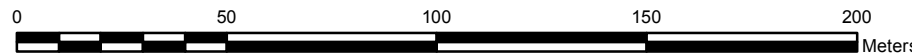
- Monitoring Well
- ⊗ Abandoned Well
- Drive Point
- Seep Monitoring Station

PROJECTION: UTM
 ZONE: 8
 DATUM: NAD 83
 UNITS: Meters
 CONTOUR INTERVAL: 2m



Groundwater Monitoring Wells
S - Cluster Area
 Faro Mine Site

SCALE



CLIENT: Yukon Government
 PROJECT: 2010 ARMC Groundwater Review
 REPORT: RGC 118018
 LOCATION: Anvil Range Mining Complex, YT, Canada



FIGURE: 2-5

DATE: 032411
 DRAWN BY: OM
 FILE: Faro_S_Cluster_11.mxd

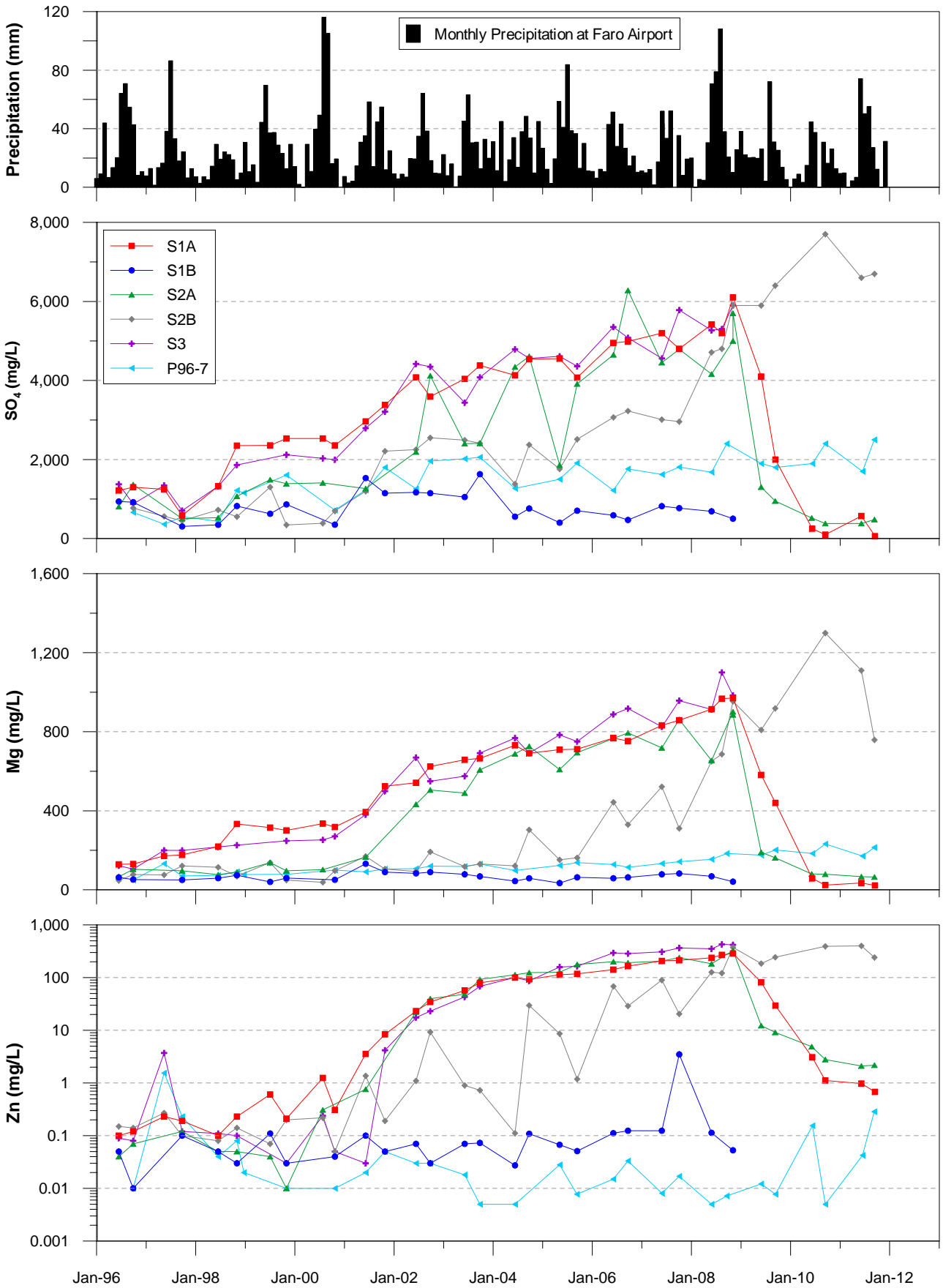


Figure 2-6a. Time Trends for SO₄, Mg and Zn in S-Cluster Wells

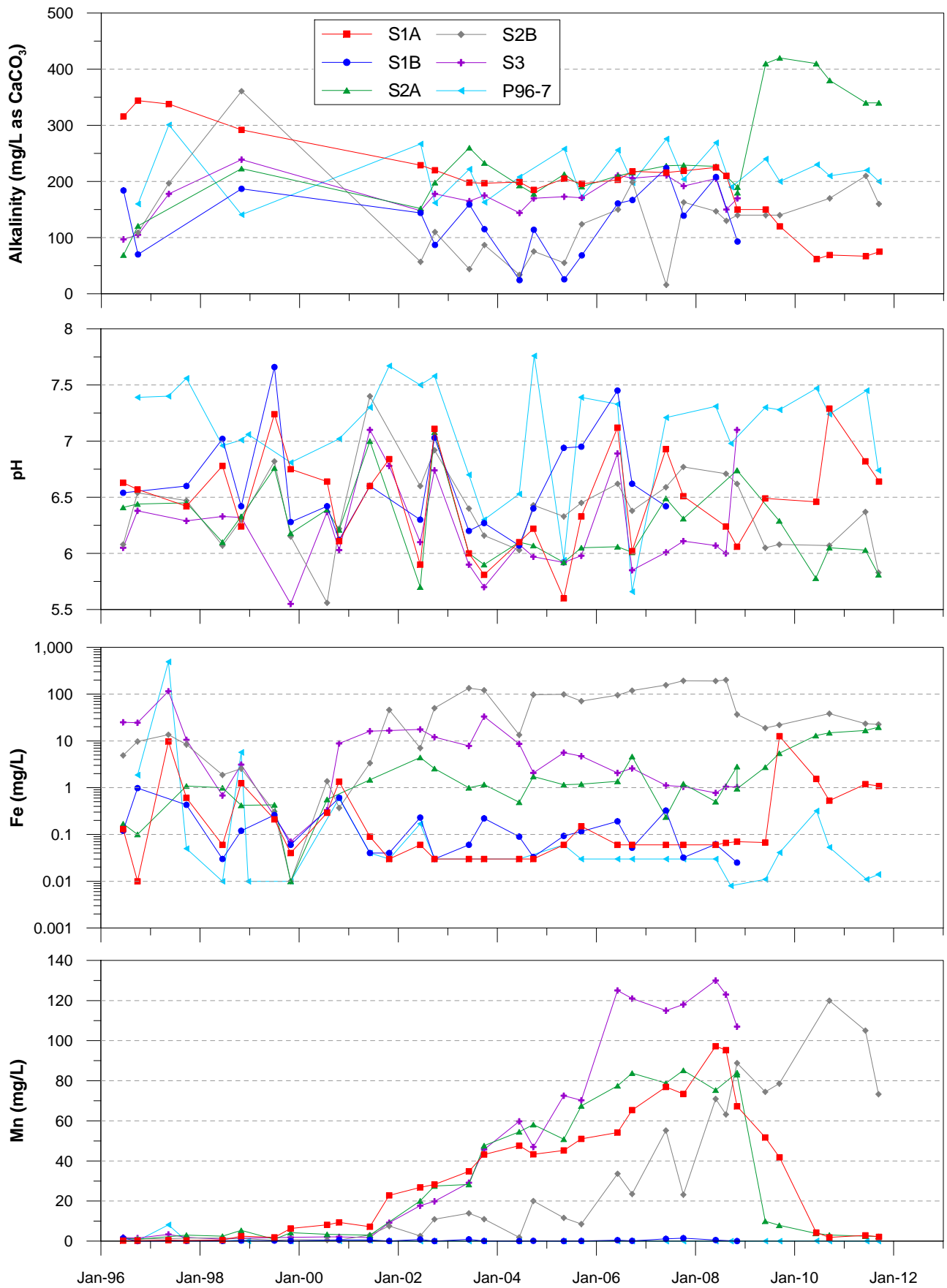


Figure 2-6b. Time trends for alkalinity, pH, Fe and Mn in S-Cluster Wells

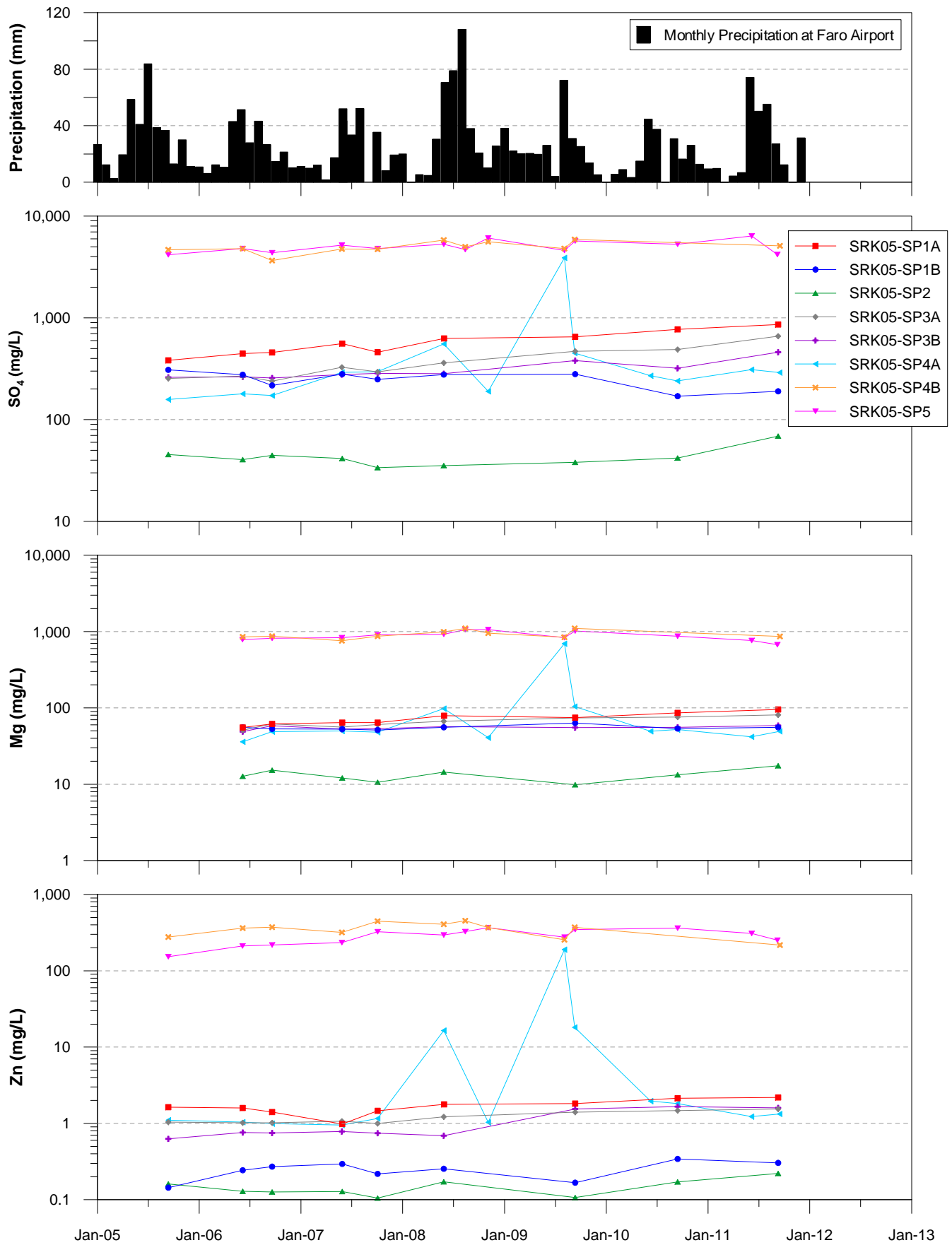


Figure 2-7a. Time trends for SO_4 , Mg and Zn in SRK-05 wells in S-Cluster Area

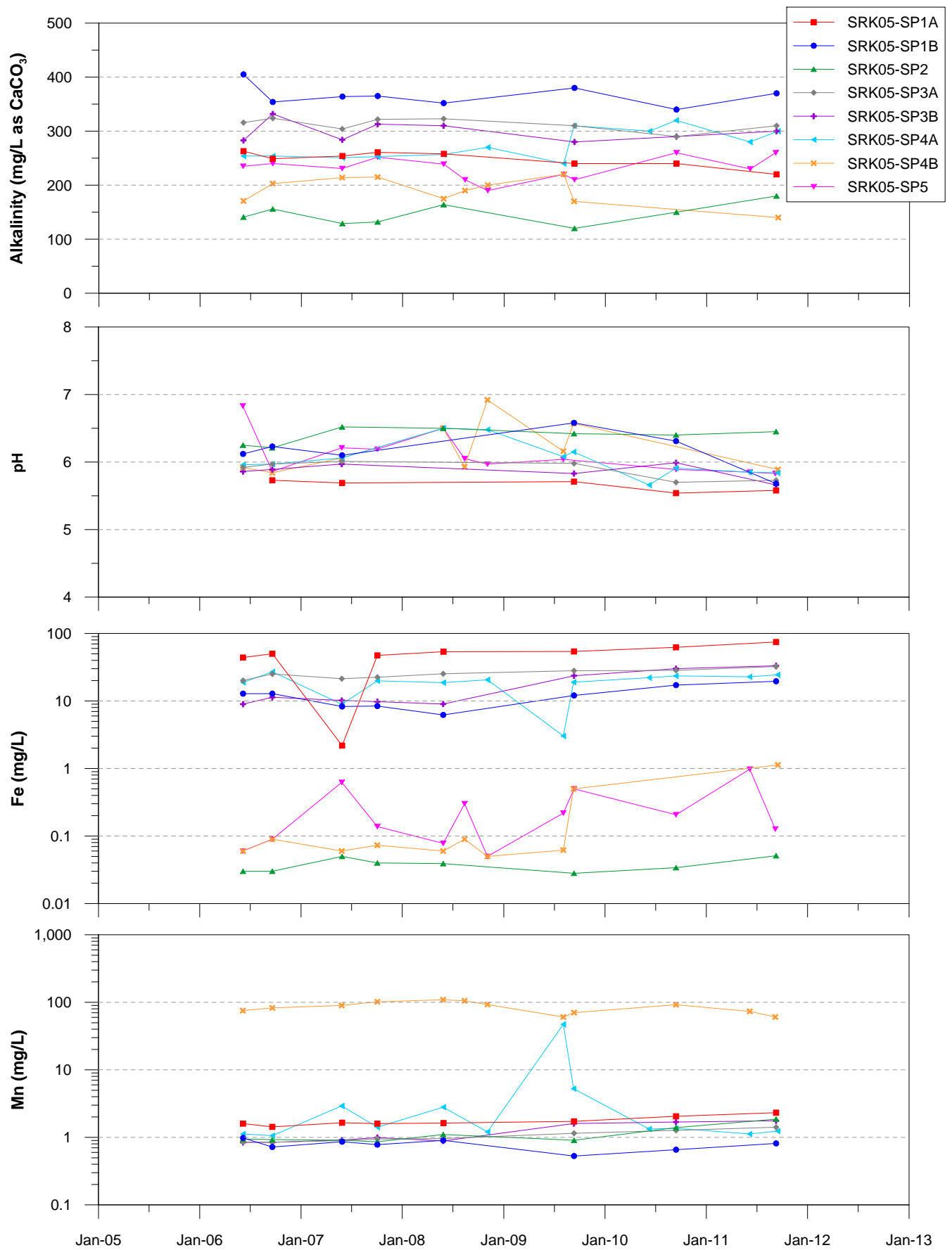


Figure 2-7b. Time trends for alkalinity, pH, Fe and Mn in SRK-05 wells in S-Cluster Area

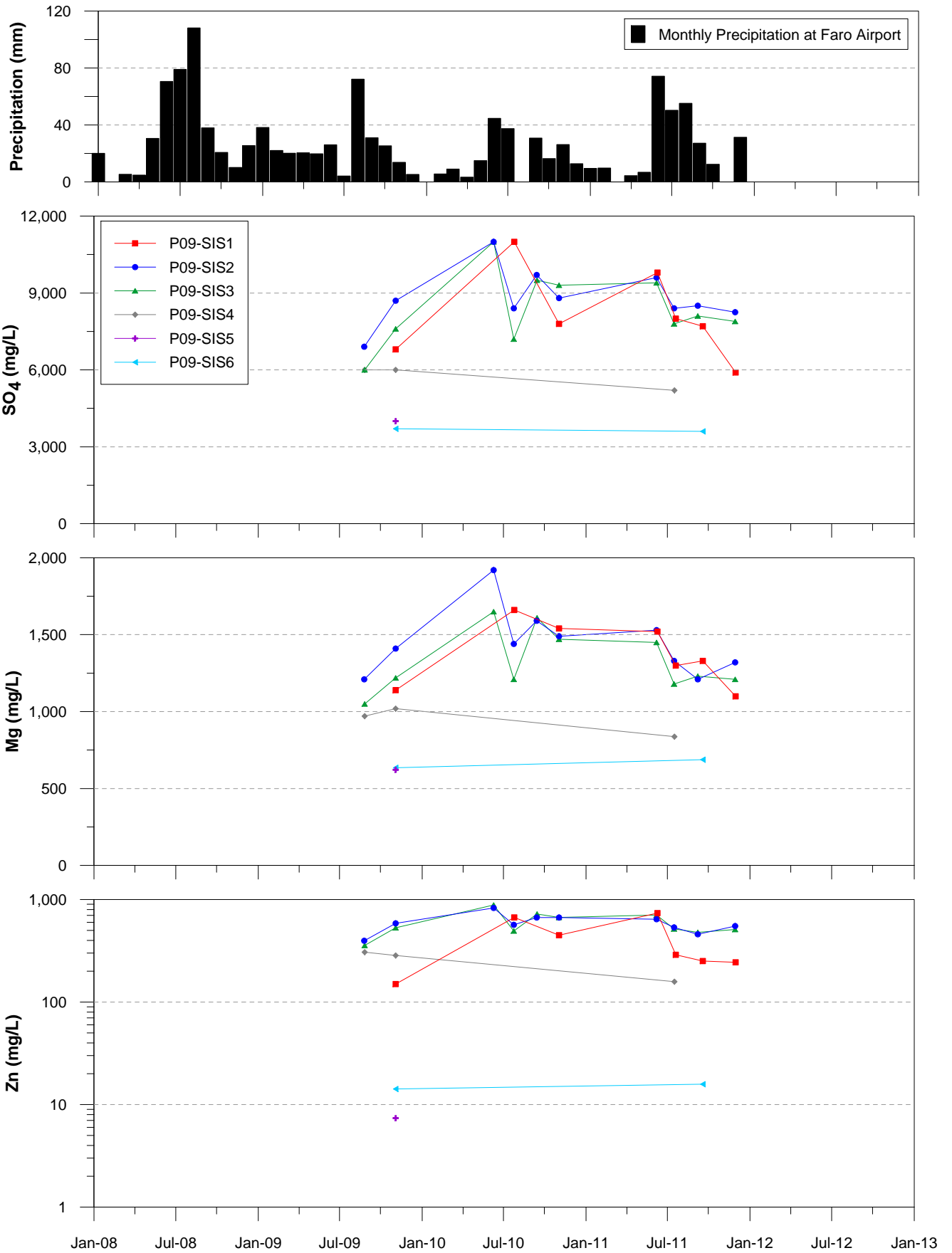


Figure 2-7c. Time trends for SO₄, Mg, Na and Zn in P09-SIS wells, S-Cluster Area

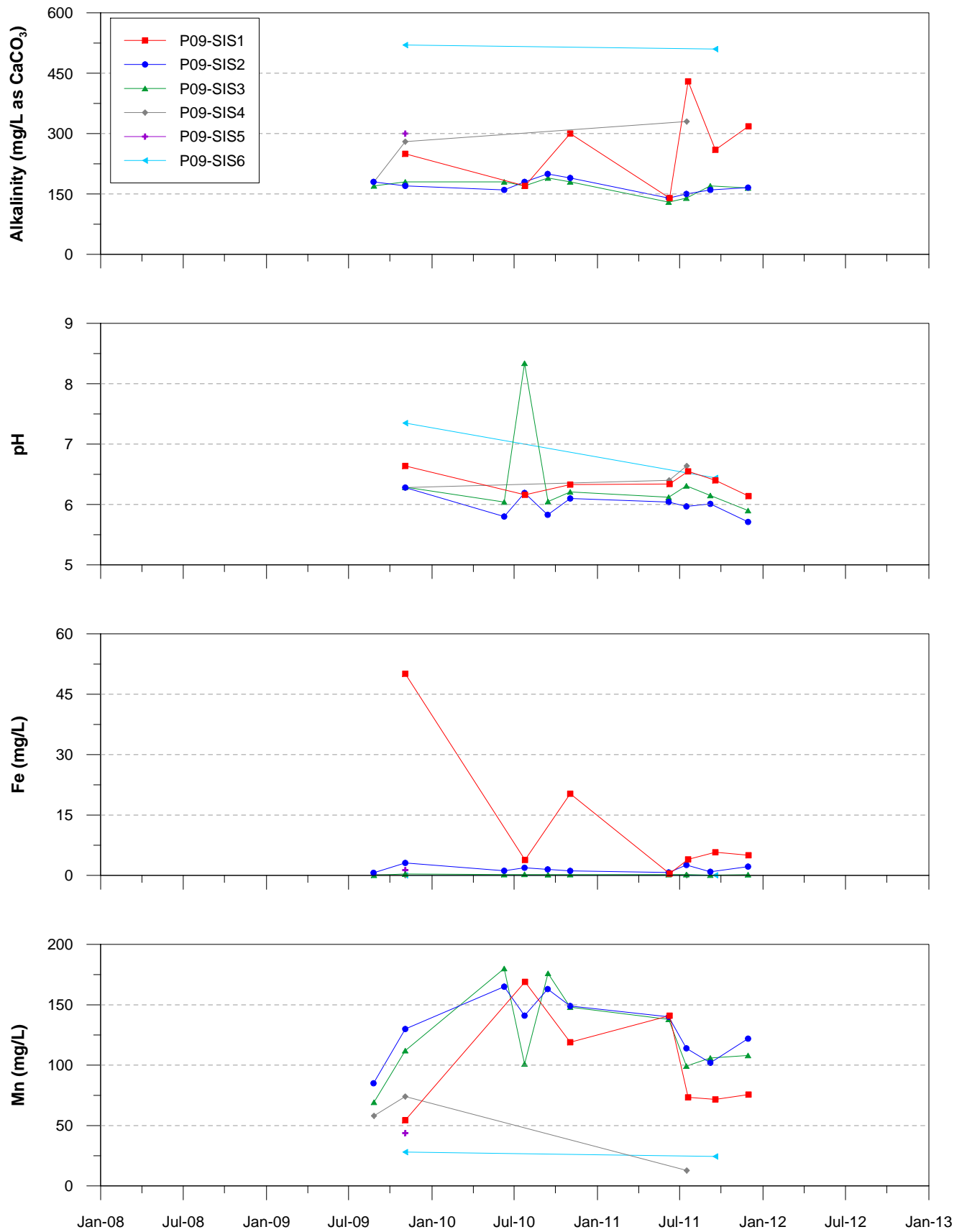


Figure 2-7d. Time trends for alkalinity, pH, Fe and Mn in P09-SIS wells, S-Cluster Area

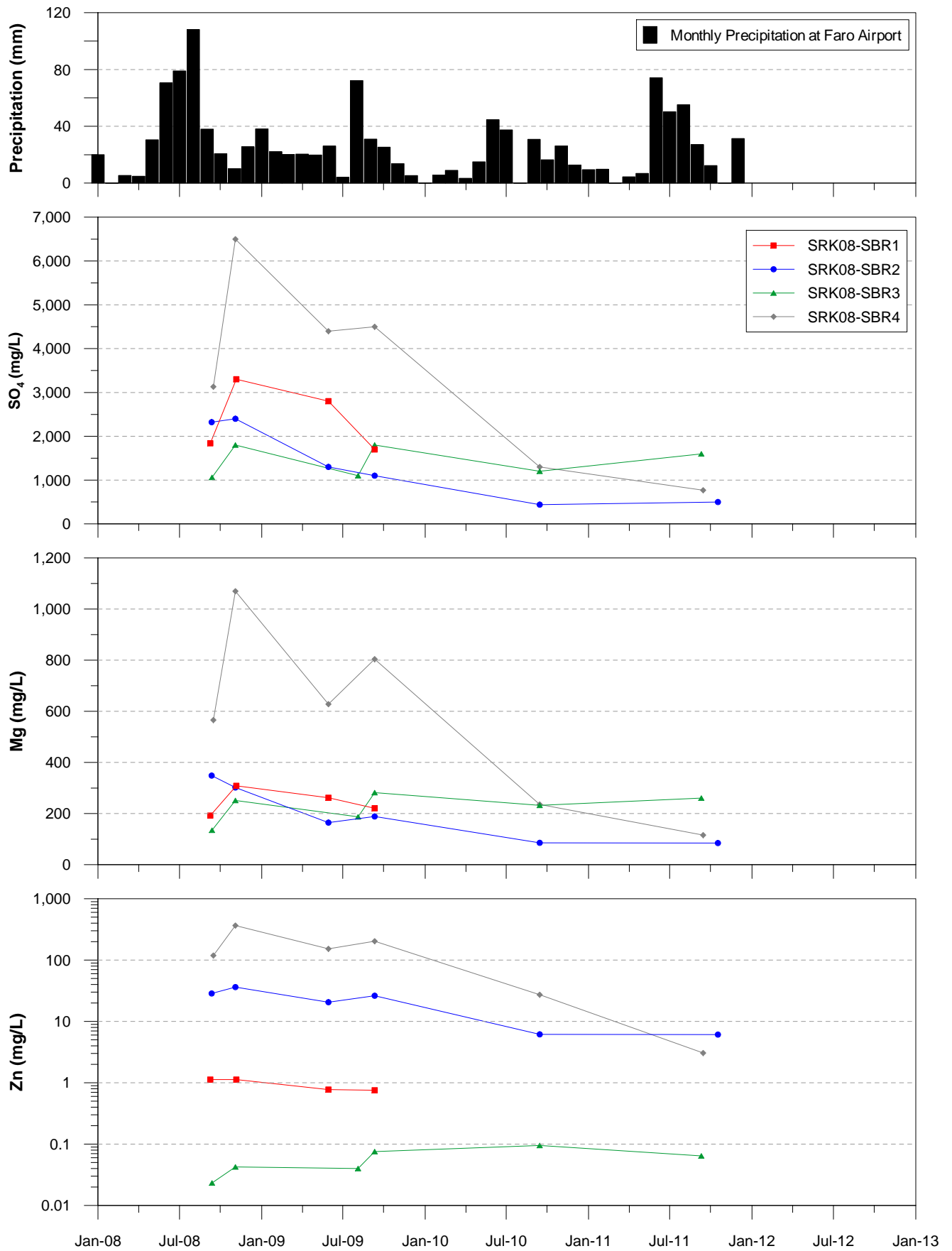


Figure 2-8a. Time trends for SO₄, Mg and Zn in SBR wells in S-Cluster Area

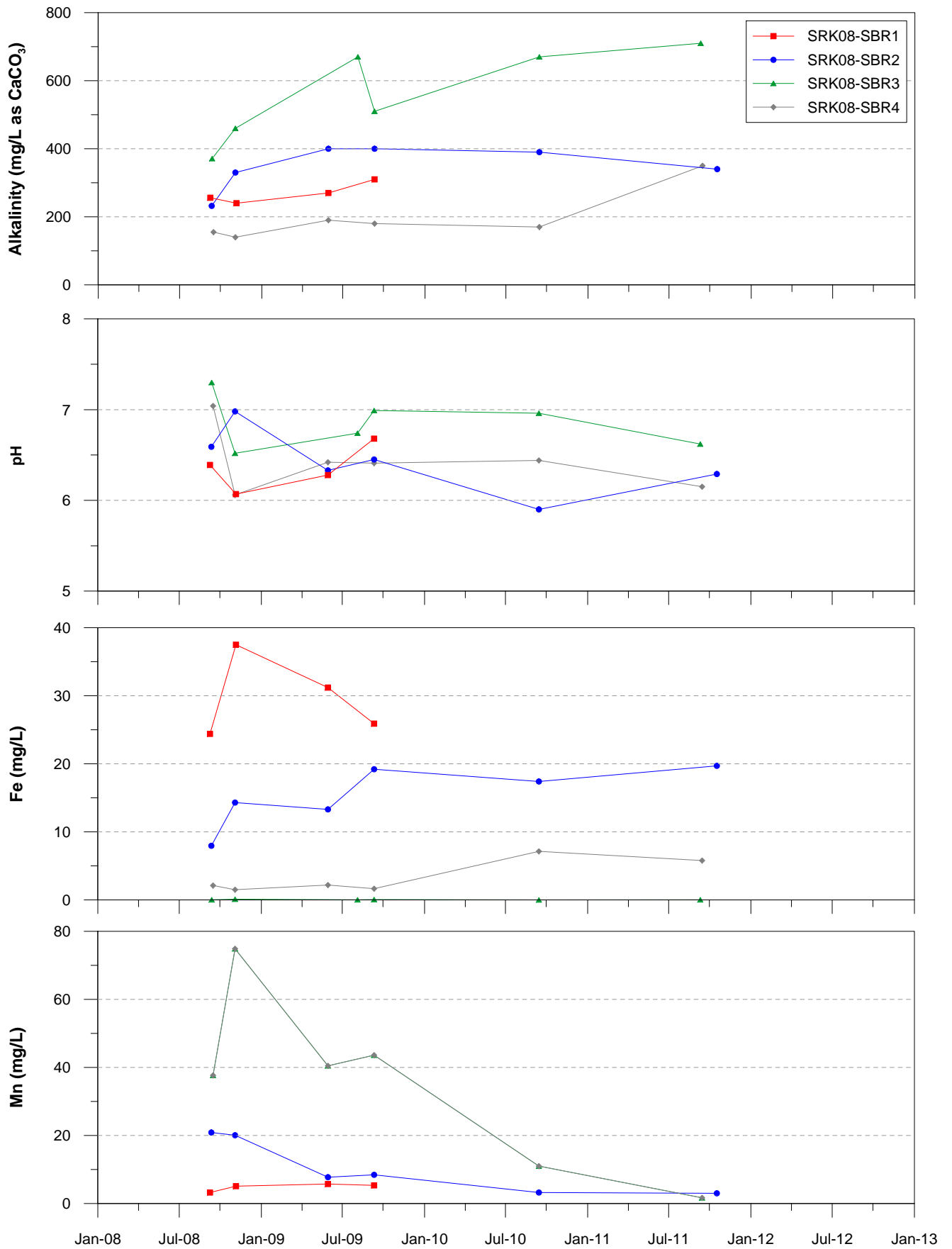


Figure 2-8b. Time trends for alkalinity, pH, Fe and Mn in SBR wells in S-Cluster Area

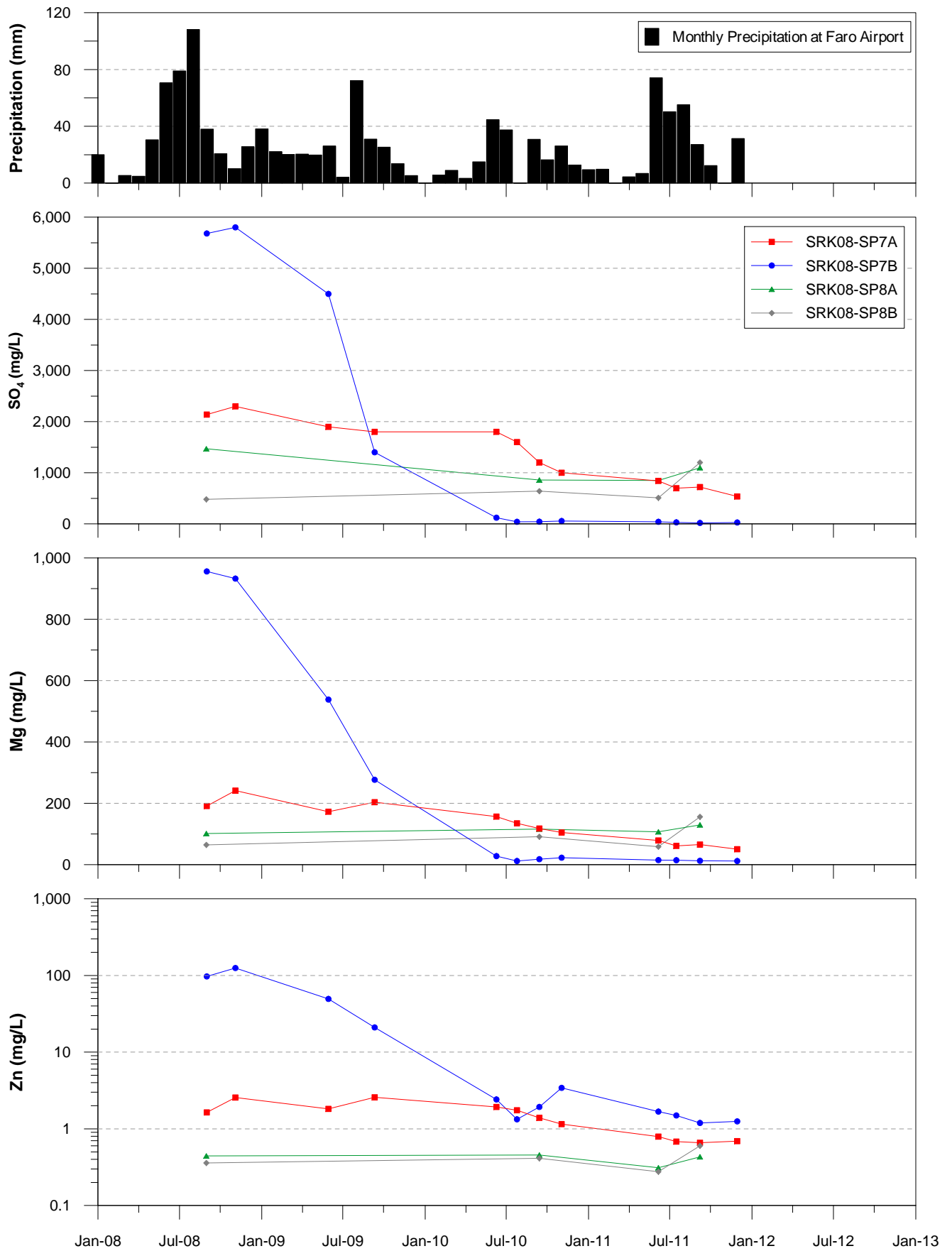


Figure 2-8c. Time trends for SO₄, Mg and Zn in SRK08-SP wells in S-Cluster Area

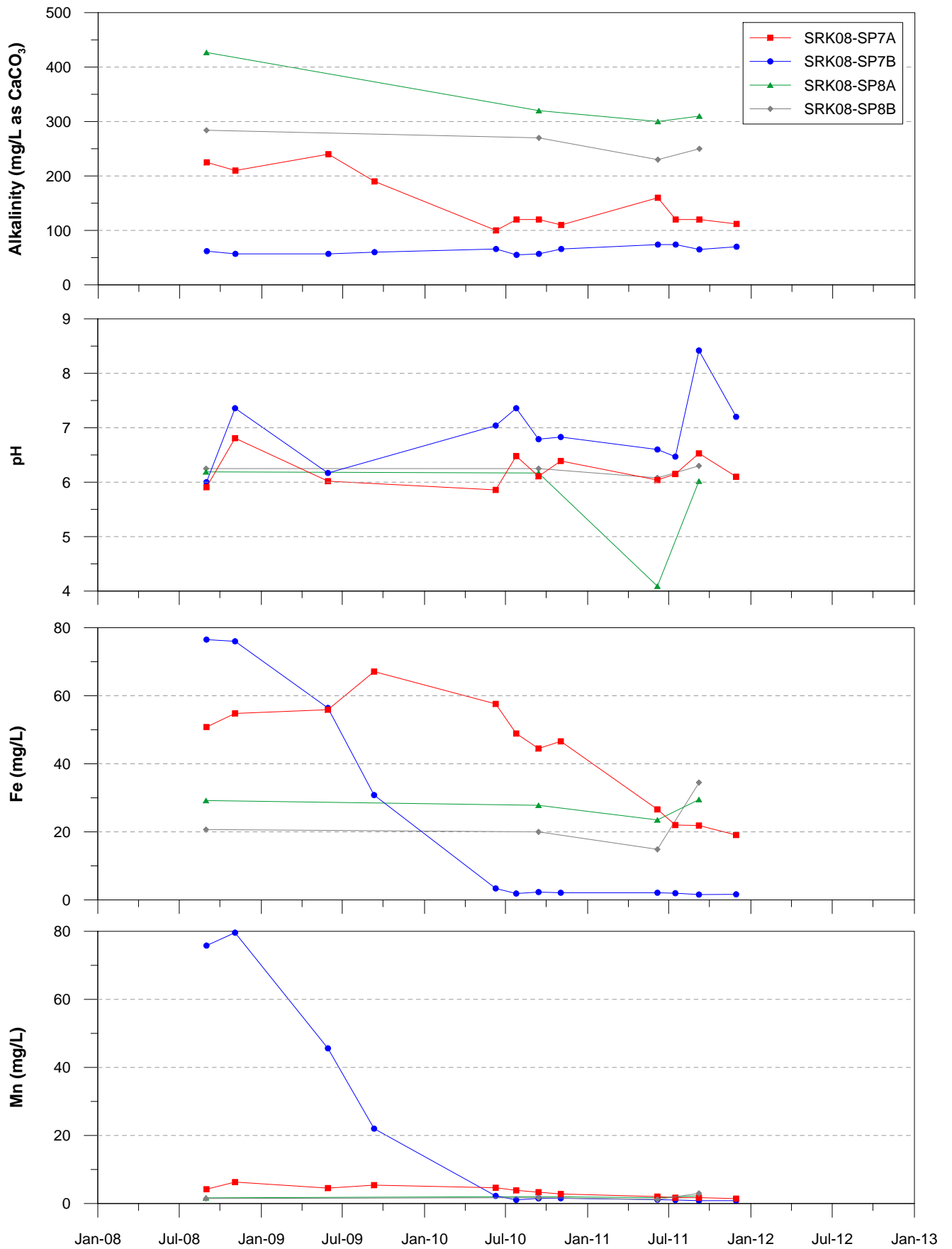


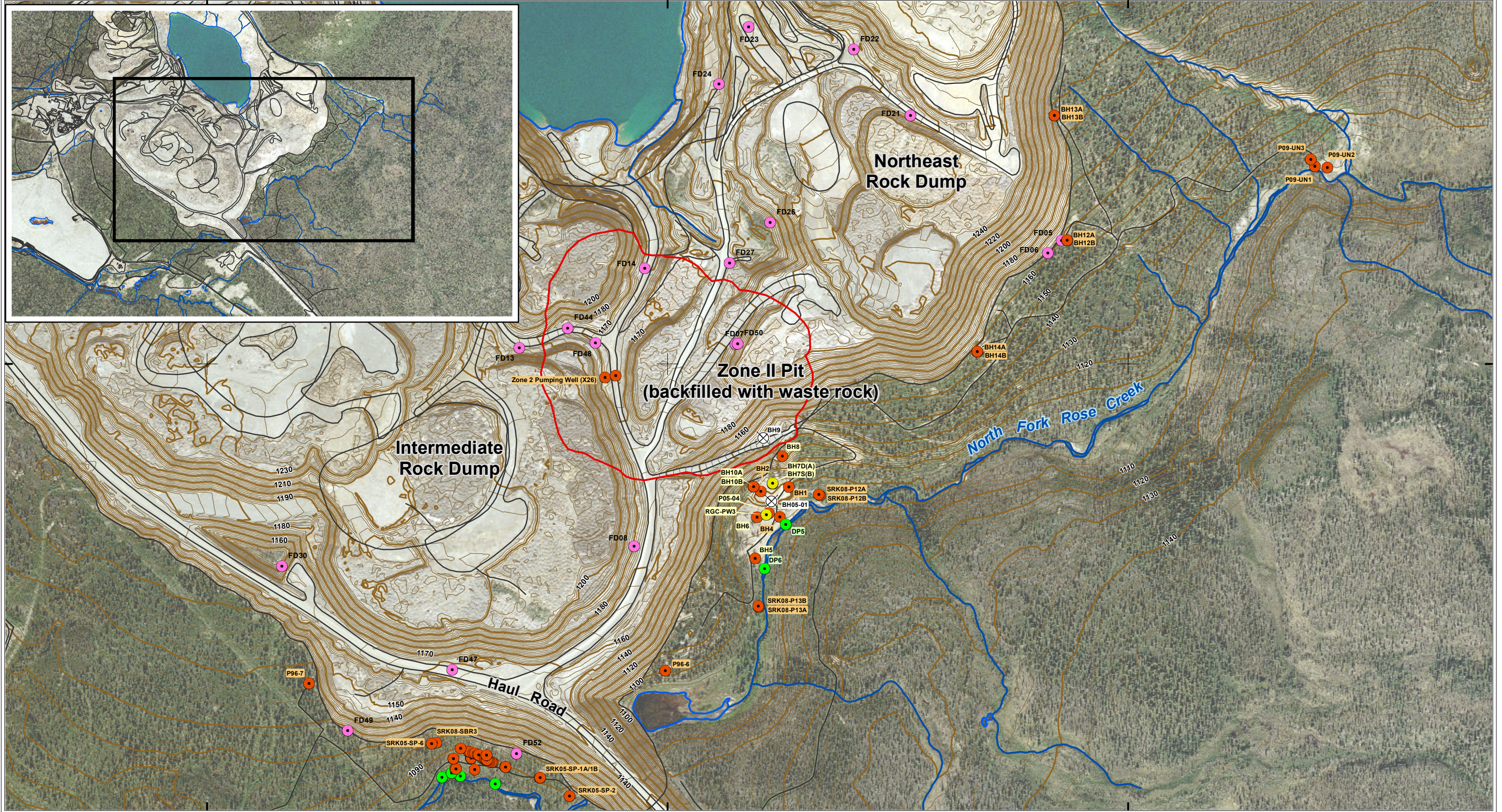
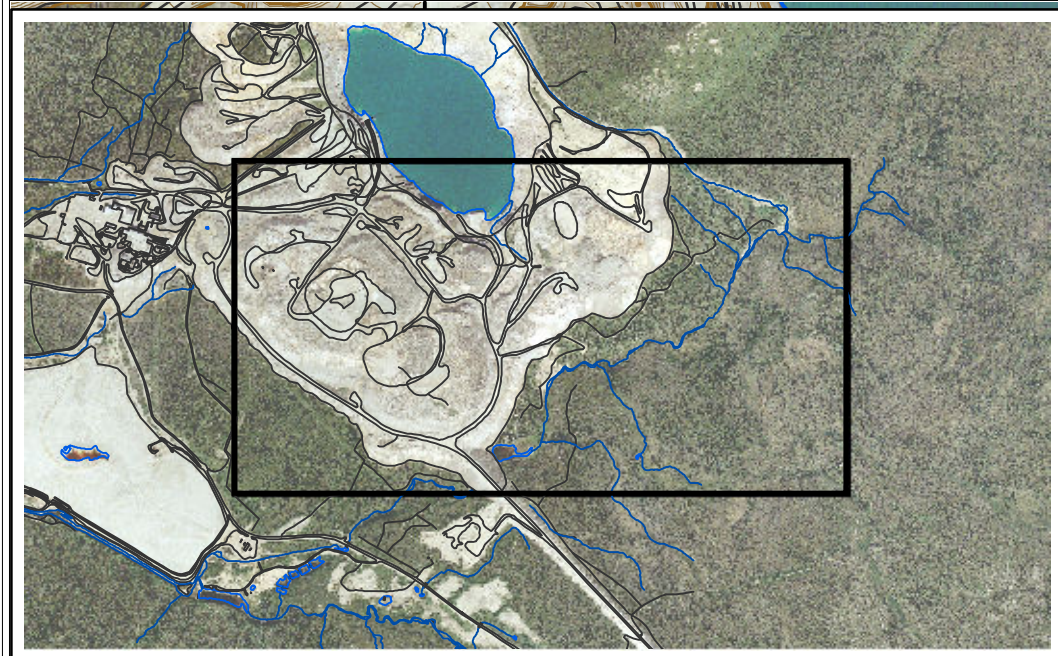
Figure 2-8d. Time trends for alkalinity, pH, Fe and Mn in SRK08-SP wells in S-Cluster Area

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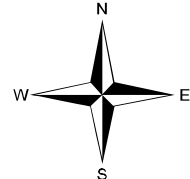
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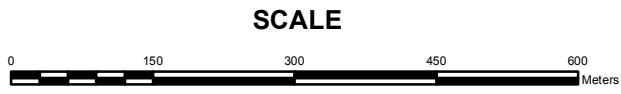
LEGEND

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

PROJECTION: UTM
 ZONE: 8
 DATUM: NAD 83
 UNITS: Meters
 CONTOUR INTERVAL: 2m



**Groundwater Monitoring Wells
 North Fork Rose Creek Area
 Faro Mine Site**

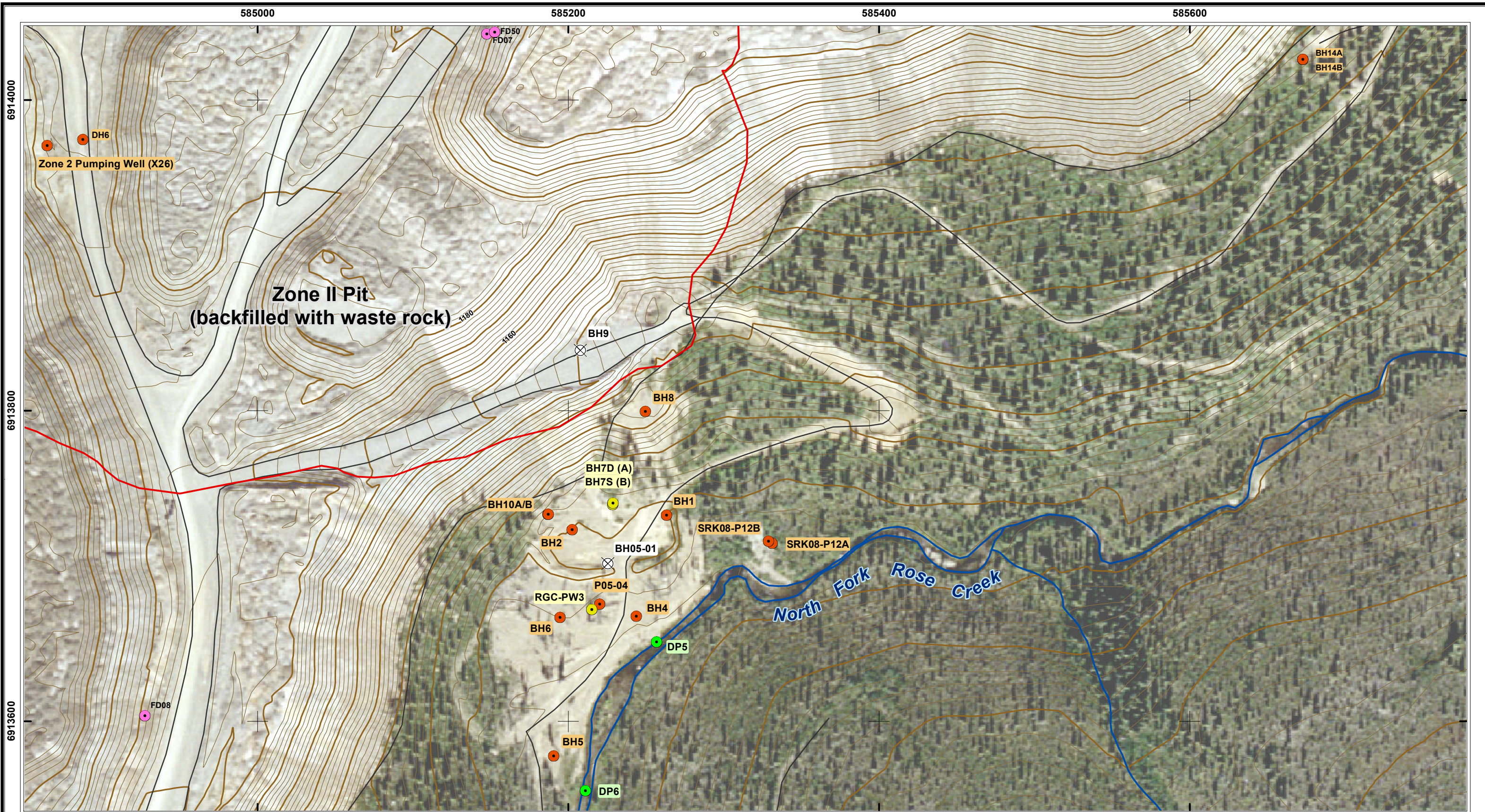


CLIENT: Yukon Government
 PROJECT: 2010 ARMC Groundwater Review
 REPORT: RGC 118018
 LOCATION: Anvil Range Mining Complex, YT, Canada



FIGURE: 2-9

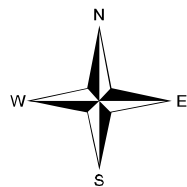
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LEGEND

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

PROJECTION: UTM
 ZONE: 8
 DATUM: NAD 83
 UNITS: Meters
 CONTOUR INTERVAL: 2m



**Groundwater Monitoring Wells
 Zone II Pit Outwash Area
 Faro Mine Site**



CLIENT: Yukon Government
 PROJECT: 2010 ARMC Groundwater Review
 REPORT: RGC 118018
 LOCATION: Anvil Range Mining Complex, YT, Canada



FIGURE: 2-10
 DATE: 032411
 DRAWN BY: OM
 FILE: Faro_Zone2_area_11.mxd

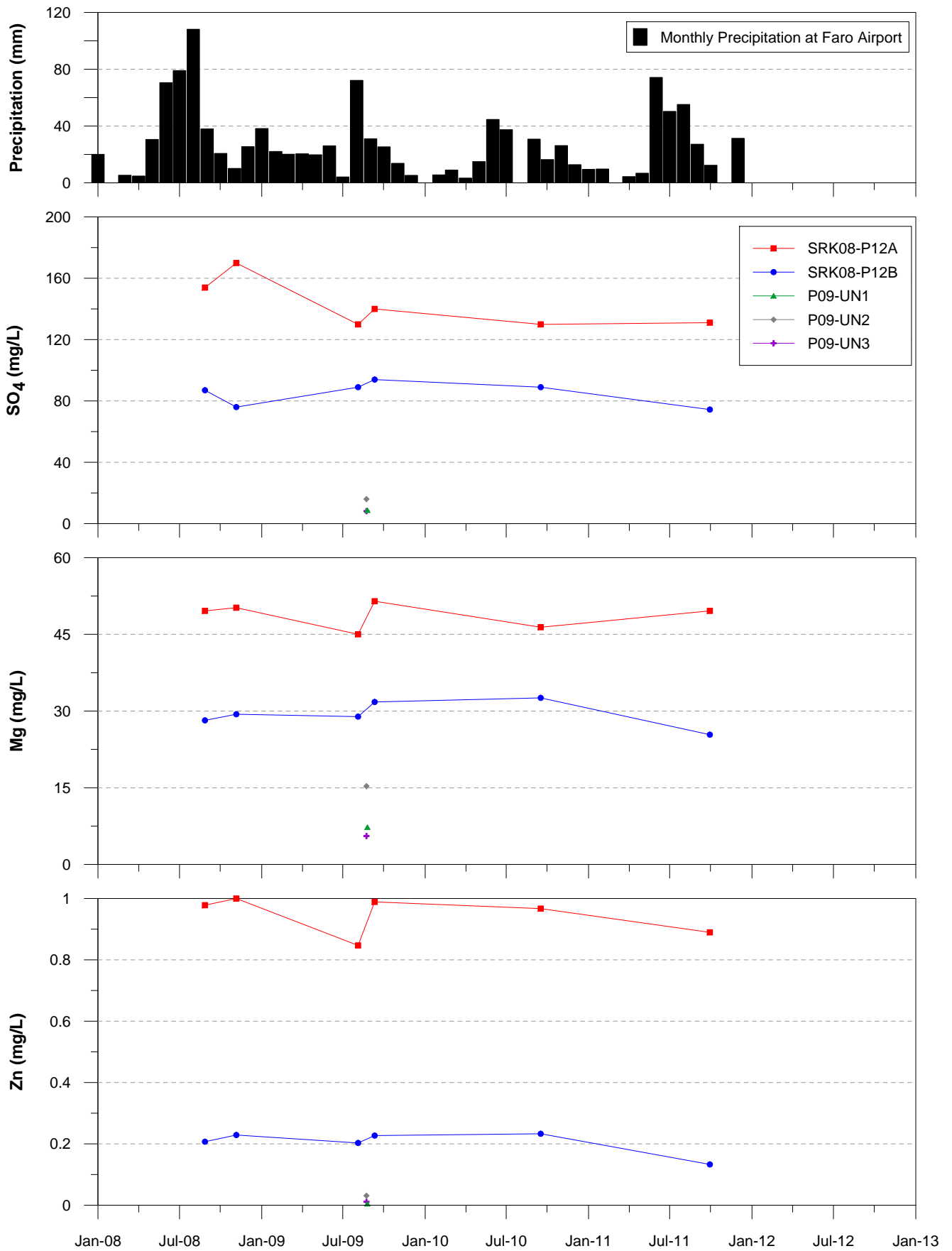


Figure 2-11a. Time trends for SO₄, Mg, Na and Zn in P09-UN wells and SRK08-P12A/B

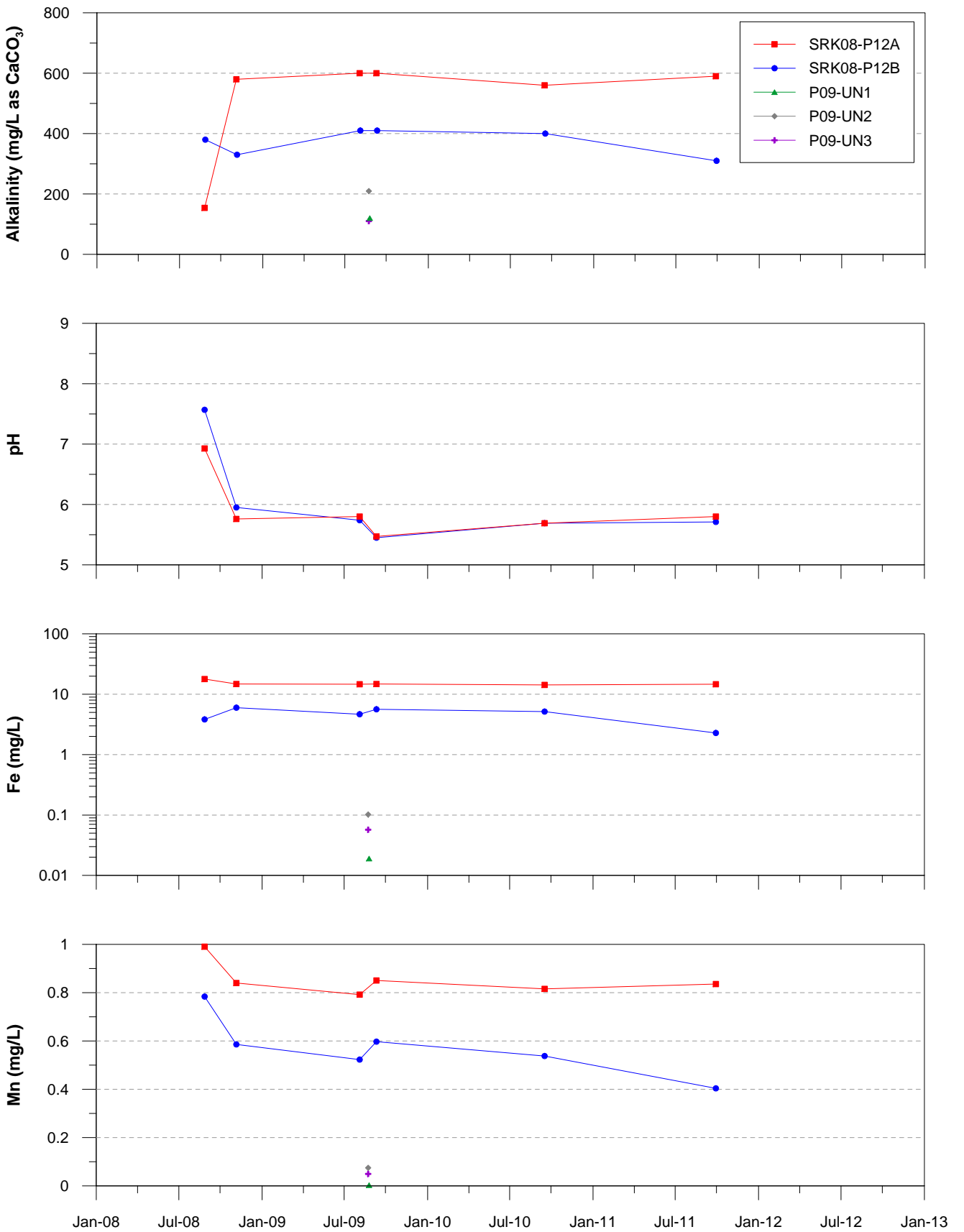


Figure 2-11b. Time trends for Alkalinity, pH, Fe and Mn in P09-UN wells and SRK08-P12A/B

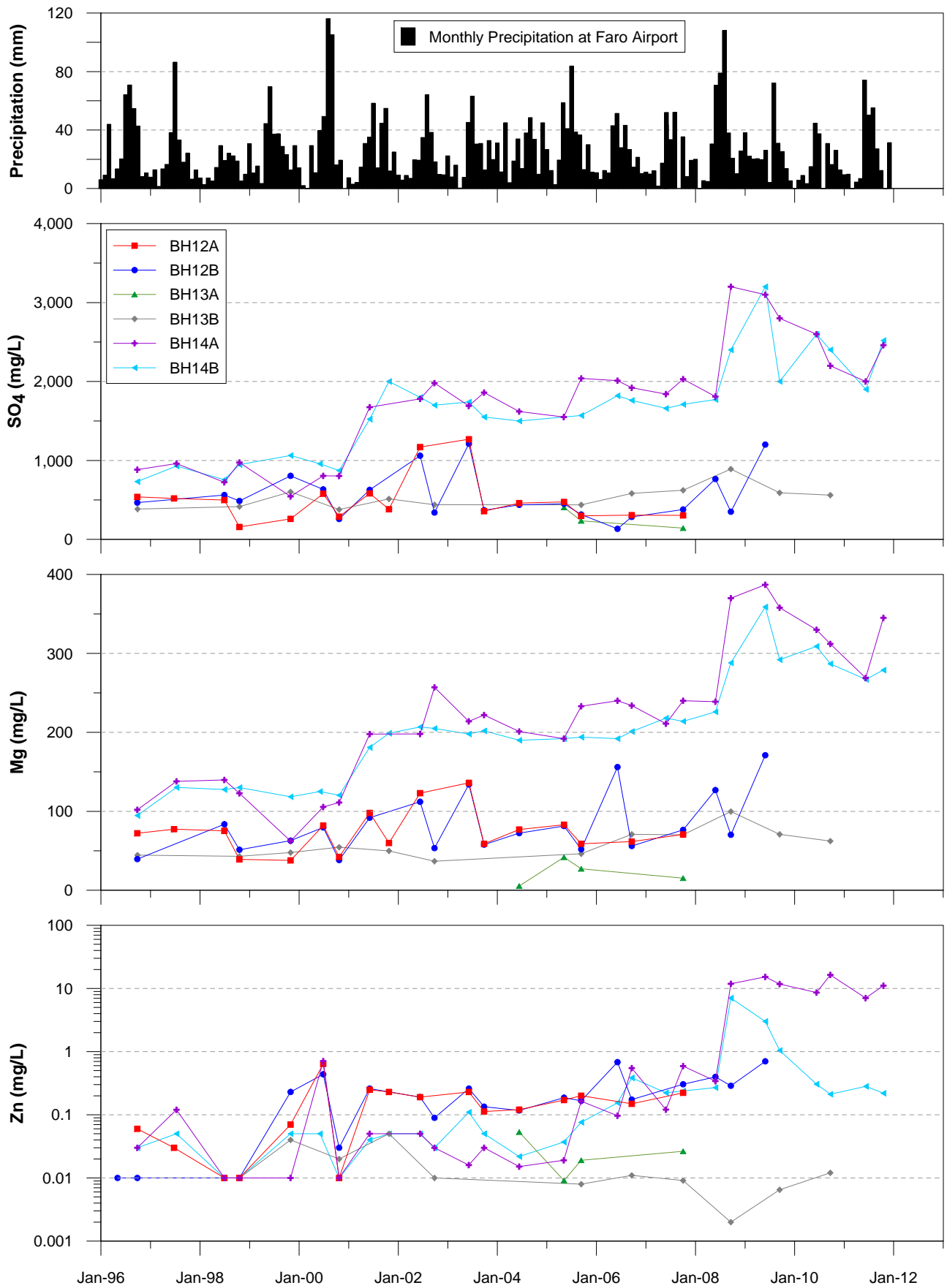


Figure 2-12a. Time trends for SO₄, Mg and Zn in wells at the toe of Northeast Rock Dump

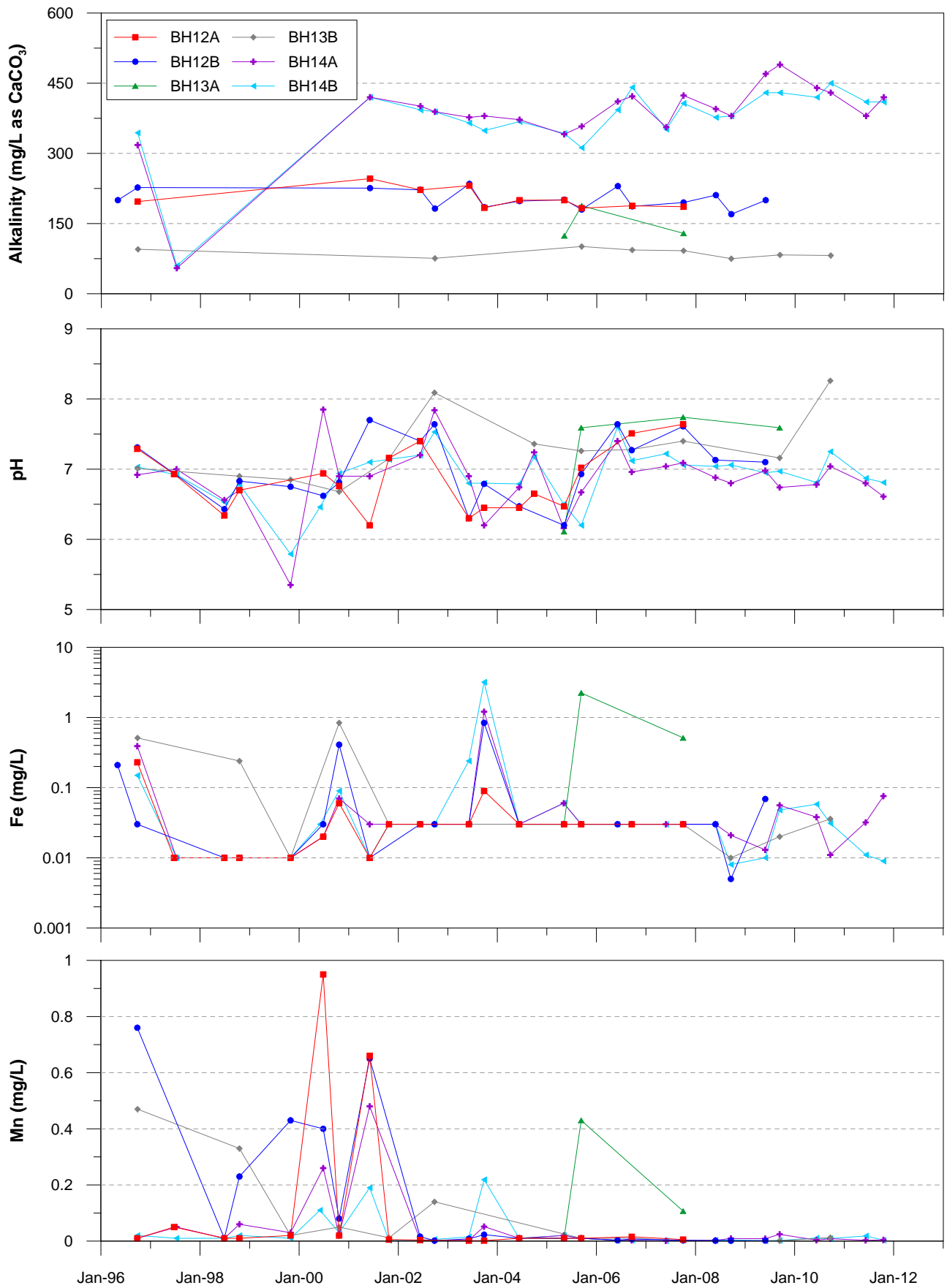


Figure 2-12b. Time trends for alkalinity, pH, Fe and Mn in wells at the toe of Northeast Rock Dump

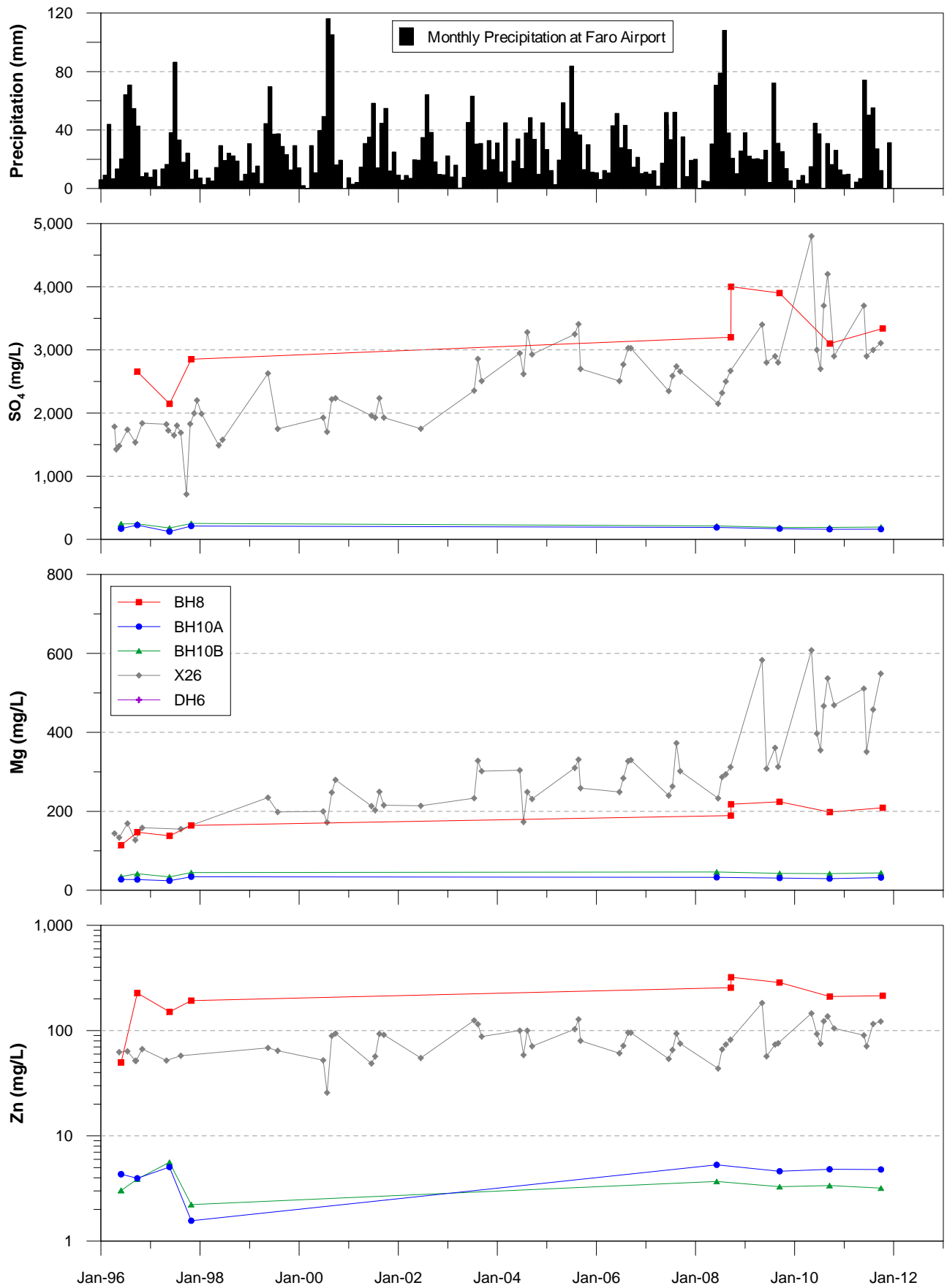


Figure 2-13a. Time trends for SO₄, Mg and Zn for Zone 2 Pit and bedrock wells

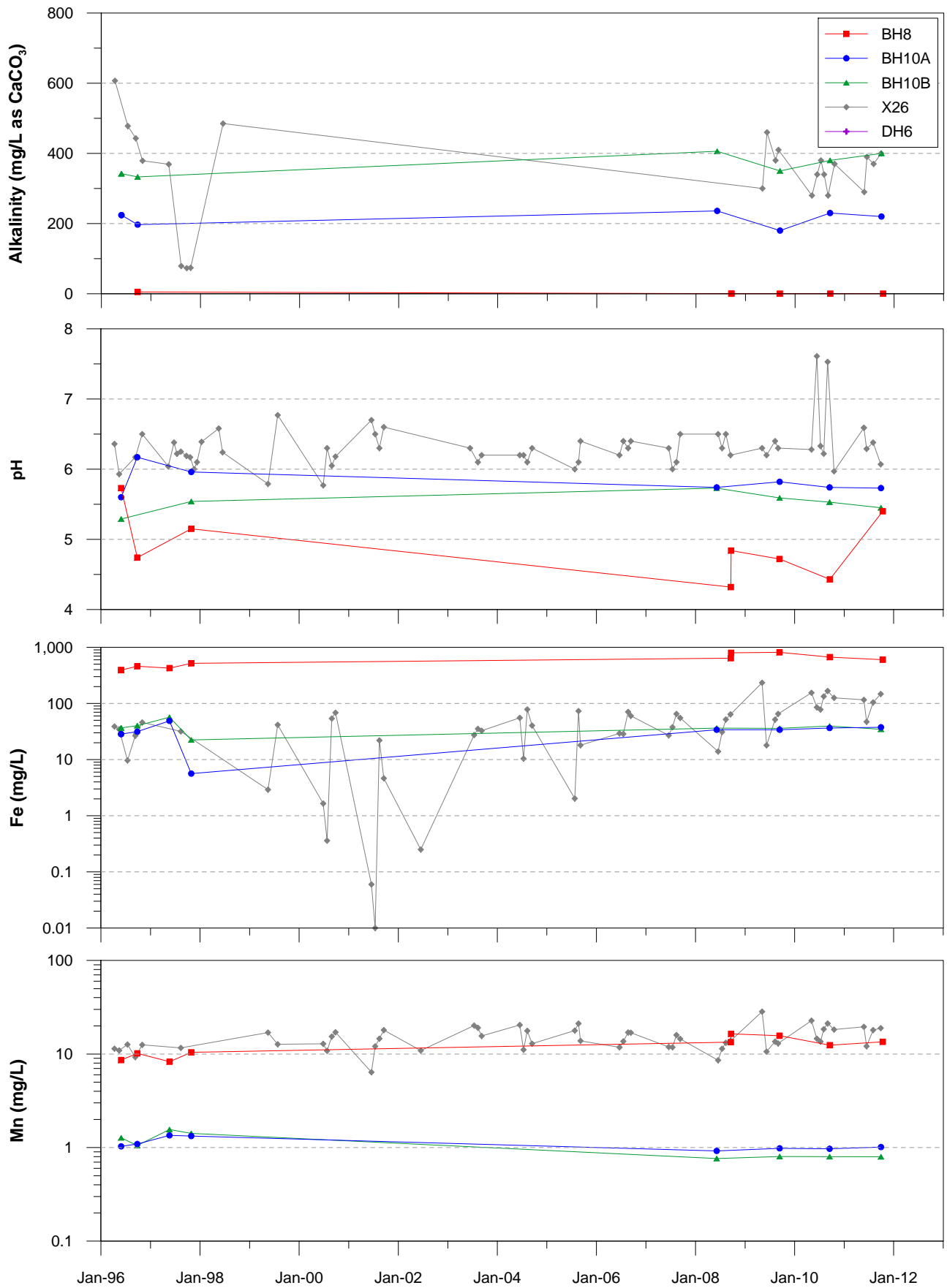


Figure 2-13b. Time trends for alkalinity, pH, Fe and Mn for Zone 2 Pit and bedrock wells

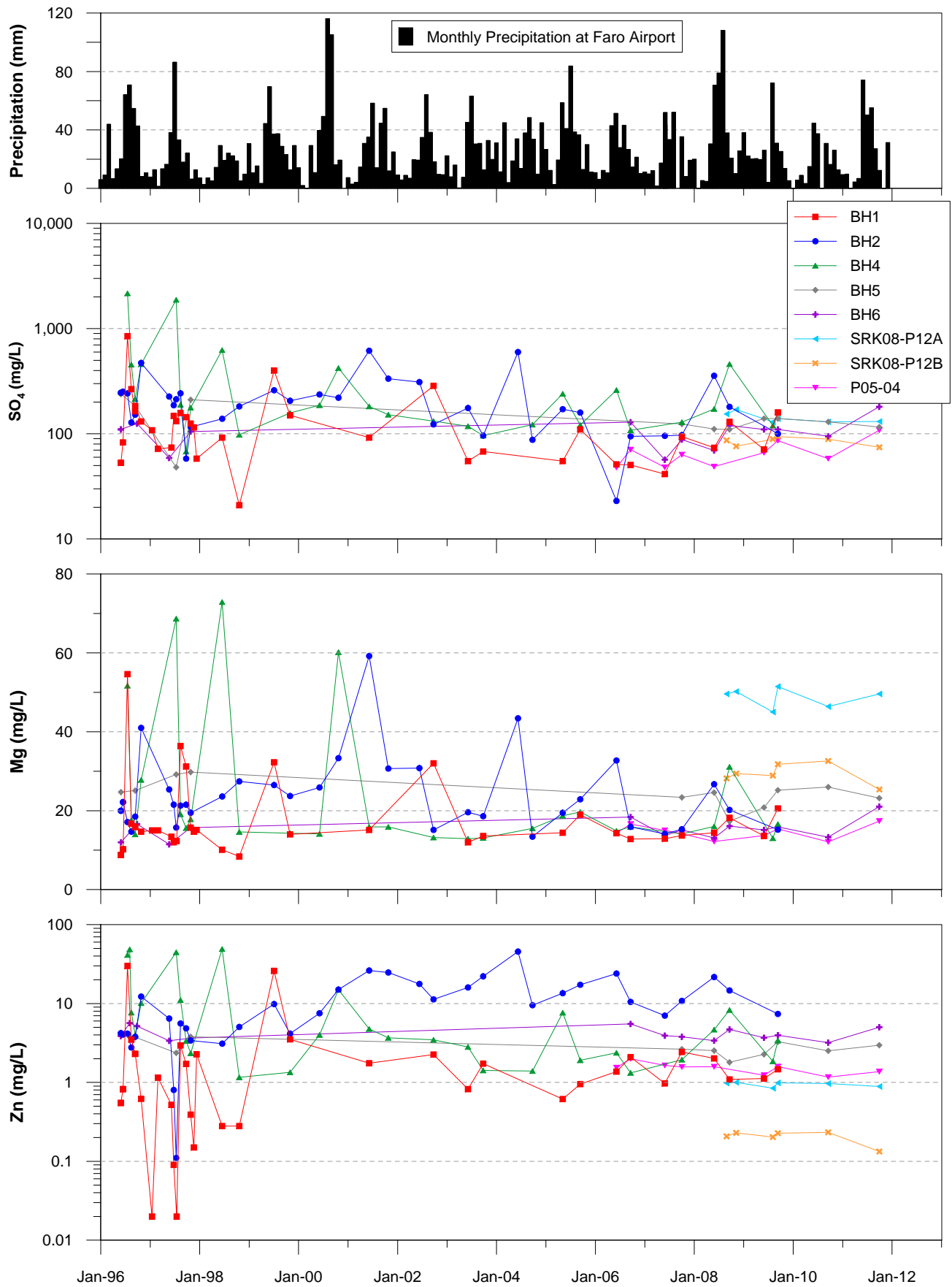


Figure 2-14a. Time trends for SO₄, Mg and Zn for wells in Zone 2 Pit outwash area

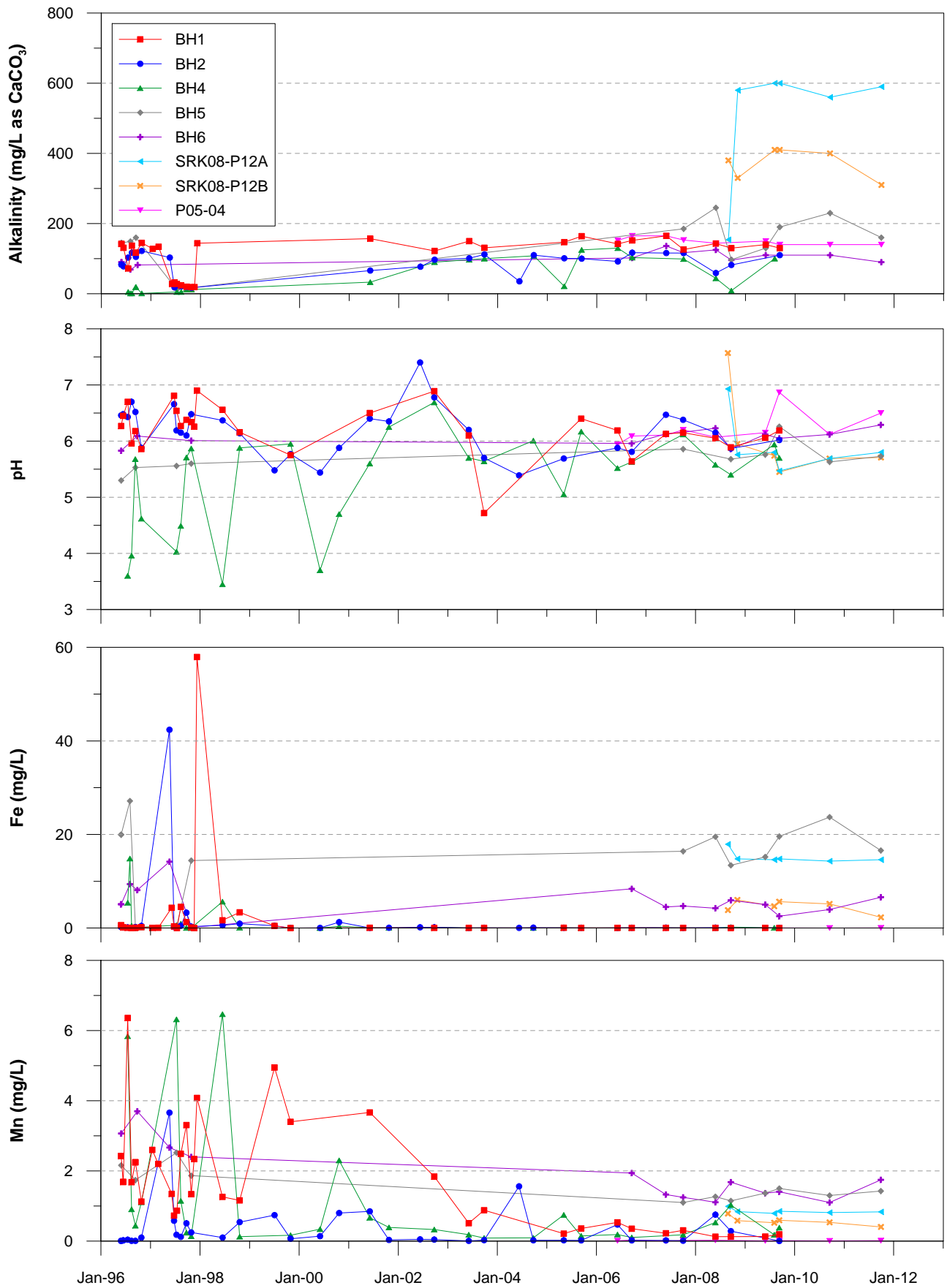


Figure 2-14b. Time trends for alkalinity, pH, Fe and Mn for wells in Zone 2 Pit outwash area

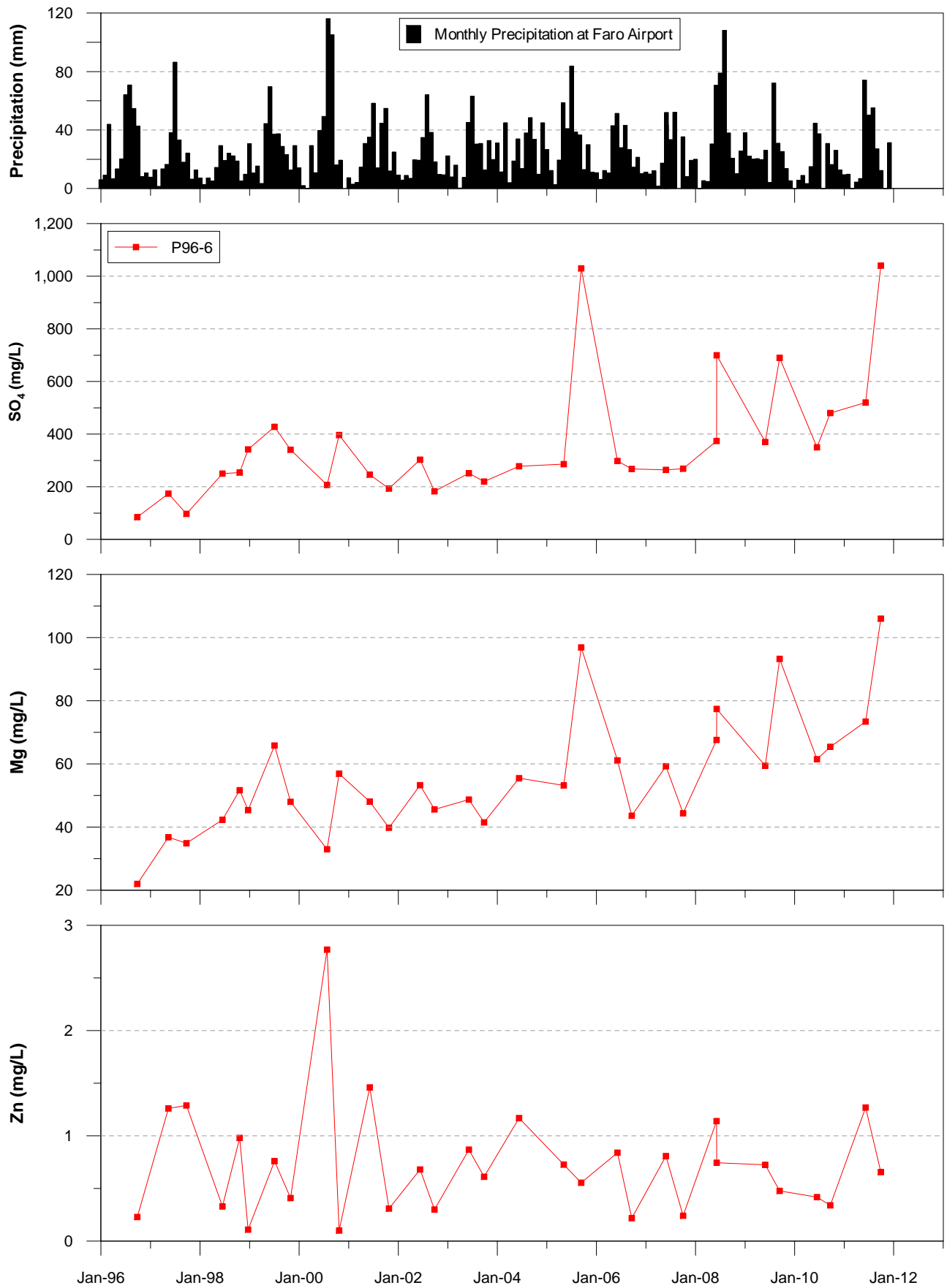


Figure 2-15a. Time trends for SO₄, Mg and Zn in P96-6 at the toe of Intermediate Rock Dump

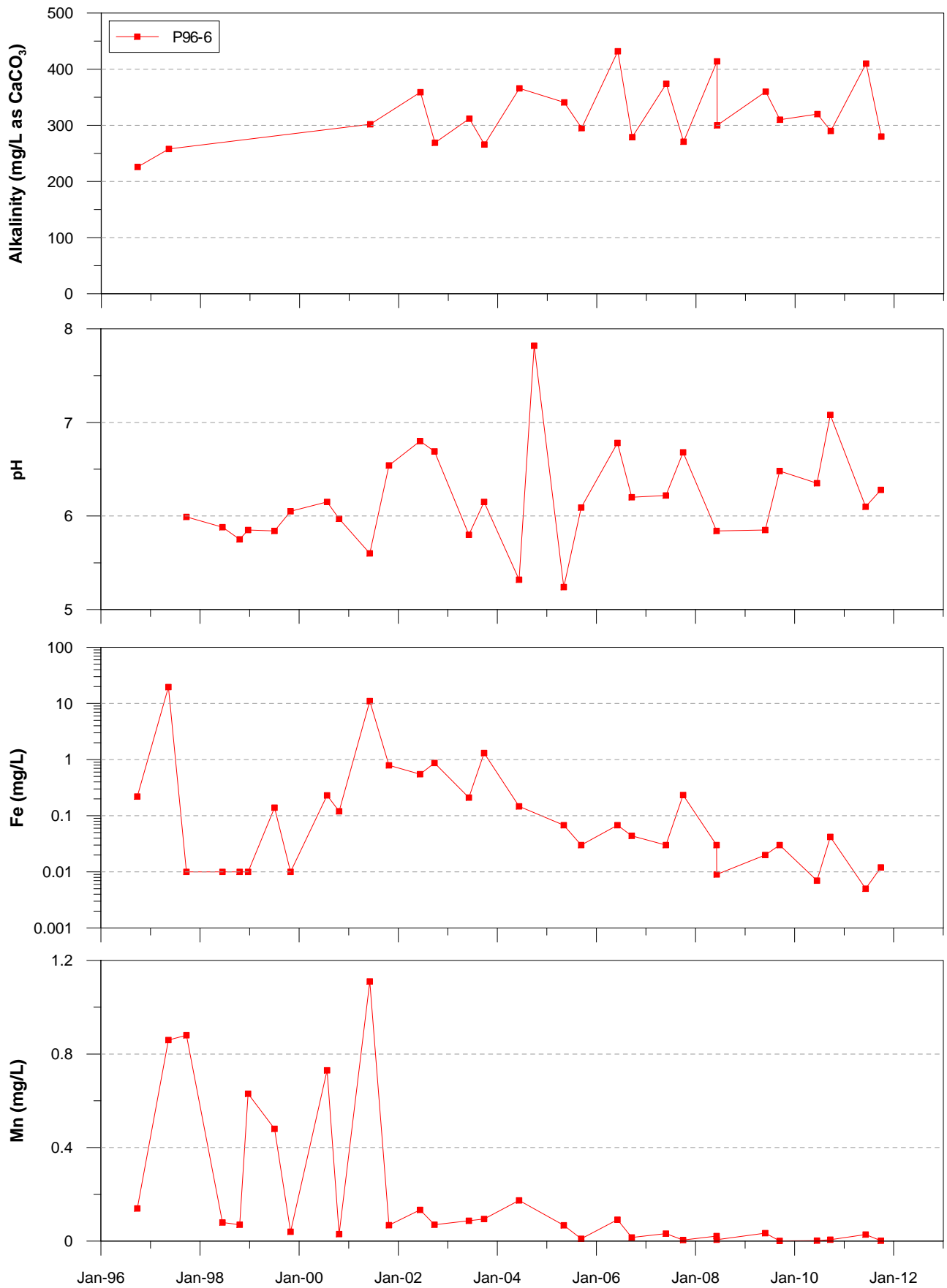


Figure 2-15b. Time trends for alkalinity, pH, Fe and Mn in P96-6 at toe of Intermediate Rock Dump

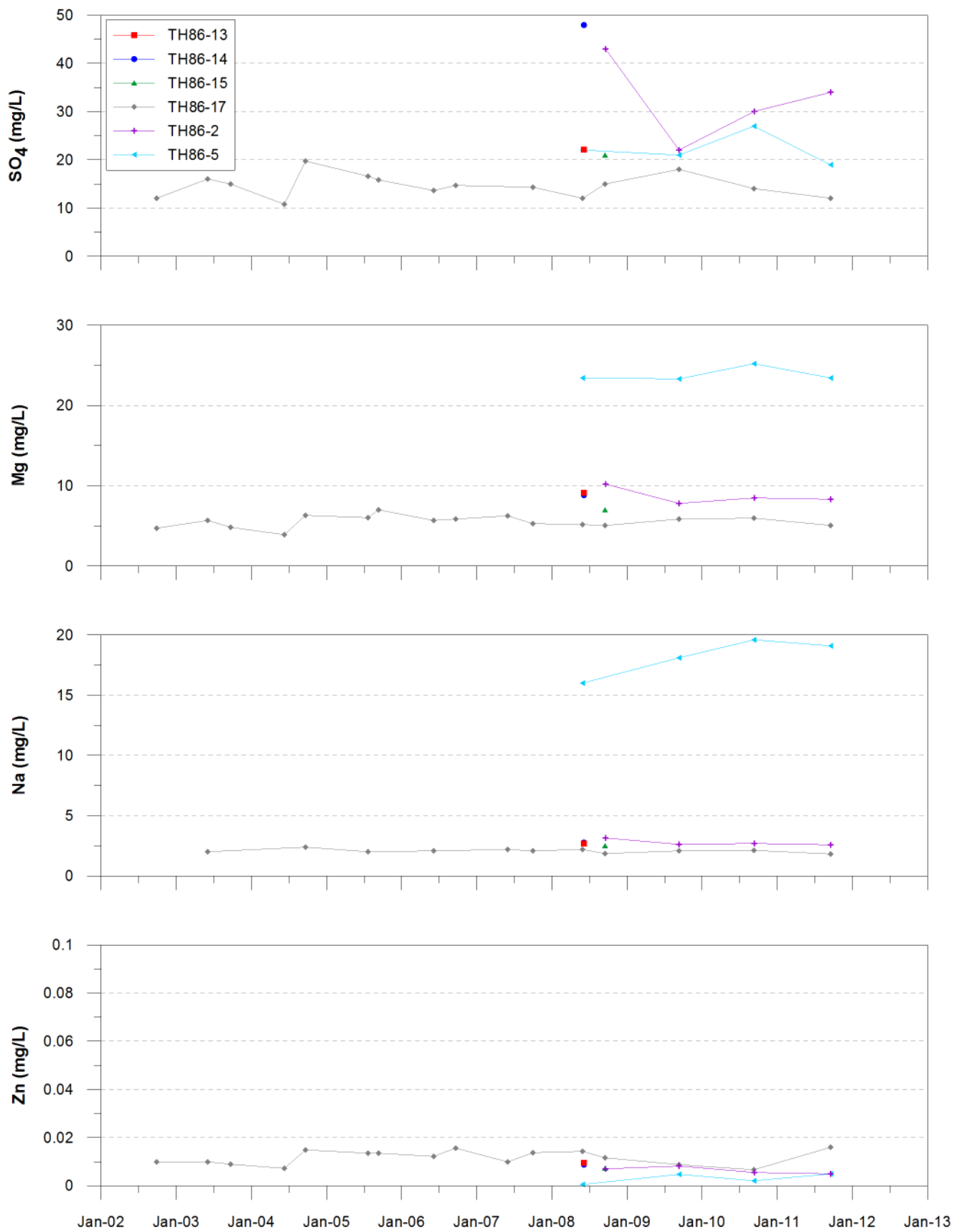


Figure 3-2a. Time trends for SO₄, Mg, Na and Zn in Rose Creek Alluvial Aquifer upgradient of RCTF

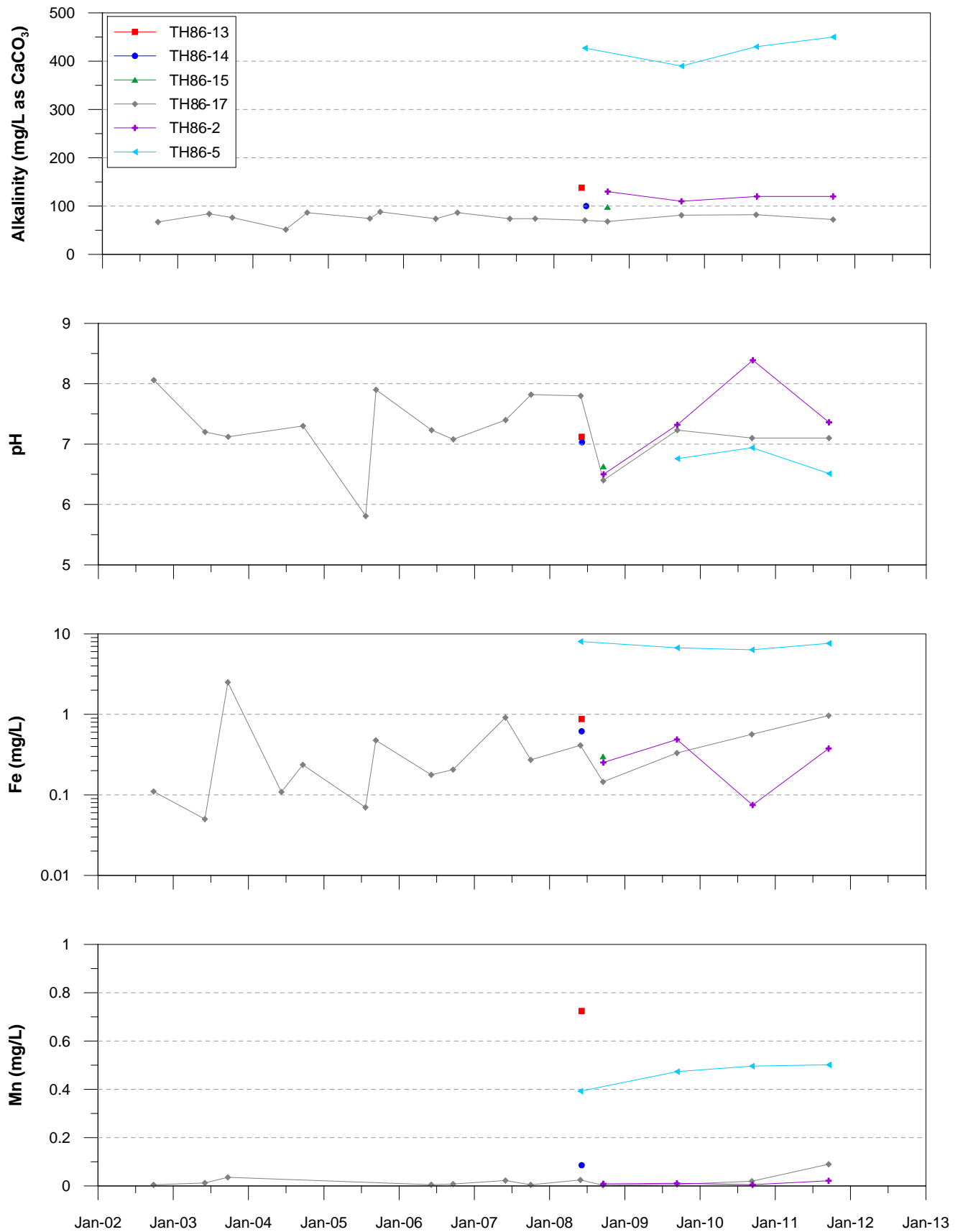


Figure 3-2b. Time trends for alkalinity, pH, Fe and Mn in well Rose Creek Alluvial Aquifer upgradient of RCTF

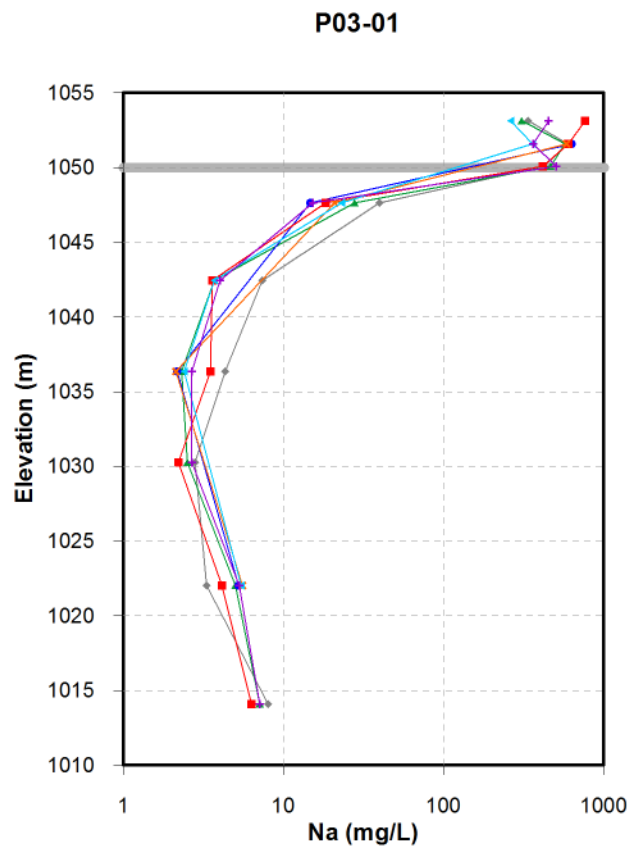
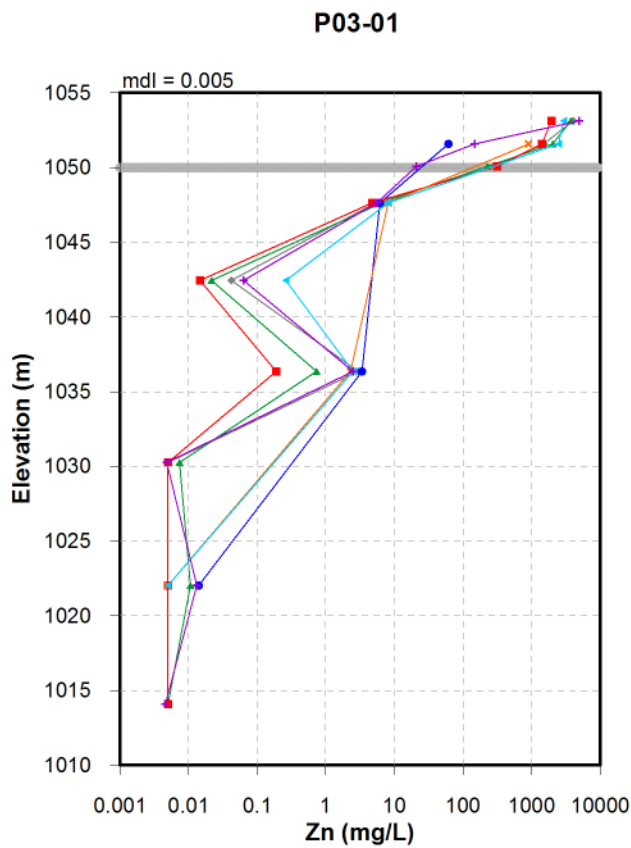
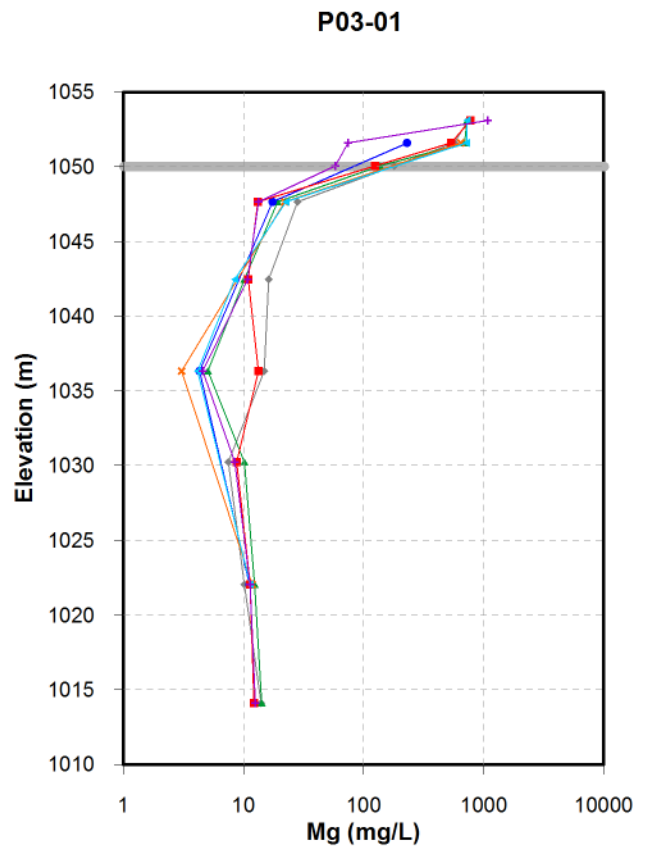
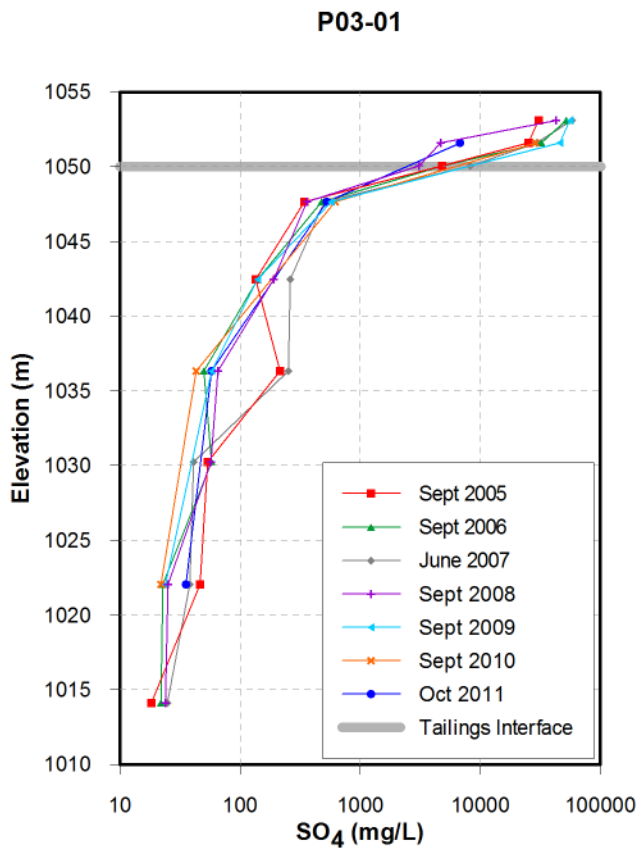


Figure 3-3a. Depth profiles for SO₄, Mg, Zn and Na in P03-01 (Original Impoundment)

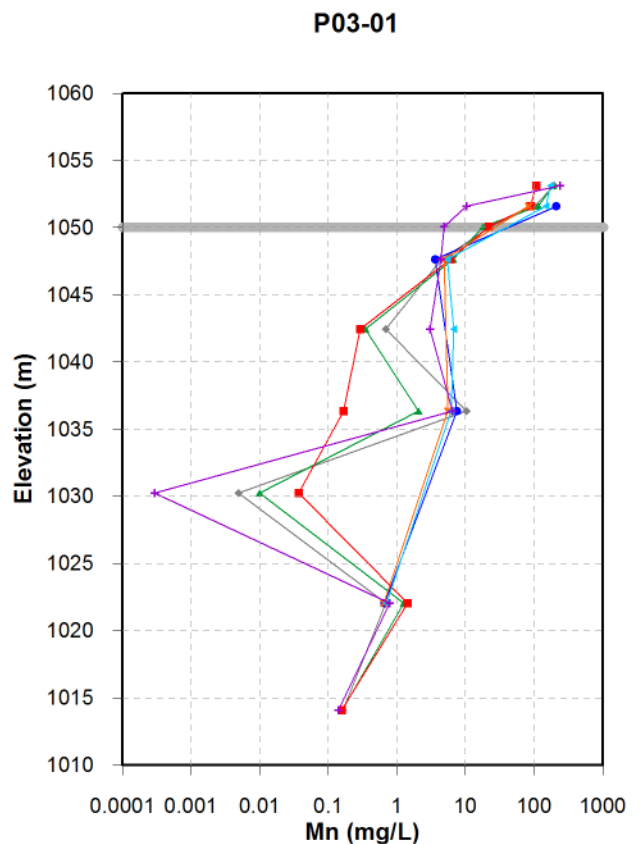
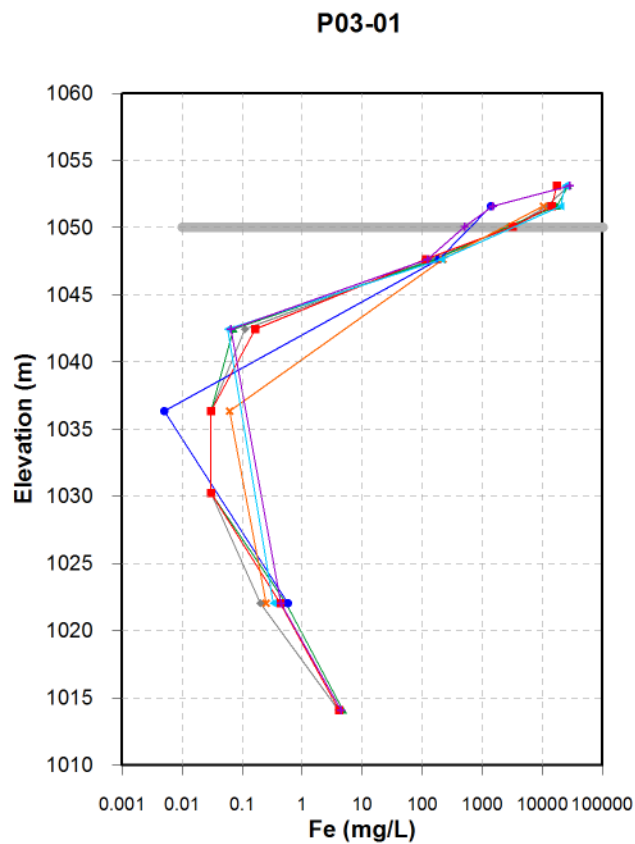
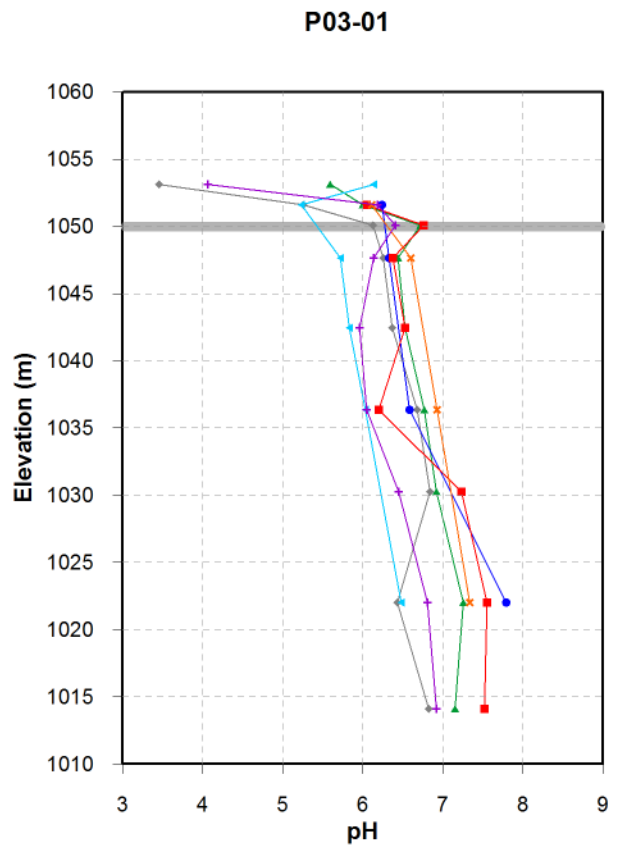
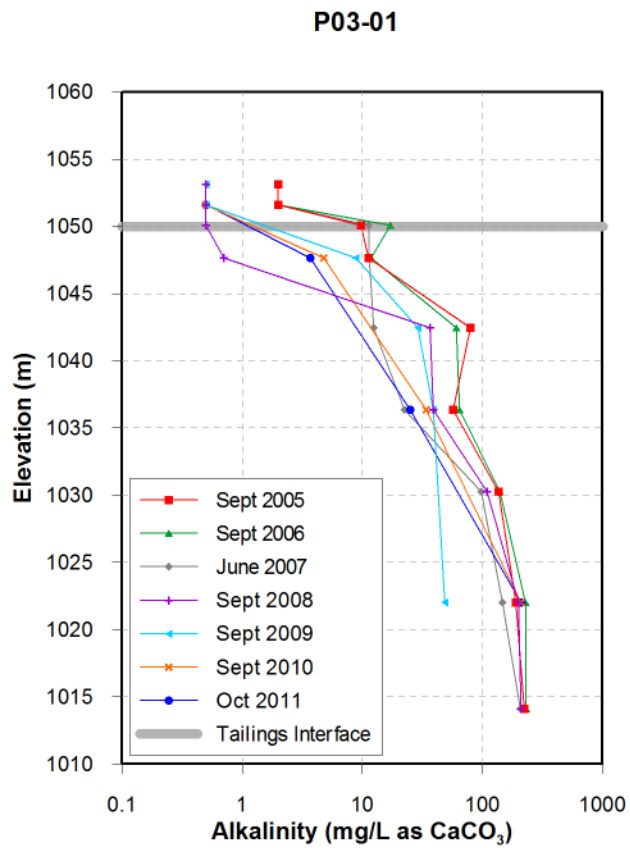


Figure 3-3b. Depth profiles for alkalinity, pH, Fe and Mn in P03-01 (Original Impoundment)

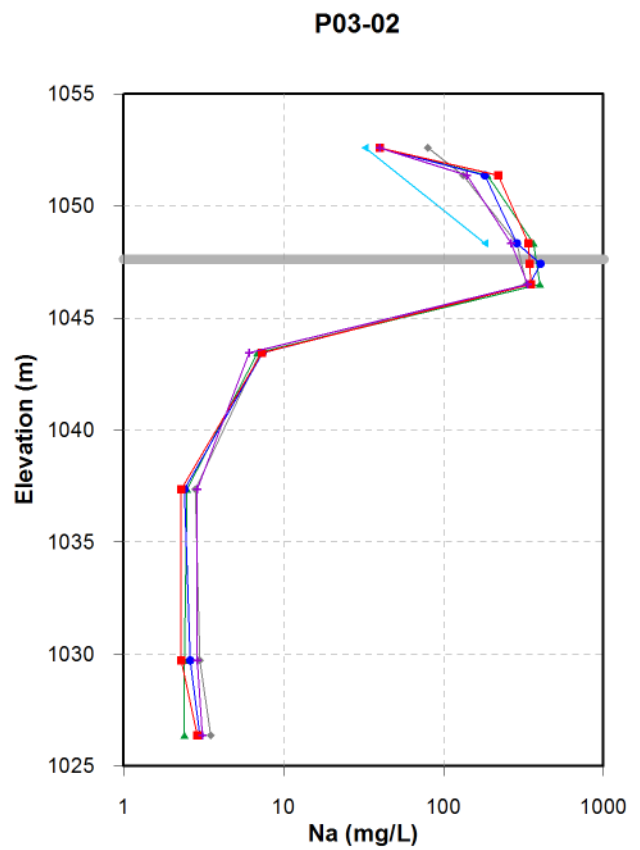
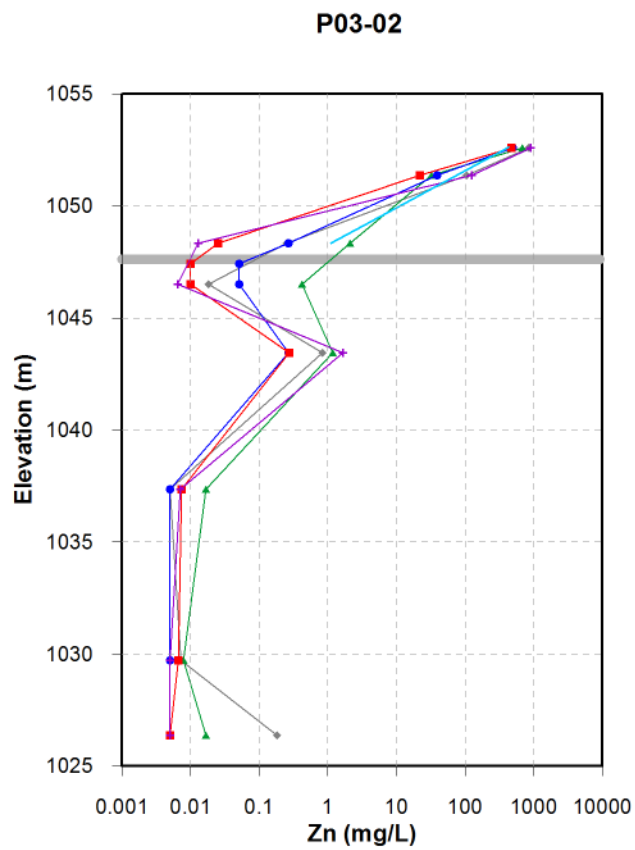
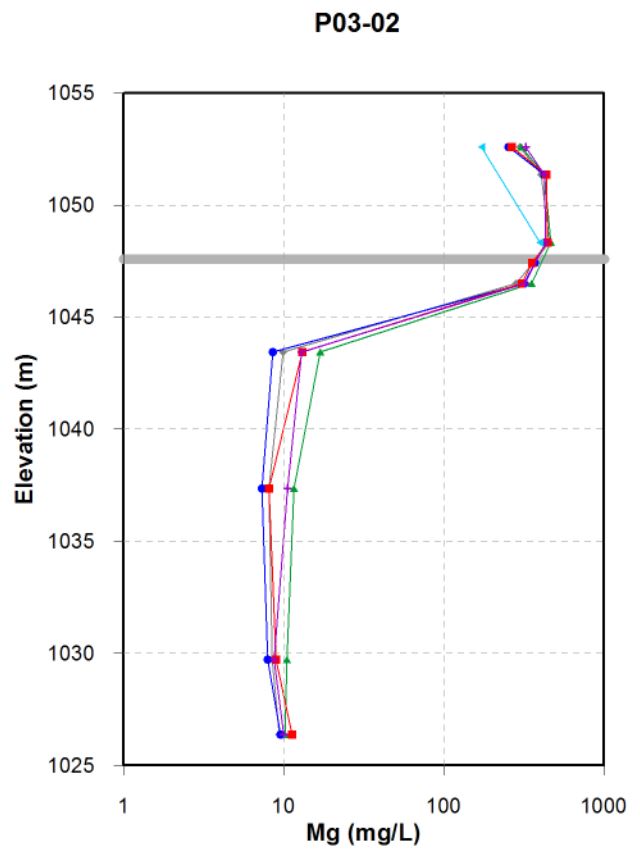
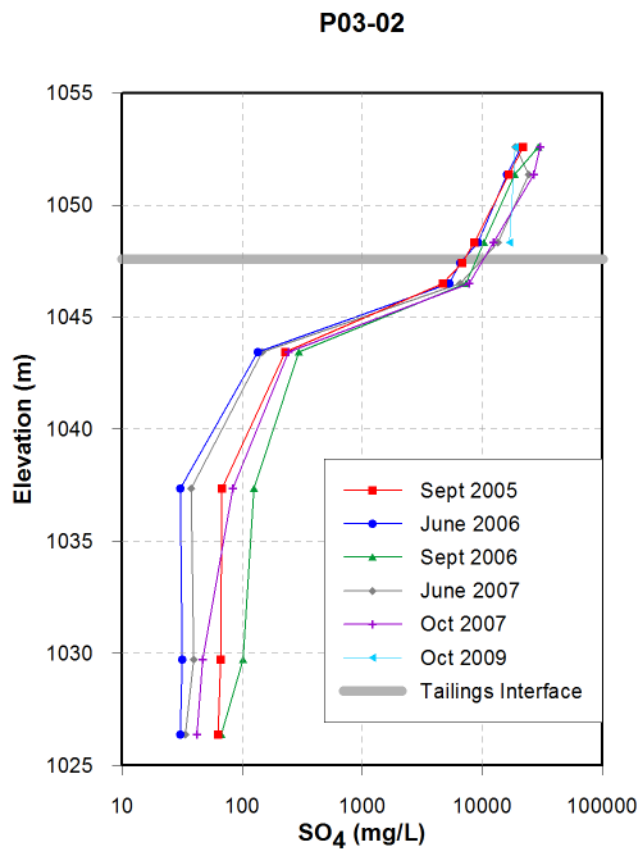


Figure 3-4a. Depth profiles of SO₄, Mg, Zn and Na in P03-02 (Second Impoundment)

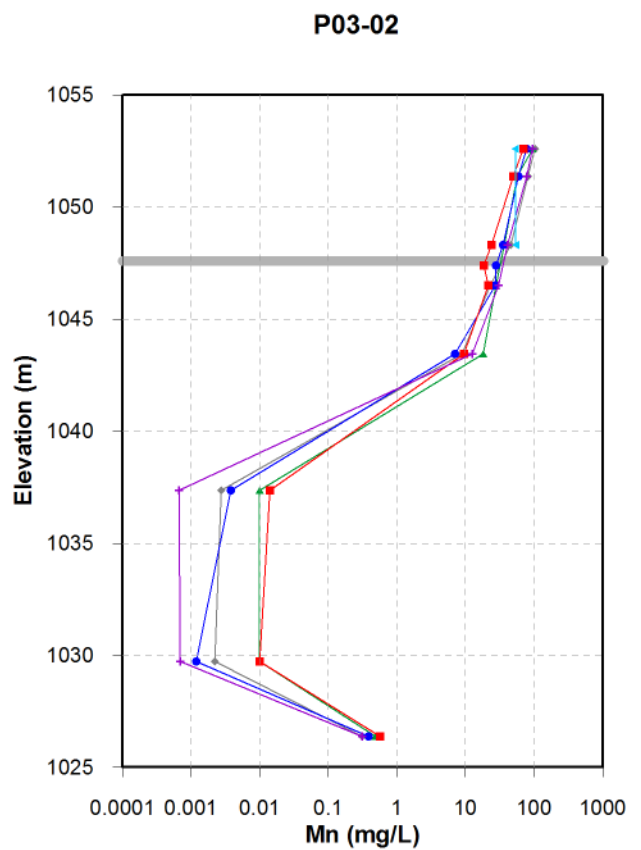
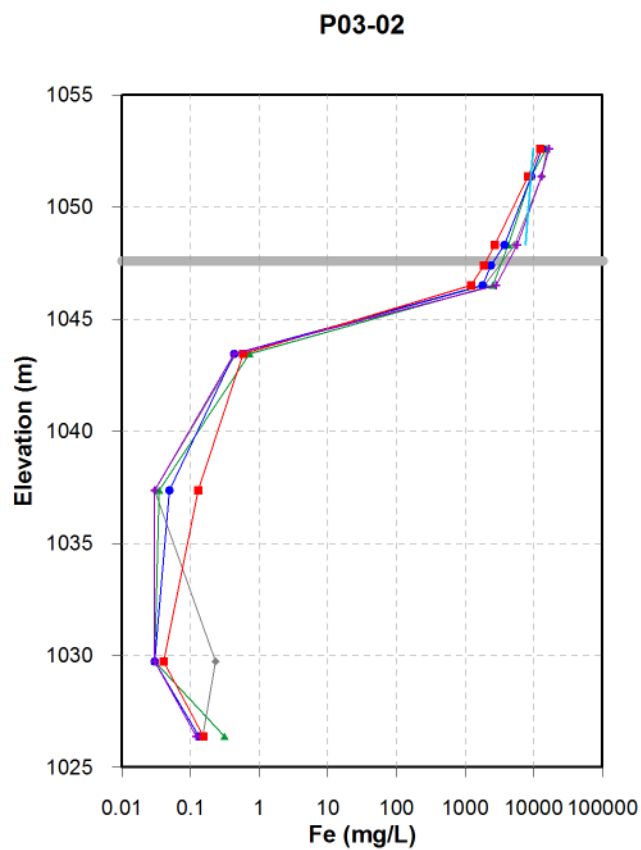
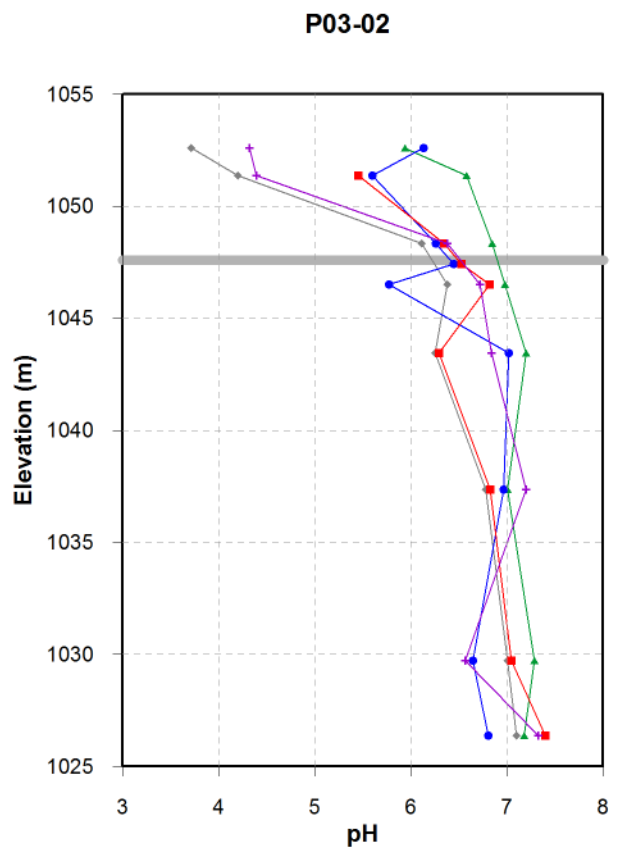
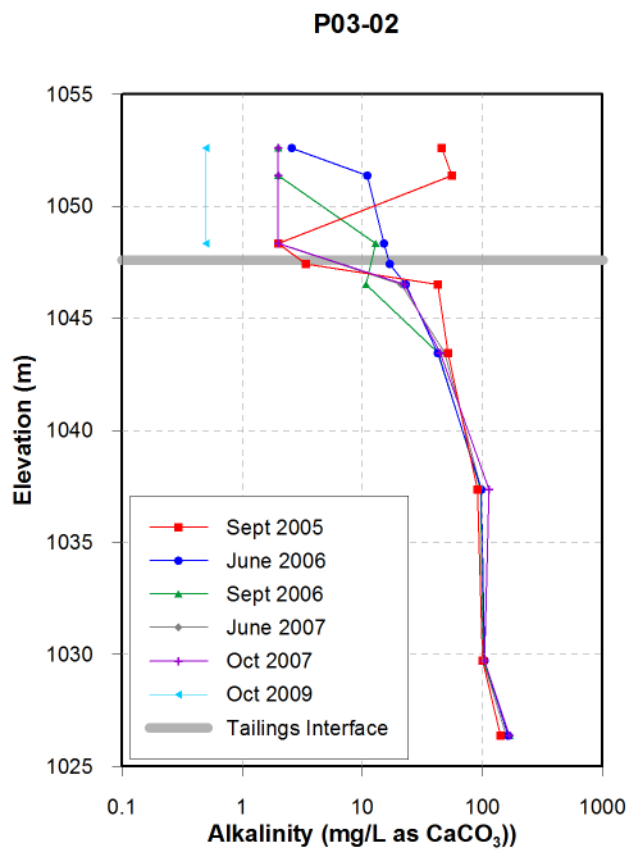


Figure 3-4b. Depth profiles for alkalinity, pH, Fe and Mn in P03-02 (Second Impoundment)

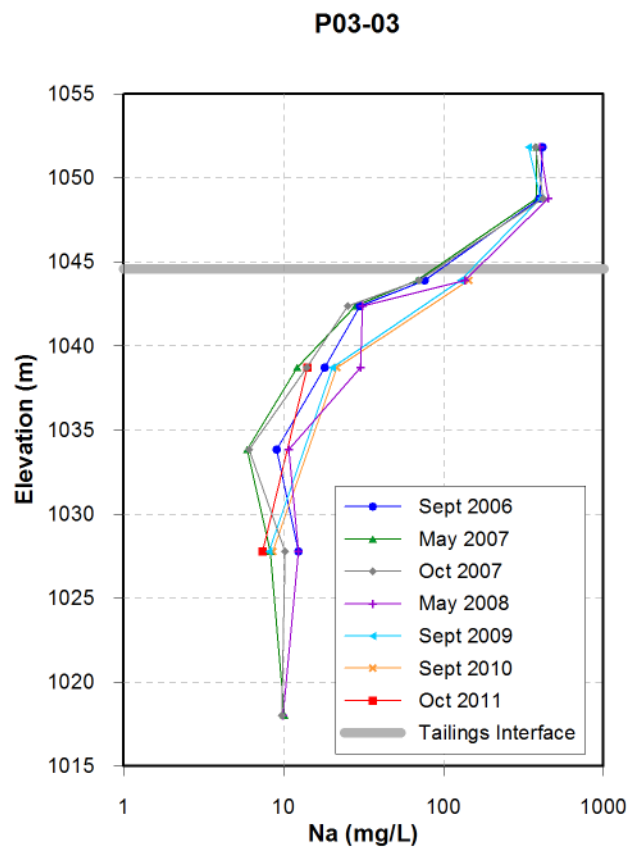
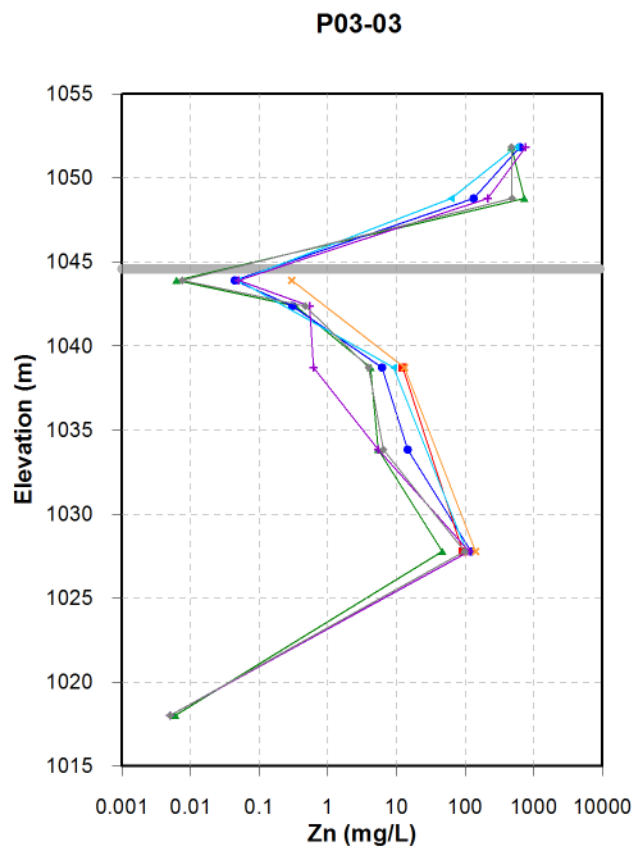
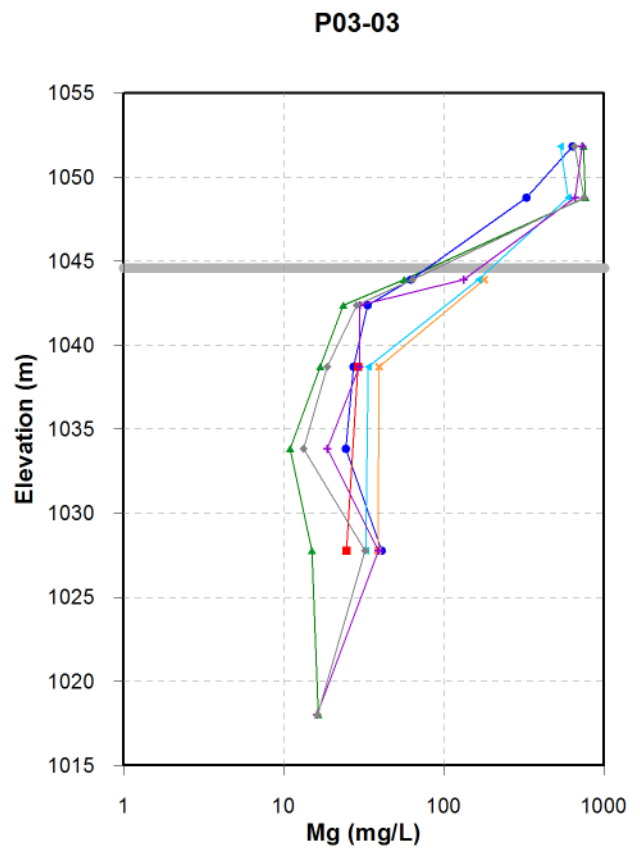
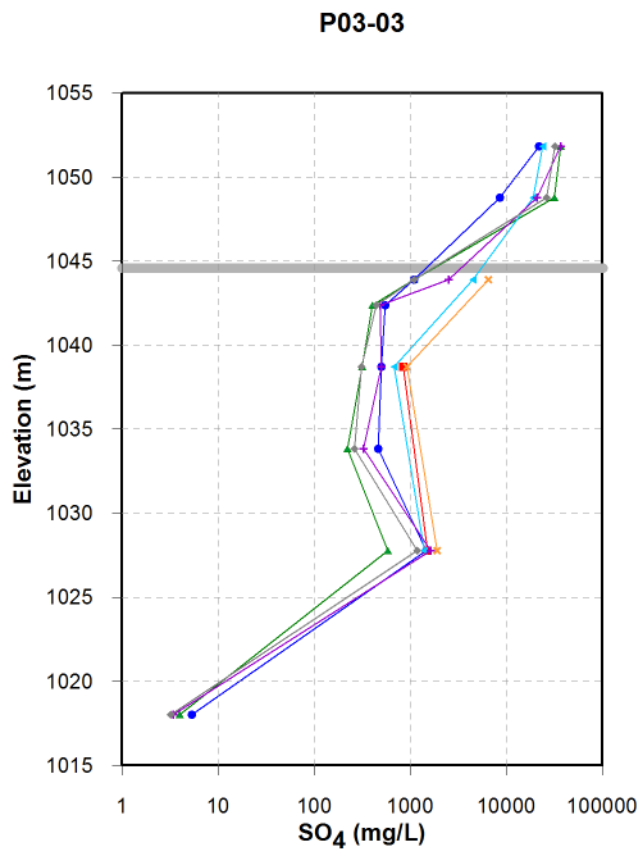


Figure 3-5a. Depth profiles for SO₄, Mg, Zn and Na in P03-03 (Second Impoundment)

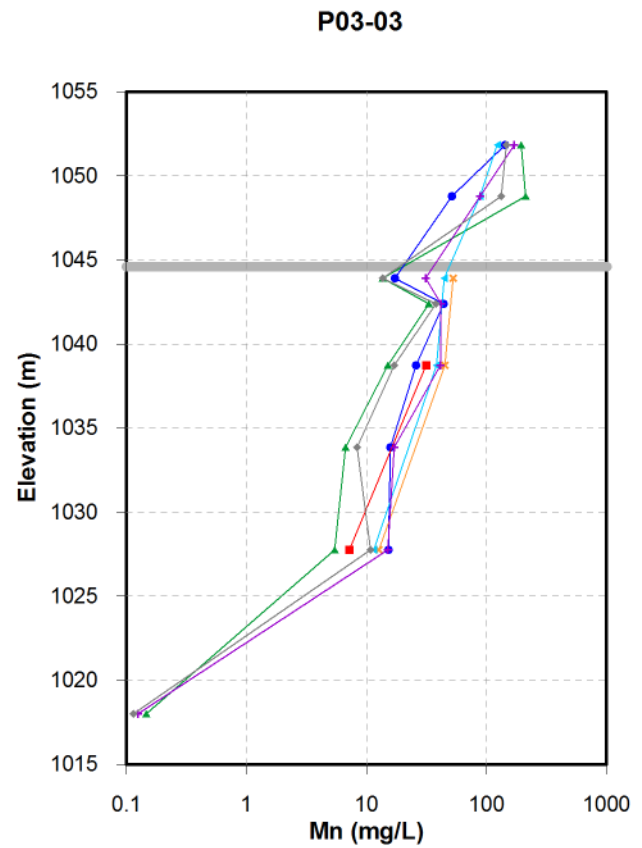
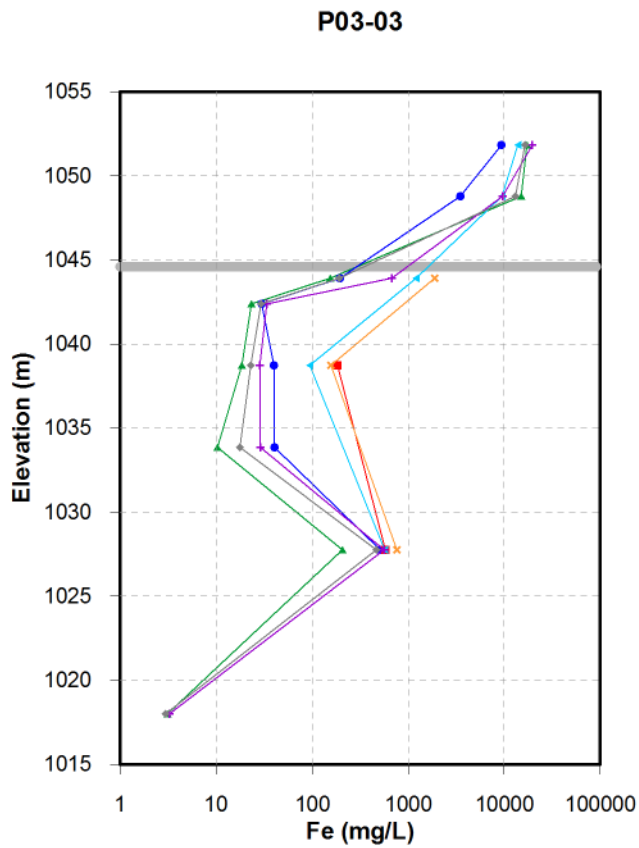
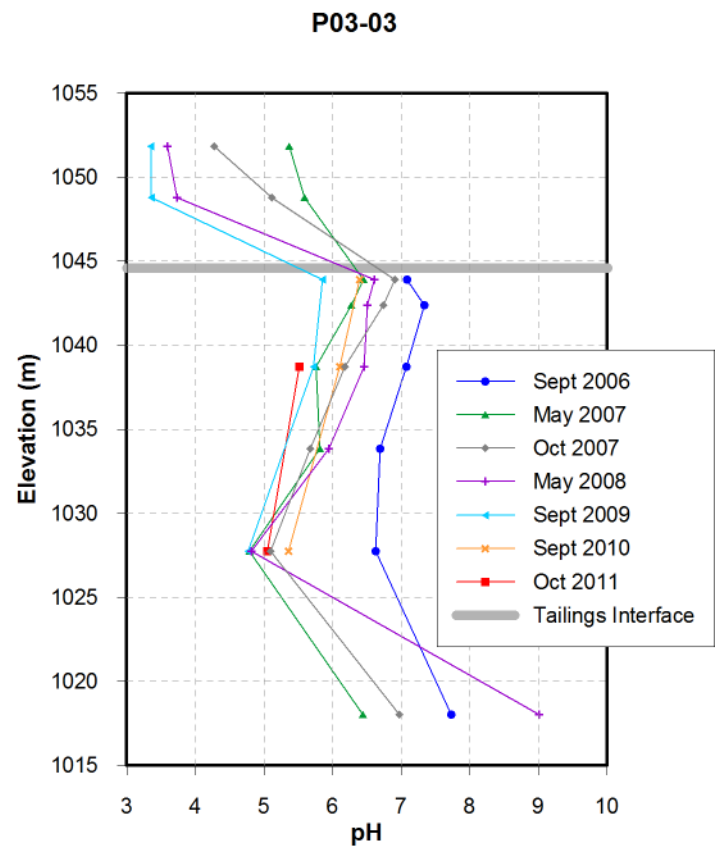
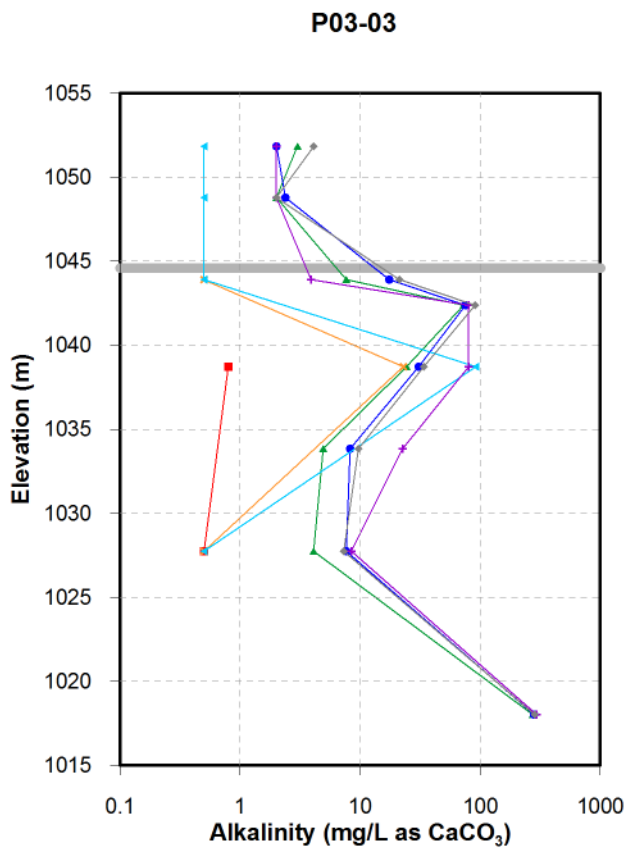


Figure 3-5b. Depth profiles for alkalinity, pH, Fe and Mn in P03-03 (Second Impoundment)

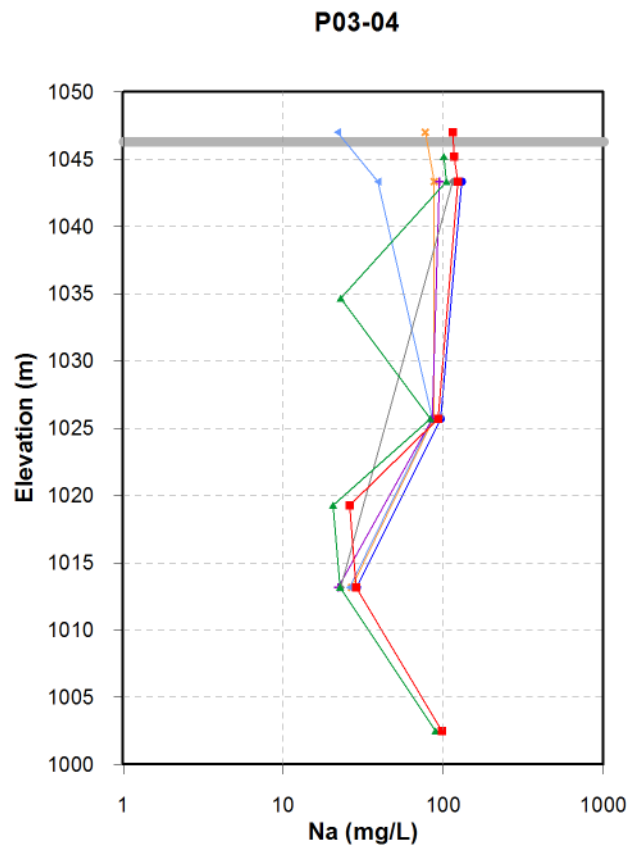
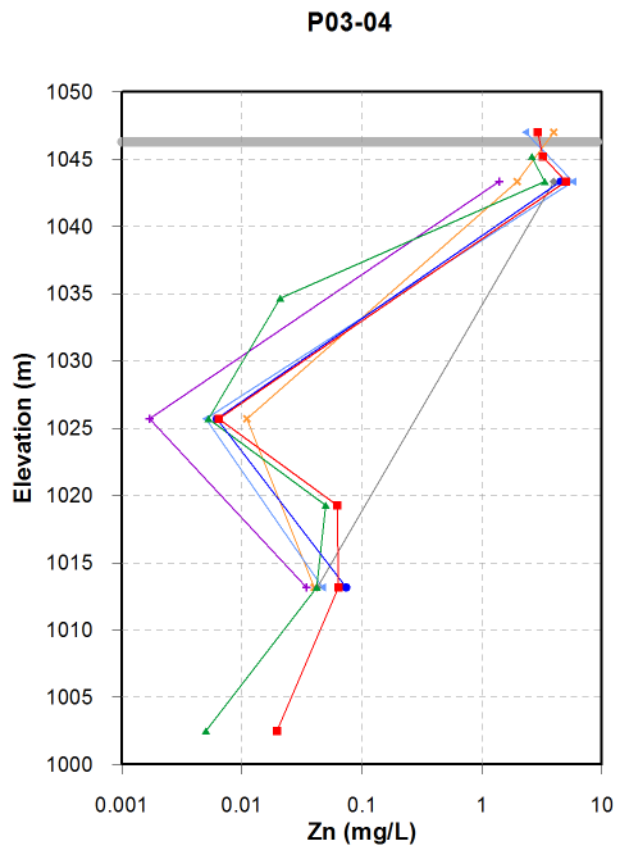
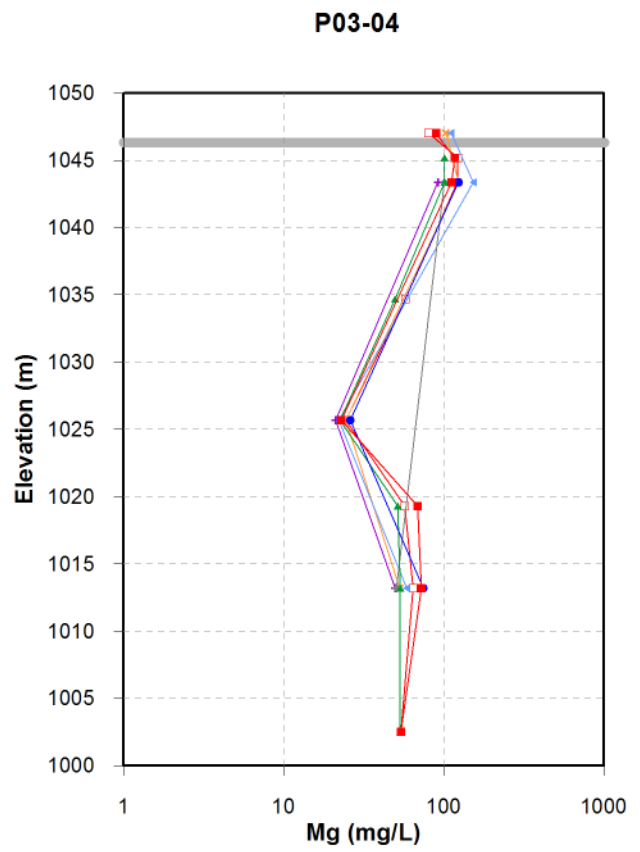
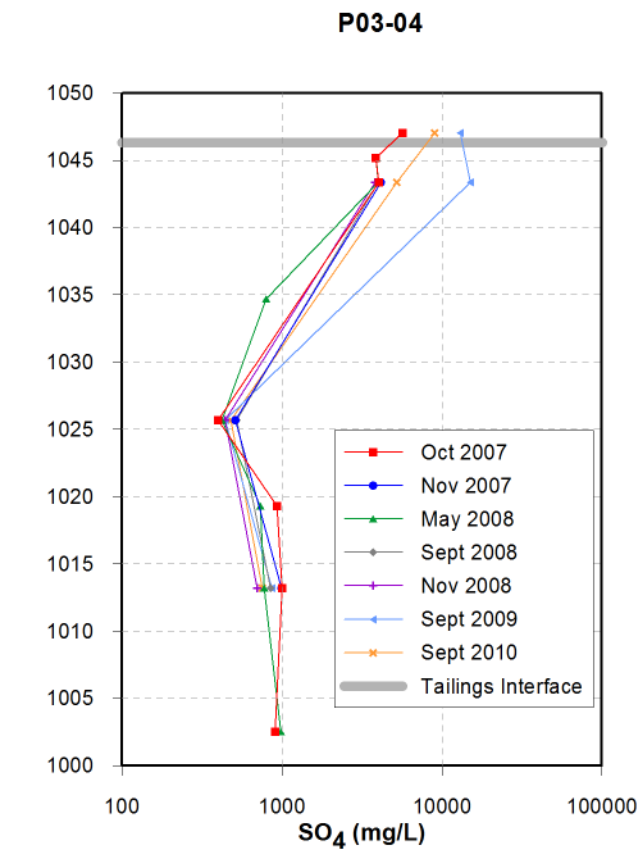


Figure 3-6a. Depth profiles for SO₄, Mg, Zn and Na in P03-04 (Second Impoundment)

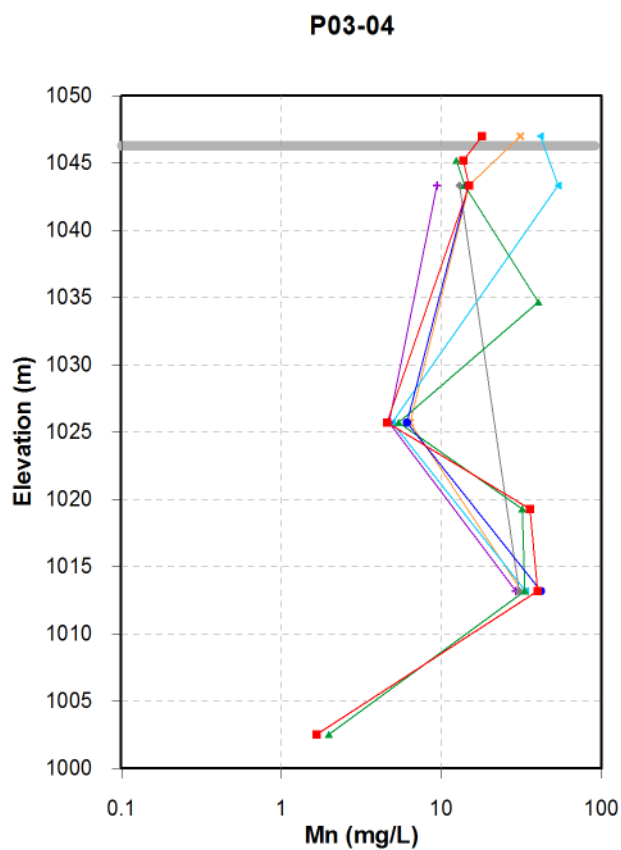
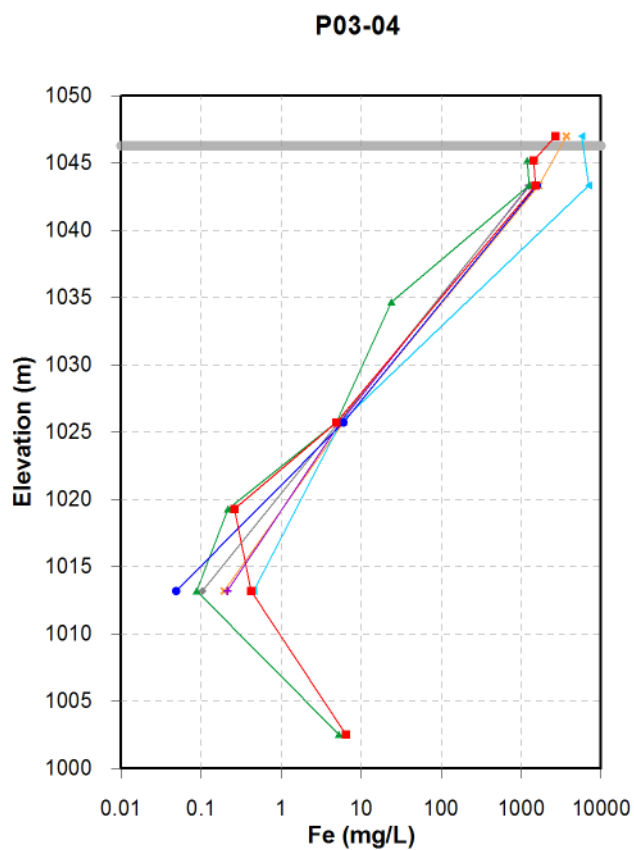
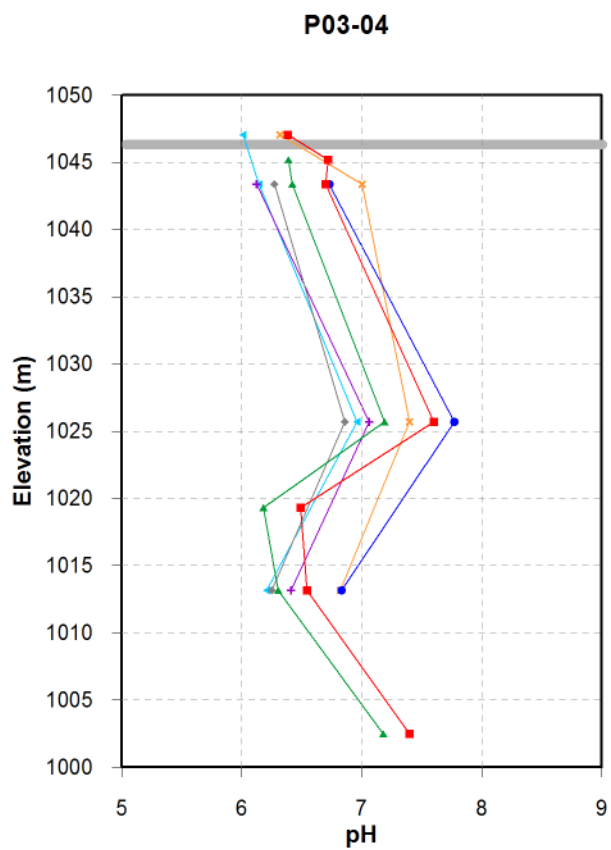
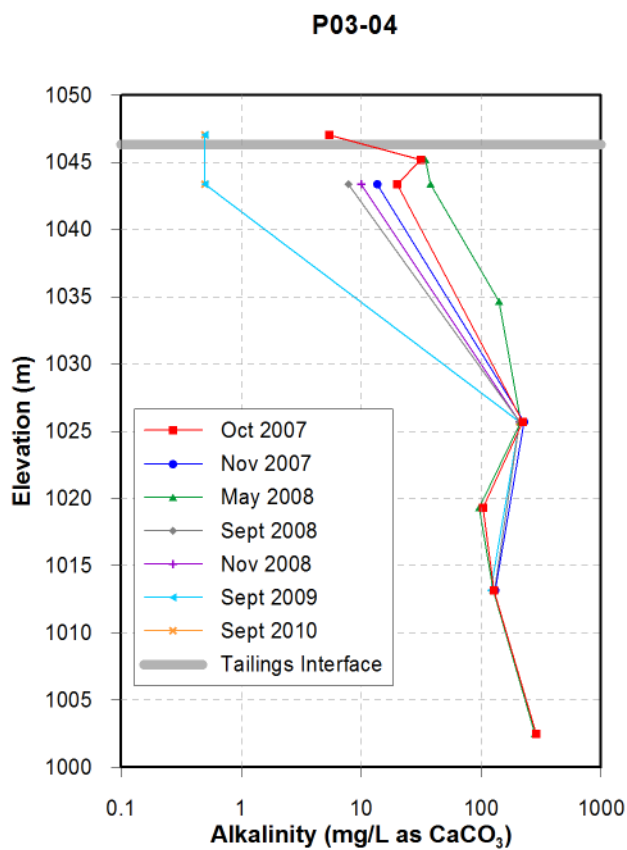


Figure 3-6b. Depth profiles for alkalinity, pH, Fe and Mn in P03-04 (Second Impoundment)

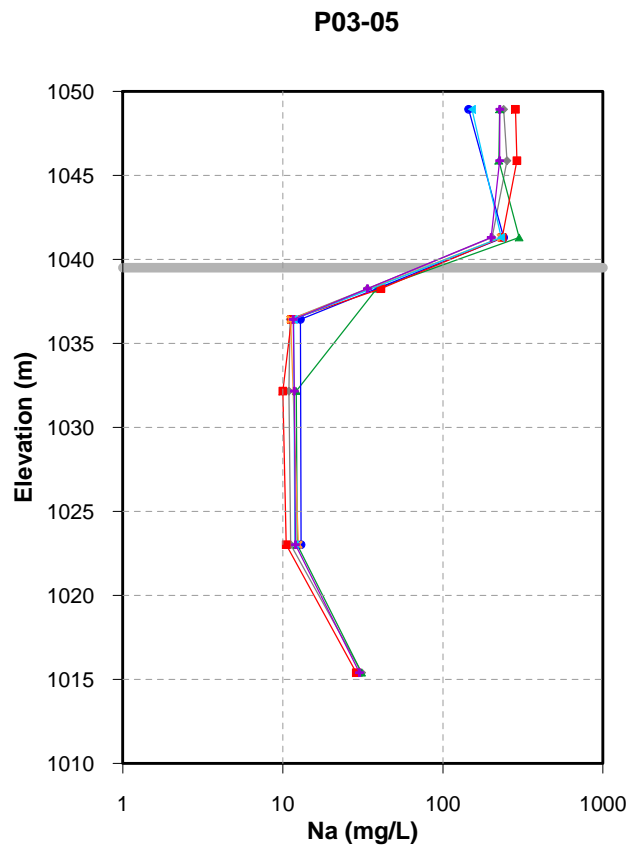
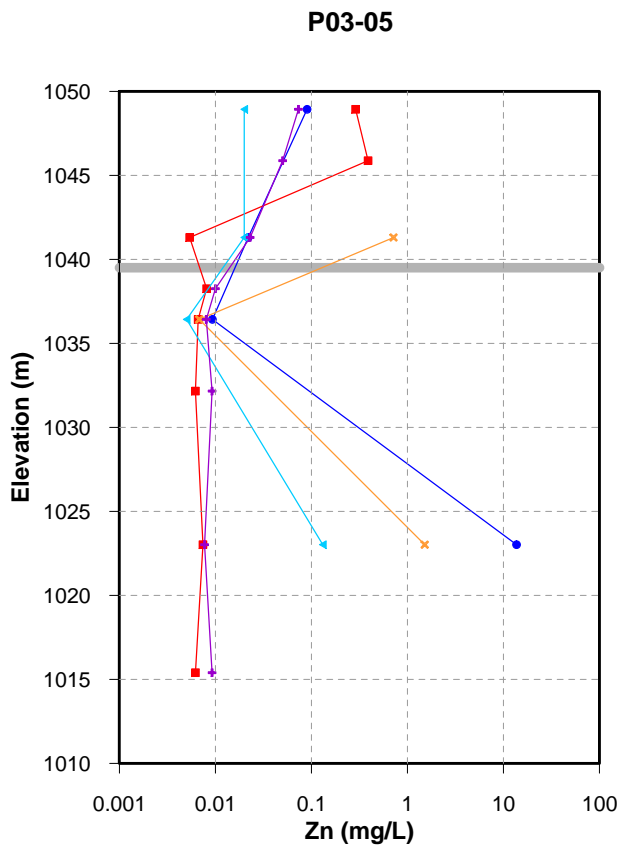
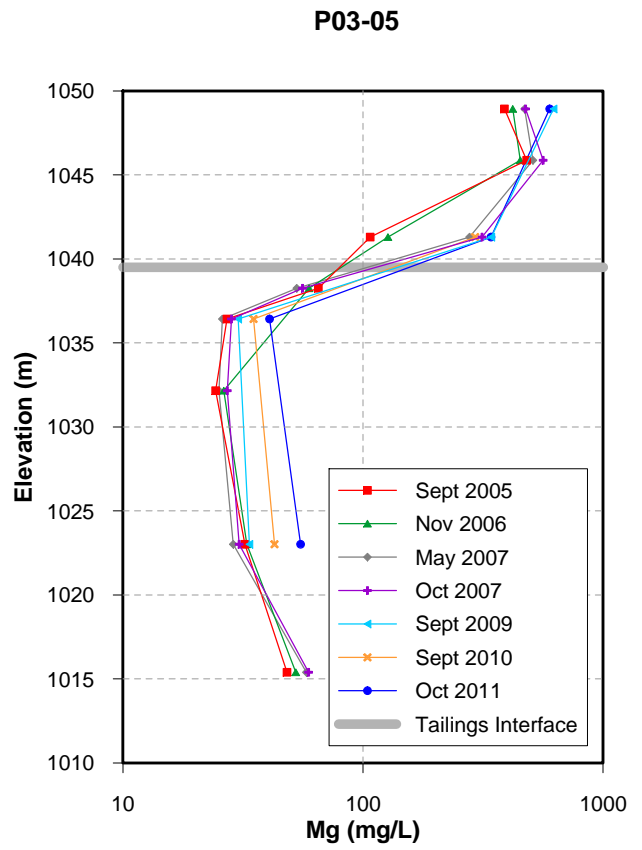
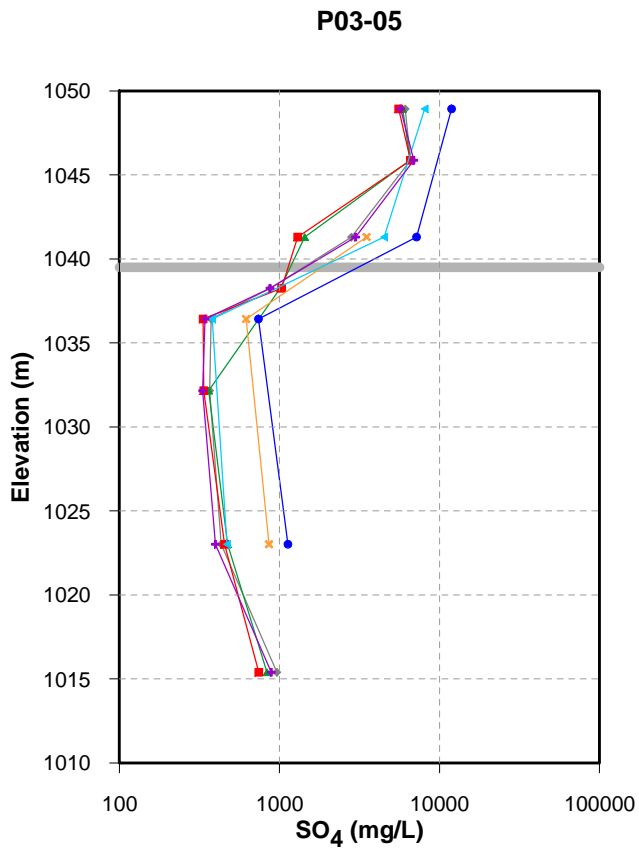


Figure 3-7a. Depth profiles for SO₄, Mg, Zn and Na in P03-05 (Second Impoundment)

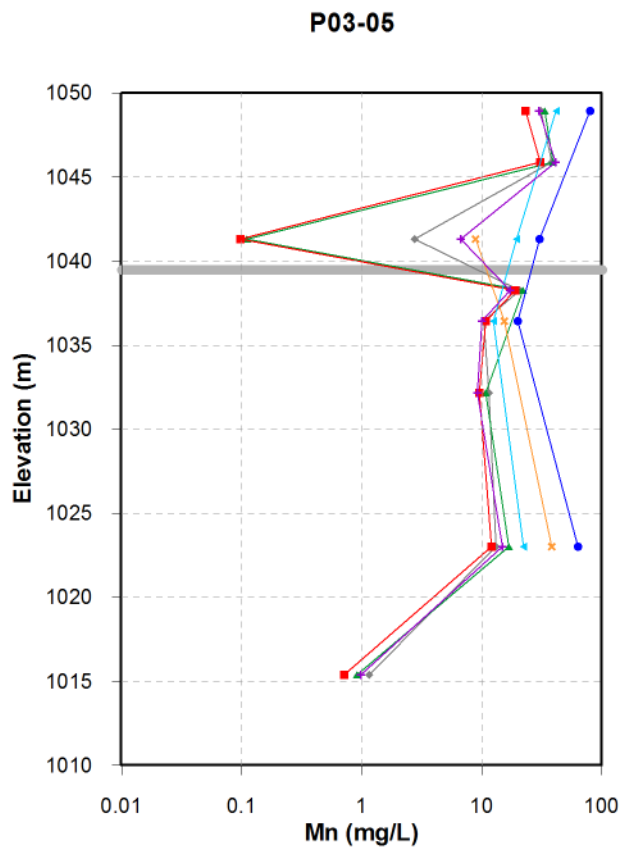
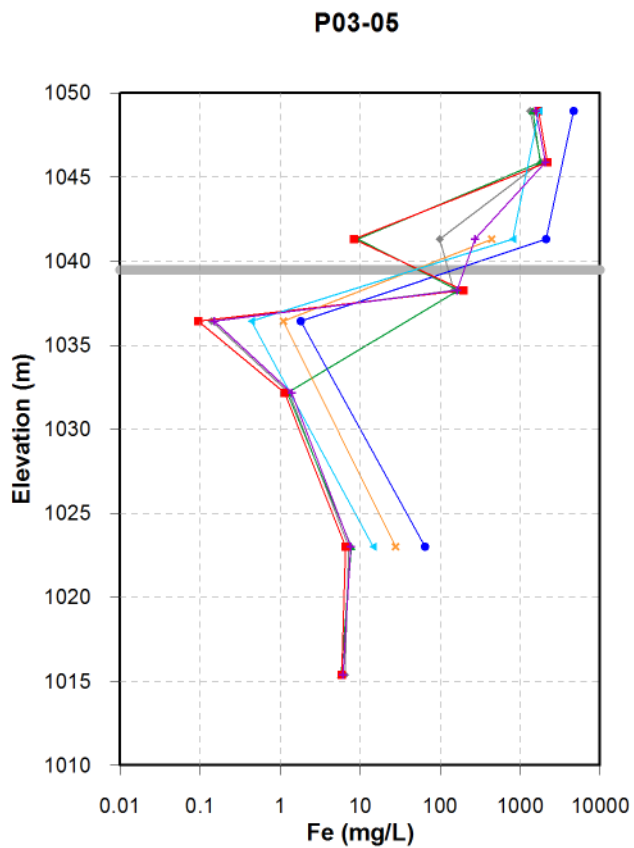
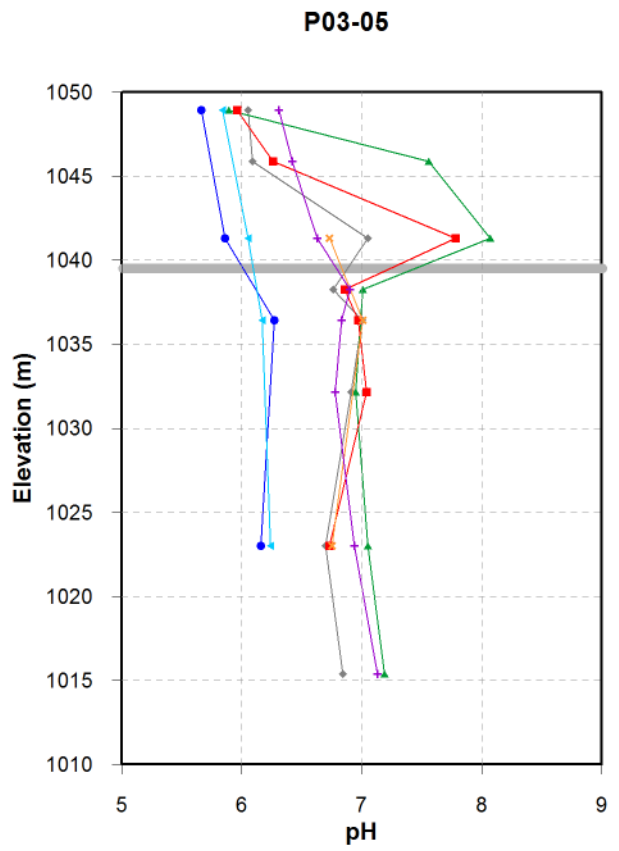
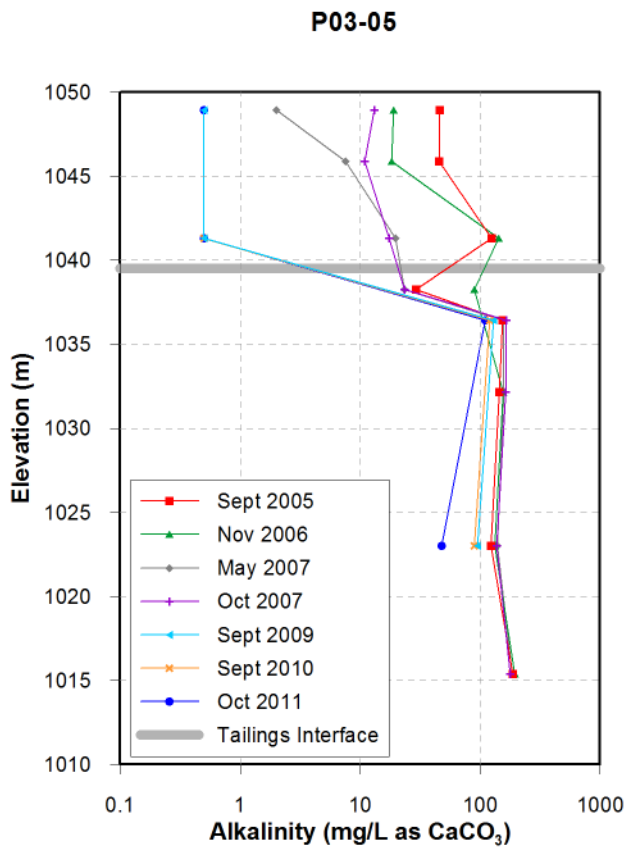


Figure 3-7b. Depth profiles for alkalinity, pH, Fe and Mn in P03-05 (Second Impoundment)

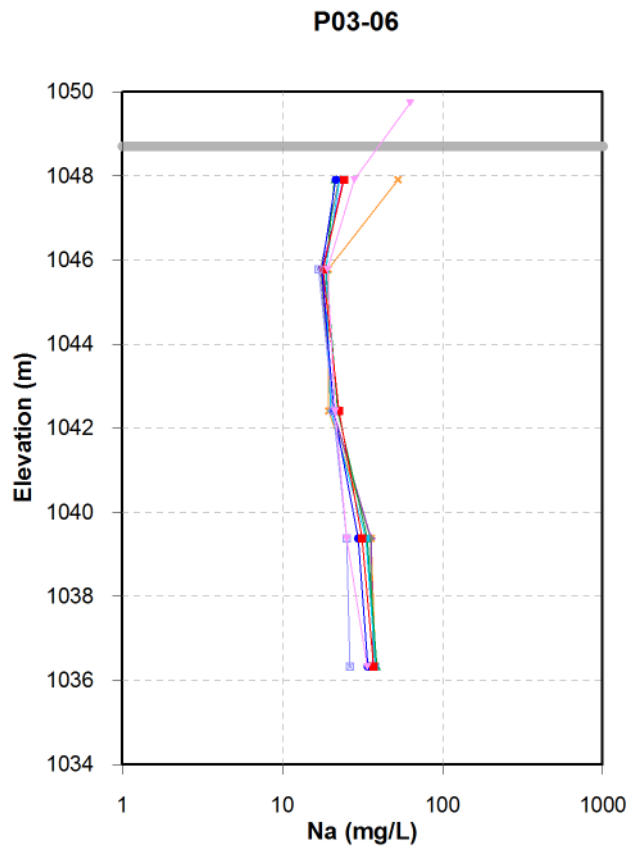
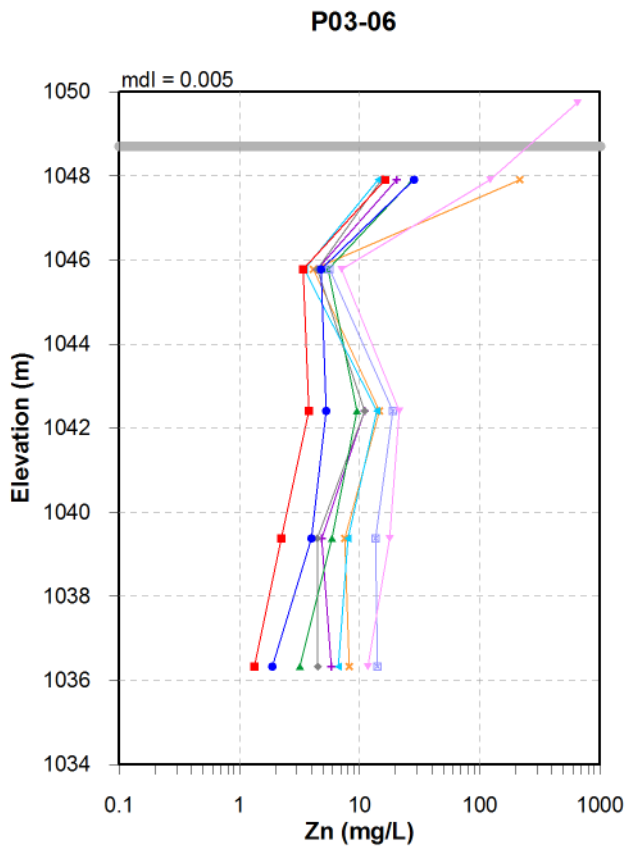
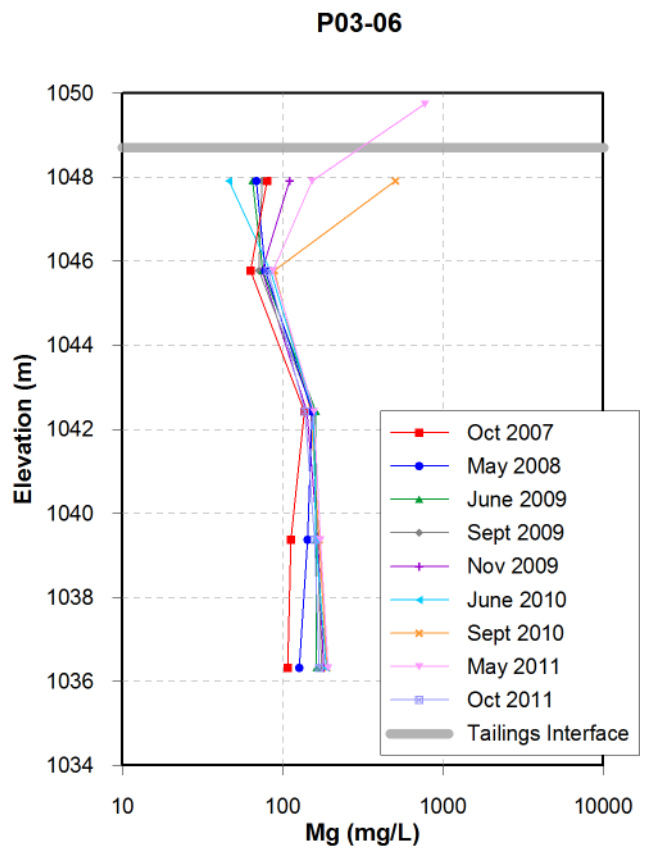
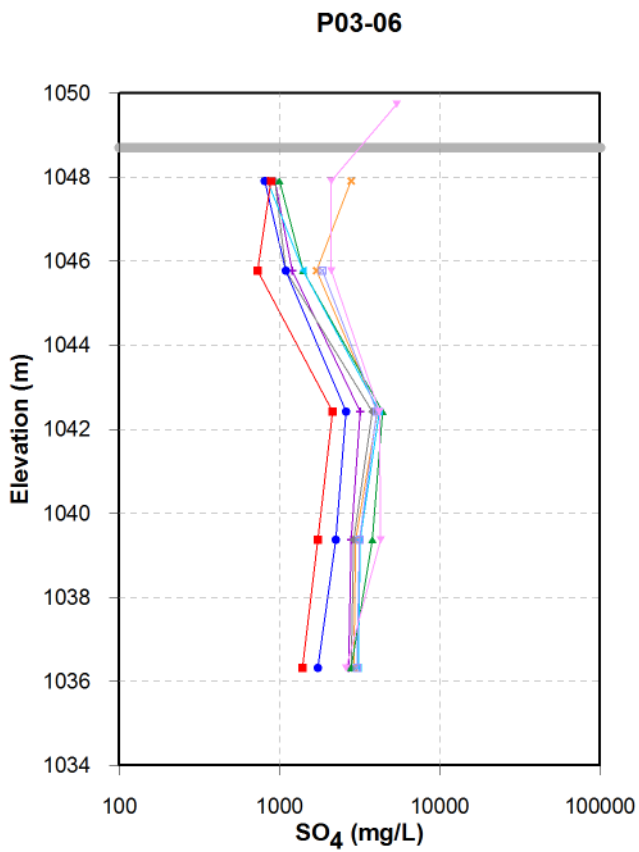


Figure 3-8a. Depth profiles for SO₄, Mg, Zn and Na in P03-06 (Second Impoundment)

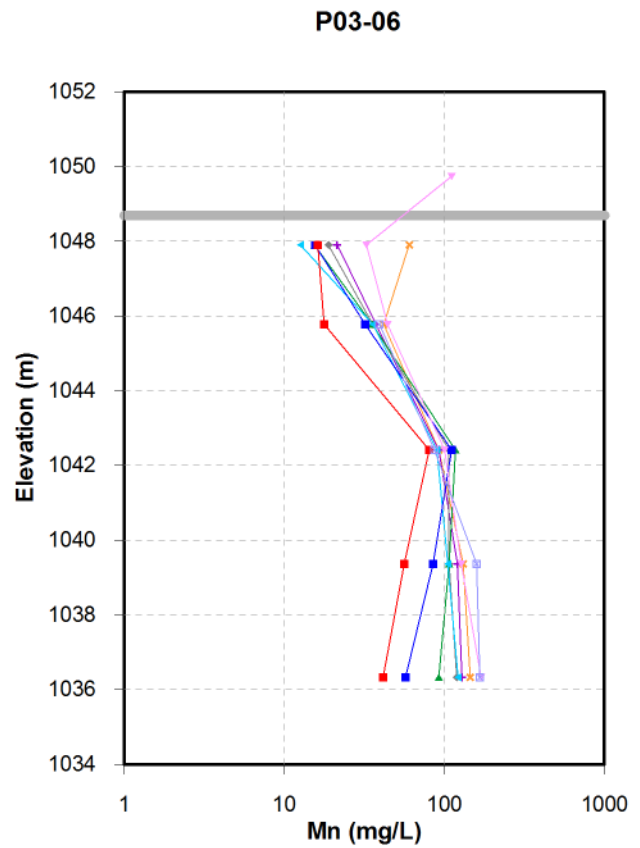
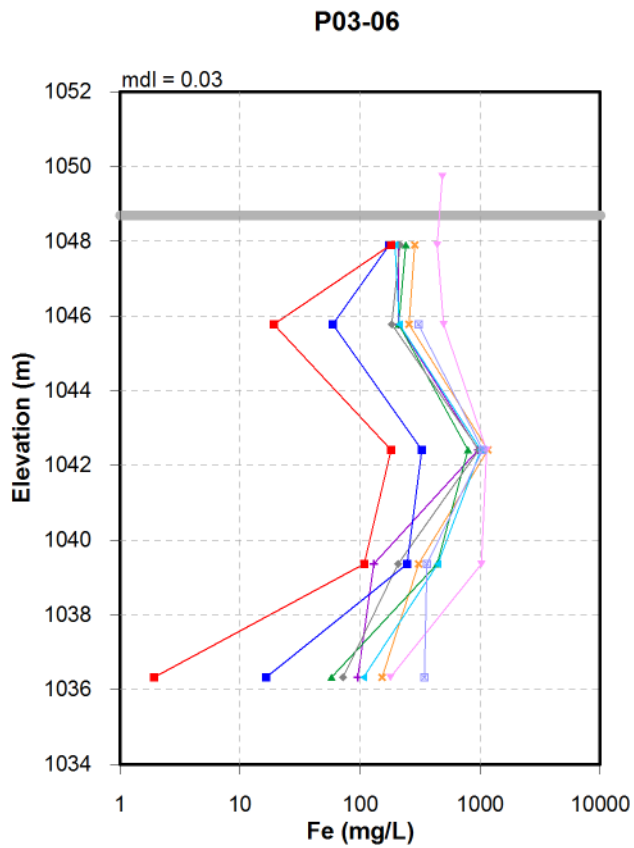
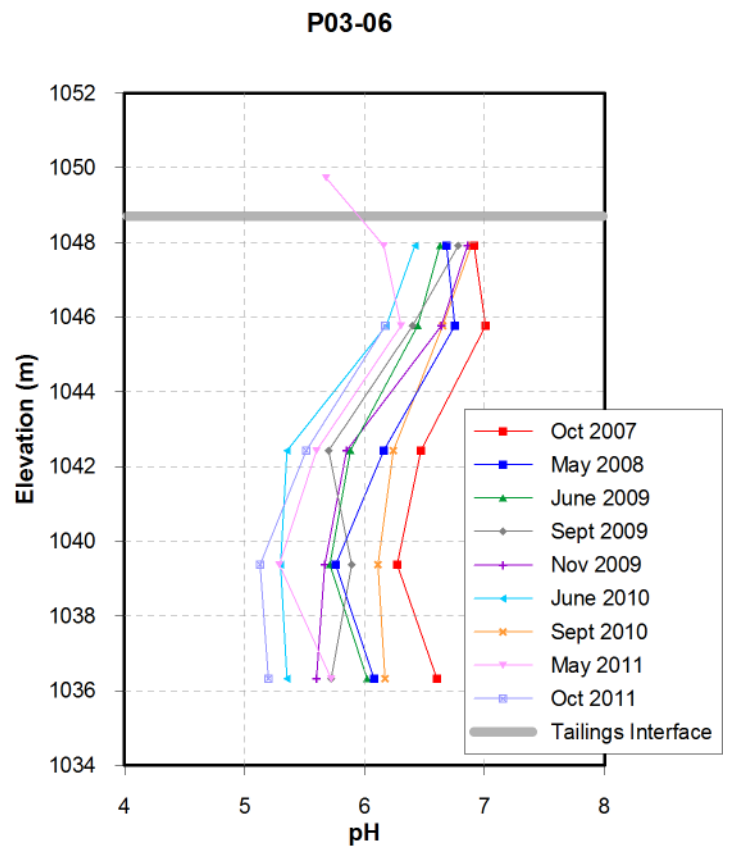
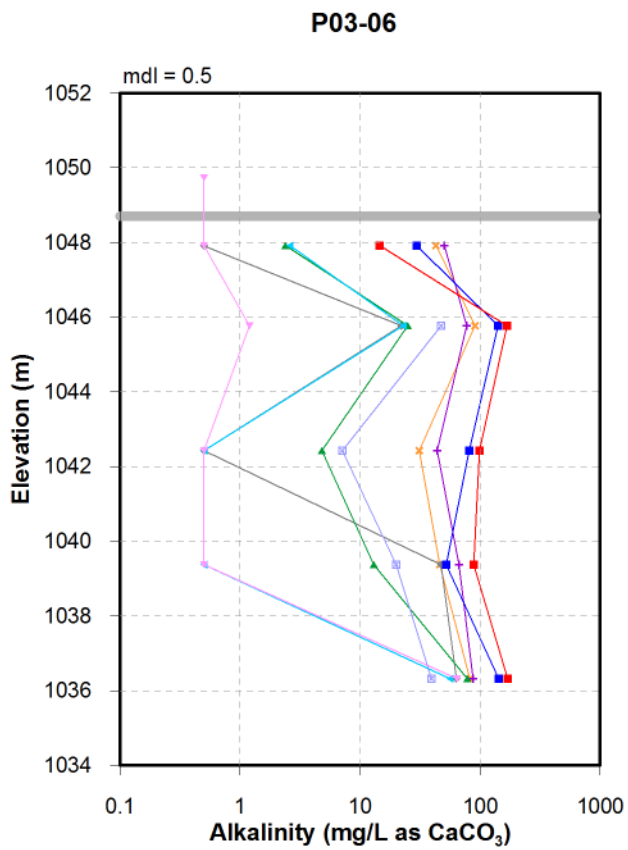


Figure 3-8b. Depth profiles for alkalinity, pH, Fe and Mn in P03-06 (Second Impoundment)

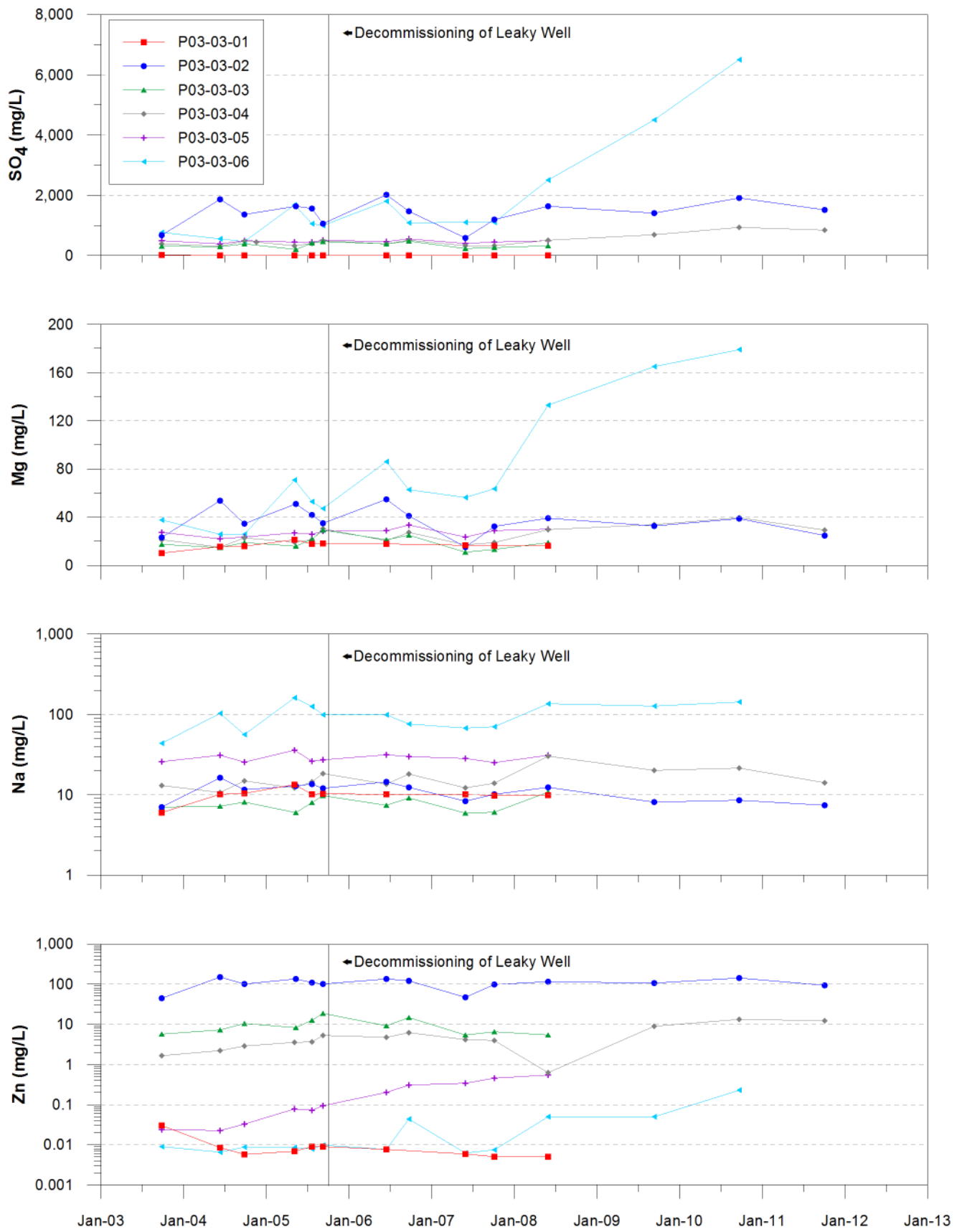


Figure 3-9a. Time trends for SO₄, Mg, Na and Zn in P03-03 (aquifer only)

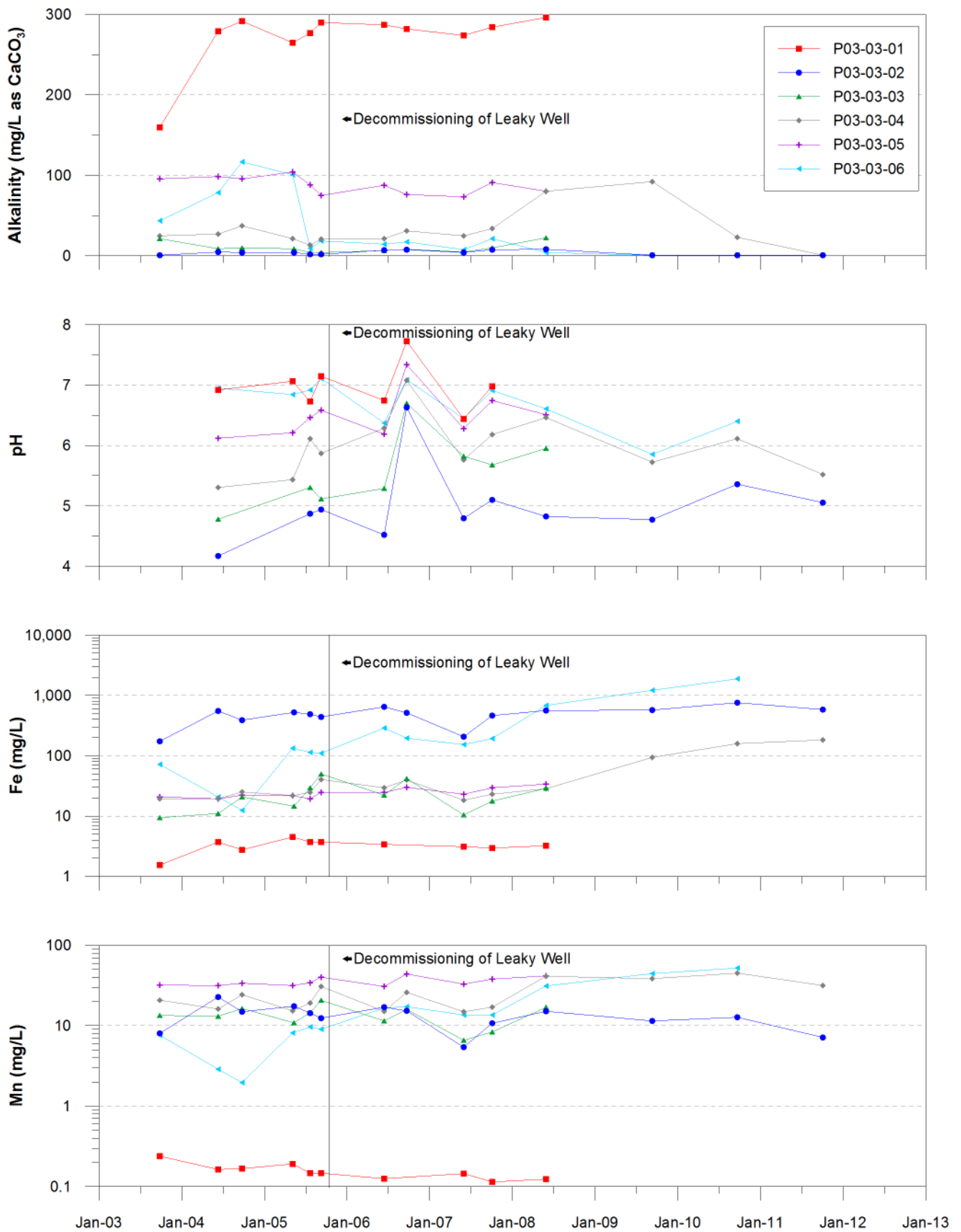


Figure 3-9b. Time trends for alkalinity, pH, Fe and Mn in P03-03 (aquifer only)

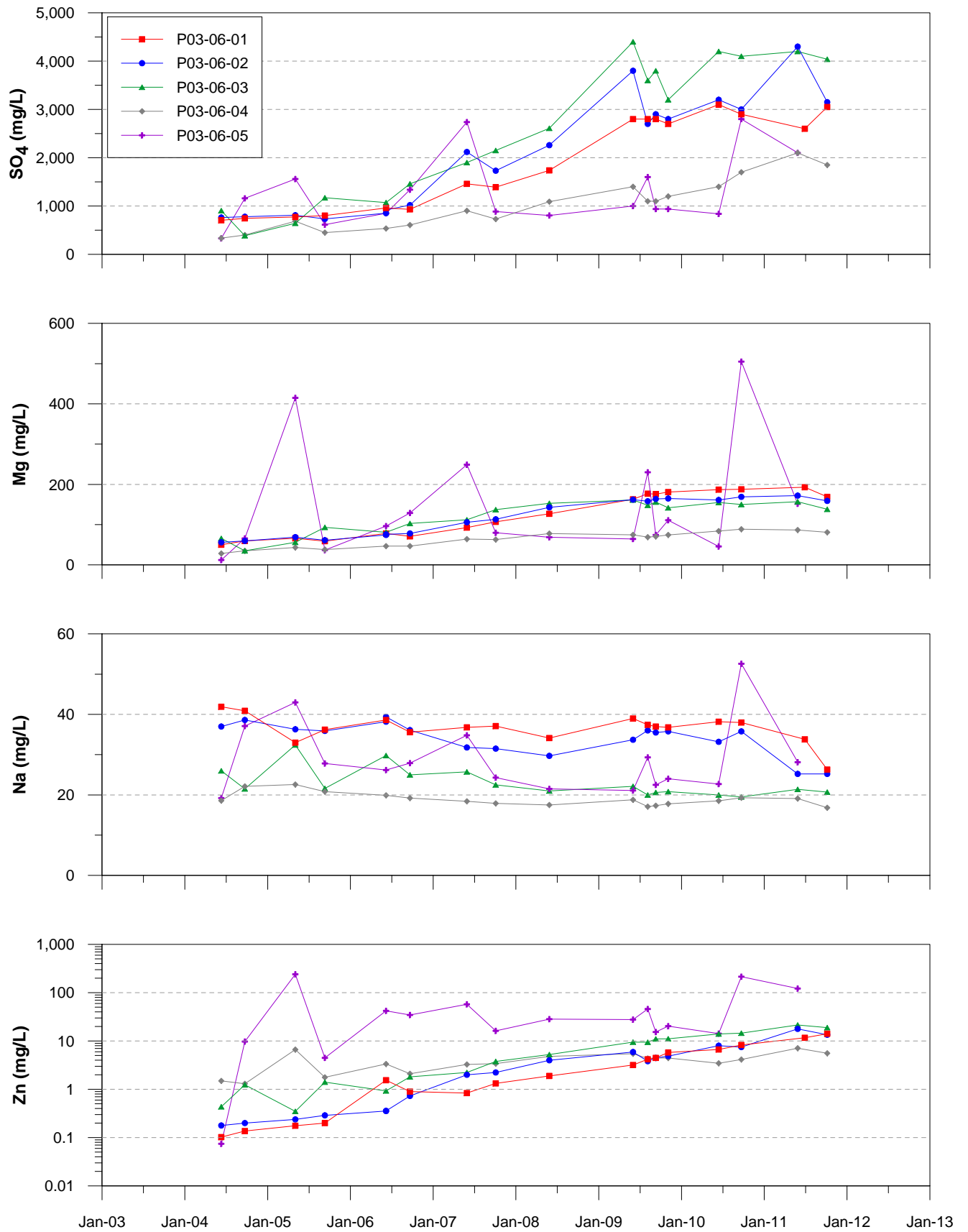


Figure 3-10a. Time trends for SO₄, Mg, Na and Zn in P03-06 (aquifer only)

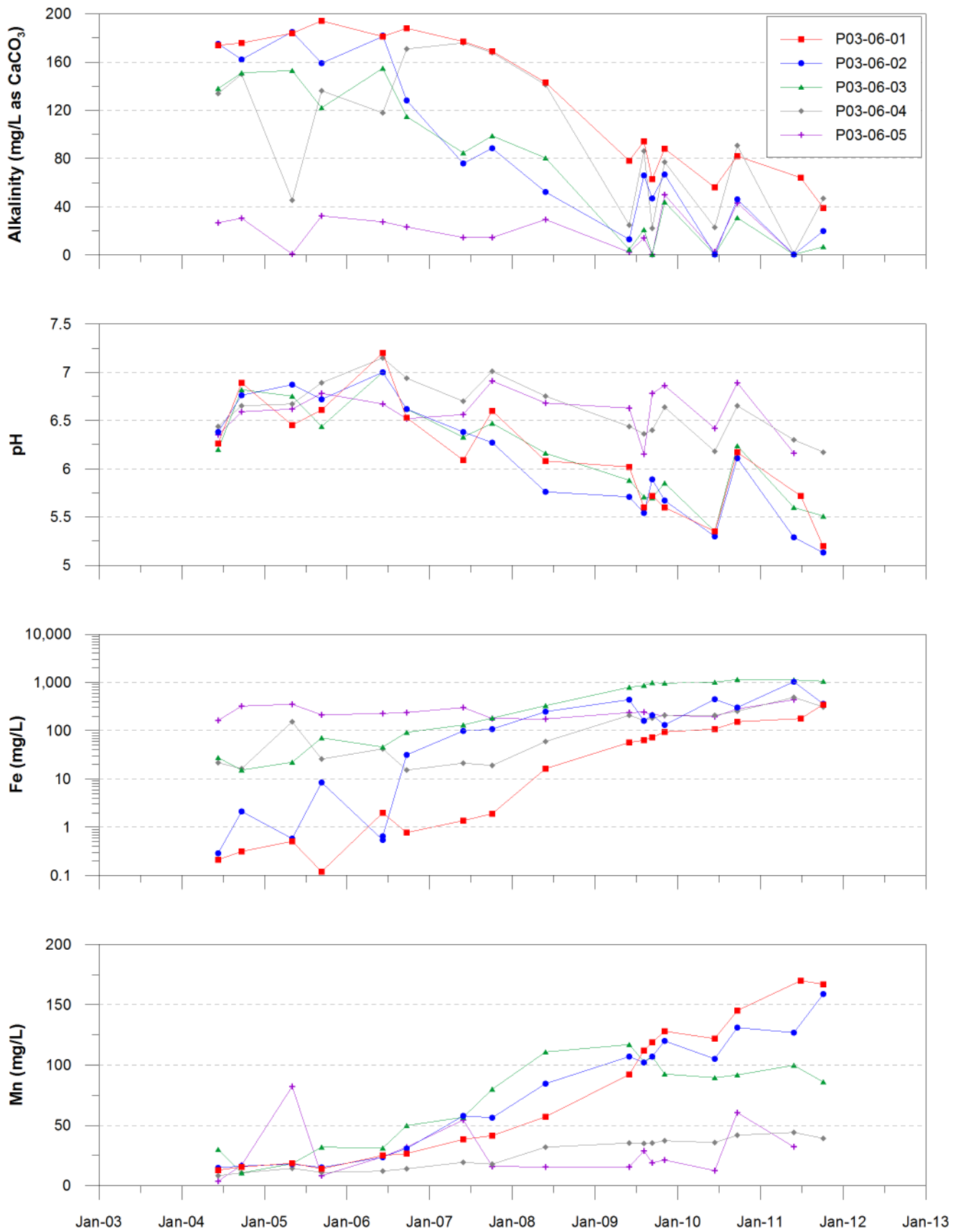


Figure 3-10b. Time trends for alkalinity, pH, Fe and Mn in P03-06 (aquifer only)

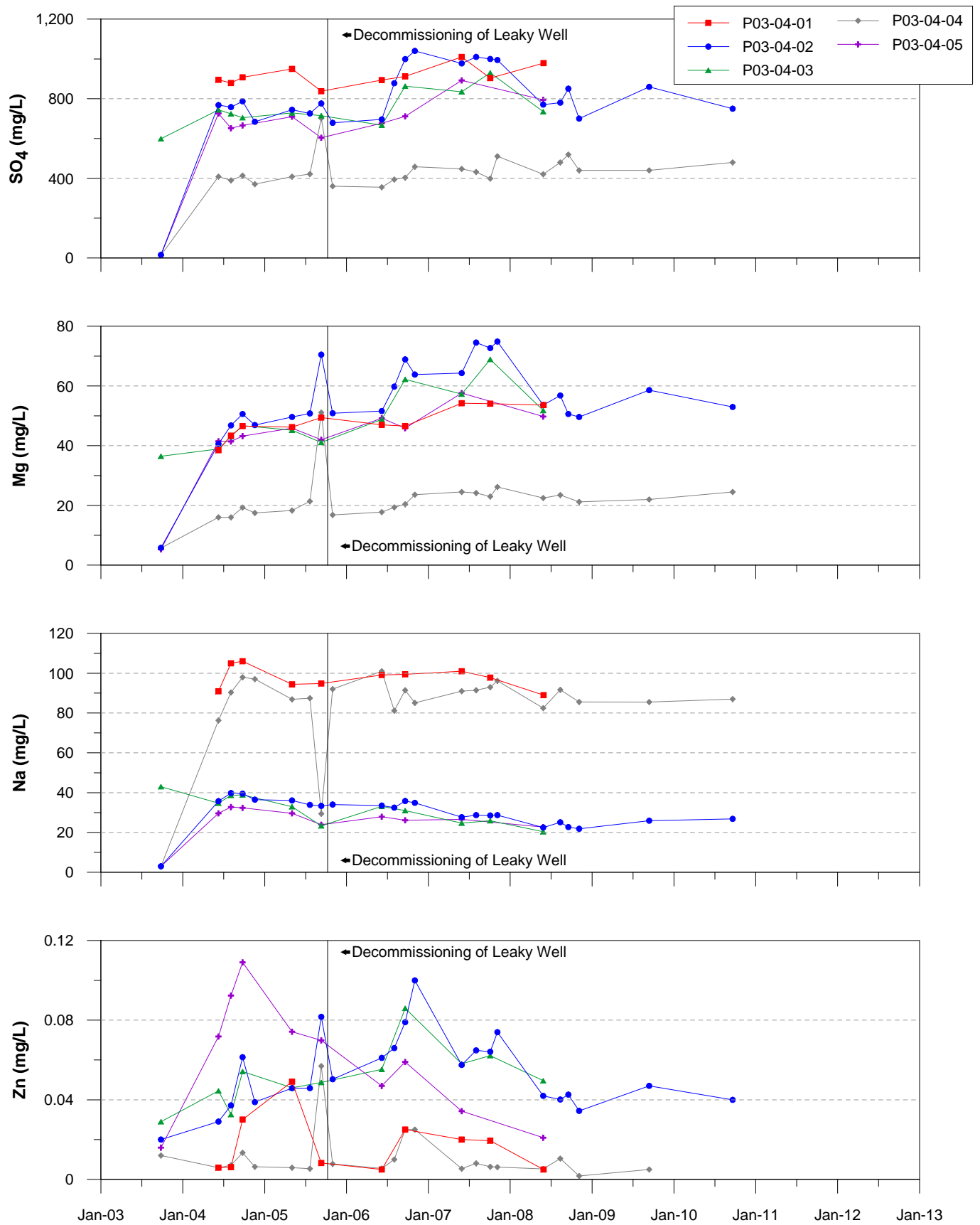


Figure 3-10c. Time trends for SO₄, Mg, Na and Zn in P03-04 (aquifer only)

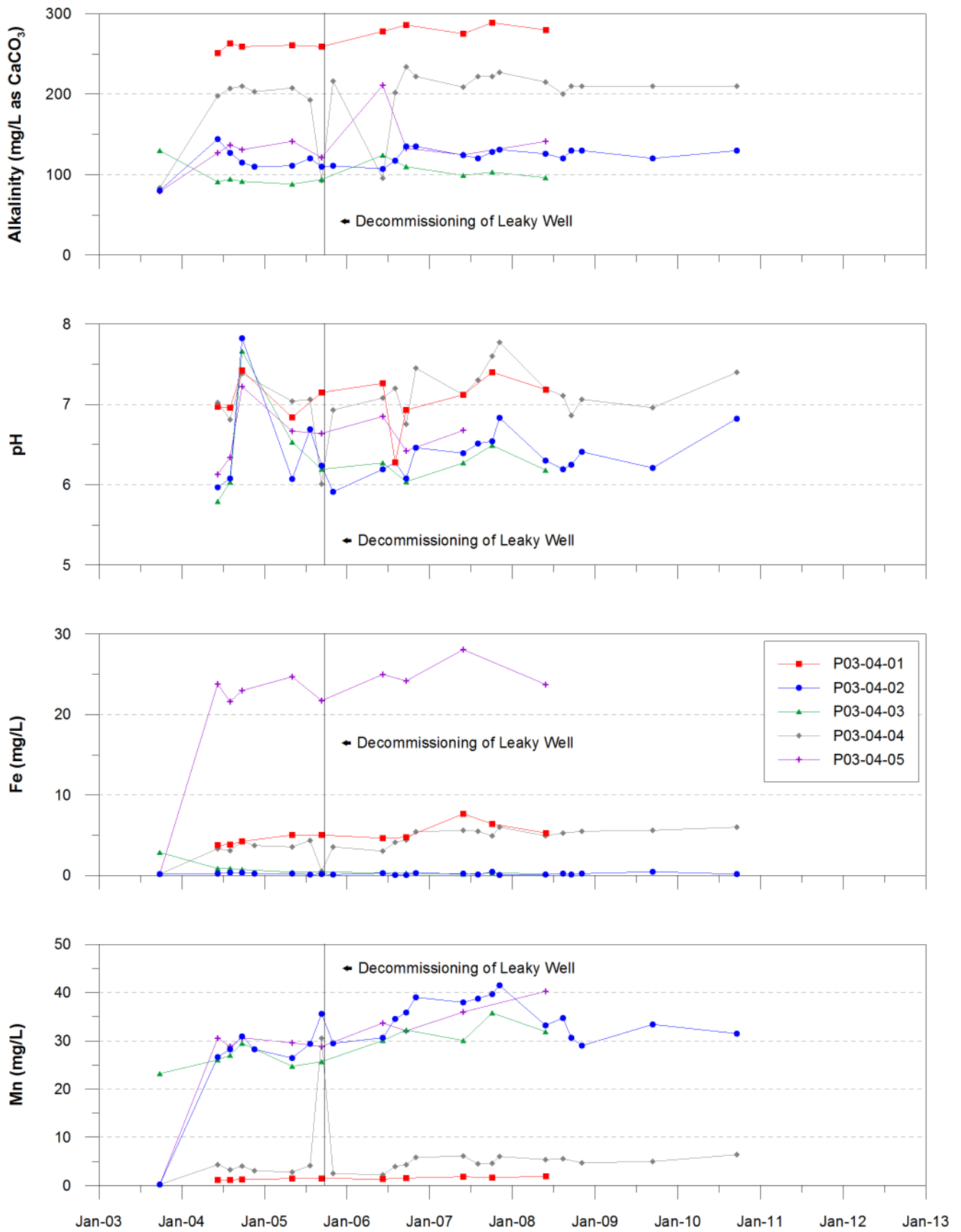


Figure 3-10d. Time trends for alkalinity, pH, Fe and Mn in P03-04 (aquifer only)

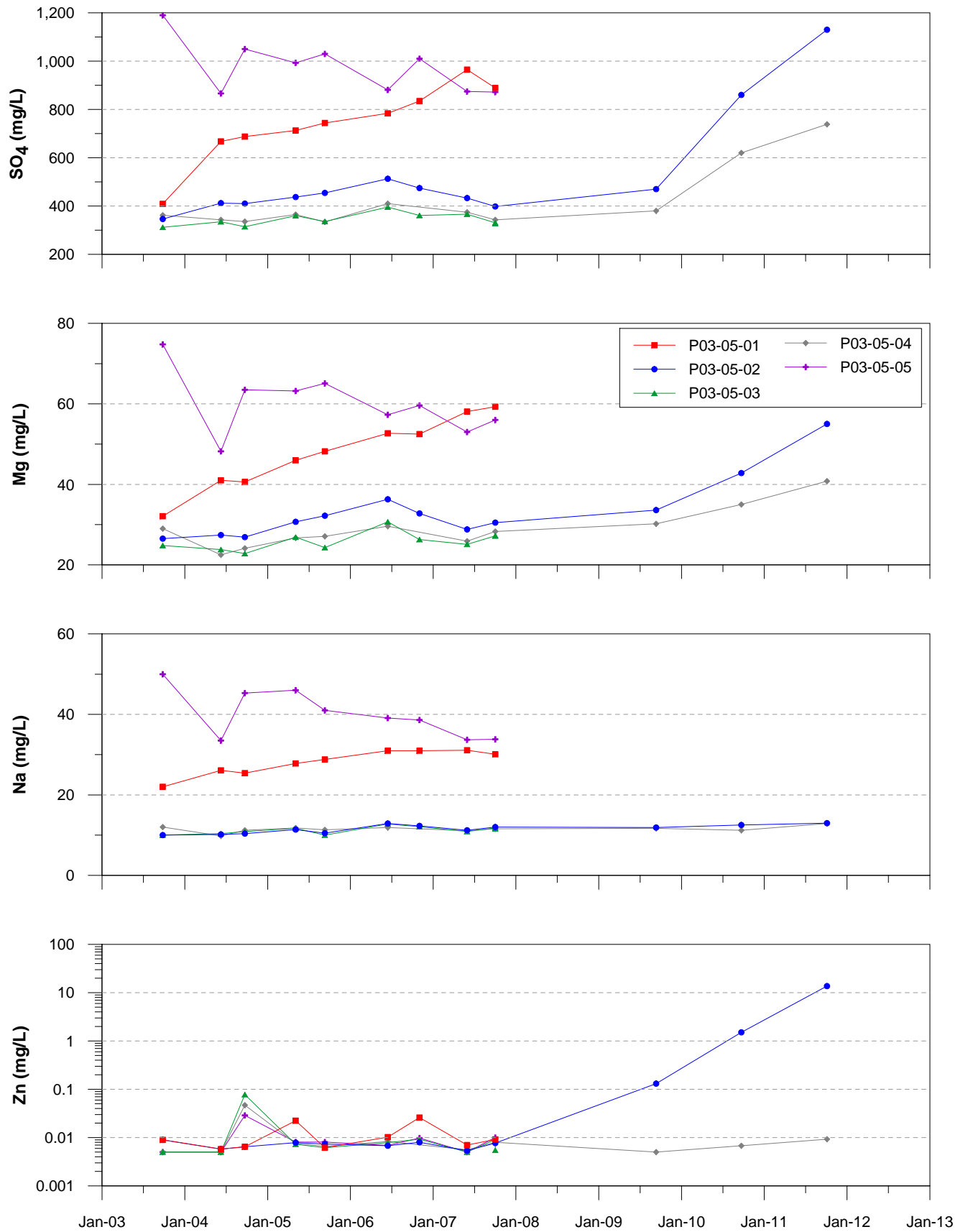


Figure 3-10e. Time trends for SO₄, Mg, Na and Zn in P03-05 (aquifer only)

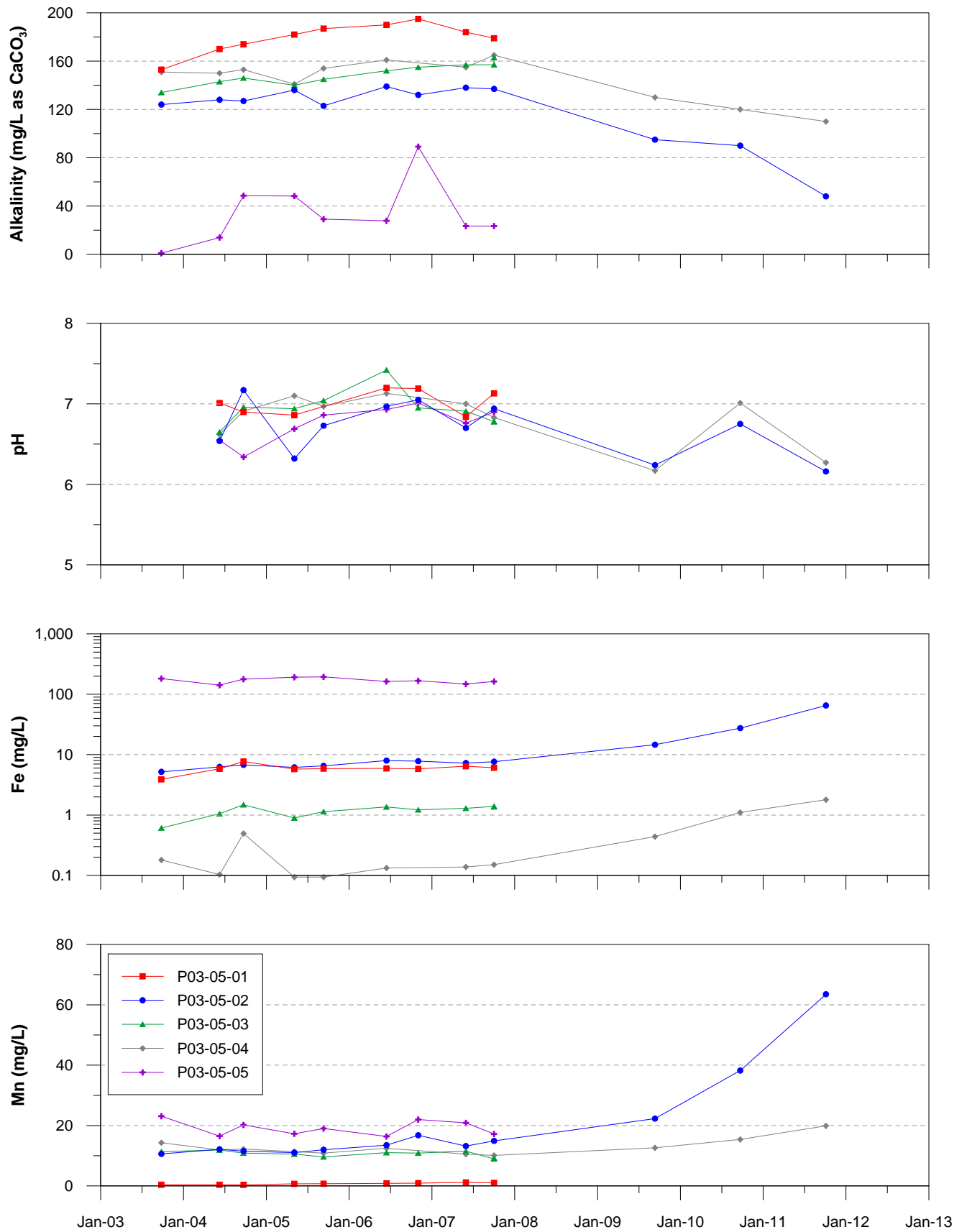


Figure 3-10f. Time trends for alkalinity, pH, Fe and Mn in P03-05 (aquifer only)

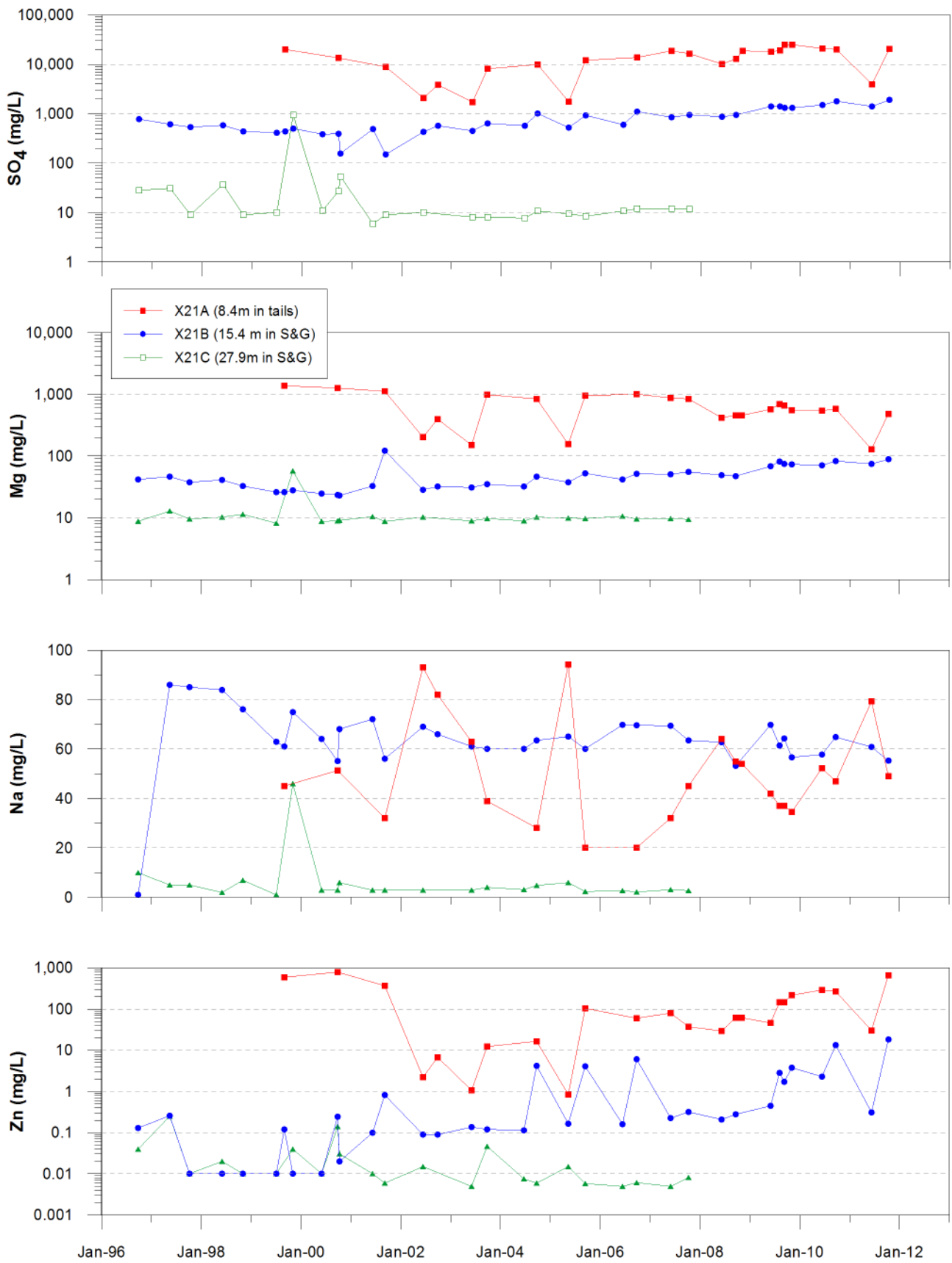


Figure 3-11a. Time trends for SO₄, Mg, Na and Zn in X21 (96), Intermediate Impoundment

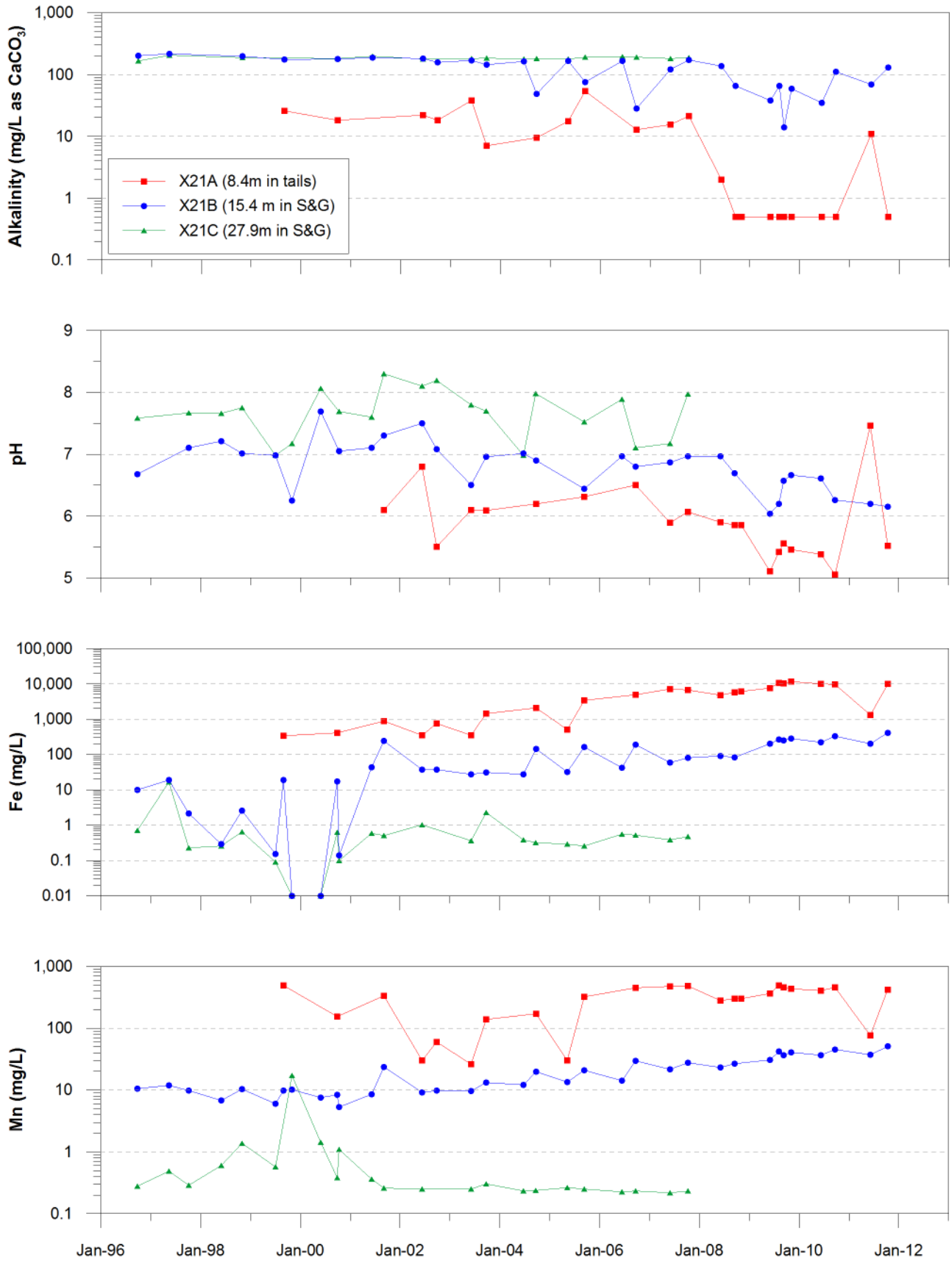


Figure 3-11b. Time trends for alkalinity, pH, Fe and Mn in X21(96), Intermediate Impoundment

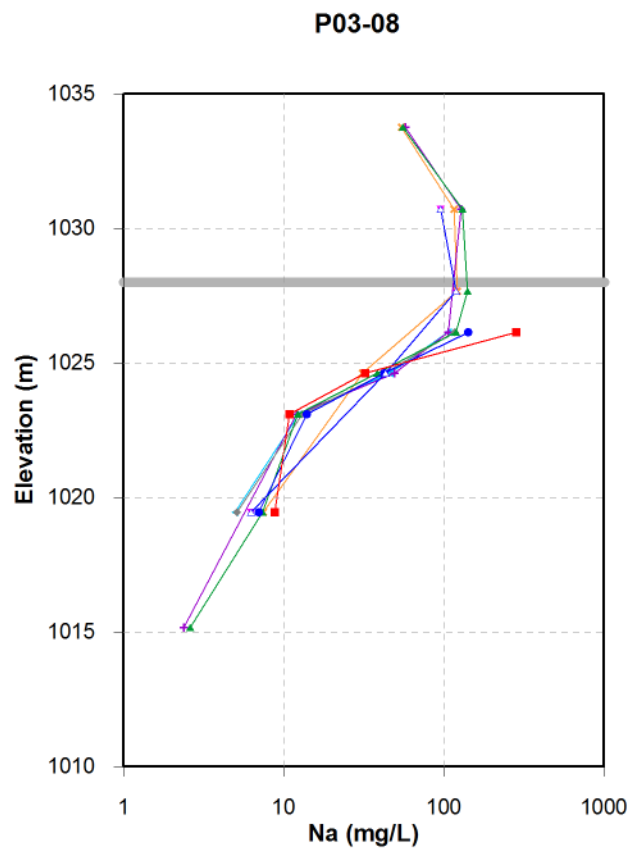
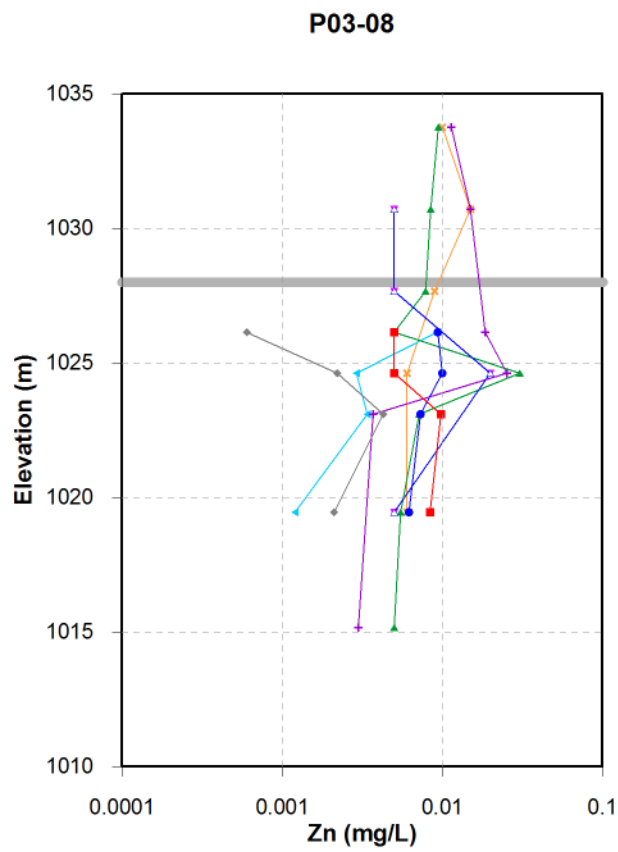
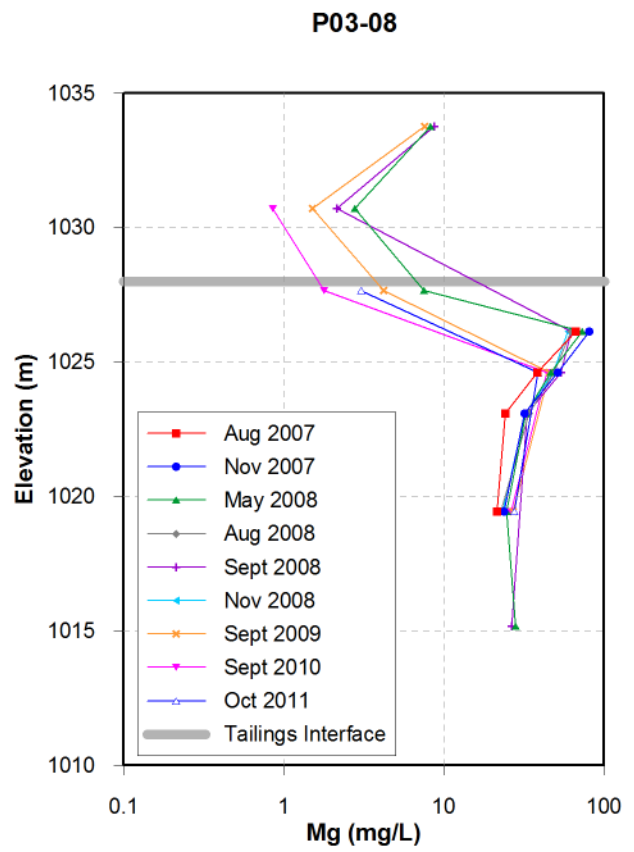
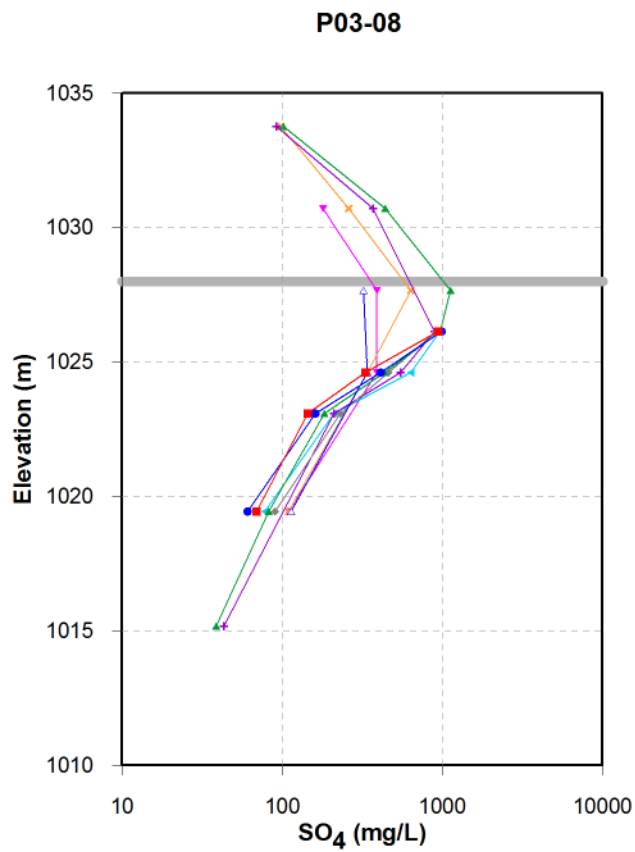


Figure 3-12a. Depth profiles for SO₄, Mg, Zn and Na in P03-08 (Intermediate Impoundment)

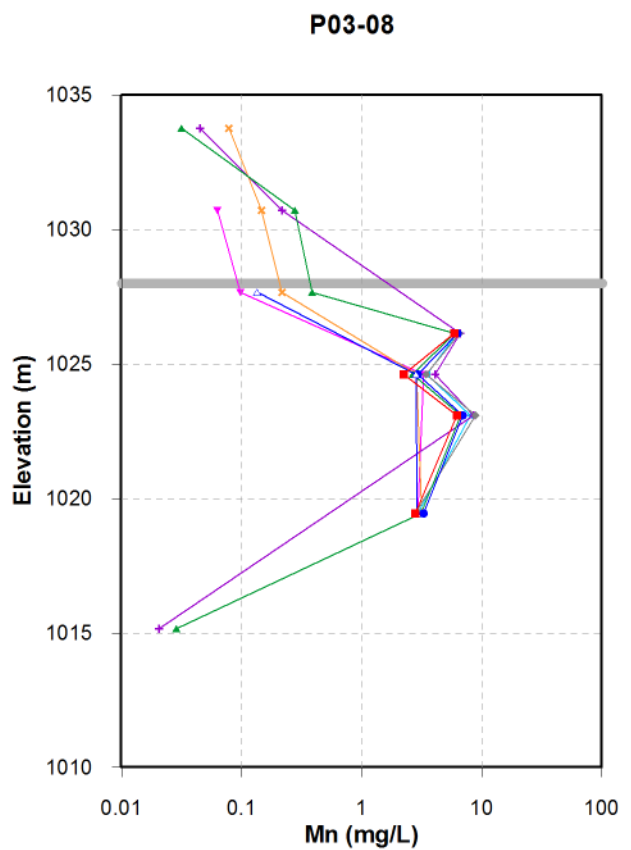
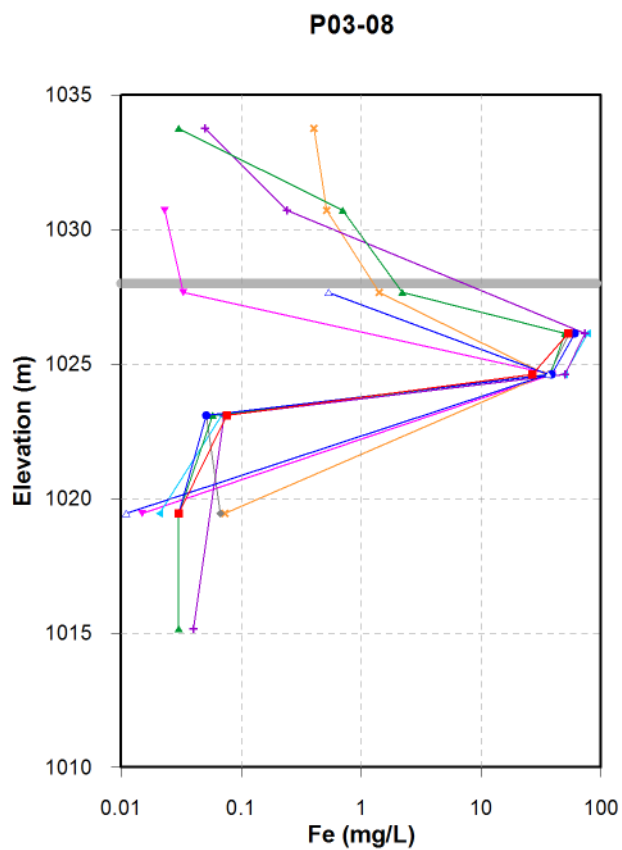
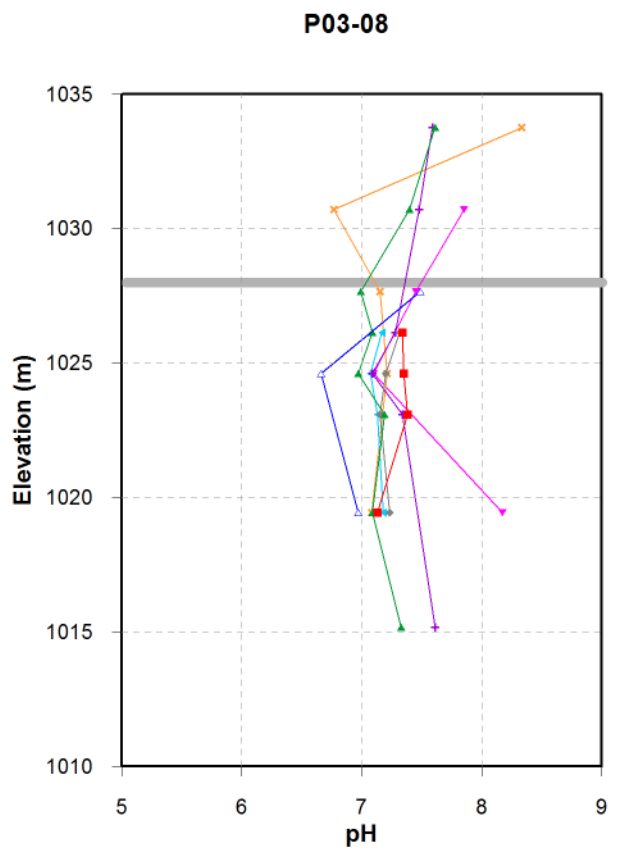
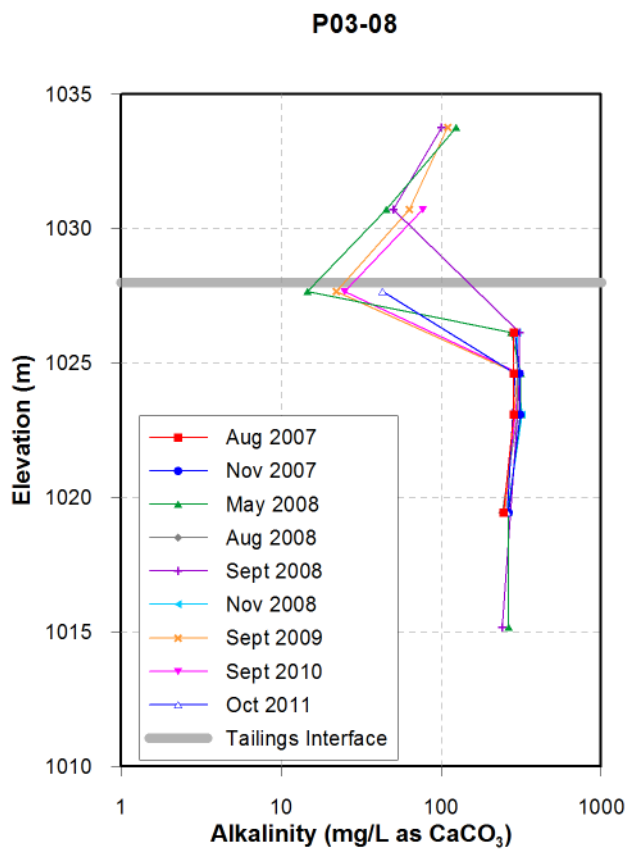


Figure 3-12b. Depth profiles for alkalinity, pH, Fe and Mn in P03-08 (Intermediate Impoundment)

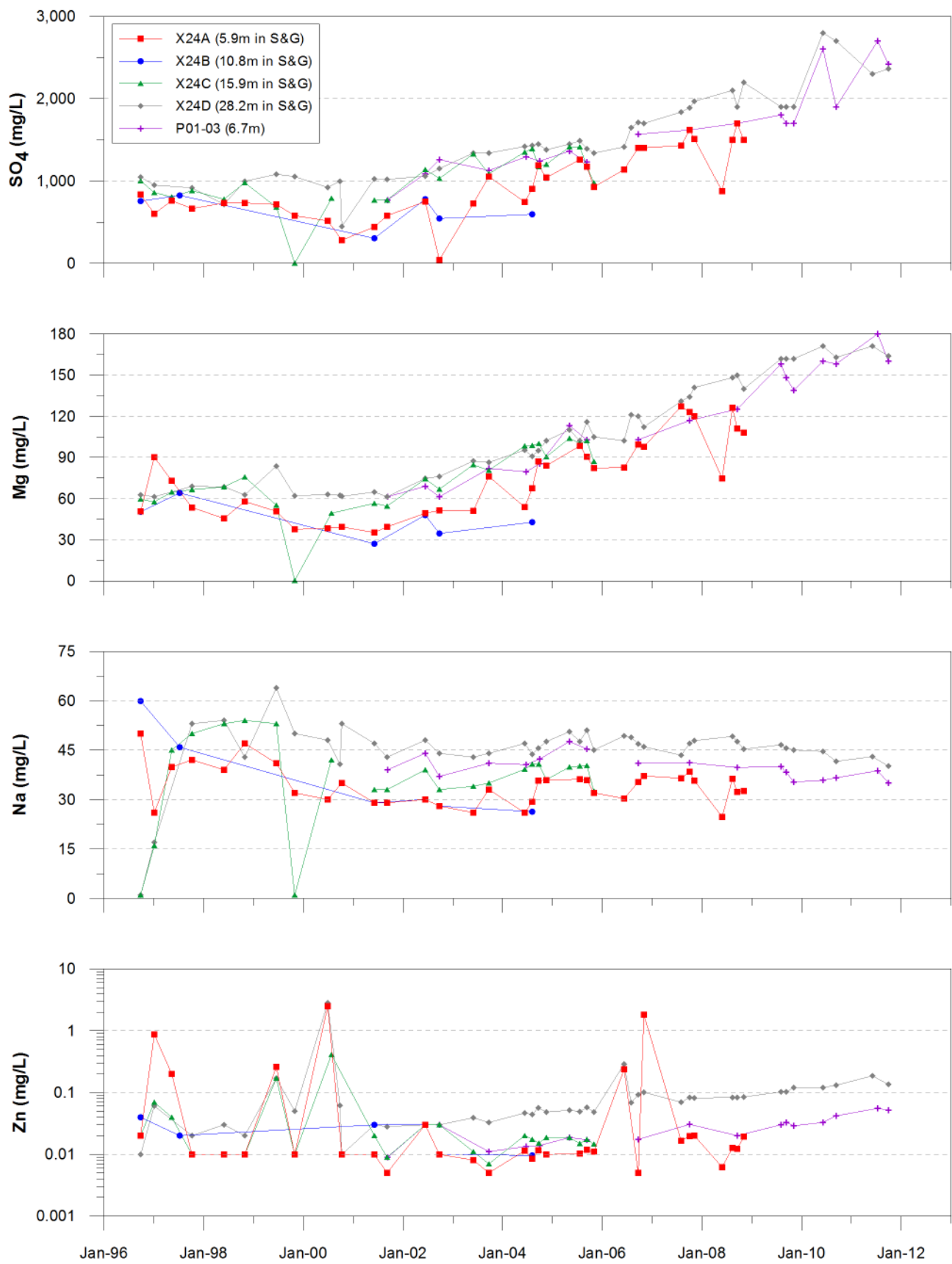


Figure 3-13a. Time trends for SO₄, Mg, Na and Zn in X24(96) and P01-03 (northern side of the Intermediate Dam)

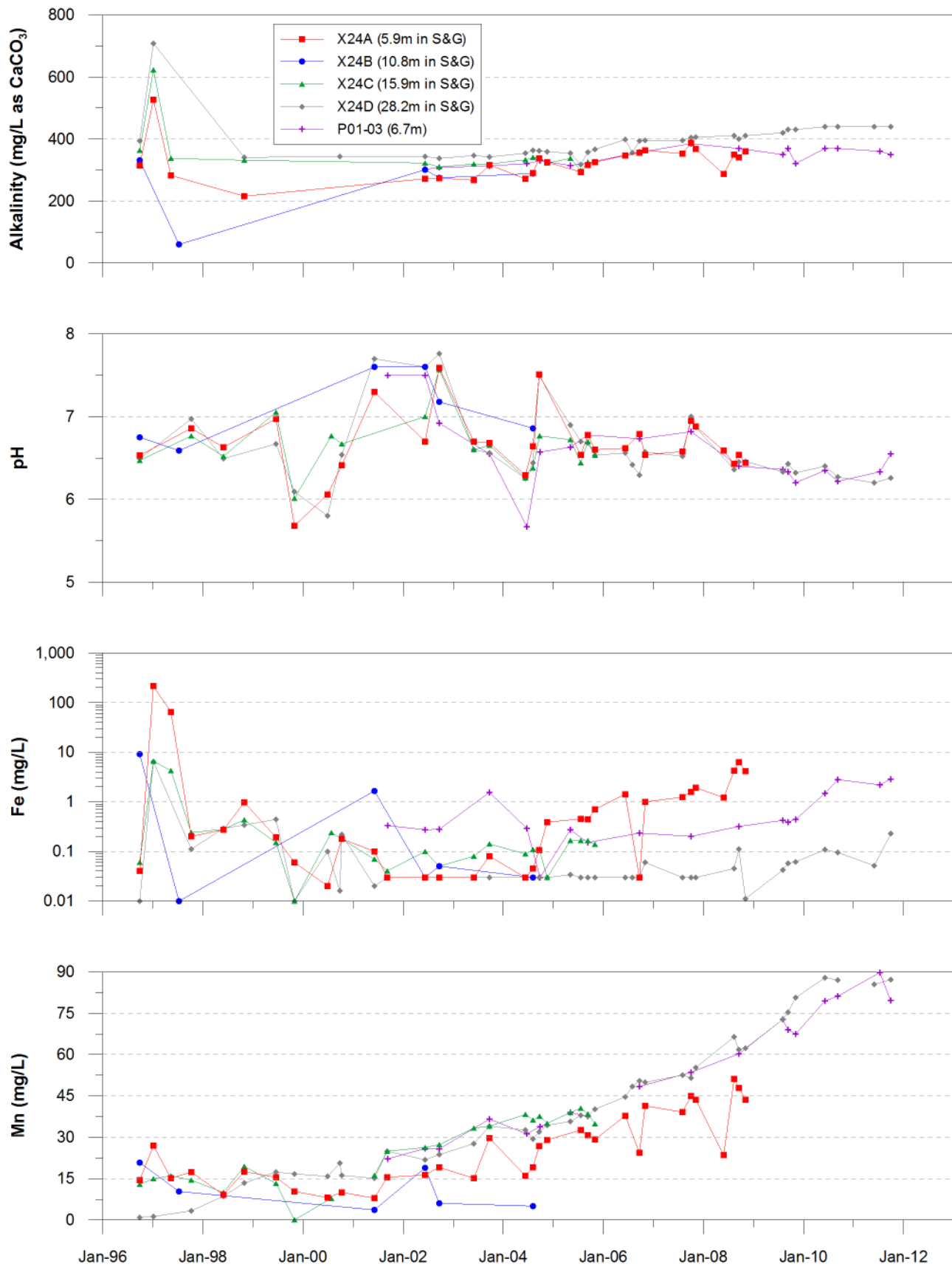


Figure 3-13b. Time trends for alkalinity, pH, Fe and Mn in X24(96) and P01-03 (northern side of the Intermediate Dam)

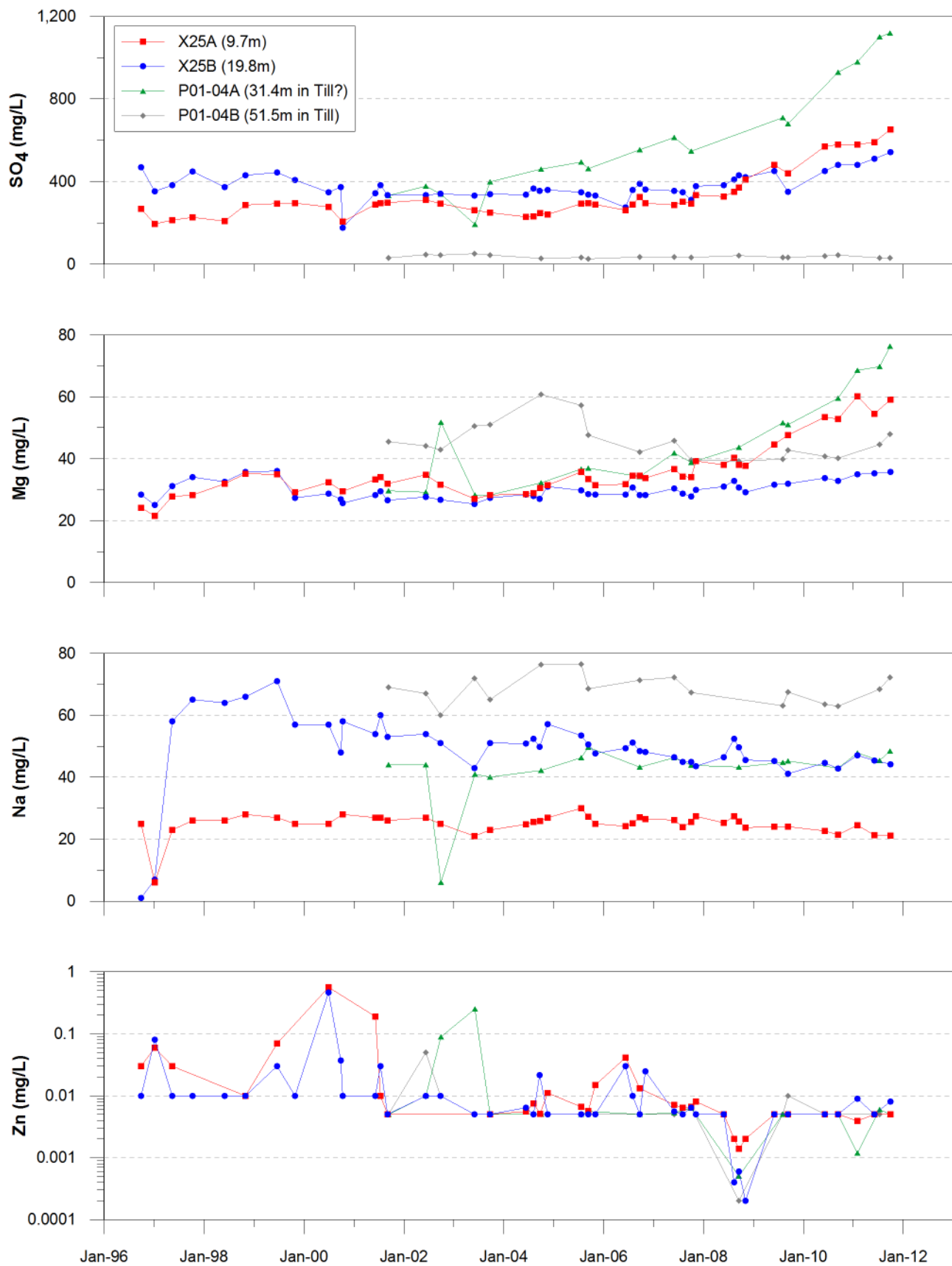


Figure 3-14a. Time trends for SO₄, Mg, Na and Zn in X25(96) and P01-04 (southern side of the Intermediate Dam)

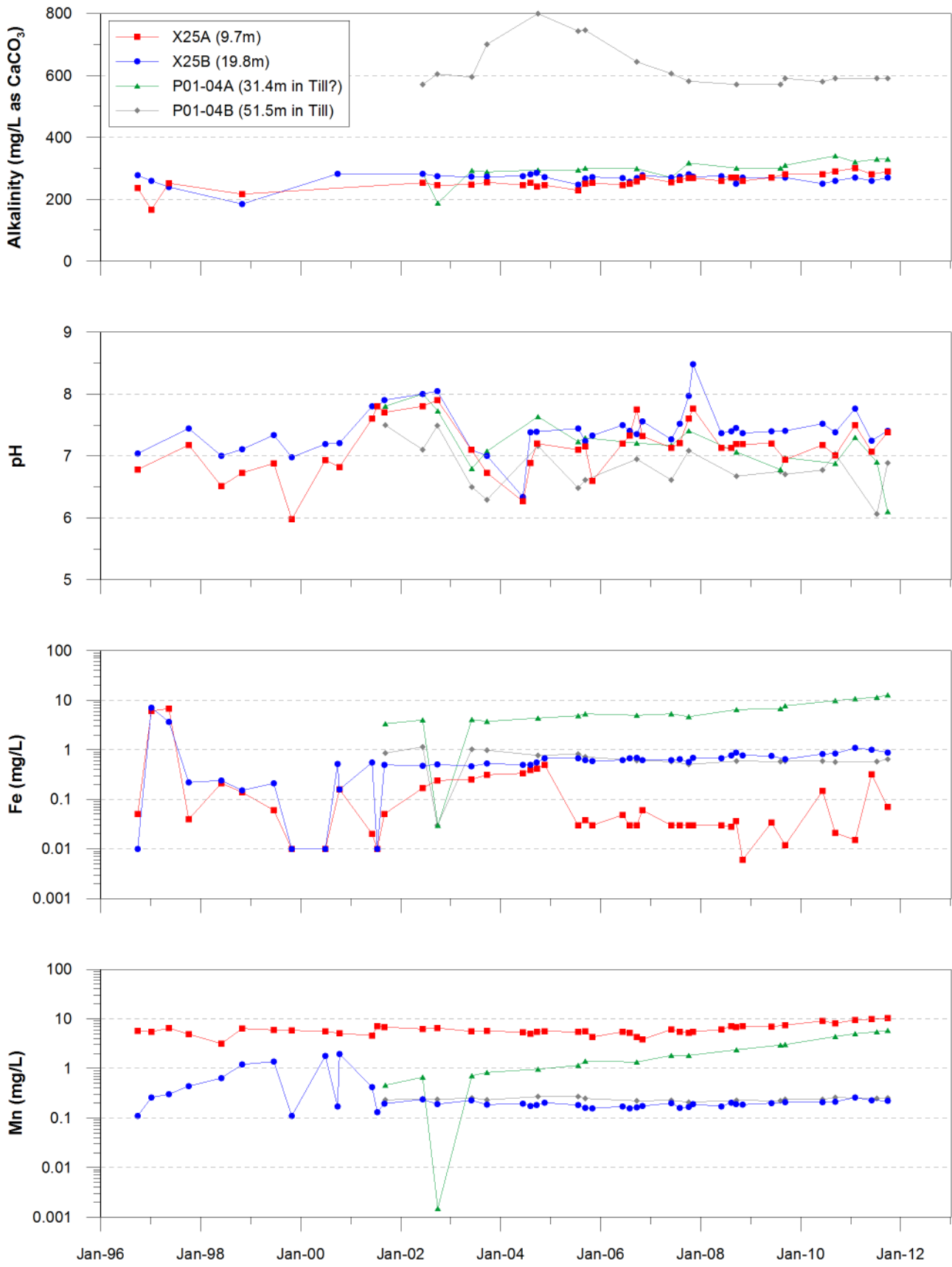


Figure 3-14b. Time trends for alkalinity, pH, Fe and Mn in X25(96) and P01-04 (southern side of the Intermediate Dam)

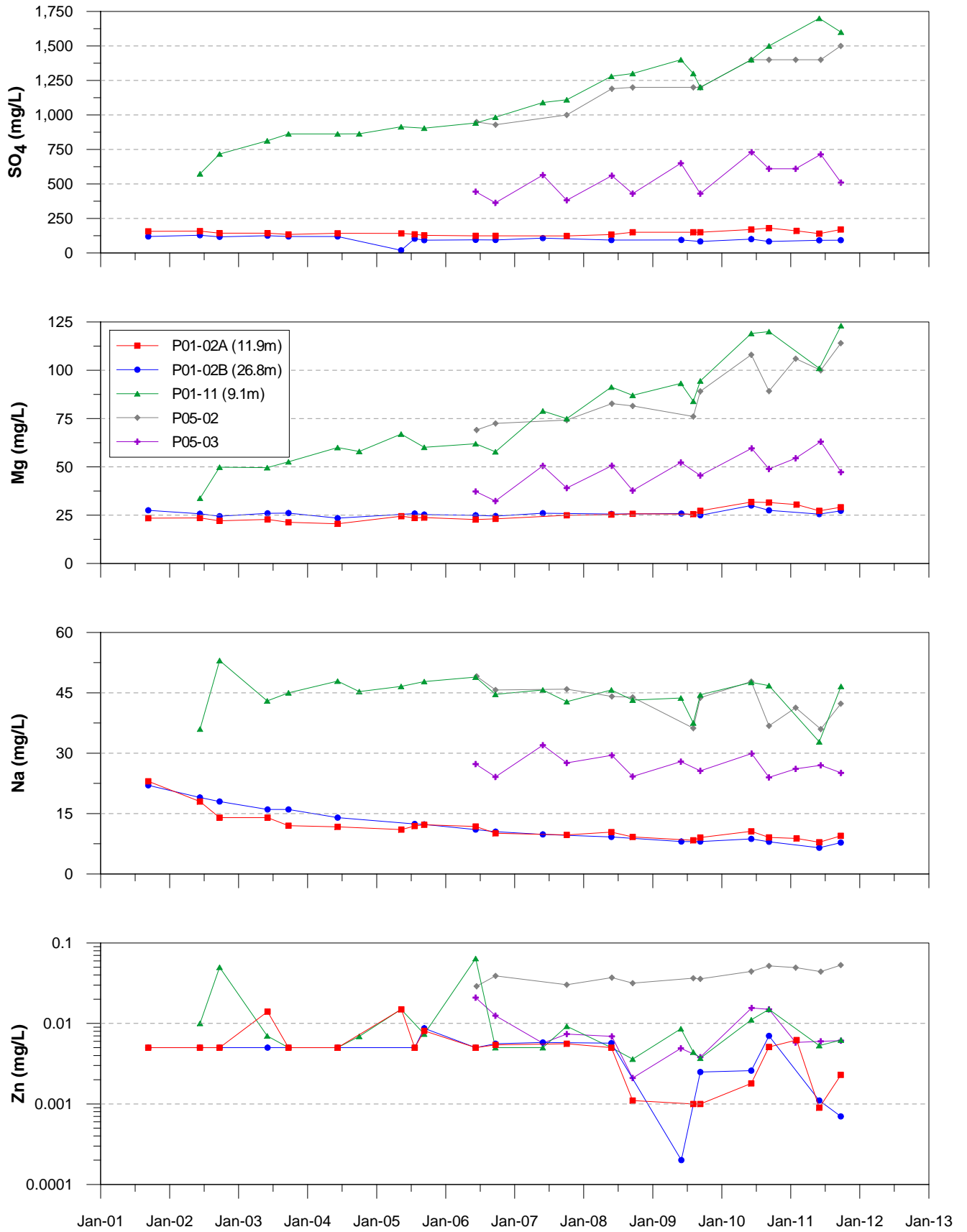


Figure 3-15a. Time trends for SO₄, Mg, Na and Zn in wells along toe of Cross Valley Dam

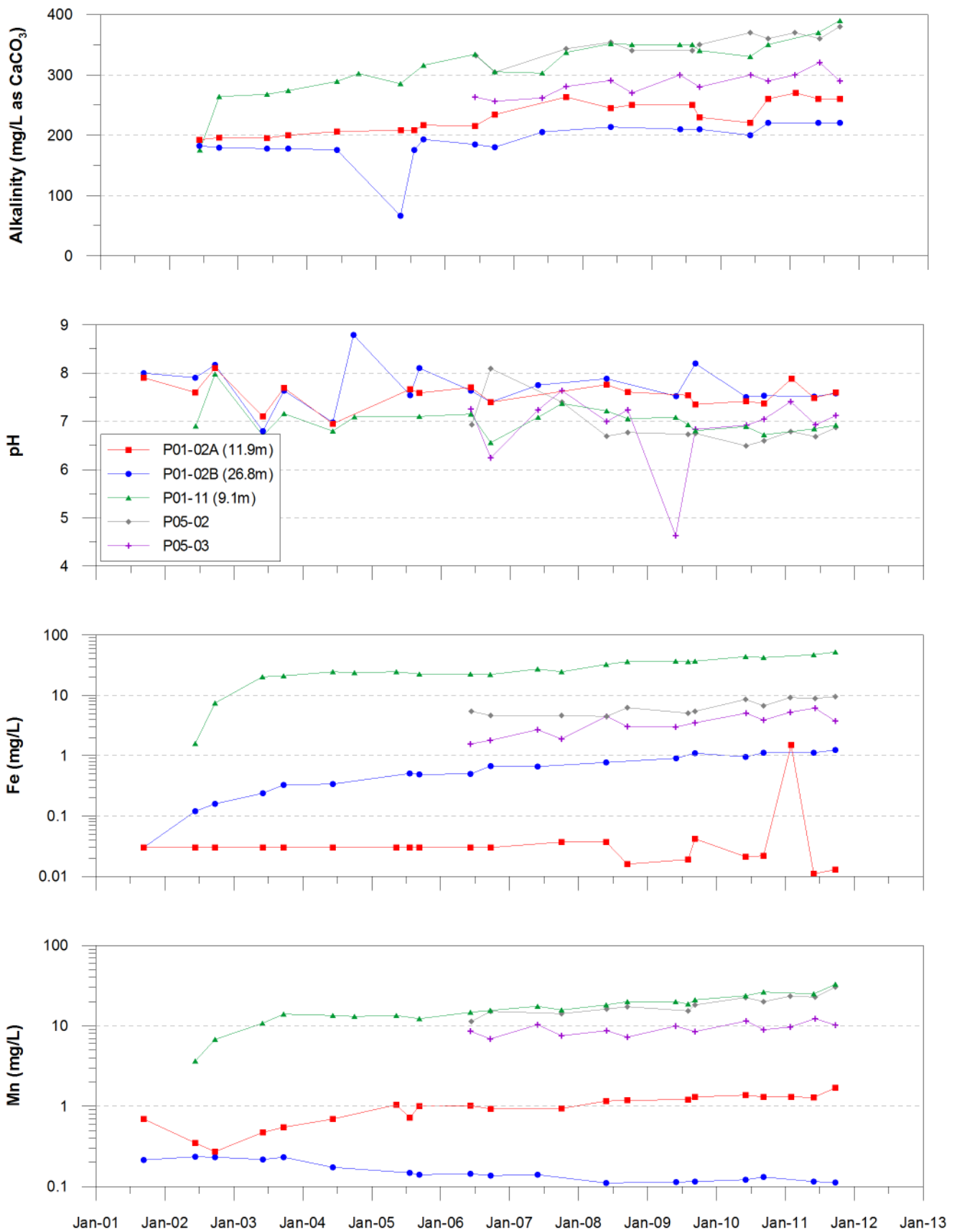


Figure 3-15b. Time trends for alkalinity, pH, Fe and Mn in wells along toe of Cross Valley Dam

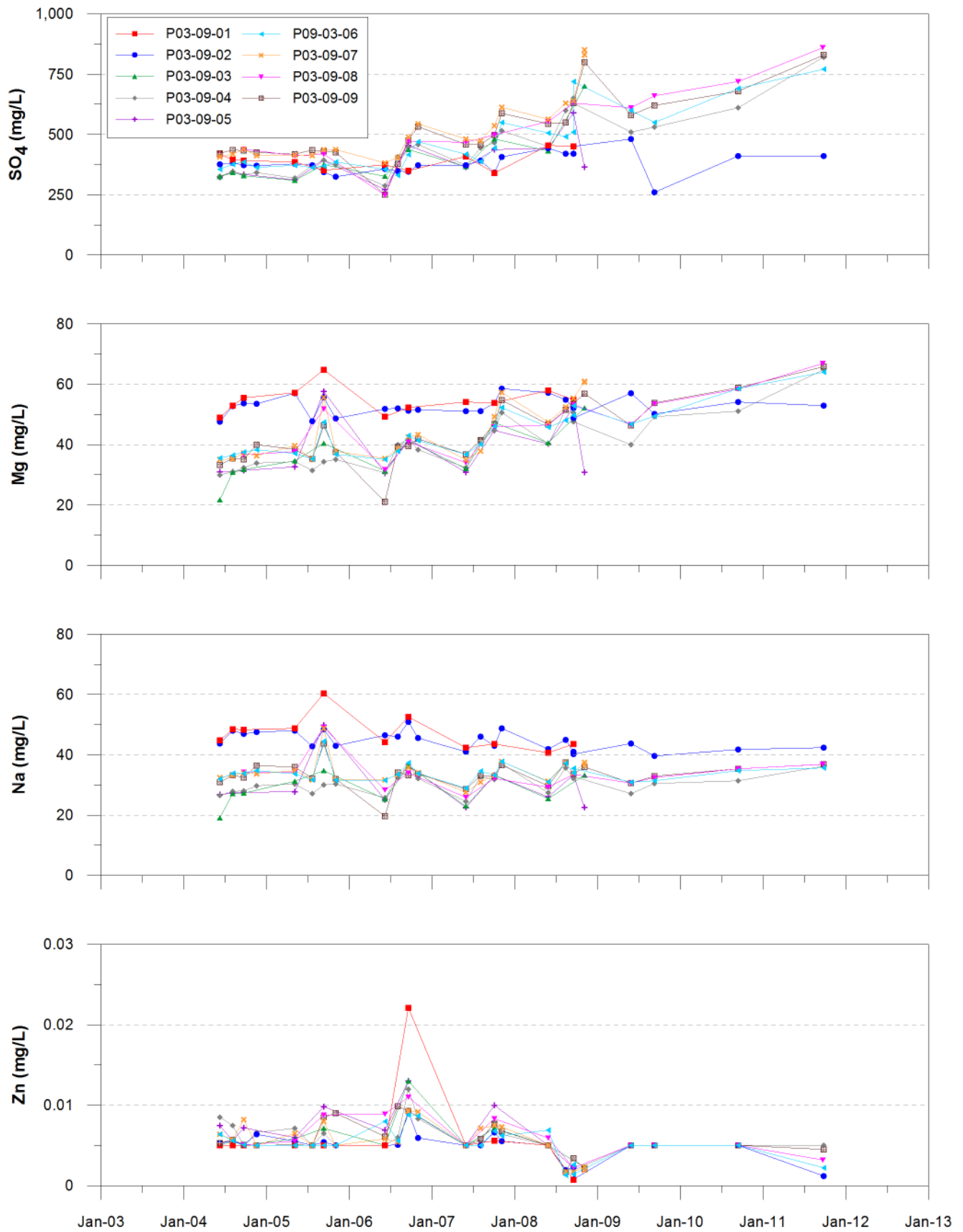


Figure 3-16a. Time trends for SO₄, Mg, Na and Zn in P03-09 (at Cross Valley Dam)

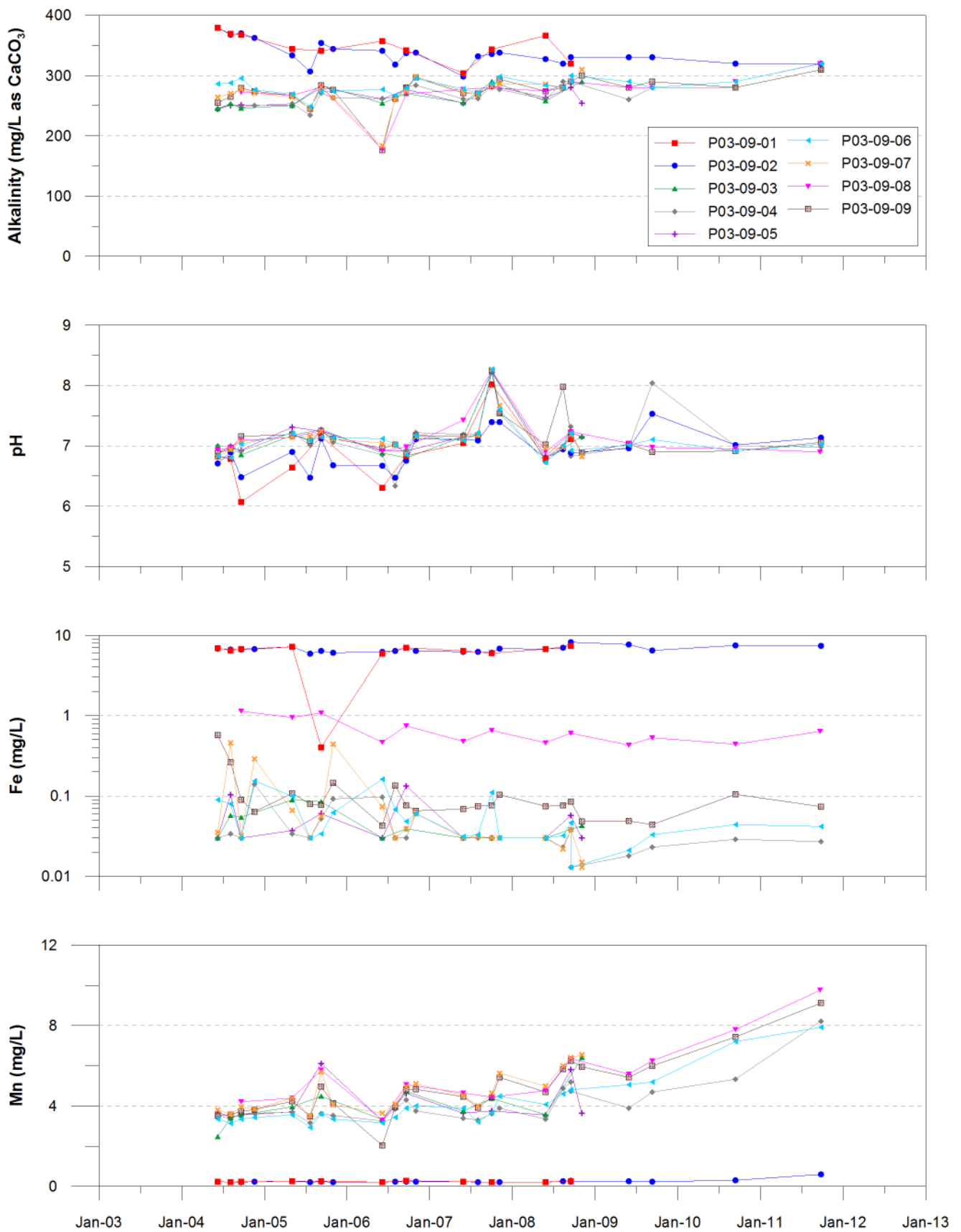


Figure 3-16b. Time trends for alkalinity, pH, Fe and Mn in P03-09 (at Cross Valley Dam)

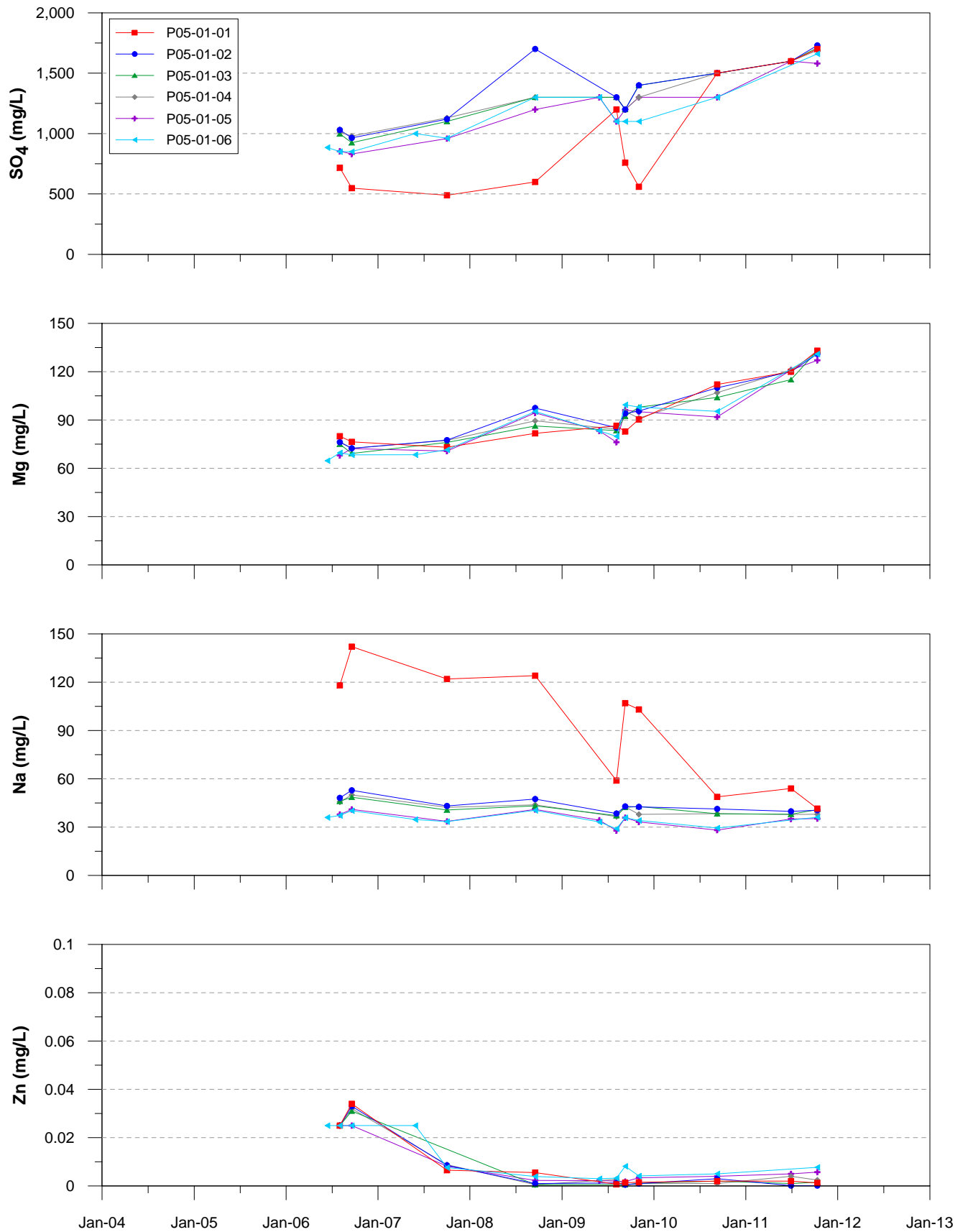


Figure 3-17a. Time trends for SO_4 , Mg, Na and Zn in P05-01 (at Cross Valley Dam)

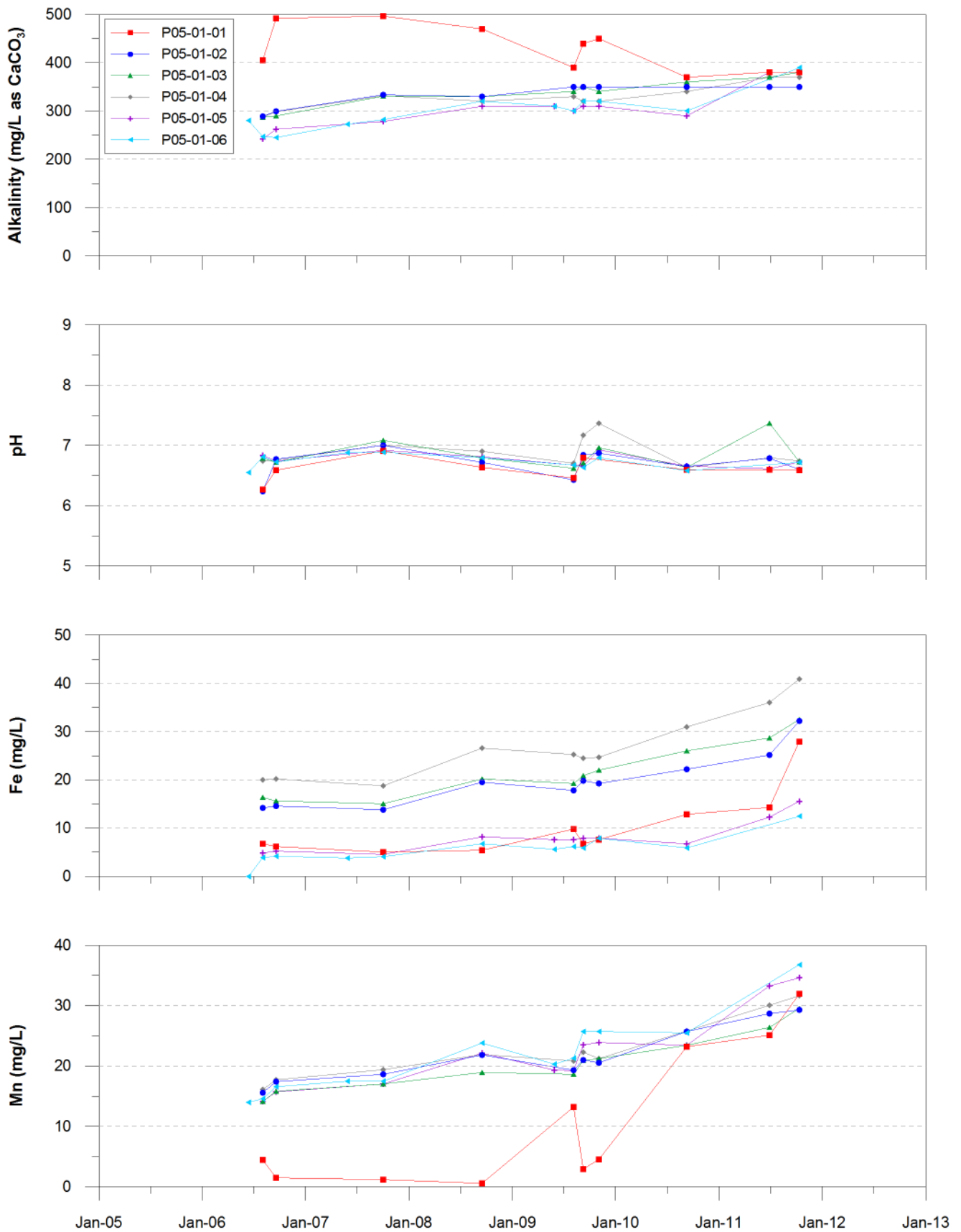


Figure 3-17b. Time trends for alkalinity, pH, Fe and Mn in P05-01 (at Cross Valley Dam)

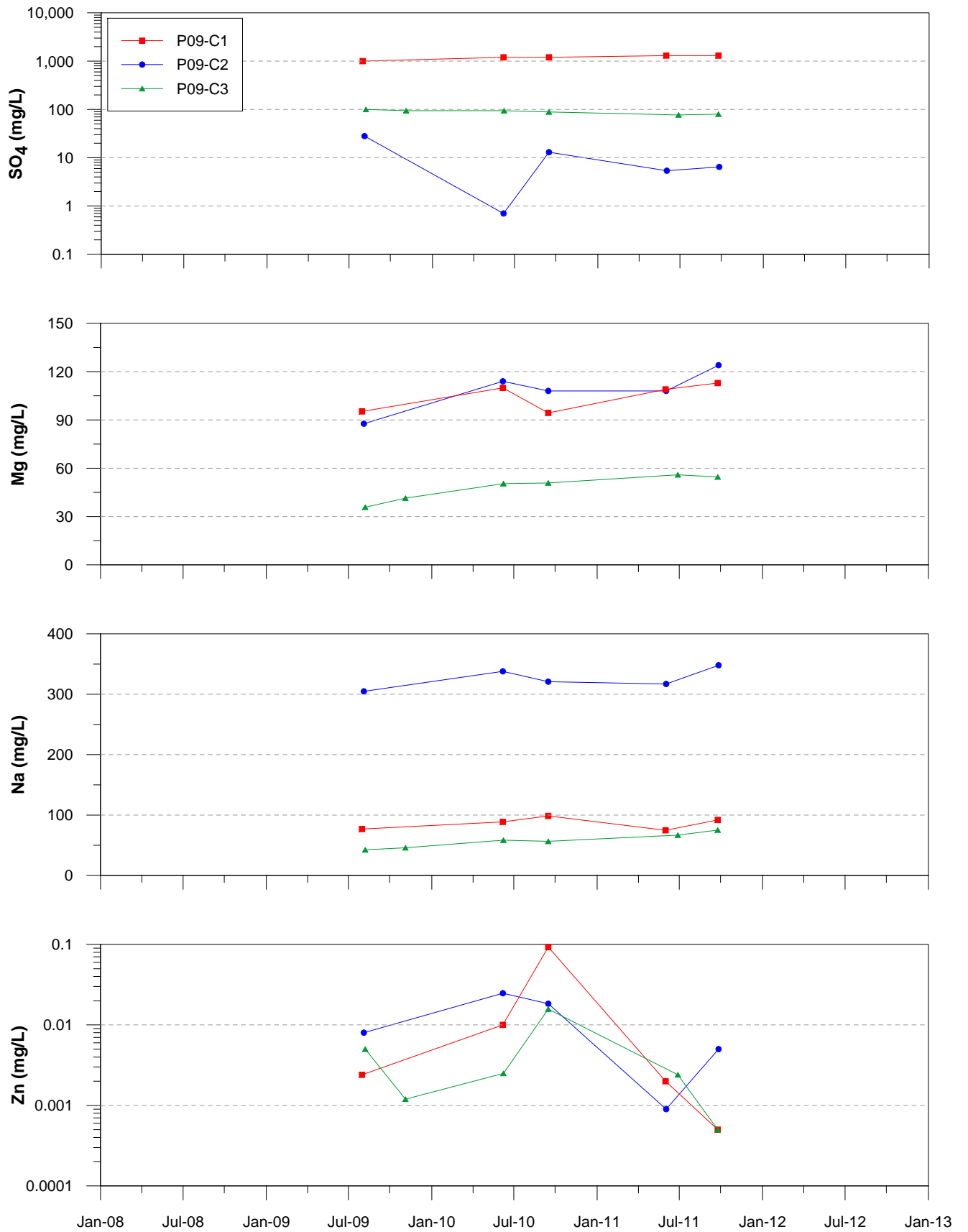


Figure 3-18a. Time trends for SO₄, Mg, Na and Zn in wells at the toe of Cross Valley Dam

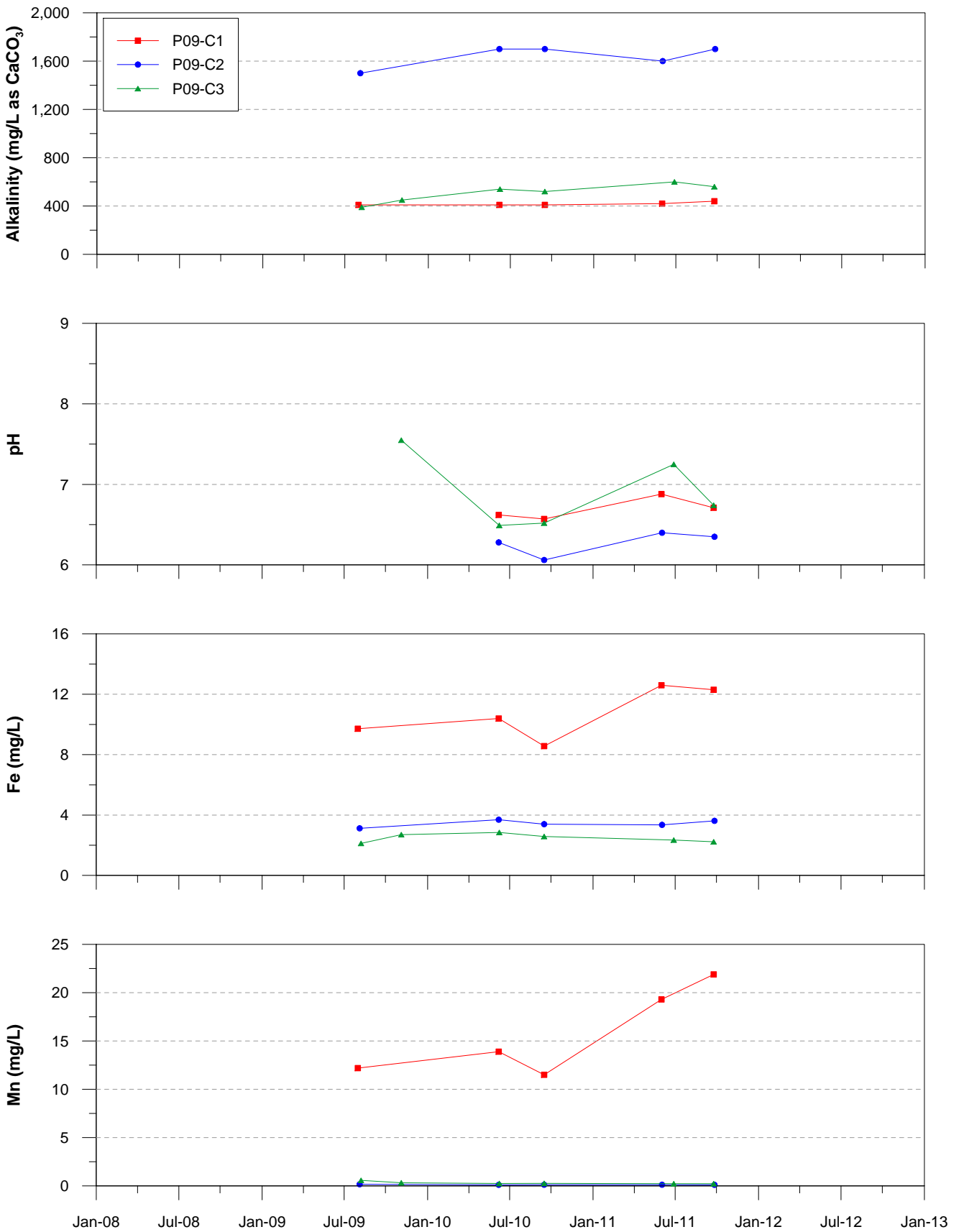


Figure 3-18b. Time trends for alkalinity, pH, Fe and Mn in wells at the toe of Cross Valley Dam

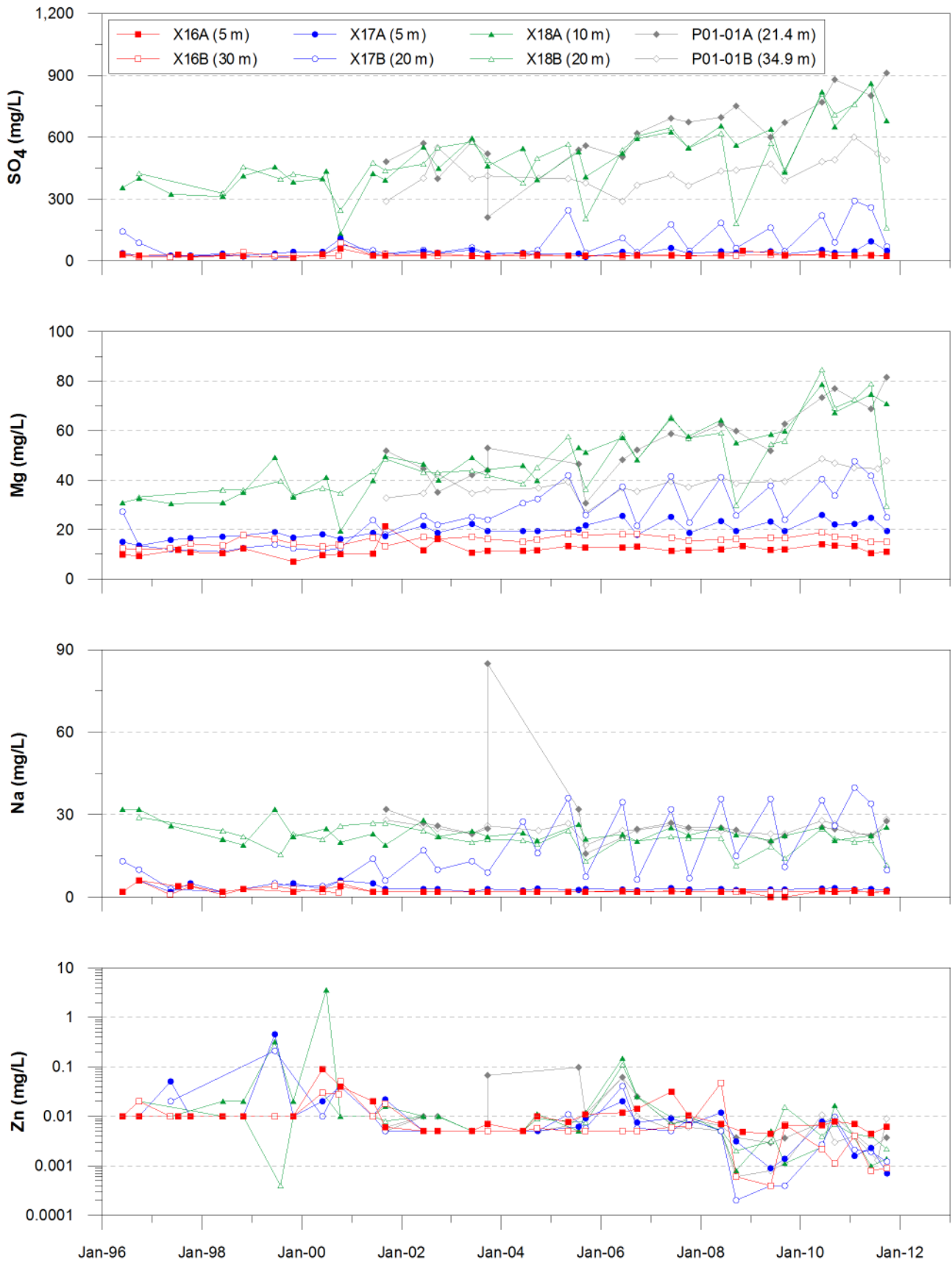


Figure 3-19a. Time trends for SO_4 , Mg, Na and Zn in wells downgradient of Cross Valley Dam

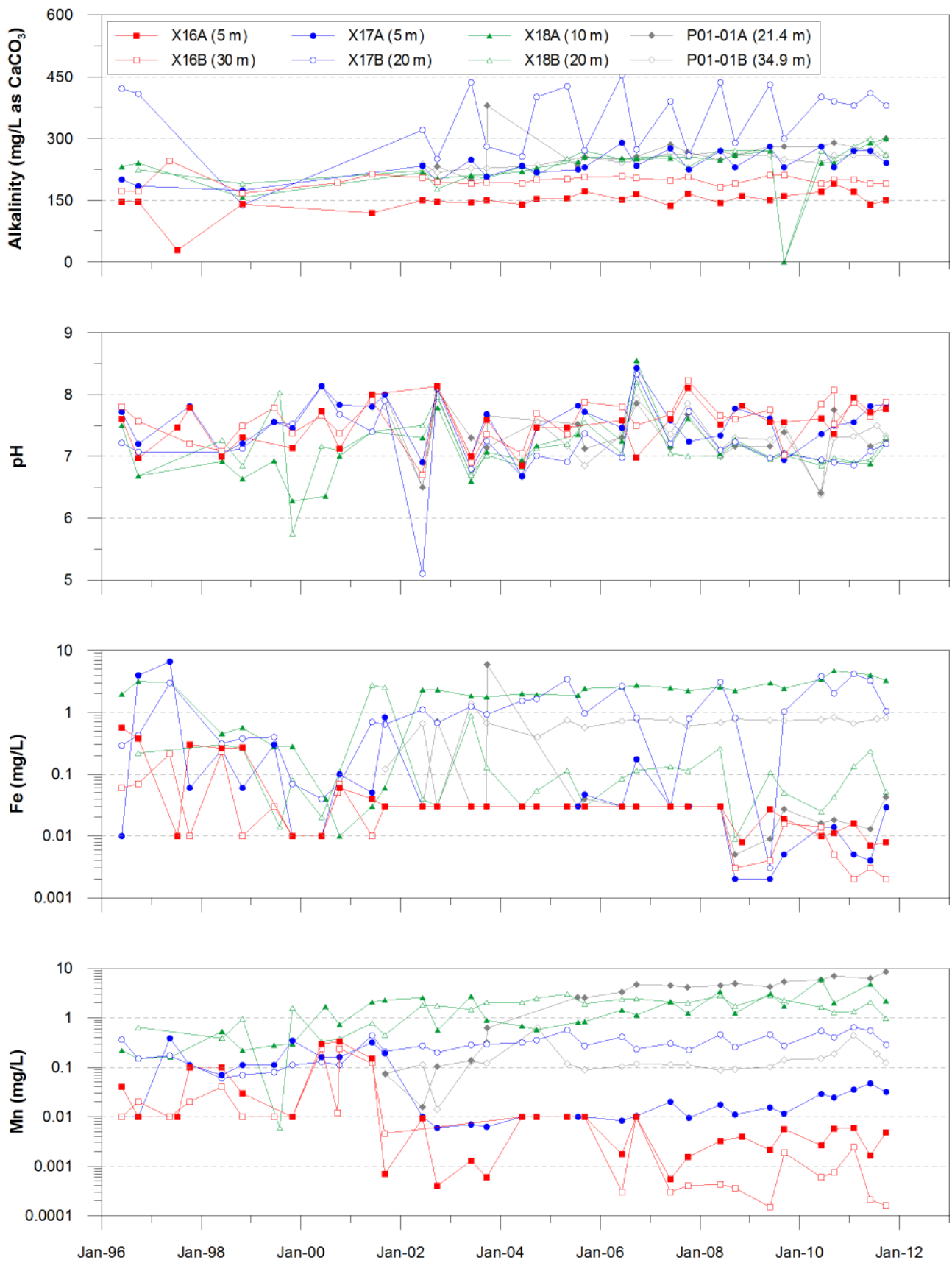
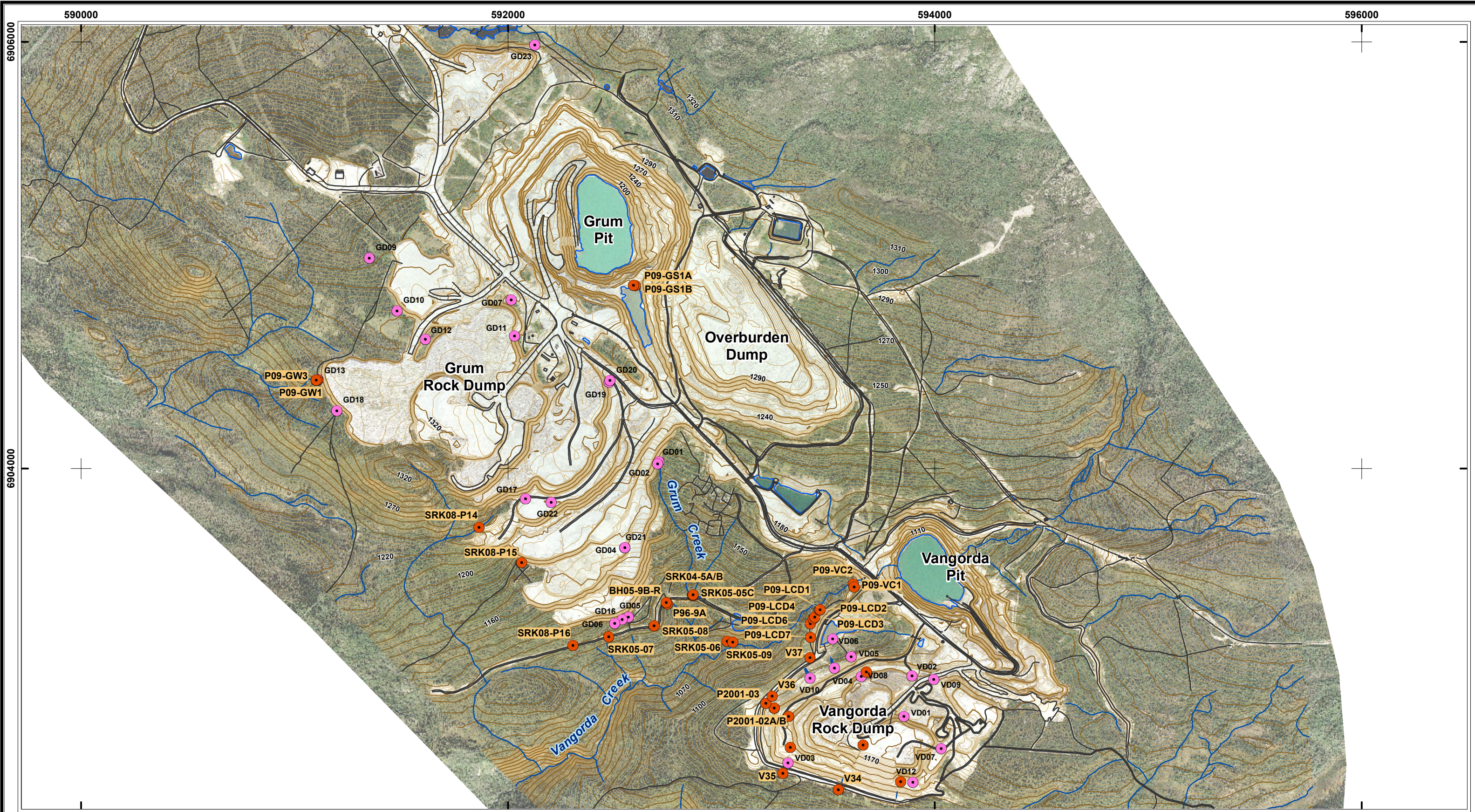
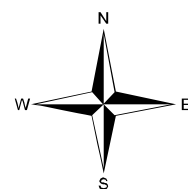


Figure 3-19b. Time trends for alkalinity, pH, Fe and Mn in wells downgradient of Cross Valley Dam

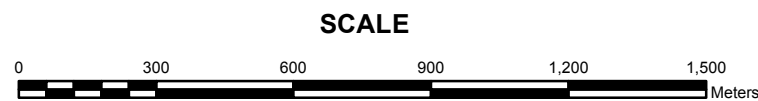


LEGEND
 ● Monitoring Well
 ● Seep Monitoring Station

PROJECTION: UTM
 ZONE: 8
 DATUM: NAD 83
 UNITS: Meters
 CONTOUR INTERVAL: 2m



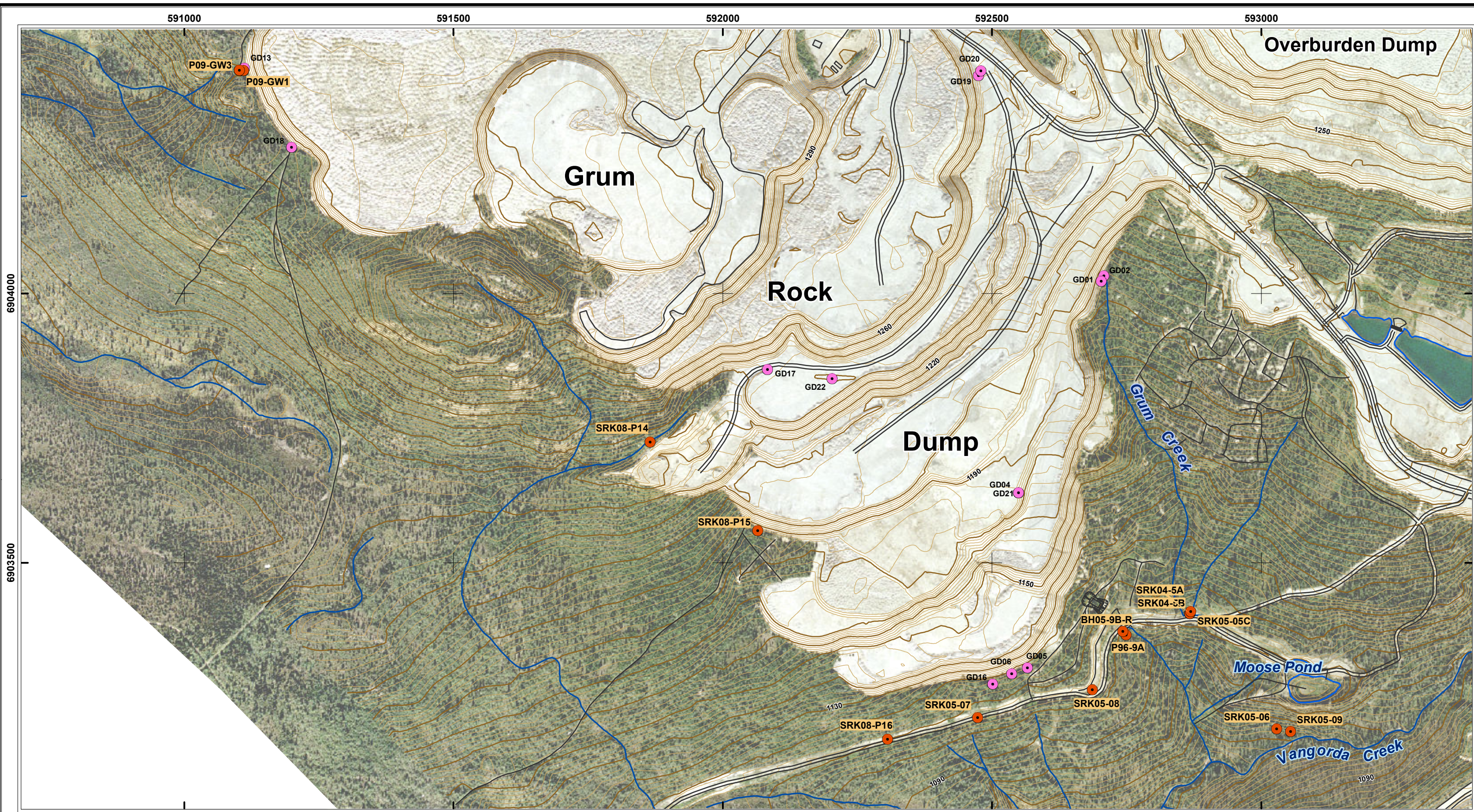
Layout of Grum & Vangorda Mine Site
 Anvil Range Mining Complex



CLIENT: Yukon Government
 PROJECT: 2010 ARMC Groundwater Review
 REPORT: RGC 118018
 LOCATION: Anvil Range Mining Complex, YT, Canada



FIGURE: 4-1
 DATE: 032411
 DRAWN BY: OM
 FILE: Faro_GrumVangorda_11.mxd

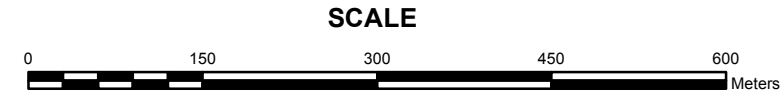
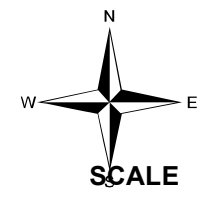


6904000
6903500

591000 591500 592000 592500 593000

LEGEND
 ● Monitoring Well
 ● Seep Monitoring Station

PROJECTION: UTM
 ZONE: 8
 DATUM: NAD 83
 UNITS: Meters
 CONTOUR INTERVAL: 2m



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



CLIENT: Yukon Government
 PROJECT: 2010 ARMC Groundwater Review
 REPORT: RGC 118018
 LOCATION: Anvil Range Mining Complex, YT, Canada



FIGURE: 4-2
 DATE: 032411
 DRAWN BY: OM
 FILE: Faro_Grum_11.mxd

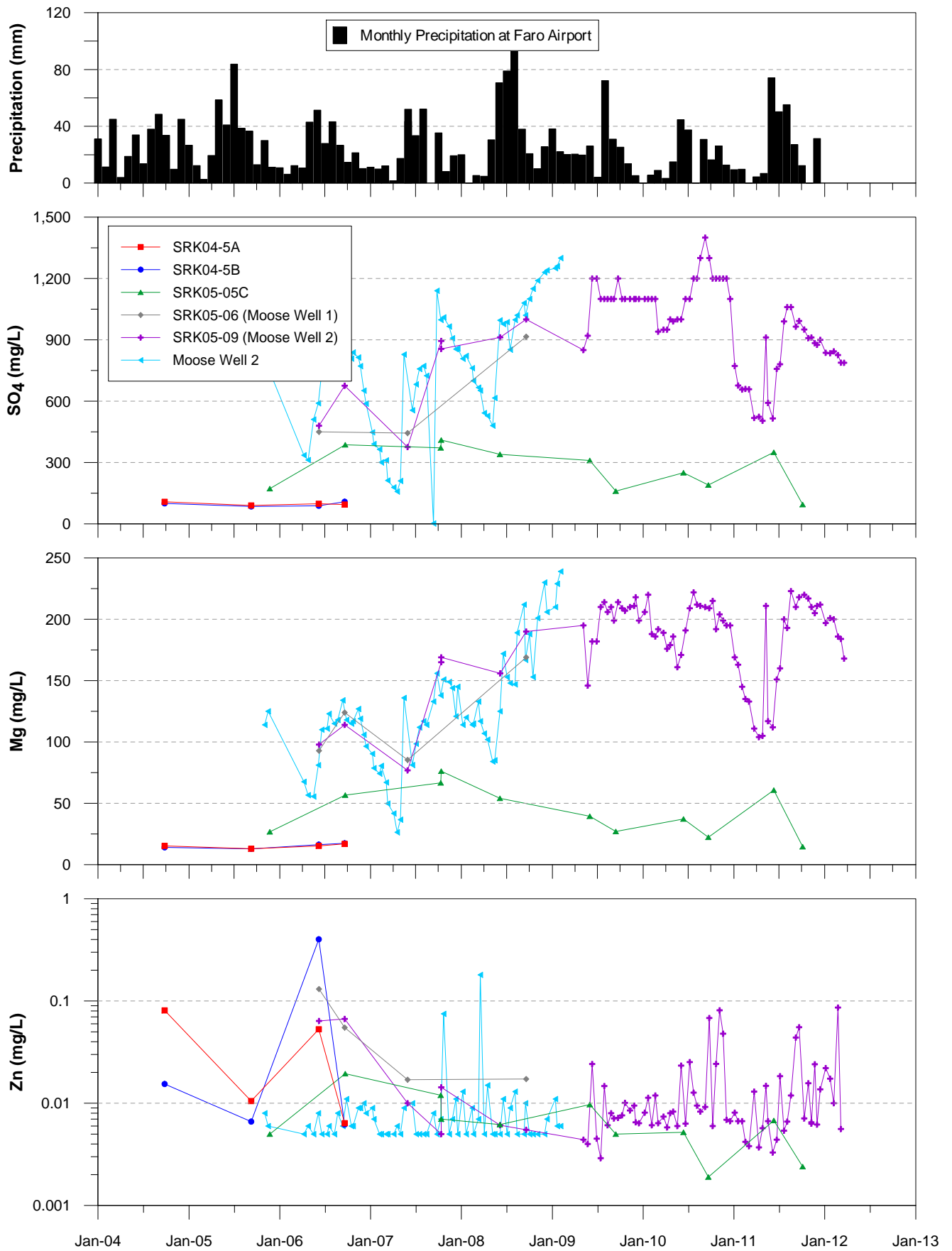


Figure 4-3a. Time trends for SO_4 , Mg and Zn in wells in Grum Creek drainage

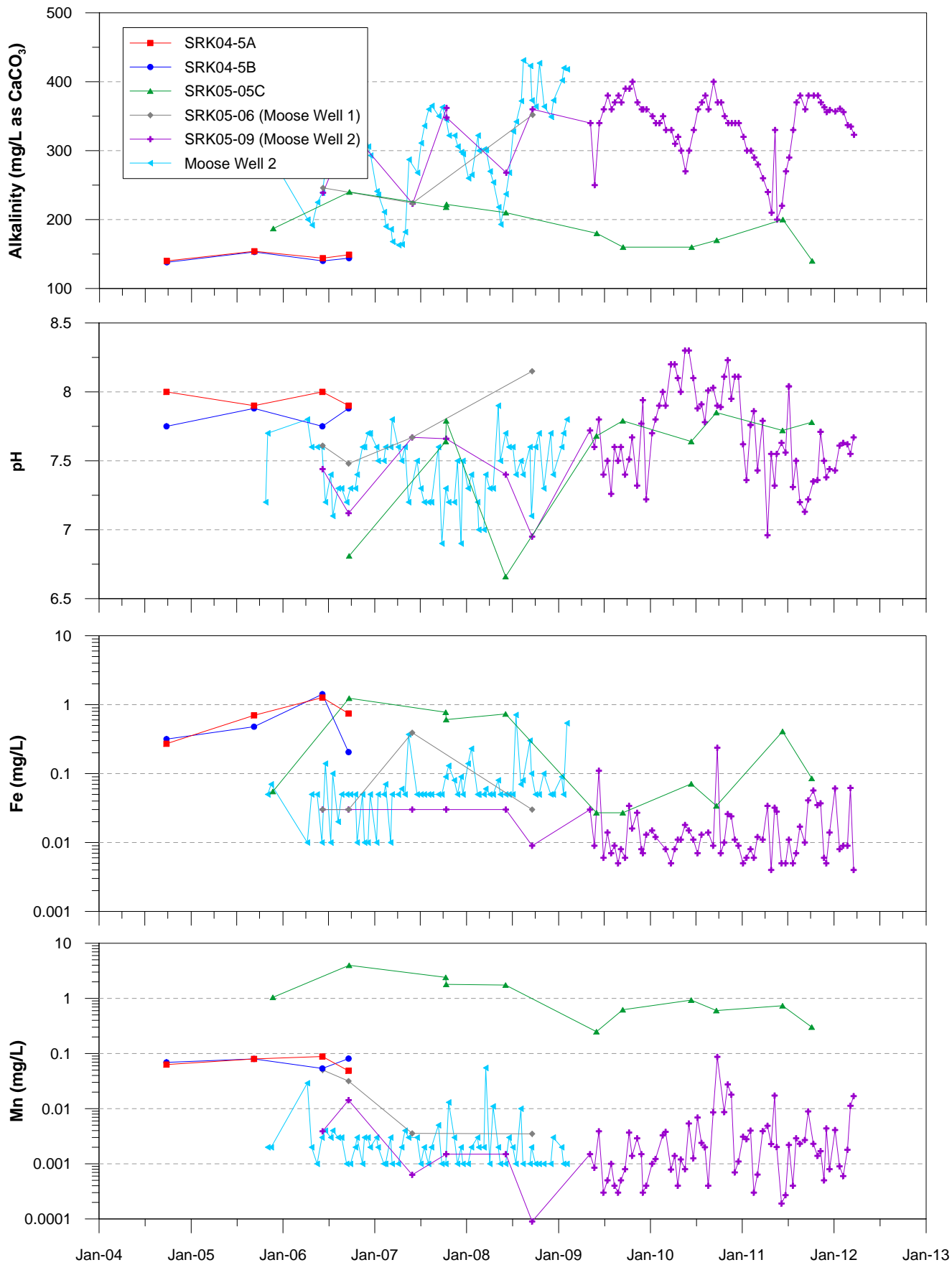


Figure 4-3b. Time trends for alkalinity, pH, Fe and Mn in wells in Grum Creek drainage

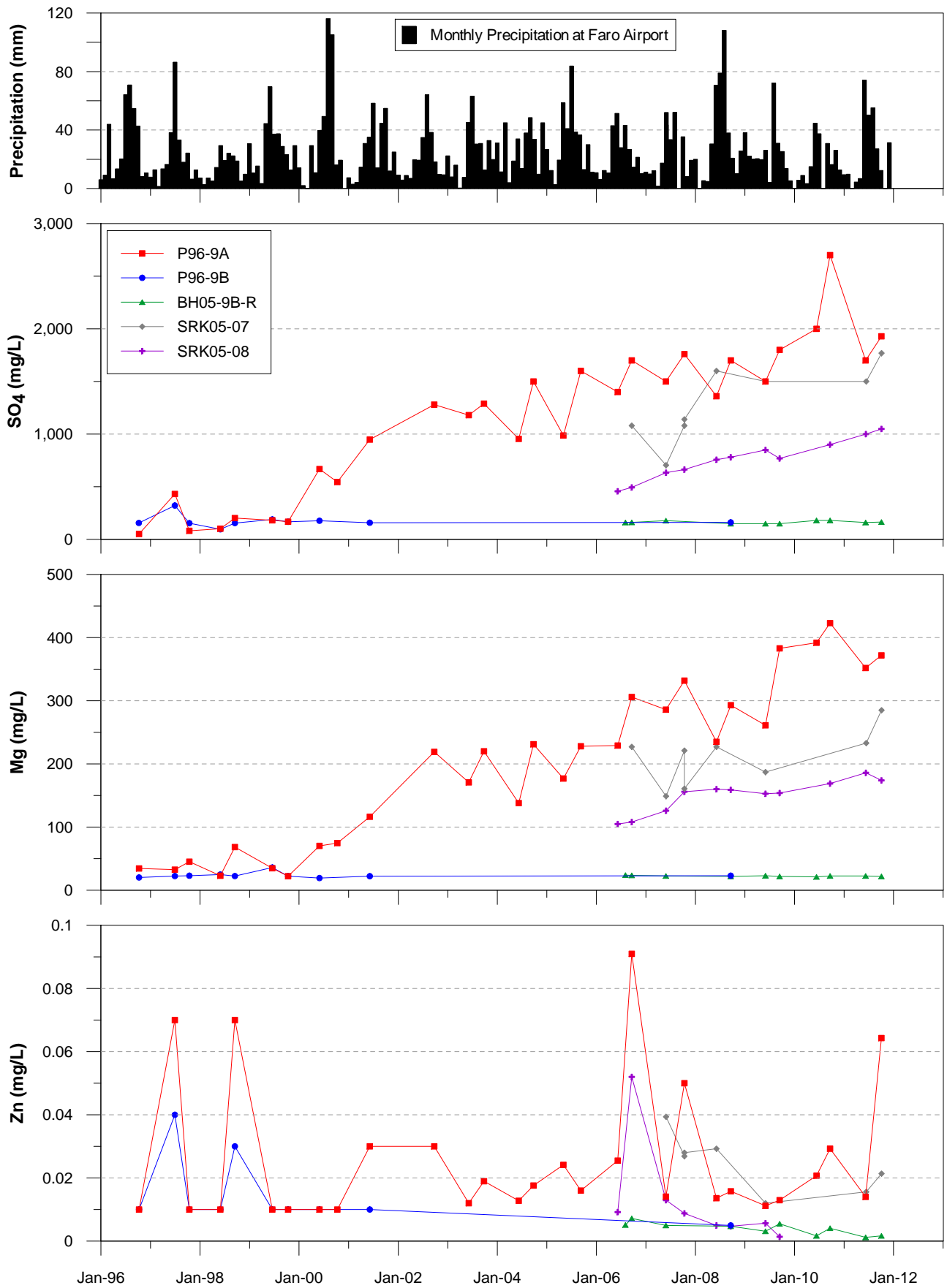


Figure 4-4a. Time trends for SO₄, Mg and Zn in wells located west of Grum Creek

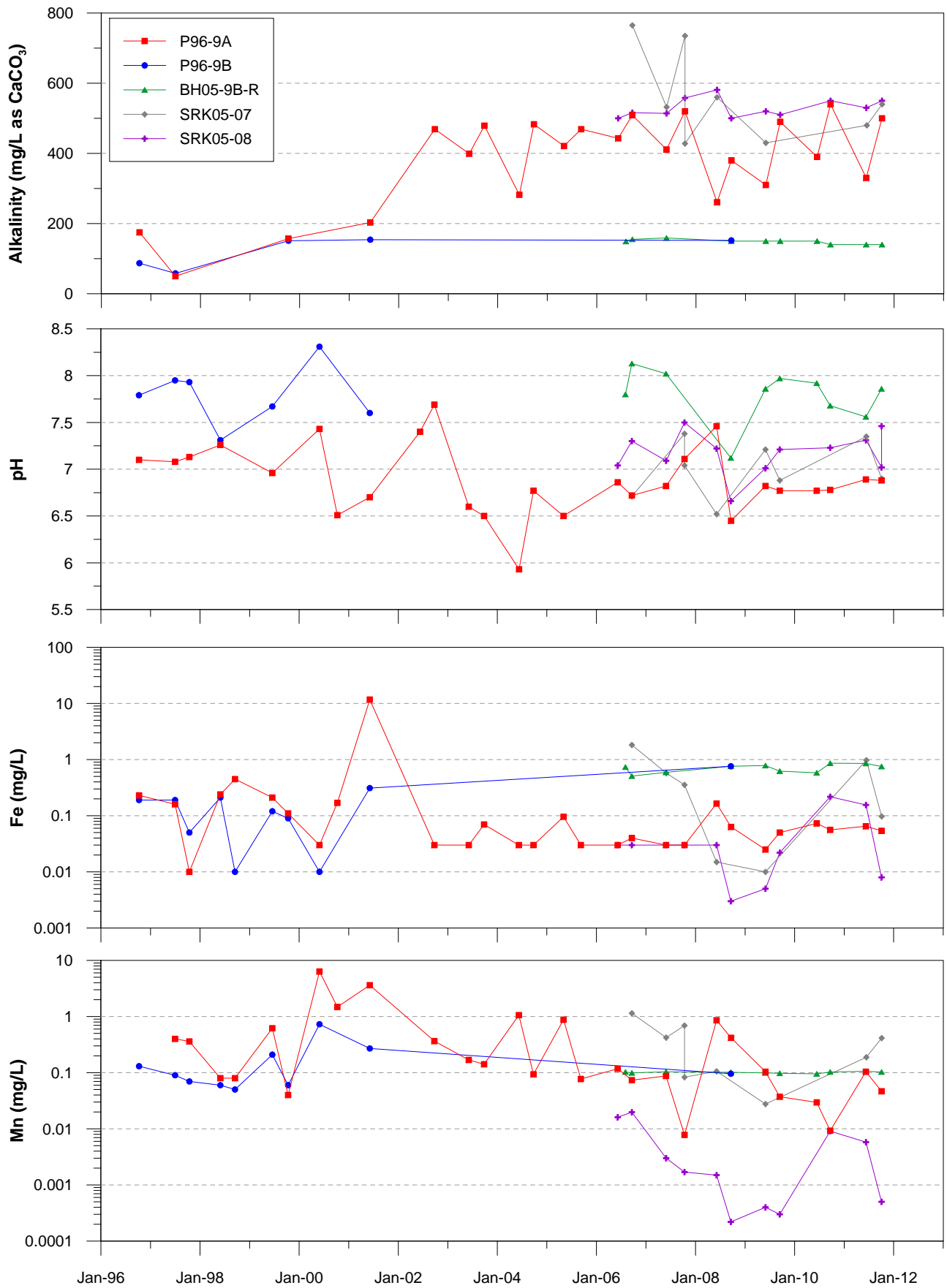


Figure 4-4b. Time trends for alkalinity, pH, Fe and Mn in wells located west of Grum Creek

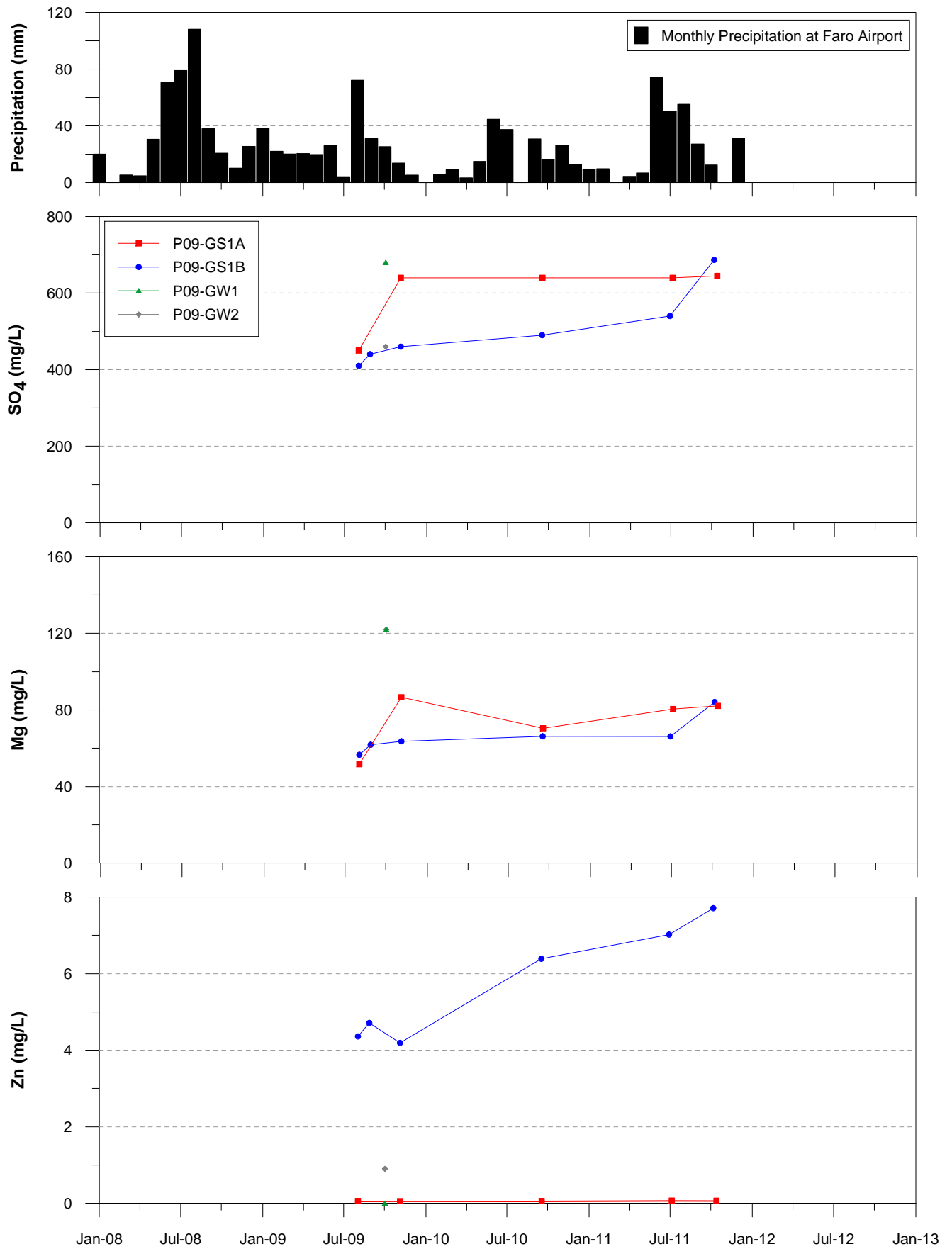


Figure 4-5a. Time trends for SO₄, Mg, Na and Zn in wells located near Grum Slot and west of Grum Dump

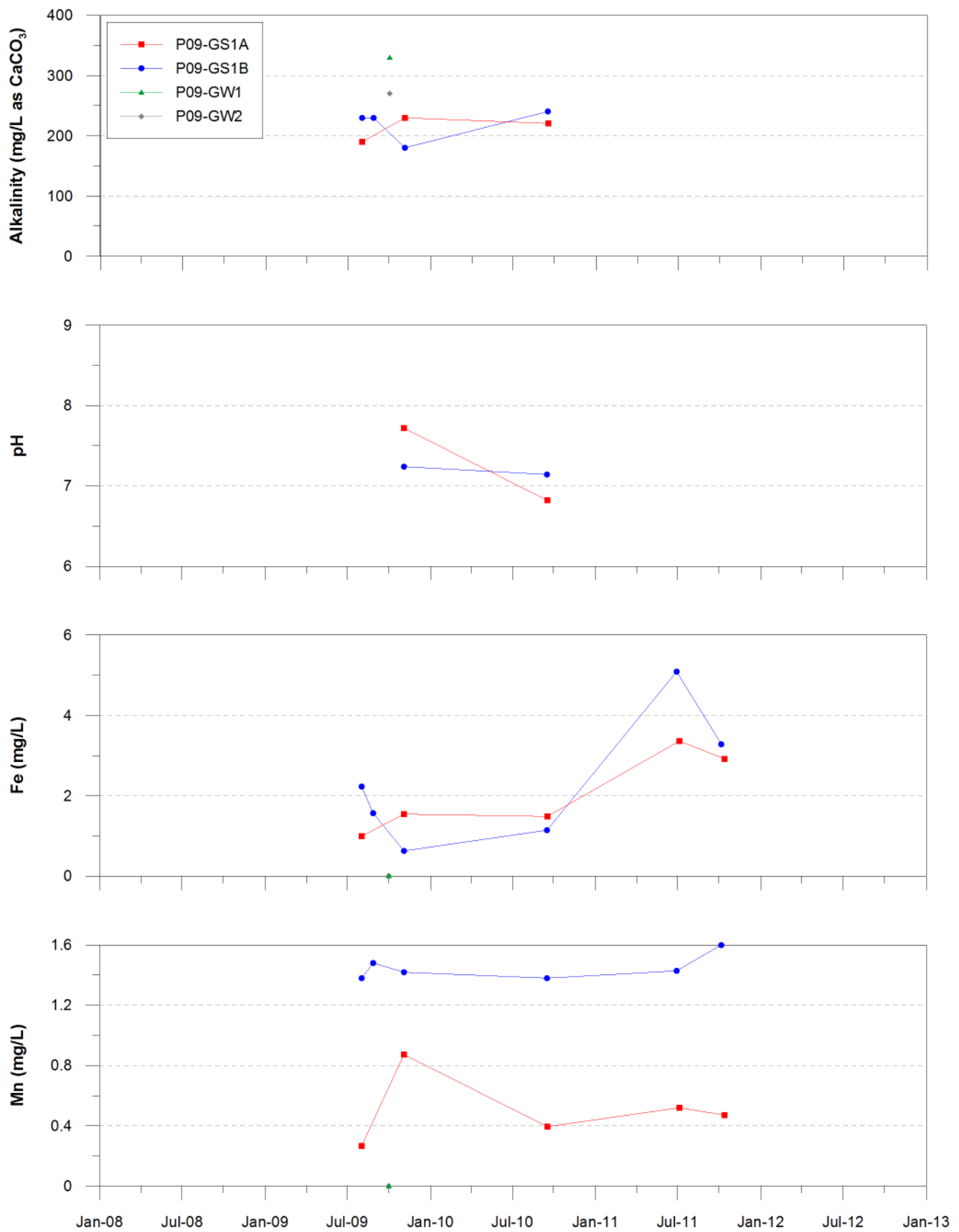


Figure 4-5b. Time trends for alkalinity, pH, Fe and Mn in wells located near Grum Slot and west of Grum Dump

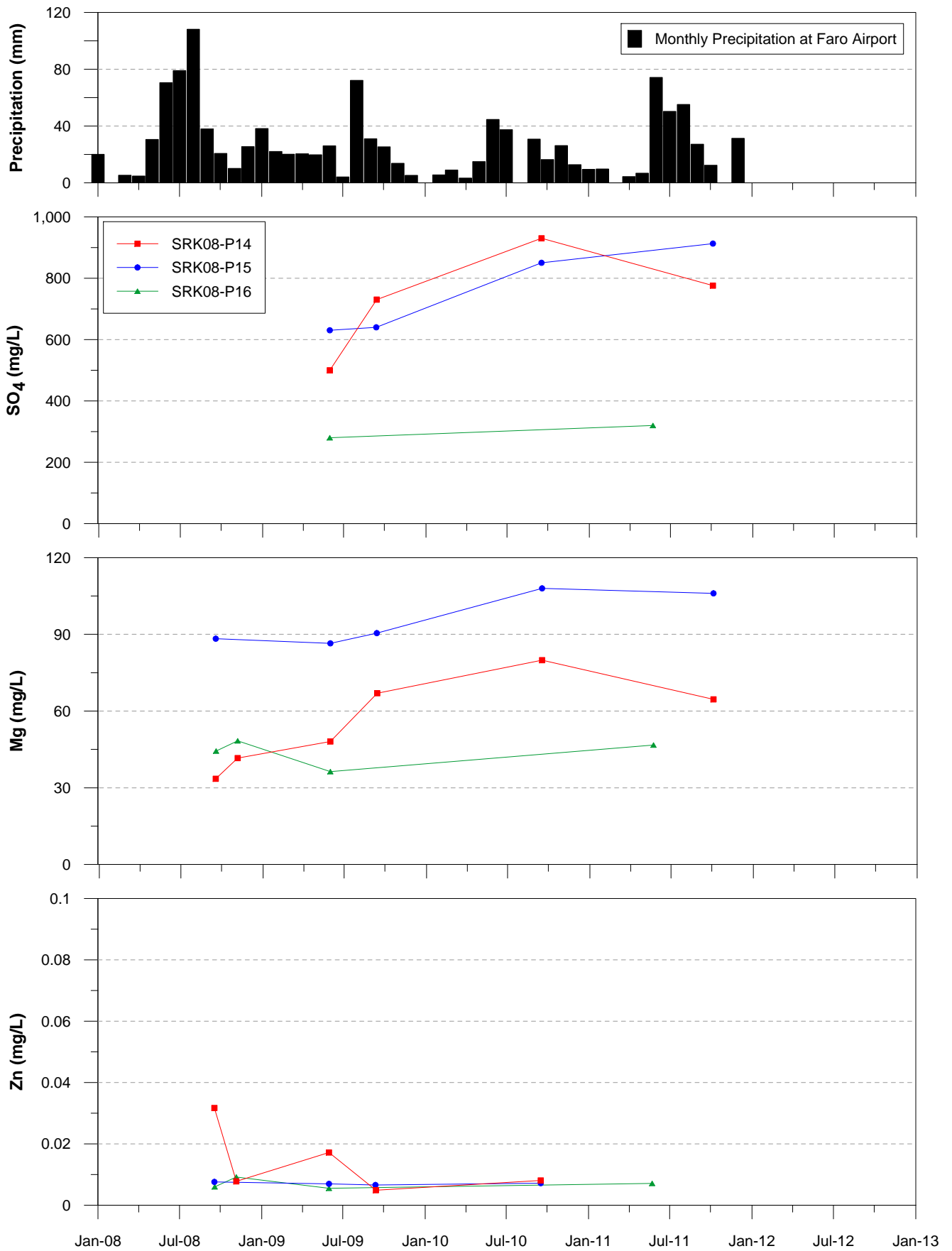


Figure 4-5c. Time trends for SO₄, Mg, Na and Zn in SRK08 wells located southwest of Grum Dump

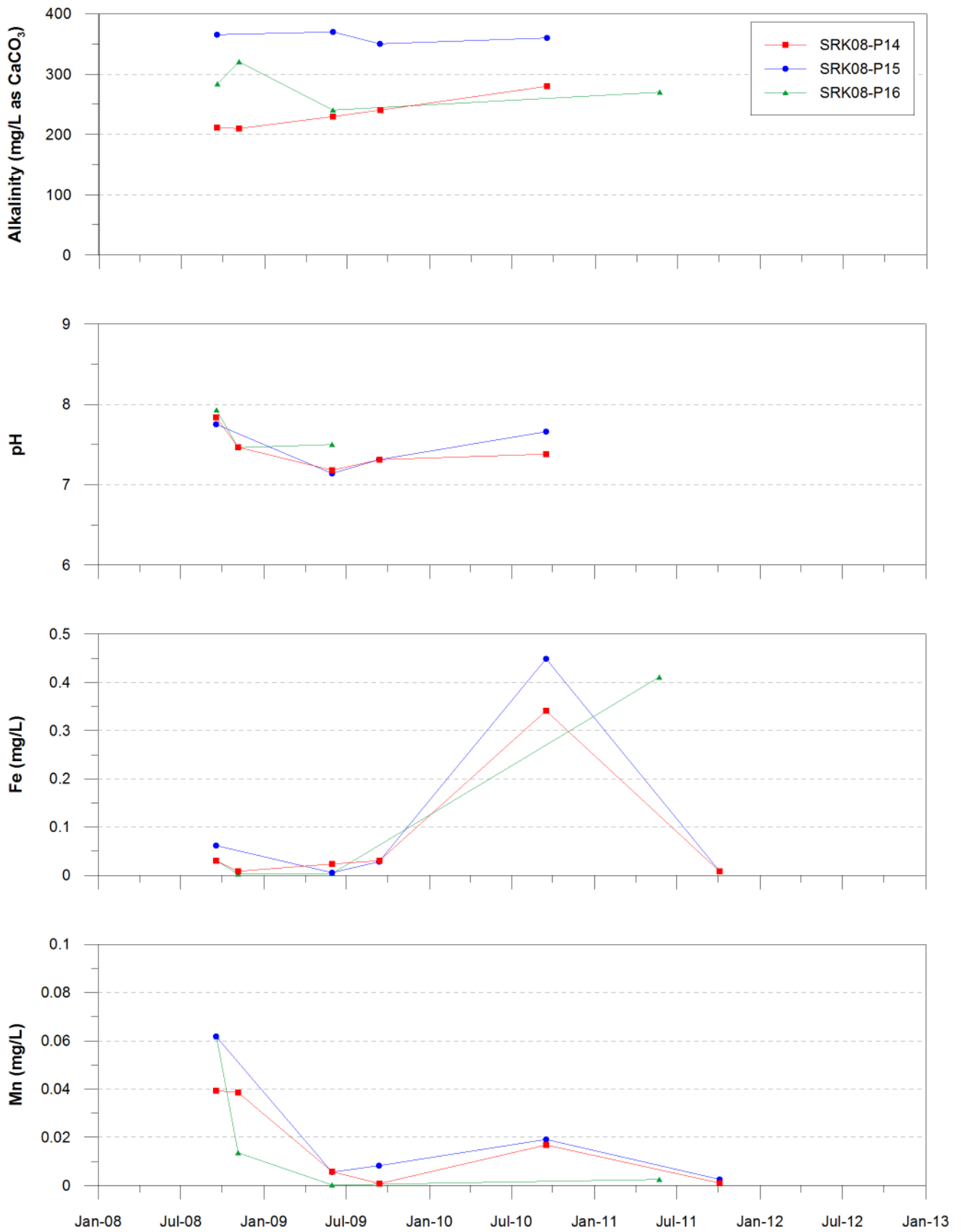
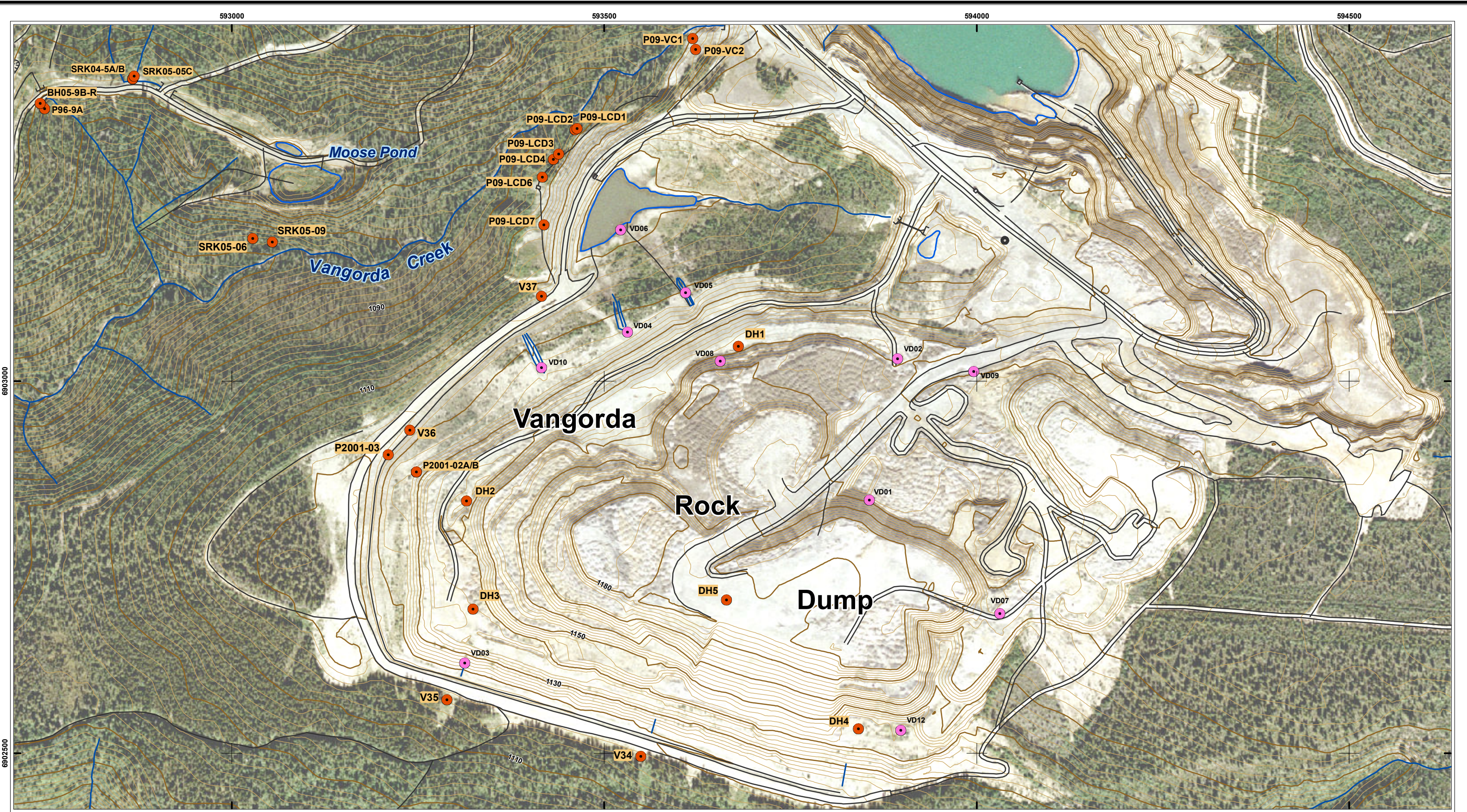


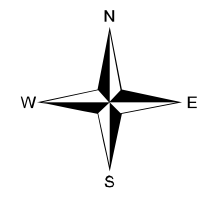
Figure 4-5d. Time trends for alkalinity, pH, Fe and Mn in SRK08 wells located southwest of Grum Dump



LEGEND

- Monitoring Well
- Seep Monitoring Station

PROJECTION: UTM
 ZONE: 8
 DATUM: NAD 83
 UNITS: Meters
 CONTOUR INTERVAL: 2m



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

SCALE



CLIENT: Yukon Government
 PROJECT: 2010 ARMC Groundwater Review
 REPORT: RGC 118018
 LOCATION: Anvil Range Mining Complex, YT, Canada



FIGURE: 4-6

DATE: 032411
 DRAWN BY: OM
 FILE: Faro_Vangorda11.mxd

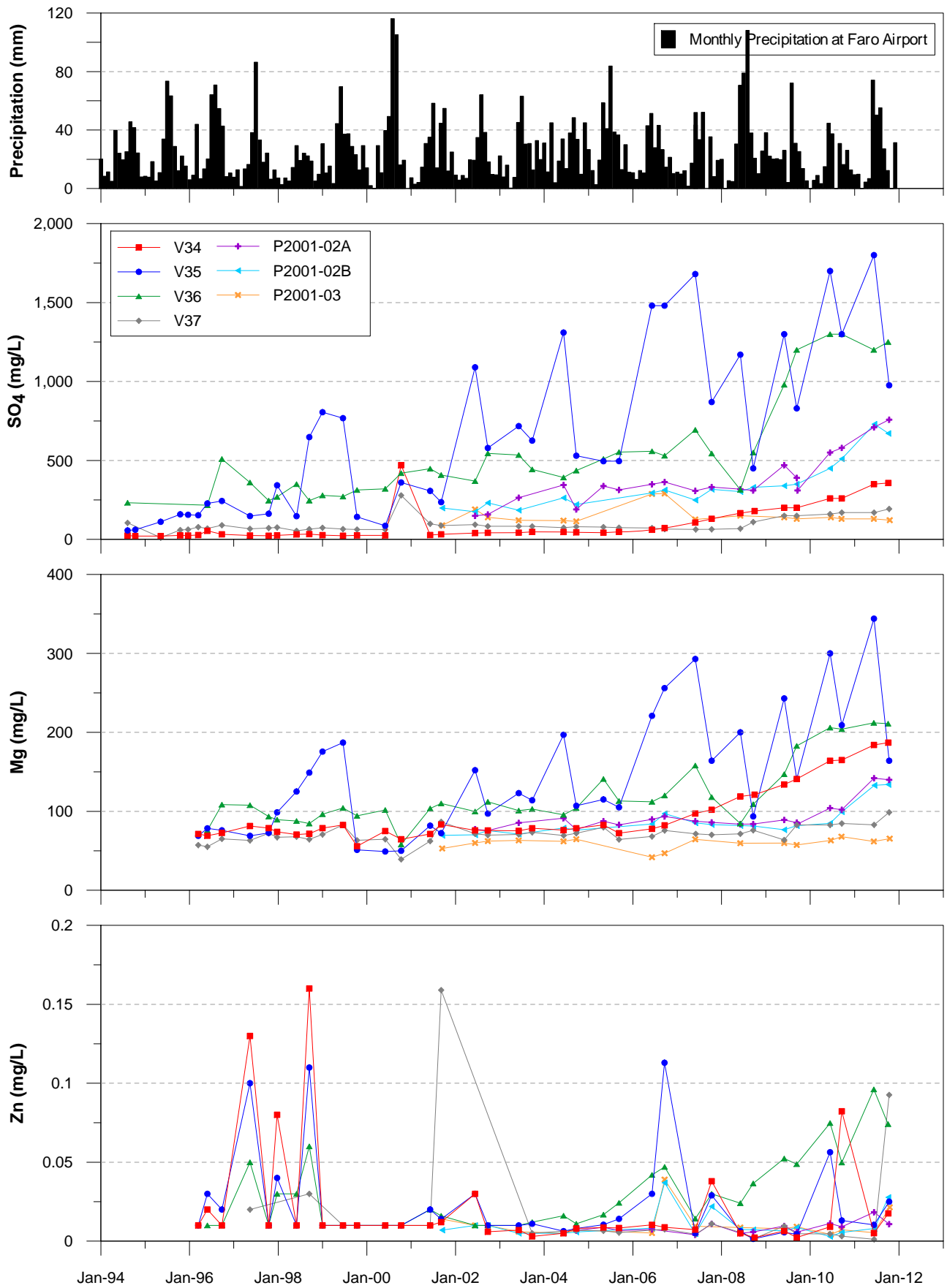


Figure 4-7a. Time trends for SO₄, Mg and Zn in wells downgradient of Vangorda Rock Dump

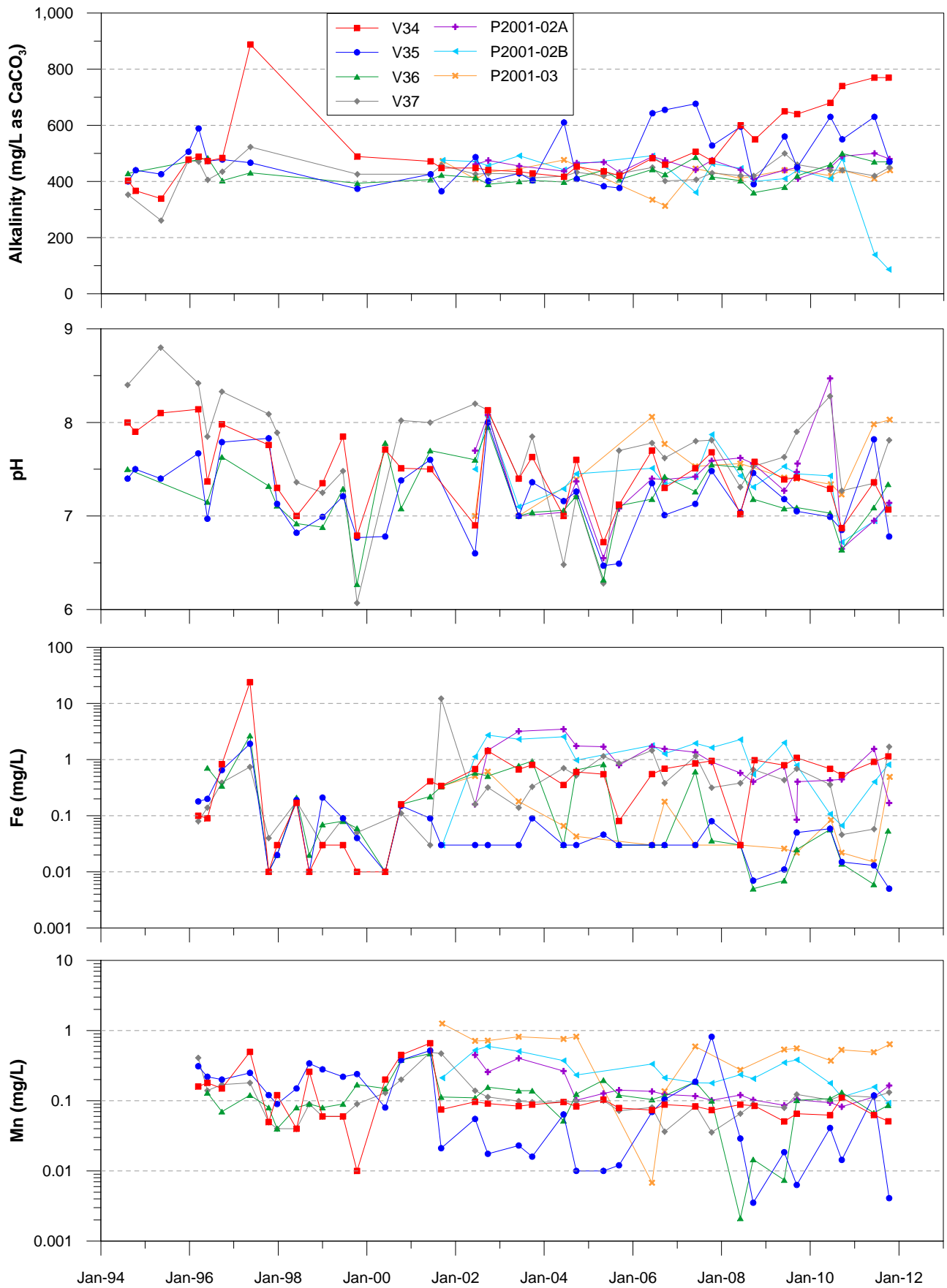


Figure 4-7b. Time trends for alkalinity, pH, Fe and Mn in wells downgradient of Vangorda Rock Dump

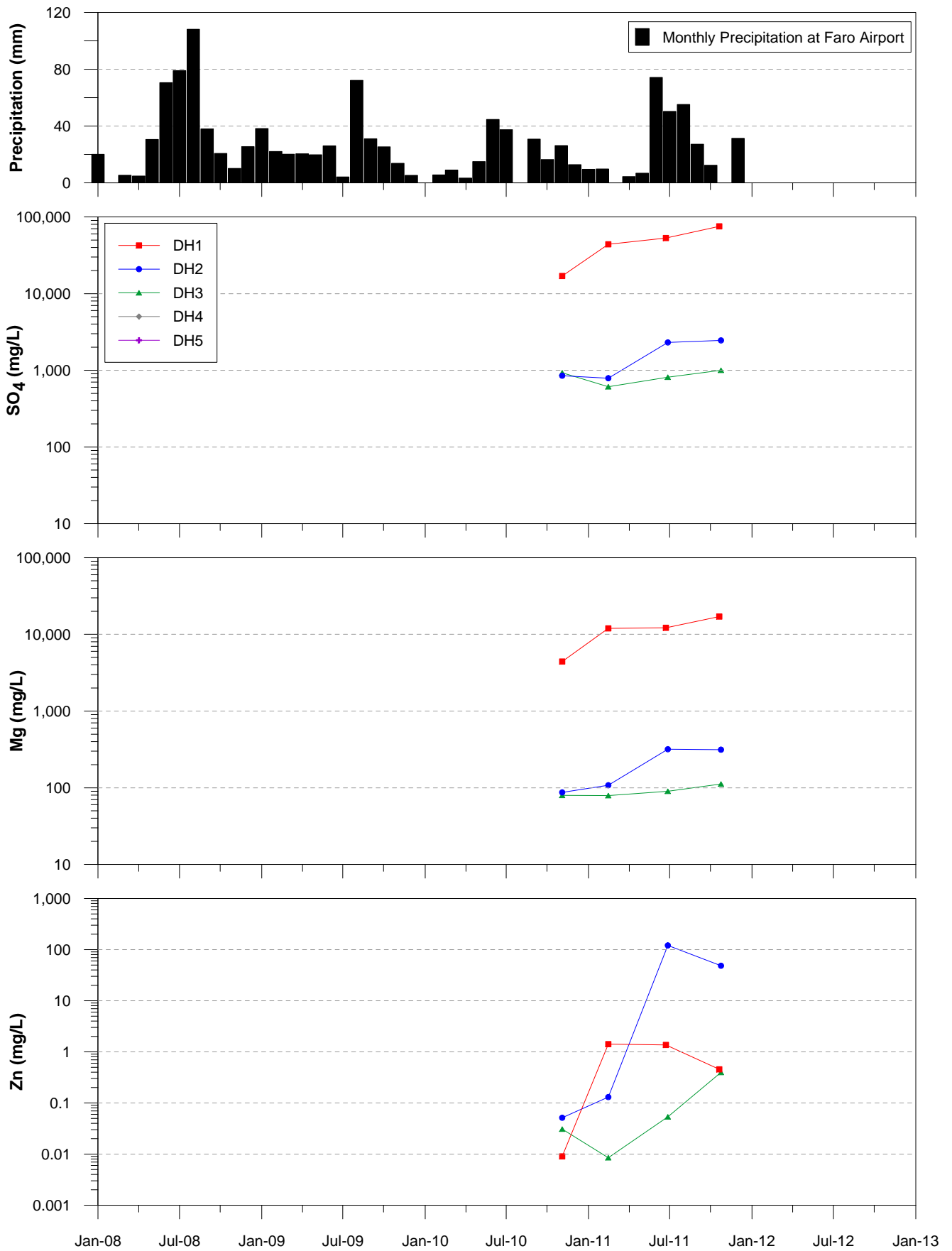


Figure 4-8a. Time trends for SO₄, Mg, Na and Zn in Vangorda Waste Rock Dump Wells

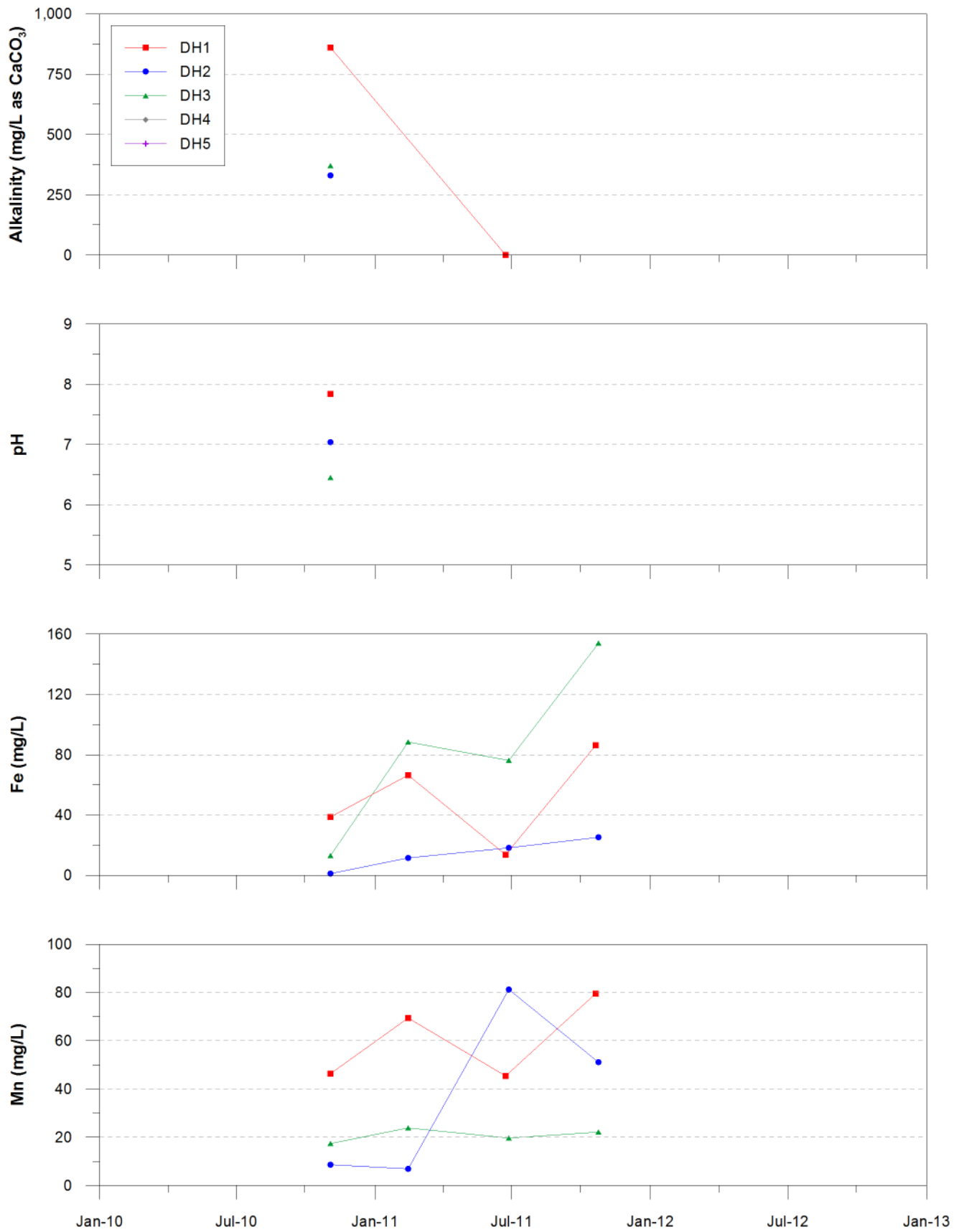


Figure 4-8b. Time trends for alkalinity, pH, Fe and Mn in Vangorda Waste Rock Dump wells

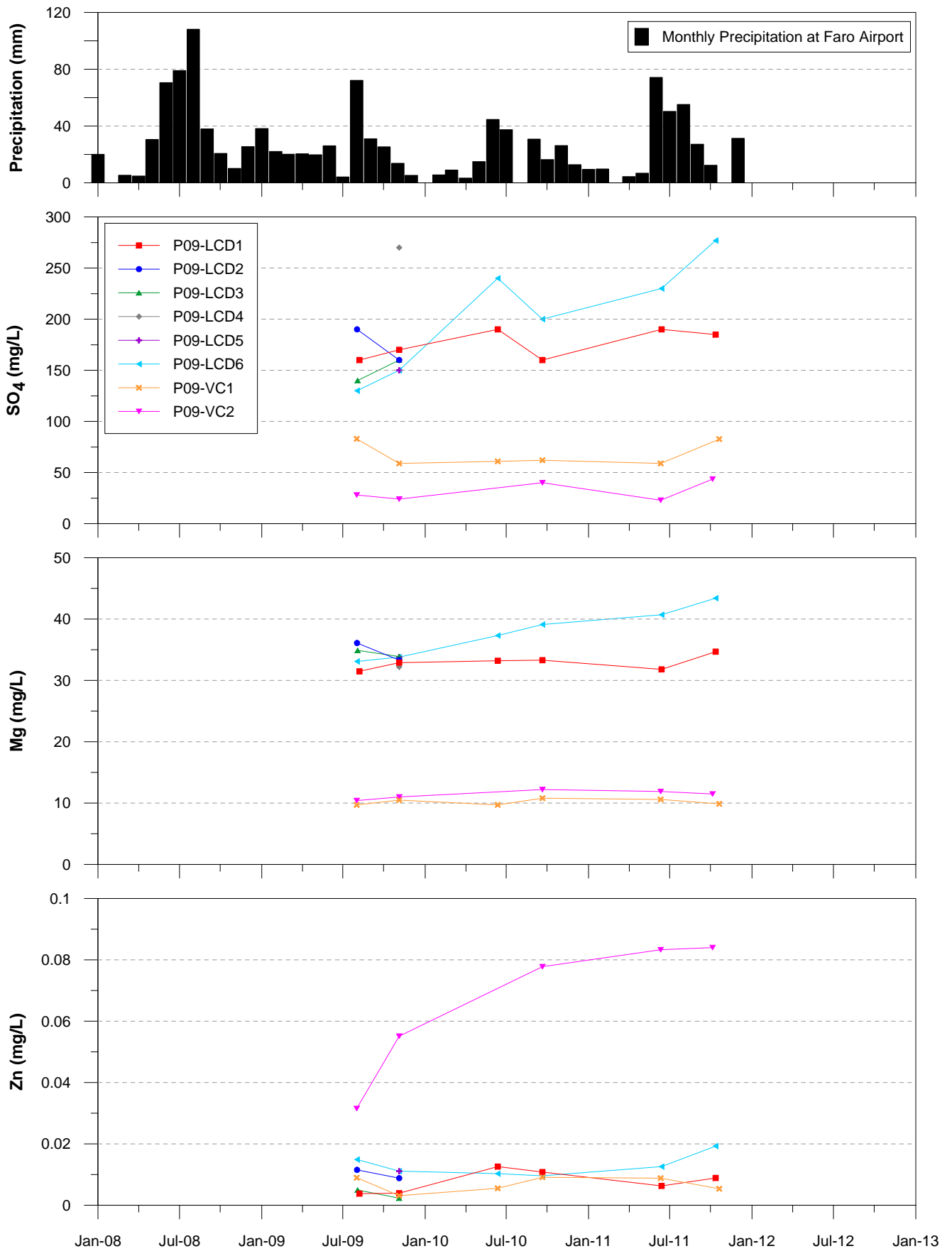


Figure 4-9a. Time trends for SO₄, Mg, Na and Zn in wells near Vangorda Creek and Little Creek Dam

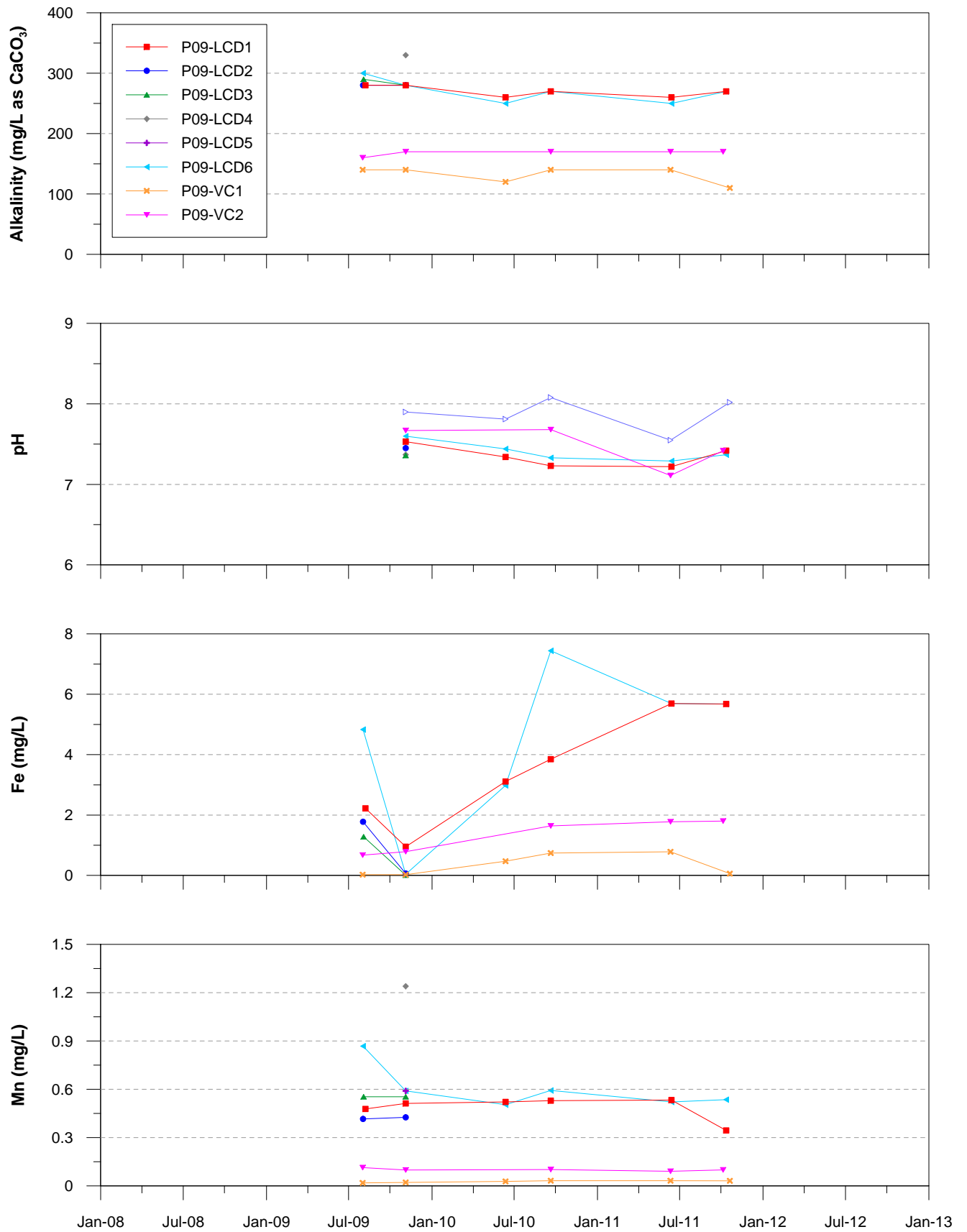


Figure 4-9b. Time trends for alkalinity, pH, Fe and Mn in wells near Vangorda Creek and Little Creek Dam