Report No. 118017/1

2009 GROUNDWATER QUALITY REVIEW

ANVIL RANGE MINING COMPLEX, YUKON TERRITORY

Prepared for:

Yukon Government

On behalf of

Faro Mine Closure Planning Office

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EXECUTIVE SUMMARY

Recent time trends in groundwater quality were reviewed in different reaches of the Anvil Range Mining Complex in order to identify changes in groundwater quality that occurred in 2009. The main conclusions of this review can be summarized as follows:

Faro Mine Site

In the Emergency Tailings Area (ETA), seepage water quality at X23 continued to deteriorate in 2009 as it has since early 2008. Increased concentrations of SO_4, Mg, and metals of interest do not appear to be related to “flushing events” caused by recharge to the Main WRD but instead seem to be related to enhanced oxidation/dissolution processes within the waste rock pile itself. The recently-installed seepage interception system has improved in groundwater quality in ETA (and in the Rose Creek aquifer downgradient of Faro Creek canyon).

Near the toe of the Northeast Rock Dump (at wells BH14A/B), SO_4, Mg, and metals of interest concentrations in groundwater continued to increase in 2009 likely due to seepage from sulphide-rich waste rock in the Northeast Rock Dump. The trend towards higher concentrations of SO_4 and metals of interest in this area is cause for concern because it appears that a substantial load of waste rock seepage is delivered to groundwater near NFRC (at wells SRK08-P12A/B).

In the S-cluster, concentrations of SO_4, Mg, and other metals of interest in highly-impacted groundwater decreased in 2009, suggesting that the S-Cluster SIS has had a positive effect on groundwater quality in this area. Several of the “P09-SIS” wells located downgradient of the interception trench showed increased concentrations of SO_4, Mg, and metals of interest from September 2009 to November 2009 but additional monitoring data is necessary to determine if there is a trend towards higher concentrations or if concentrations will decrease in 2010 as expected.

In the Zone 2 Pit outwash area, groundwater remains impacted by seepage but groundwater quality did not deteriorate further in 2009.

Rose Creek Tailings Facility

Groundwater quality in the northern portion of the Rose Creek aquifer remains highly-impacted by mine waste seepage but some improvement in groundwater quality was observed near the mouth of Faro Creek canyon (at well P03-06) due to operation of the ETA SIS.

Impacted groundwater continues to move downgradient along the northern side of the Rose Creek aquifer, as evidenced by a gradual breakthrough of SO_4, Mg, alkalinity and selected metals (Fe, Mn) in monitoring wells at the Intermediate dam (well X24), Cross Valley Dam (wells P01-11 and P05-01) and further downgradient (wells X18 and P01-01). The transport of Zn, however, is still delayed, likely due to chemical attenuation in the aquifer.

Concentrations of major ions and metals of interest have remained consistent (or even increased slightly) in wells P03-03 and P03-06 since decommissioning of the “leaky wells” in 2005. The lack of improvement in groundwater quality suggests that the “leaky wells” may not have been a primary source of major ions and metals of interest to groundwater at P03-03 and that an ongoing source(s) of these contaminants remains in the Original Impoundment.

Grum/Vangorda Mine Site

Gradually increasing concentrations of SO_4 and Mg in the wells along the toe of the Grum Dump suggest that seepage from the Grum waste rock dump has not only impacted groundwater quality in narrow side-valleys comprised of permeable alluvial sediments (at well P96-9A) but has also impacted groundwater in less permeable bedrock nearby (at wells SRK05-07 and SRK05-08). However, Zn concentrations remained low in these wells, suggesting the breakthrough of a “TDS front” may have occurred but dissolved metals have not yet reached groundwater in this area.

Groundwater quality in wells located downgradient of the Vangorda Rock Dump continued to show some impact by neutralized mine drainage, as did groundwater near the Little Creek Dam. Groundwater near Vangorda Creek, however, appears to be unimpacted by mine waste seepage.

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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 variations 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, 2004; 2006a). In 2007, RGC was commissioned to carry out a more comprehensive review of groundwater quality across the ARMC, including the Rose Creek Tailings Facility, the Zone 2 Pit outwash area, and the areas surrounding the Grum and Vangorda rock dumps (RGC, 2008). Since then, RGC has conducted an annual review of groundwater quality data in order to (i) identify any changes in groundwater quality that occurred over the previous monitoring period and (ii) provide recommendations regarding future groundwater monitoring. The current report provides a review of groundwater quality data collected from October 2008 to November 2009.

1.2 Study Objectives

The objectives of this report were to:

- Review groundwater quality data collected from October 2008 to November 2009 across the ARMC and identify any improvements and/or degradations in groundwater quality that occurred over that time period; and

- Recommend any changes, if required, to the routine groundwater monitoring program at the ARMC for 2010.

The focus of this monitoring report is to document routine monitoring data and, specifically to highlight any significant changes in groundwater quality over time. A detailed geochemical interpretation of the groundwater quality data was beyond the scope of this report. For a more detailed assessment of groundwater quality in selected areas of the ARMC the reader is referred to (RGC 2010a) and SRK (2010).

1.3 Scope of Work

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

- Faro Mine Site (Faro WRDs & ETA)
- Rose Creek valley
- Grum and Vangorda Mine Site

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 January 11 2010. A complete QA/QC of the data was beyond the scope of this review so time trends were based on the raw data that was downloaded. Some inconsistencies in the data entered into the database were identified in a separate study (RGC, 2010a) but the interpretation of groundwater quality time trend was not significantly affected by these minor data entry errors.

2 FARO MINE SITE

2.1 Geographic Overview

The Faro mine site consists of the Faro Pit, the surrounding Faro 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 are illustrated in Figure 2-1. Note that only wells installed in 2008 and 2009 are labelled in Figure 2-1.

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

- the Emergency Tailings Area (ETA) & Main Dump Area;
- 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)

2.2.1 Background & Well Locations

Figure 2-2 shows the general layout of the ETA and the groundwater monitoring wells located 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 (total depth, screening interval), and the current status of monitoring.

Two wells were installed in 2009 near the mouth of Faro Creek canyon. Well P09-ETA-01 is screened in low permeability bedrock whereas well P09-ETA-02 is screened in highly-permeable material near the overburden-bedrock contact (SRK, 2010). Both of these wells were sampled initially upon their completion and then again in November 2009 as part of the routine monitoring program. Installation of a third well (P09-ETA-03) in the ETA was unsuccessful due to poor drilling conditions (SRK, 2010).

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

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
ETA Area							
P96-8A	1996	4.2	1.15	4.17	1109.39	Bi-annual	Alluvium
P96-8B	1996	8.6	5.50	8.52	1109.48	Bi-annual	Alluvium
SRK04-3A	2004	11.9	10.40	11.90	1104.55	Annual	Tailings/All
SRK04-3B	2004	7.1	5.50	7.00	1104.63	Not routinely monitored	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	Bi-annual	OB/BR Contact
Main Dam/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	Not routinely monitored	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	Not routinely monitored	Weathered BR
SRK08-P11B	2008	6.1	3.05	6.1	1137.226	Not routinely monitored	Overburden

2.2.2 Review of Time Trends

Figure 2-3a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest in seepage from the Main WRD (the V-notch weir at X23) and groundwater from wells P96-8A/B. Wells P96-8A/B are screened in alluvium near the toe of the Main WRD approximately 15 m southwest of X23. The V-notch weir at X23 is also referred to as station 'FCS-1' in ETA SIS monitoring but X23 is used in this report for simplicity (RGC, 2010b).

In seepage at X23, the concentrations of SO_4, Mg, and metals of interest (Zn, Fe, and Mn) increased in 2009. This increase follows a trend of increasing concentrations that began in early 2008. The Zn concentration at X23, for instance, increased from ~150 mg/L in January 2008 to ~1,000 mg/L at the end of 2009. The recent trend towards higher concentrations of major ions and key metals of interest in seepage at X23 is also observed in wells P96-8A/B. Short-term changes in the concentrations of major ions and metals of interest in wells P96-8A/B have often mimicked the trends observed in surface seepage at X23 and have previously been attributed to the 'flushing' of accumulated oxidation products from the Main WRD to groundwater during high rainfall periods (RGC, 2008). This apparent 'flushing' effect was particularly evident during a period of high rainfall in the year 2000.

Because precipitation has not been unusually high over the past two years, recent increases in major ions and metals of interest are unlikely to be related to 'flushing' events. Instead, it seems more likely that some breakthrough of more highly-contaminated seepage from the Main WRD (and other dumps draining towards X23) has occurred. The breakthrough of this more contaminated seepage explains deteriorating water quality conditions at X23 and in groundwater downgradient at wells P96-8A/B. Note that highly acidic conditions have been observed at X23 on several occasions in 2008/2009, which suggests a gradual depletion in buffering capacity along the flowpath in the WRD. More acidic seepage has also resulted in a gradual decrease in pH (and alkalinity) in groundwater from alluvial sediments downgradient.

If seepage water quality were to continue to deteriorate, concentrations of SO_4, Mg, and and metals of interest in seepage at X23 may continue to increase in the future. In turn, groundwater quality in wells P96-8A/B would also deteriorate further until the contaminant load from the Main WRD is reduced and current contaminant levels are flushed from the area. Future/additional monitoring data is required to confirm that seepage from the Main WRD is deteriorating and that groundwater quality downgradient is being affected.

Wells SRK08-P09, SRK08-P10A/B, and SRK08-P11A/B are each located in the Mill Site area (Figure 2-1). Specifically, SRK08-P09 is located below the toe of the Main WRD to the southeast of the mill. SRK08-P10A/B is located downgradient of the mill near the ETA and SRK08-P11A/B is located near Guardhouse Creek (Table 2-1). Elevated SO_4 concentrations are observed in each of these wells but Zn concentrations remain low (< 0.15 mg/L) (Figure 2-3c/d). Concentrations of SO_4, Zn, and other metals have not increase substantially since 2008 and hence groundwater quality appears to be relatively stable in the mill area. Of particular interest are the low concentrations of Zn and metals of interest in well SRK08-P9, which suggest that seepage from the Main WRD has not yet affected groundwater in this area to the same extent as groundwater near wells P96-8A/B.

Figure 2-4a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest in the four monitoring wells (wells SRK04-3A, SRK04-3B, SRK05-ETA-BR1, and SRK05-ETA-BR2) located up-gradient of the mine access road in the ETA and the two new wells near the mouth of Faro Creek canyon (wells P09-ETA-1 and P09-ETA-2). Groundwater in wells screened in the alluvial sediments of the Faro Creek channel (wells SRK04-3A and SRK05-ETA-BR1) or in a mixture of tailings and alluvial sands (well SRK04-3B) is characterized by slightly lower pH values and alkalinity concentrations and significantly higher concentrations of SO_4, Mg, and metals of concern (Zn, Fe, and Mn) than groundwater that resides in bedrock beneath the alluvium at well SRK05-ETA-BR2. These differences in groundwater quality indicate that groundwater in deep bedrock within the ETA is much less affected by mine waste seepage than the overlying alluvial channel (which is highly-impacted). Nonetheless, metal concentrations in deeper groundwater in the ETA area (e.g. 10 mg/L of Zn) are higher than natural background levels for groundwater at the ARMC and have risen slightly in the last two years.

Groundwater collected from well P09-ETA-01 (screened in deep bedrock near the mouth of Faro Creek canyon) is slightly alkaline (pH 8.0) and characterized by a higher concentration of alkalinity and orders-of-magnitude lower concentrations of dissolved metals than groundwater from well P09-ETA-02 (screened in overburden just below tailings). These concentrations indicate that groundwater in deep bedrock near the mouth of the Faro Creek canyon is not impacted by mine waste seepage. Conversely, well P09-ETA-02 is clearly impacted by seepage from tailings and/or the ETA area.

A more detailed geochemical and isotopic analysis suggested that high concentrations of SO_4 (~4,500 mg/L), Mn (40 mg/L), and Zn (71 mg/L) in well P09-ETA-02 are more likely related to FCS than tailings porewater although both sources likely contribute (RGC, 2010a). A Seepage Interception System (SIS) was recently installed in the ETA to capture seepage from the ETA area during ice-free months at the ARMC and subsequently divert it to the Intermediate Pond. A performance review completed by RGC for 2009 estimates that the ETA SIS captures almost 90% of total seepage in the ETA during ice free months but captures less than 50% of total seepage year-round due to winter shut-down (RGC, 2010b). Improvements to the ETA SIS, in particular year-round collection of seepage, would likely improve groundwater quality at well P09-ETA-2 (and in areas downgradient of Faro Creek canyon).

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 groundwater monitoring wells located in the area. Aside from well P96-7 (located near the western toe of the Outer Haul Road Rock Dump), the wells in this area are located between the southern toe of the Intermediate Rock Dump and NFRC. Table 2-2 summarizes pertinent information related to the groundwater monitoring wells located in the S-cluster area, including year of construction, installation details (total depth, screening interval), and the current status of monitoring.

In 2008, wells SRK08-SBR1, -SBR2, -SBR3, and -SBR4 were installed in bedrock in the S-cluster area to determine hydraulic properties and enable routine groundwater quality monitoring. Two additional sets of nested monitoring wells (wells SRK08-SP7A/B and SRK08-SP8A/B) were also completed downgradient of the S-cluster SIS near the North Fork of Rose Creek (NFRC). In the winter of 2008/2009, a SIS was constructed in the S-Cluster area to intercept seepage from the Intermediate Waste Rock Dump before it discharges to the NFRC (SRK, 2010).

Six monitoring wells (P09-SIS-1 to P09-SIS-6) were installed downgradient of the S-wells interceptor trench to allow SRK to monitor SIS performance. Each of these wells is screened in shallow, unconsolidated sediments (i.e. sand and gravel) (SRK, 2010). Wells P09-SIS-1 to P09-SIS-4 are spaced 10 m apart in a line that includes well SRK05-SP4B. Wells P09-SIS-5 and P09-SIS-6 are located 5 m apart and are located beyond the southeast end of the primary interceptor trench.

Table 2-2. Monitoring wells in the S-Cluster area, Faro mine site

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
S-cluster Area							
S1A	1989	12.0	9.2	12.2	1085.43	Bi-annual	BR (phyllite)
S1B	1989	3.8	1.3	4.3	1085.27	Bi-annual	Till
S2A	1989	11.2	9.2	12.2	1086.03	Bi-annual	BR (phyllite)
S2B	1989	7.0	3.7	6.7	1086.30	Bi-annual	Till
S3	1989	4.8	2.6	5.6	1085.53	Not routinely monitored	Till
P96-7	1996	9.2	6.26	9.24	~1127	Bi-annual	Overburden/BR
SRK04-2B	2004					Not routinely monitored	Alluvium
SRK04-2A	2004					Not routinely monitored	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	Bi-annual	Overburden
SRK05-SP-5	2005	14.0	9.4	12.5	1087.53	Bi-annual	Overburden/BR
SRK05-SP-6	2005	11.0	3.1	11	1097.73	Annual	BR(Schist)
DP1	2005	n/a	1.14	1.14	1083.97	Not routinely monitored	NFRC sediments
DP2	2005	n/a	0.53	0.53	1082.55	Not routinely monitored	NFRC sediments
DP3	2005	n/a	0.75	0.75	1081.89	Not routinely monitored	NFRC sediments
DP4	2005	n/a	0.94	0.94	1082.19	Not routinely monitored	NFRC sediments
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	Annual	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	Quarterly	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	Quarterly	Overburden
P09-SIS5	2009	3.7	2.8	3.7	1087.49	Bi-annual	Overburden
P09-SIS6	2009	4.6	4.6	5.5	1087.39	Bi-annual	Overburden

2.3.2 Review of Time Trends

Figures 2-6a/b shows the 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 trend plots for the recently installed bedrock wells in the S-cluster area ('SBR' series) and monitoring wells further downgradient of the SIS (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 can be classified into three broad categories:

- Highly-impacted groundwater (wells SRK08-S1A, SRK08-S2A/B, SRK08-S3, SRK05-SP4B, SRK05-SP5, P09-SIS1, P09-SIS2, P09-SIS3, and P09-SIS4);
- Moderately-impacted groundwater (wells SRK05-SP1A, SRK05-SP3A, SRK05-SP3B and SRK05-SP4A, SRK08-SP7B, SRK08-SP8A, SRK08-SBR4);

- Slightly-impacted groundwater (wells SRK08-S1B, SRK05-SP1B, SRK05-SP2, P09-SIS5, P09-SIS6, SRK08-SP7A, SRK08-SP8B, SRK08-SBR1, SRK08-SBR2, and SRK08-SBR3).

Major ions and metals of interest concentrations in groundwater that is classified as moderately-impacted or slightly-impacted have been relatively stable in recent years and this trend generally continued in 2009. In highly-impacted groundwater, however, the concentrations of major ions and metals of interest had increased steadily since 2000. The concentrations of SO_4, Mg, Mn, and Zn in well SRK08-S2B were identified as of particular concern in RGC (2008) because they reached similar levels to SRK08-S1A, SRK08-S2A, and SRK08-S3 in 2008.

In 2009, the concentrations of major ions and metals of interest decreased considerably in wells SRK08-S1A and SRK08-S2A. Both of these monitoring wells are completed in shallow bedrock that is considered highly-impacted by seepage. The rapid improvement in water quality is likely due to seepage recovery from the high-yielding recovery well SRK05-SPW2, which is located upgradient of SRK08-S1A and SRK08-S2A and also completed in shallow bedrock. Wells SRK08-SBR1 and SRK08-SBR4 are also screened in bedrock near well SRK08-SPW2 but groundwater quality did not improve in these wells in 2009. The lack of consistent improvement in groundwater quality in the local bedrock suggests significant heterogeneity in local bedrock and a lack of hydraulic connectivity within the aquifer.

Despite continuous operation of the S-cluster interception trench, monitoring wells screened in shallow, highly-impacted sediments immediately downgradient of the SIS did not show any significant improvement in groundwater quality (see, for example, wells SRK05-SP4B, P09-SIS2, and P09-SIS3). This suggests that an improvement in groundwater quality downgradient of the SIS may take longer than in the deeper, actively-pumped bedrock aquifer because of residual seepage stored in the shallow aquifer and/or a lack of gradient reversal/groundwater influx downgradient of the interceptor trench. Longer-term monitoring in the existing ‘SP’ wells and recently-installed ‘SIS’ wells will therefore be required to further assess SIS performance.

The “P09-SIS” series of wells assisted in better delineating the eastern limit of “highly-impacted” groundwater. Based on the initial 2009 data, it appears that concentrations of SO_4, Mg, and metals of interest are much lower in the wells located to the southeast end of the primary interceptor trench (wells P09-SIS5 and P09-SIS6) than in wells immediately downgradient of the trench (wells P09-SIS1 to P09-SIS4). It was further noted that concentrations of SO_4, Mg, and metals of interest in several wells (P09-SIS1 and P09-SIS3) showed a significant increase from September 2009 to November 2009. Additional monitoring in those wells will be required to determine if there is a trend towards higher concentrations or if concentrations will decrease as expected.

No appreciable changes in groundwater quality were observed in the monitoring wells located to the east of the S-cluster SIS and screened in the ‘moderately-impacted’ aquifer (i.e. SRK05-SP3A/B, SRK05-SP1A) or ‘slightly impacted’ groundwater (e.g. SRK05-SP1B and SRK05-SP2).

The pair of nested monitoring wells located downgradient of the S-cluster SIS in closer proximity of the NFRC (SRK08-SP7A/B) showed a different trend than those in close proximity to the SIS. At this location, the shallow well (screened in overburden) showed a decline in SO_4, Mg, and metals of interest that is likely due to operation of the S-cluster SIS. Recharge of shallow groundwater by very dilute stream water from the NFRC may have contributed to the rapid improvement in groundwater quality in this shallow overburden well. In contrast, the deeper well screened in weathered bedrock did not show any improvement in groundwater quality in 2009.

The pair of nested monitoring wells located near the NFRC about 200 m downstream of the S-cluster area were sampled once in 2008 immediately after installation. At this location, the deeper well screened in weathered bedrock (SRK08-SP8A) showed some moderate impact whereas the shallow well completed in the NFRC alluvium (SRK08-SP8B) showed only slightly elevated concentrations of SO_4 and Zn. The two nested monitoring wells are reportedly frozen (D. Mackie, pers, comm.), which may preclude future monitoring at this downgradient location.

2.4 North Fork of Rose Creek (NFRC) Reach

2.4.1 Background & Well Locations

Figure 2-9 shows the general layout of the NFRC reach upstream of the rock drain. The NFRC valley is filled with permeable, alluvial sediments. Groundwater in this alluvial aquifer flows down the valley and eventually discharges into the Rose Creek alluvial aquifer. The NFRC alluvial aquifer is influenced by seepage from the Northeast Rock Dumps, the Zone 2 Pit (backfilled with waste rock) and the Intermediate Dump. No surficial drainage of waste rock seepage is observed in this part of the ARMC. Instead, most of the seepage from the waste rock dumps reports to the NFRC alluvial aquifer via overburden soils and/or fractured bedrock.

The NFRC reach can be conveniently subdivided into four reaches:

- NFRC upgradient of the Faro Mine
- Northeast Waste Rock Dump Reach
- Zone 2 Pit Outwash Area
- Intermediate Waste Rock Dump Reach

Figure 2-9 shows the locations of all monitoring wells located upgradient and downgradient of the Zone 2 Pit outwash area. Figure 2-10 magnifies the Zone 2 Pit Outwash area where the majority of monitoring wells are located.

Table 2-3 summarizes pertinent information related to the groundwater monitoring wells located in the NFRC reach (grouped by reach), including year of construction, installation details (total depth, screening interval), and the current status of monitoring.

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

Well ID	Year of Construction	Total Depth (m bgs)	Top of Screen (m bgs)	Bottom of Screen (m bgs)	Top of Casing Elevation (m asl)	Current Status of Monitoring	Formation
Toe of Northeast Dumps (NFRC)							
BH12A	1994	3.1	1.53	3.05	1157.39	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 Review of Time Trends

In the following sections, the groundwater monitoring results observed in the four sub-reaches of the NFRC reach are briefly reviewed (from upstream to downstream).

2.4.2.1 NFRC Upgradient of Faro Mine

Wells P09-UN1, P09-UN2, and P09-UN3 were installed in 2009 in the NFRC alluvial aquifer ~50 m downstream of the confluence of NFRC and the Faro Creek diversion. These wells are screened in alluvial sediments of the NFRC valley (i.e. sand with gravel and cobbles). These wells provide information on geology and groundwater conditions that is relevant to the proposed re-alignment of NFRC into a lined channel (SRK, 2010).

Time trends for pH, alkalinity, selected major ions, and metals of interest for the ‘P09-UN’ wells series are shown in Figure 2-11a/b. Water quality time trends for monitoring wells SRK08-P12A/B, located immediately upstream of the Zone 2 Pit Outwash area are shown for comparison. SO_4 concentrations in each of the ‘P09-UN’ wells are low (< 20 mg/L) and concentrations of metals of interest (Fe, Mn, and Zn) are less than 0.05 mg/L. These concentrations are representative of background groundwater quality at the ARMC and suggest that groundwater near the confluence of NFRC and the Faro Creek diversion is unimpacted by mine waste seepage at this time.

The nearest downgradient monitoring wells completed in the NFRC alluvial aquifer are wells SRK08-P12A and SRK08-P12B. These wells are located immediately upgradient of the Zone 2 Pit Outwash area but downgradient of the Northeast WRDs (see below). Well SRK08-P12B is screened in the NFRC alluvium near the contact with weathered bedrock, whereas well SRK08-P12A is screened deeper in the bedrock aquifer (SRK, 2009). Zn concentrations in wells SRK08-P12A and SRK08-P12B are 0.2 mg/L and 1 mg/L, respectively. These elevated Zn concentrations are the most convincing evidence that mine waste seepage is present in this area but SO_4 concentrations are also higher than background levels in the NFRC aquifer (i.e. the P09-UN wells). The most like source of mine waste seepage in the NFRC is seepage from the Northeast Rock Dump (see discussion below).

2.4.2.2 Northeast Rock Dump 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 Rock Dump (Figure 2-9).

Historically, groundwater from well BH14A/B has been more impacted by seepage than groundwater from wells BH12A/B and BH13A/B. In 2008, SO_4, Mg, Mn, and Zn concentrations in wells BH14A/B increased substantially and this trend continued in early 2009. Some improvement in water quality was observed in late 2009 but concentrations of SO_4, Mg, Mn, and Zn in wells BH14A/B were higher by the end of 2009 than in 2008. Groundwater collected from wells BH12A/B and BH13A/B did not deteriorate considerably in 2009.

The trend towards higher concentrations of SO_4, Mg, Mn, and Zn in wells BH14A/B is likely indicative of seepage from the sulphide-rich waste rock that has been identified in the Northeast Rock Dump (RGC, 2008). If seepage from this source continues to impact groundwater at BH14A/B, groundwater quality in this reach could potentially deteriorate further and concentrations of SO_4, Mg, and Zn may reach the levels observed in the ETA and S-Cluster areas.

Given the proximity of the Northeast Rock Dump (and wells BH14A/B) to the NFRC aquifer, it seems likely that elevated Zn and SO_4 concentrations in wells SRK08-P12A/B are a result of loads delivered from the Northeast Rock Dump. Zn concentrations of 1 mg/L in the highly-permeable NFRC alluvial aquifer suggests a substantial load from the Northeast Rock Dump but further monitoring is necessary to affirm this scenario.

2.4.2.3 Zone 2 Pit Outwash Area

Figure 2-13a/b shows the time trends for pH, alkalinity, selected major ions, and metals of interest in monitoring wells located within the Zone 2 Pit outwash area. Figure 2-14a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest in Zone 2 Pit water and for wells screened in in bedrock.

The Zone 2 Pit outwash area is located immediately down-gradient of the backfilled (waste rock) Zone 2 Pit. Concentrations of major ions and metals of interest in samples from pumping well X26 are representative of water that accumulates in the backfilled Zone 2 Pit. Seasonal variations in the concentrations of major ions and metals of interest are evident in water from the Zone 2 Pit due to dilution during periods of recharge in the spring yet concentrations have remained relatively constant over the last few years.

Well BH8 is located immediately downgradient of the Zone 2 Pit and is screened in a fault zone within weathered bedrock. This well was sampled in 2008 (for the first time since 1997) and again in 2009. Concentrations of major ions and metals of interest did not increase in 2009 but groundwater at this location remains highly-impacted presumably by seepage from the Zone 2 Pit. Note that Zn and Fe concentrations in groundwater from well BH8 are often higher than in water pumped from the Zone 2 pit via X26.

In 2009, the concentrations of major ions and metals of interest in groundwater within the Zone 2 Pit outwash area were consistent with historic time trends. For instance, concentrations in wells that are screened at least partially in outwash sediments (wells BH1, BH2 and BH4) remain similar to concentrations observed in the deeper wells screened in the alluvial sediments (BH5, BH6, P05-04).

Groundwater quality in the Zone 2 Pit outwash area differs from other areas that are impacted by waste rock seepage (e.g. ETA and S-cluster) in that elevated Zn concentrations are observed but the concentrations of SO_4, Mg, Fe, and Mn remain relatively low by comparison. This characteristic of groundwater quality could be related to a different metals content of sulphide-rich waste rock in the Zone 2 Pit and/or the *in situ* oxidation of sulphides in outwash sediments (RGC, 2010a). Note that modest increases in Zn and several other ARD products in the NFRC alluvial aquifer along the Zone 2 Pit outwash reach (i.e. between wells SRK-P12A and BH5) suggests some incremental loading from the Zone 2 Pit area.

2.4.2.4 Intermediate Rock Dump Reach

Figure 2-15a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest for well P96-6. This well is located along the toe of the Intermediate Dump and monitors the quality of groundwater flowing from the area near the toe of Intermediate Rock Dump towards the NFRC. Similar to selected wells in the S-cluster area (e.g. wells SRK05-SP1A, SRK05-SP3A, SRK05-SP3B and SRK05-SP4A), groundwater quality in this monitoring well is considered “moderately-impacted” by seepage. Concentrations of SO_4 and Mg in well P96-6 increased slightly in 2009 but Fe, Mn, and Zn concentrations remained low. The small increases in SO_4 and Mg could be indicative of a small load of ARD products from the Intermediate Rock Dump and could precede similar increases in the concentrations of certain metals of interest (which are transported more slowly due to sorption).

3 ROSE CREEK VALLEY

3.1 Geographic Overview

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

The groundwater monitoring network in the Rose Creek valley is extensive. Most wells are screened in the highly-permeable Rose Creek alluvial aquifer (RCAA) that runs the entire length of the valley. However, several wells have recently been completed in the less permeable bedrock that underlies the RCAA.

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

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

Note that the majority of “P01” series of monitoring wells that were installed in 2001 have been decommission due to concerns about the integrity of these wells (RGC, 2006b). Historic water quality time trends for those “leaky wells” were discussed in RGC (2008) and hence are not discussed in this in this report.

3.2 Upstream of Rose Creek Tailings Facility

3.2.1 Background & Well Locations

Table 3-1 summarizes pertinent information related to the groundwater monitoring wells located upgradient of the RCTF, including year of construction, installation details (total depth, screening interval) and status of monitoring. No new wells were constructed in this area in 2009.

Groundwater quality upgradient of the RCTF is routinely monitored in well TH86-17, which is located approximately 450 m southeast of the Original Impoundment. Starting in 2008, additional 'background wells' located upgradient of the RCTF were monitored, including wells TH86-2 and TH86-5 (in 2008 and 2009) and wells TH86-13 and TH86-15 (2008 only).

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 other nearby piezometers. Groundwater quality in TH86-17 reflects natural base-line conditions in the Rose Creek valley sediments. Groundwater from well TH86-17 remains dilute in terms of major ions and dissolved metals and there is still no indication that mine waste seepage is present in groundwater at this location. This is supported by similarly low concentrations of SO_4, Mg, Mn, and Zn in most of the nearby piezometers.

Concentrations of major ions and some metals of interest (Fe, Mn) are higher in well TH86-5 than in the other wells in the area. SO_4 concentrations, however, are very low in well TH86-5 and other metals of interest are still at or near the detection limit (e.g. < 0.02 mg/L Zn). Well TH86-5 is screened in the deeper portion of the RCAA that is isolated from the upper aquifer by a till layer. The water quality in well TH86-5 is therefore believed to be representative of natural baseline conditions in the deeper sediments of the RCAA.

Note that the 'TH' wells are located downgradient of the NFRC aquifer that is influenced by seepage from the Faro WRDs (e.g. in the S-Cluster area). The pristine groundwater quality conditions observed in these wells suggests that this portion of the RCAA is not yet influenced by waste rock seepage from the Intermediate WRD.

3.3 Original Impoundment

3.3.1 Background

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

No new monitoring wells were installed in this reach of the Rose Creek valley.

3.3.2 Review of Time Trends

Neither the nested piezometers at P03-07 nor well NA05-11A are monitored routinely and hence no additional groundwater quality data was collected in 2009.

3.4 Second Impoundment

3.4.1 Background & Well Locations

Table 3-2 summarizes pertinent information related to the groundwater monitoring wells located in the Second Impoundment, including year of construction, installation details (total depth, screening interval), and the status of monitoring. No new monitoring wells were installed in this reach of the Rose Creek valley.

3.4.2 Review of Time Trends & Water Quality Depth Profiles

Multi-level piezometers P03-01 to P03-06 were installed within the footprint area of the Second Impoundment in 2003. Water quality depth profiles for these wells are illustrated in Figures 3-3a/b to 3-8a/b. The general shapes of the depth profiles observed in 2009 are similar to those observed in previous years. In accordance with previous findings, the highest levels of SO_4 and metals of interest are still observed in tailings pore-water in the south-eastern (wells P03-01, P03-03) and north-western sections (wells P03-06) of the Second Impoundment, whereas the lowest levels of ARD products are observed in the south-western section (well P03-05).

Concentrations of selected major ions and metals of interest are typically highest in the wells that are screened near the interface of the sand and gravel aquifer and the overlying tailings. The water quality depth profiles for wells P03-03 and P03-06 differ from the trend observed in the other profiles. At wells P03-03, SO_4 concentrations are elevated throughout the aquifer and Zn concentrations actually increase at greater depths in the Rose Creek aquifer. At wells P03-06, SO_4 and Zn concentrations are elevated throughout the entire depth of the aquifer. The depth profile for wells P03-03 and P03-06 suggests a contribution of SO_4 and metals of interest not only from the overlying tailings profile but from a source further upgradient. A more detailed analysis of isotopic and geochemical data suggests that well P03-06 is significantly impacted by waste rock seepage that was allowed to discharge down the Faro Creek canyon and partially recharge the northern portion of the RCAA (RGC, 2010a).

The source of highly-elevated SO_4 and Zn in the deeper portion of the RCAA at well P01-09 is less certain. Historically, leakage from well P01-09 (in particular from well P01-09E) was thought to represent an upgradient source of SO_4 and Zn to well P03-03 (RGC, 2006a; RGC, 2008). Consequently, well P01-09 (and well P01-07) was decommissioned in October 2005 by sealing the well with bentonite in order to eliminate the source. However, the time trends of selected major ions and metals of interest for P03-03 show no appreciable decrease since decommissioning of the "leaky wells" (Figure 3-9a/b). In fact, SO_4 and Mg concentrations in piezometer P03-03-06 have increased considerably over the last two years although Zn and Mn concentrations have remained low. The lack of improvement in groundwater quality over the last 5 years suggests that the "leaky wells" may not have been a source of major ions and metals of interest to groundwater at well P03-03. Instead, tailings seepage from further upgradient (e.g. highly-oxidized tailings in the coarse tailings beaches near well P03-01) is a more likely source of the elevated SO_4 and Zn in the RCAA at well P03-03.

Figure 3-10a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest in well P03-04 (located ~140 m downgradient of the decommissioned wells P01-07). At this location, the shallow piezometer P03-04-06 (screened near the interface with the tailings) had shown an improvement in groundwater quality since decommissioning of well P01-07 but this trend did not continue in 2009. Instead, slight increases in the concentrations of SO_4 and each of the metals of interest were observed. These increases were small in magnitude and future monitoring will be required to assess whether groundwater quality in this reach of the RCAA is further deteriorating over time.

Figure 3-10c/d shows the time trends for pH, alkalinity, selected major ions, and metals of interest in groundwater at well P03-06. This well is located in the northwest portion of the Second Impoundment near the mouth of Faro Creek canyon. Previous reports have identified substantial increases in the concentrations of SO_4 and metals of interest at this location since 2005 and particularly at greater depths in the aquifer (RGC, 2008; 2009). In 2009, SO_4 concentrations in piezometers P03-06-02 and P03-06-03 decreased, whereas the concentrations of metals in these wells (and most others) remained relatively unchanged. A gradual rise in Zn concentrations in prior years has been a matter of particular concern but Zn concentrations appear to have stabilized in 2009. Mn concentrations in piezometers P03-06-01 and P03-06-02 did, however, increase in 2009.

A recently-completed geochemical assessment of ARD sources at the ARMC suggested that groundwater at well P03-06 may be impacted by a combination of seepage from coarse and well-drained tailings located in the Original Impoundment and Faro Creek seepage (FCS) from the Faro Creek canyon/diversion channel (RGC, 2010a). That study suggested that the recent increases in

SO_4 and Zn in the Rose Creek aquifer at well P03-06 are likely the result of the recent deterioration of water quality in FCS (see Section 2.2.2).

Table 3-2. Monitoring wells downgradient of Faro Creek canyon, 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

Seepage from the ETA area is currently collected in the ETA SIS during the open water season (since spring 2007). This seasonal operation of the ETA SIS is estimated to intercept about 50% of the annual SO_4 and metal loads from the ETA area (RGC, 2010b). It is plausible that the reduction in SO_4 concentrations observed in late 2008/2009 in the deeper profile at well P03-06 (at P03-06-02 and P03-06-03) is a direct result of this reduction in contaminant loading from the Faro Creek canyon/diversion channel to the northern side of Rose Creek valley. The apparent delay in a similar decrease of Zn concentrations could be a result of attenuation of this metal along the flow path. Continued monitoring will be required to confirm these preliminary conclusions.

In summary, groundwater quality data collected from wells in the Second Impoundment suggest an incremental loading from east (upstream) to west (downstream). However, detailed groundwater quality monitoring data suggest significant local variations in contaminant concentrations between wells and even at different depth of the aquifer at the same location. Furthermore, while some wells in this reach of the RCAA experience continued deterioration of groundwater quality, other reaches appear to have stabilized or even improved. These observations suggest that groundwater quality in the Second Impoundment is locally influenced by different sources, including concentrated seepage from coarse, fully-oxidized tailings beaches and FCS. Monitoring data collected in 2009 did, however, suggest that the “leaky wells” are unlikely to have represented an appreciable source of major ions and metals of interest to groundwater in this reach of the RCAA.

3.5 Intermediate Impoundment

3.5.1 Background & Well Locations

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

No new monitoring wells were installed in 2009 in this reach of the Rose Creek valley.

Table 3-3. Monitoring wells downgradient of Faro Creek canyon 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. In 2009, pore water quality monitored at well X21A showed further increases in SO_4, Zn, and Fe. These trends are consistent with earlier time trends suggesting gradual breakthrough of an acid front with highly elevated metals in this coarse tailings beach of the Intermediate Impoundment.

Groundwater in the shallow aquifer underlying these tailings (at well X21B) also showed a continued deterioration in 2009, including a decrease in alkalinity and a significant increase in Zn. However, contaminant concentrations in the groundwater at well X21B were typically at least an order of magnitude lower than in the overlying tailings. Note also that current concentrations of SO_4, Zn and other metals (Fe, Mn) in this reach of the RCAA are still significantly lower than those observed further upgradient (at P03-06). Assuming a direct hydraulic connection in a contiguous aquifer, a further increase in contaminant concentrations can therefore be expected for X21B (likely within the next few years).

Depth profiles for pH, alkalinity, selected major ions, and metals of interest in well P03-08 are shown in Figure 3-12a/b. Depth profiles for the current monitoring period were similar to those defined by previously-collected data and no appreciable changes in water quality were apparent in 2009.

3.6 Toe of Intermediate Dam

3.6.1 Background & Well Locations

Table 3-4 summarizes pertinent information related to the groundwater monitoring wells located at the toe of the Intermediate Dam, including year of construction, installation details (total depth, screening interval), and the status of monitoring. Installation of two additional bedrock wells (P09-ID1 and P09-ID2) near the Intermediate Dam was attempted in 2009 but difficult drilling conditions prevented their completion (SRK, 2010).

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 are shown in Figure 3-13a/b for wells located near the northern end of the Intermediate Dam (wells X24A/B/C/D and P01-03). SO_4 Mg, Zn and Mn concentrations have increased in each of these wells since 2001 and this trend generally continued in 2009. Note that the highest concentrations of major ions and metals of interest have been consistently observed at well X24D (the deepest well in this area). Notably, Mn concentrations at X24D consistently exceeded 75 mg/L in 2009 and Zn concentrations exceeded 0.1 mg/L.

The trend towards higher concentrations of SO_4 and metals of interest in the aquifer at well X24 is indicative of the presence of mine waste seepage near the northern end of the Intermediate Dam. Potential sources of ARD products in this portion of the Rose Creek aquifer include tailings 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. Seepage from the Intermediate Pond, however, has been ruled out as a significant source of ARD products (RGC, 2008; 2010a).

As previously noted, a detailed geochemical assessment of groundwater quality at well P03-06 suggests that FCS is the predominant source of ARD products to the northern portion of the Rose Creek aquifer in the Second Impoundment (RGC, 2010a). It was further concluded that Faro Creek seepage is also the likely source of ARD products to groundwater below the Intermediate Dam (at X24) due to the hydraulic connection between the Second Impoundment and Intermediate Impoundment via the Rose Creek aquifer. Hence an improvement in groundwater quality at well X24 can be expected in the coming years due to recent start-up of the ETA SIS that effectively reduces contaminant loading to the northern side of the RCAA. However, a decrease in metals concentrations, including Zn, could be delayed for many years due to the long travel distance and potential for retardation of metals along the flow path (RGC, 2009).

Time trends for pH, alkalinity, selected major ions, and metals of interest for wells located on the southern side of the Intermediate Dam (wells X25A/B, P01-04A/B) are shown in Figure 3-14a/b. SO_4 and Mg concentrations are generally lower in groundwater on the southern side of the Intermediate Dam than in groundwater on the northern side indicating that groundwater in this area is much less impacted by mine waste seepage (likely due to the absence of loading by FCS). Nevertheless, SO_4, Mg, Fe, and Mn have shown a gradual increase over the last 6 to 7 years and this trend continued in 2009 (most notably in well P01-04A). Tailings seepage from the Intermediate and/or Second Impoundment is the most likely source of these ARD products. Note that Zn concentrations have not yet significantly increased in these wells due to natural attenuation along the flow path.

3.7 Toe of Cross Valley Dam

3.7.1 Background & Well Locations

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

Three new wells were installed below the toe of the Cross Valley Dam in 2009. Wells P09-C1 and P09-C2 are screened in fresh, fractured bedrock, whereas well P09-C3 is screened in the RCAA just above bedrock. Wells P09-C1 and P09-C3 are located on the northern and southern side of the Cross Valley Dam, respectively, whereas well P09-C2 is located near its center. These wells were sampled initially upon their completion and again in November 2009 as part of the routine groundwater monitoring program. An additional sample was collected from a high-permeability fracture zone in deep bedrock beneath the installation at P09-C3 during drilling but a monitoring well could not be completed at this depth (SRK, 2010).

The sample of groundwater from deep bedrock beneath P09-C3 was of particular interest because it revealed a slightly elevated Zn concentration (~0.2 mg/L) in groundwater. However, the sample did not show any other signs of mine waste seepage (i.e. very low SO_4, Mn and Fe). The source of Zn in groundwater at this bedrock location remains uncertain and will require further study (RGC, 2010a). The reader is referred to RGC (2010a) for additional discussion of the geochemical and isotopic interpretation of this sample.

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

3.7.2 Review of Time Trends

Time trends for pH, alkalinity, selected major ions, and metals of interest in groundwater from wells located along the toe of the Cross Valley Dam are shown in Figures 3-15a/b to 3-17a/b. Monitoring wells located in the southern portion of the valley (well P01-02) continue to show very low concentrations of major ions and metals of interest suggesting no discernible impact of mine waste seepage on the local groundwater.

In contrast, monitoring wells located on the northern side of the Cross Valley Dam (e.g. wells P01-11 and P05-02) continue to show significant impact (i.e. elevated SO_4, Mg, Fe, Mn, and Zn). SO_4 and Mg concentrations in these wells continue increase gradually as they have since monitoring began in 2001.This gradual increase mimics the breakthrough of those same constituents upgradient at the Intermediate Dam (at well X24) but the breakthrough of these major ions is delayed by several years.

In wells located along the northern side of the Cross Valley Dam, Fe, Mn, and Zn concentrations remained above background levels but did not show any significant increase in 2009. This suggests that the sorption of metals along the flowpath causes a lag between the breakthrough of metals and conservatively-transported SO_4 and Mg. Despite this lag, metals concentrations are expected to increase in the coming years and eventually reach concentrations observed near the Intermediate Dam at well X24.

Monitoring well P05-03 and multilevel piezometer P03-09 are both located near the central portion of the RCAA. Major ion and metals concentrations in these wells remain lower than in the northern portion of the RCAA but higher than in southern portion. SO_4 and Mg concentrations are gradually increasing though but metals concentrations remain low.

Time trends for pH, alkalinity, selected major ions, and metals of interest in wells P09-C1, P09-C2, and P09-C3 are shown in Figure 3-18a/b. At well P09-C1 (located near the northern side of the Rose Creek valley), SO_4, Mg, Fe and Mn concentrations are comparable to concentrations in shallow impacted groundwater in this area and are much higher than in well P09-C2 and P09-C3. Note that Zn concentrations in well P09-C1 are, however, very low (< 0.01 mg/L). These data suggest that groundwater in deep bedrock near the northern end of the Cross Valley Dam is impacted to a similar extent as the RCAA in this area but that groundwater near the southern side of the Rose Creek valley remains unaffected by mine waste seepage.

Metals concentrations in groundwater at well P09-C1 are expected to increase in the future due to transport of impacted groundwater in the bedrock aquifer. However, this transport process may take many years and long-term monitoring of the 'P09-C' well series will be required to identify the breakthrough of metals in the bedrock aquifer underlying the Cross Valley Dam.

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. Table 3-6 lists pertinent information regarding these wells, including year of construction, installation details (total depth, screening interval) and status of monitoring.

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 times 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 2009, yet concentrations of Zn remained low (< 0.1 mg/L). The increase in SO_4 and Mg in this area is thought to be caused by the leading edge of the breakthrough that has been observed upgradient near the northern end of the Cross Valley Dam (at wells P01-11, P05-01) and near the Intermediate Dam at well X24.

No evidence of impacted groundwater is evident near the center of the Rose Creek valley at X16A/B and X17A/B. This suggests that the impact of tailings seepage is limited to groundwater closer to the Cross Valley Dam and near the northern side of Rose Creek valley. Slightly-elevated Zn concentrations observed in the shallow well X16A (~0.01 mg/L zinc) 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 close to well X16.

4 GRUM & VANGORDA MINE SITE

4.1 Geographic Overview

Figure 4-1 shows the general layout of the Grum/Vangorda mine sites, including mine waste-units and the groundwater monitoring wells in these areas. The Grum mine site consists of the Grum Pit, Grum Rock Dump (w/ sulphide cell) and the overburden stockpile, whereas the Vangorda mine site consists of the Vangorda Pit (w/ in-pit rock dumps) and the Vangorda Rock Dump. Groundwater monitoring wells are located primarily along the toes of the various rock dumps in order to monitor potential seepage to groundwater.

Groundwater quality data for the Grum mine site and Vangorda mine site 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 down-gradient of the Grum Rock Dump. Table 4-1 lists pertinent information of these monitoring wells and others in the area, including year of construction, installation details (total depth, screening interval), and current status of monitoring.

In 2009, wells P09-GS1A/B were installed in the Grum Slot area to assess the permeability of the bedrock-overburden contact zone near the Grum Pit and thereby evaluate the risk of leakage from the pit towards Grum Creek. Also installed in 2009 were wells P09-GW1 and P09-GW2. These wells are located in the Grum Dump West area near seep monitoring station SRKGD13 and were part of a targeted investigation of the potential impact of seepage on groundwater quality in the numerous drainages that exist to the northwest of the Grum Dump.

Table 4-1. Monitoring wells location near Grum Slot, west of Grum Dump, 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	Not routinely monitored	BR (weathered)
SRK04-5B	2004	14.7	13.7	14.7	1103.95	Not routinely monitored	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	Bi-annual	Overburden/BR
SRK05-08	2005	7.6	2.1	7.6	1105.25	Bi-annual	Overburden
SRK05-09 ("Moose Well 2")	2005	3.7	0.5	3.5	1072.82	Bi-annual	Overburden
SRK05-09	2005	3.3	0.9	3.3	1060.64	Bi-annual	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	Annual	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	Annual (Spring)	Overburden
P09-GW2	2009	2.4	1.4	2.4	1279.80	Annual (Spring)	Overburden

4.2.2 Review of Time Trends

Figure 4-3a/b shows time trends for pH, alkalinity, selected major ions, and metals of interest for the monitoring wells located near Grum Creek and down-gradient of the Moose Pond. SO_4 and Mg concentrations in SRK05-09 (Moose Well #2) increased in 2009 but Fe, Mn, and Zn concentrations remained low. Groundwater quality in this well is likely impacted by seepage from Moose Pond (Station V2A), which collects seepage from the Grum Rock Dump (RGC, 2008). The recent increase in SO_4 and Mg likely reflects higher source concentrations in the Moose Pond located immediately upgradient.

Time trends for pH, alkalinity, selected major ions, and metals of interest in wells located west of Grum Creek are shown in Figure 4-4a/b. SO_4 and Mg concentrations in well P96-9A (screened in alluvial sediments in a narrow side drainage from Grum Creek) have been increasing since the year 2000 and continued to do so in 2009. The concentrations of SO_4 and Mg in November 2009 were the highest on record at ~1800 mg/L and 390 mg/L, respectively. Zn concentrations in P96-9A increased temporarily in early 2007 but have since decreased again to less than 0.02 mg/L. Mn and Fe concentrations also remained low in P96-9A. Because the concentrations of Fe, Mn, and Zn remain low, there is little cause for concern at this time but groundwater quality in P96-9A should continue to be monitored.

Wells SRK05-07 and SRK05-08 are located southwest of well P96-9A and are screened in shallow bedrock (phyllite). SO_4 and Mg concentrations have been rising steadily since early 2000 in both of these wells and this trend continued in 2009. These increases in SO_4 and Mg suggest a gradual breakthrough of waste rock seepage from Grum Dump through weathered bedrock. Zn concentrations in both wells have remained low (< 0.01 mg/L) and Mn concentrations have decreased over the last few years (particularly in SRK05-08). This delay in breakthrough of these metals (including Zn, Fe and Mn) is likely caused by retardation due to sorption and/or precipitation along a flowpath in weathered bedrock downgradient of the Grum Dump.

Gradually increasing concentrations of SO_4 and Mg in the wells along the toe of the Grum Dump suggest that seepage from the Grum waste rock dump has not only impacted groundwater quality in narrow side-valleys comprised of permeable alluvial sediments (at P96-9A) but has also impacted groundwater in less permeable bedrock at wells SRK05-07 and SRK05-08. The higher concentrations of SO_4 and Mg in the highly-permeable sediments screened by well P96-9A suggest that the side-valleys in this area receive a higher load from waste rock seepage than weathered bedrock because flow rates are expected to be proportionally higher in alluvial sediments than in bedrock.

Time trends for pH, alkalinity, selected major ions, and metals of interest in wells located near Grum Slot and west of the Grum Dump are shown in Figure 4-5a/b. As only one or two samples were collected from the ‘P09-GS’ and ‘P09-GW’ well series in 2009, an additional year of monitoring data is required to establish time trends for these wells. However, the 2009 data indicate that groundwater from wells P09-GS1A and P09-GS1B is moderately-impacted by mine waste seepage. Specifically, SO_4 concentrations in groundwater from both wells are elevated (400 to 600 mg/L) and higher than in standing water from the Grum Slot. Note that the Zn concentration in well P09-GS1B (screened in overburden) is 4 to 5 mg/L or about two orders of magnitude higher than in groundwater from P09-GS1A. These high Zn concentrations are likely a result of *in situ* leaching of mineralized waste rock observed in the drill cuttings of P09-GS2 (SRK, 2010).

Because wells P09-GW1 and P09-GW2 were dry for several months of the year, the only groundwater quality data that was available for interpretation was collected from well P09-GW1 in November 2009. SO_4 and Mg concentrations in this sample were elevated (700 mg/L SO_4 and 125 mg/L Mg) but concentrations of Fe, Mn, and Zn were at or below the respective detection limits for these metals. Hence it appears that groundwater from P09-GW1 is impacted by a ‘TDS front’ but does not yet receive a substantial load of metals. Future monitoring data will be required to assess groundwater quality (and groundwater levels) in the area west of the Grum Dump.

Wells SRK08-P14, SRK08-P15, and SRK08-P16 are located along the southwest toe of the Grump Dump (Figure 4-2). Time trends for pH, alkalinity, selected major ions, and metals of interest in these wells are shown in Figure 4-5c/d. SO_4 concentrations in these wells are elevated (300 to 800 mg/L) but pH remains circum-neutral (pH 7.5 to 8.0) and metals concentrations are very low (i.e. < 0.03 µg/L Zn). These trends are consistent with the presence of mine waste seepage in this area but at this point only the breakthrough of conservatively-transported ions has occurred. Future monitoring data will be required to identify the breakthrough of dissolved metals into groundwater in this area (which is expected in the next few years).

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 Rock Dump. Table 4-2 summarizes pertinent information related to those monitoring wells, including year of construction, installation details (total depth, screening interval), and current status of monitoring.

Wells P09-VC1 and P09-VC2 were installed in the Vangorda Creek area in 2009. Both of these wells are located downgradient of the mine access road and were completed in order to characterize groundwater quality in overburden (well P09-VC1) and bedrock (well P09-VC2) beneath Vangorda Creek. Characterizing groundwater quality in this area has been a priority for several years because of the potential for leakage from the Vangorda Pit to Vangorda Creek via bedrock pathways but had been deferred until the proper drilling equipment became available in 2009 (SRK, 2010).

The Little Creek Dam (LCD) is located between the northwest toe of the Vangorda Rock Dump and Vangorda Creek (Figure 4-6). Water behind the LCD is of very poor quality due to the controlled capture of seepage from the Vangorda Rock Dump. Due to its location upgradient of Vangorda Creek, seepage from the LCD could enter groundwater and ultimately impact water quality in Vangorda Creek. In 2009, the 'P09-LCD' well series was installed to establish current groundwater quality conditions in the LCD area and enable future monitoring (SRK, 2010).

Table 4-2. Monitoring wells downgradient of Vangorda Rock Dump 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 monitoring wells located down-gradient of the Vangorda Rock Dump are shown in Figure 4-7a/b. In general, groundwater quality time trends observed in 2009 generally conformed to previously-established time trends. Specifically, SO_4, and Mg concentrations continued to increase in all monitoring wells located downgradient of the Vangorda Rock Dump. However, these gradual increases in major ions (and sometimes alkalinity) were typically not associated with an increase in the concentrations of any metals of interest. This suggests the ongoing attenuation of metals along the groundwater flowpath. The notable exception is well V36, which is located on the western side of Vangorda Rock Dump and continued to show a gradual increase in Zn concentrations over time. Zn concentrations are relatively low (~0.05 mg/L) in this area but concentrations are expected to increase over time and should be monitored closely.

Time trends for pH, alkalinity, selected major ions, and metals of interest in monitoring wells located in the LCD area and near Vangorda Creek are shown in Figure 4-8a/b. SO_4 and Mg concentrations in groundwater from the ‘P09-VC’ and ‘P09-LCD’ well series were lower than in the other wells near the Vangorda Rock Dump. For the ‘P09-LCD’ wells series, small differences were observed between wells screened in overburden and bedrock but major ion and metal concentrations in each of the wells was generally consistent with groundwater that is moderately-impacted by seepage from the LCD (i.e. elevated SO_4 but low concentrations of metals). Future monitoring data will be required to better assess the impact of LCD on groundwater in this area.

Major ion and metal concentrations in wells P09-VC1 and P09-VC2 are consistent with groundwater that is unimpacted by mine waste seepage. Slightly elevated Zn concentrations (~0.05 mg/L) were observed in well P09-VC2 but all other ARD indicator parameters (including SO_4) were close to background levels. The slightly elevated Zn concentrations could be the result of leaching of mineralized waste rock used for road construction. Hence there is no evidence of seepage from the Vangorda Pit in overburden and/or fractured bedrock in this area. Moreover, 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. Wells P09-VC1 and P09-VC2 should both be monitored routinely though in order to ensure that this situation does not change.

5 CONCLUSIONS & RECOMMENDATIONS

Historic time trends for pH, alkalinity, selected major ions, and metals of interest were reviewed in different reaches of the ARMC in order to identify any changes in groundwater quality that occurred in 2009. The main conclusions of this review are summarized in the sub-sections below with recommendations regarding future groundwater monitoring.

5.1 Faro Mine Site

- Concentrations of SO_4, Mg, and other metals of interest in seepage from the Main WRD at X23 and two wells P96-8A/B screened in alluvium nearby continued to increase in 2009; these increases were attributed to the breakthrough of more highly-contaminated waste rock seepage from the Main WRD rather than seasonal 'flushing' of accumulated oxidation products due to intense rainfall;
- In the ETA, deep groundwater in bedrock remains significantly less impacted by mine waste seepage than shallower groundwater in alluvial sediments of the Faro Creek channel; metals concentration in deep groundwater in bedrock in the ETA are nonetheless elevated (~10 mg/L) and suggest some impact by seepage;
- Near the mouth of Faro Creek canyon, groundwater immediately below the tailings profile is impacted by a combination of seepage from the Faro Creek canyon and seepage from the overlying tailings, which is consistent with the contention that the ETA provides a substantial load to the northern side of the Rose Creek alluvial aquifer; groundwater in bedrock near the mouth of Faro Creek canyon is unimpacted by mine waste seepage;
- In the S-cluster area, concentrations of SO_4, Mg, and other metals of interest decreased significantly in several, highly impacted, deeper monitoring wells screened in shallow bedrock in response to pumping from one deep recovery well SRK08-SPW2); in contrast, most monitoring wells screened in the overburden soils did not show an immediate improvement in groundwater quality, possibly due to the lack of recharge (and hence dilution); nevertheless, the S-Cluster SIS has eliminated a considerable proportion of the ARD load to this reach of the NFRC aquifer and further groundwater quality improvement is expected in the future;
- Near the toe of the Northeast Rock Dump, SO_4, Mg, Mn, and Zn concentrations in groundwater continued to increase in 2009 likely due to seepage from sulphide-rich waste rock in the Northeast Rock Dump;
- Groundwater in the NFRC valley immediately upstream of the Zone 2 Pit outwash area (at wells SRK08-P12A/B) shows significantly elevated concentrations of zinc and other metals (Fe, Mn); the most likely source of these ARD products is seepage from the Northeast Rock Dump (near BH14A/B);

- In the Zone 2 Pit outwash area, groundwater near the toe of the Zone 2 Pit remained highly-impacted by waste rock seepage but groundwater quality did not deteriorate further in 2009; in wells screened within outwash sediments or alluvium nearby, groundwater quality in 2009 was consistent with historic time trends;
- Further downgradient in the NFRC valley, near the toe of the Intermediate Dump, groundwater is "moderately-impacted" by waste rock seepage yet concentrations of Fe, Mn, and Zn concentrations remained low in 2009; small increases in SO_4 and Mg could precede increases in some metals but deteriorating groundwater quality in this area is not yet considered a cause for concern.

5.2 Rose Creek valley

- Groundwater quality in the Rose Creek alluvial aquifer in the reach of the Original and Second Impoundment has generally shown no significant changes in 2009. The notable exception is well P03-06, which is located near the mouth of Faro Creek canyon. Groundwater in this area had shown a significant increase in ARD products (SO_4, Mg, Zn) in the past 2 to 3 years but has shown some recovery starting in late 2008. The recent improvement in groundwater quality is believed to be a result of seepage interception in the ETA SIS which reduces ARD loading to the RCAA along the north side of the Rose Creek valley;
- In the reach of the Intermediate Dam and Cross Valley Dam, groundwater in the alluvial aquifer continued to show a gradual increase of SO_4, Mg, and selected metals of interest (Mn in particular). Although increases were observed on both sides of the valley, groundwater continues to be significantly more impacted on the north side than the south side of the Rose Creek valley, likely due to additional loading from waste rock seepage (discharging from the Faro Creek canyon). By the end of 2009, Zn concentrations on the northern side of the Cross Valley Dam had increased to about 0.1 mg/L (at well X24A) but remained unchanged below the Cross Valley Dam (~ 0.025 mg/L at well P05-02). In contrast, Zn concentrations remained at or near the detection limit on the side of the Intermediate Dam and Cross Valley Dam.
- Groundwater quality monitoring in the bedrock wells recently completed at the toe of the Cross Valley Dam ('P09-C' well series) clearly indicates impacted groundwater in deep, fractured bedrock on the northern side of the valley (at well P09-C1) but very limited, if any, impact in the center of the valley (at well P09-C2). Groundwater in fractured bedrock on the south side of the valley (only sampled once at well P09-C3 during a pumping test) was very dilute but showed elevated Zn concentrations potentially due to recharge from the Rose Creek diversion.

5.3 Grum/Vangorda Mine Site

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

- Concentrations of SO_4 and Mg continued to increase in 2009 both in narrow side-valleys comprised of permeable alluvial sediments (at well P96-9A) but also in less permeable weathered bedrock at wells SRK05-07 and SRK05-08 indicating seepage from the Grum waste rock dump. Zn concentrations in both overburden and weathered bedrock remained very low in 2009 suggesting continued attenuation of this metal along the flowpath;
- Southeast of the Vangorda Rock Dump, SO_4 and Mg concentrations in groundwater continued to increase in 2009 but increases in these major ions was not accompanied by an increased in metals concentrations. This suggests the ongoing breakthrough of neutralized mine seepage to groundwater in this area.
- Near the Little Creek Dam, SO_4 and Mg concentrations in groundwater were characteristics of moderately-impacted groundwater although metals concentrations remained low; however, limited data is currently available so future monitoring data will be required to better assess the impact of LCD on groundwater in this area.
- Groundwater near Vangorda Creek appears to be unimpacted by mine waste seepage and hence there is little risk of impact from the Vangorda Pit to Vangorda Creek itself at this time.

5.4 Recommendations

5.4.1 Routine Groundwater Monitoring

In general, the 2009 groundwater monitoring program at the ARMC followed the scope of monitoring proposed in RGC (2009) (see Tables 5.1 to 5.3 of the 2009 monitoring report). Based on the review of the 2009 data, we recommend the following changes to the groundwater monitoring program for 2010 (see Tables 5-1 to 5-3):

- Add the following recently installed monitoring wells to the routine monitoring program:
    - P09-ETA-1 and P09-ETA-2 (Faro Creek canyon)
    - P09-C1, P09-C2, and P09-C3 (toe of CVD)
    - P09-SIS1 to P09-SIS6, SRK-08-SP7A/B, SRK08-SP8A/B (S-cluster area)
    - P09-UN1 to P09-UN3 (upper NFRC)
    - P09-GS1A and P09-GS1B (Grum slot)
    - P09-GW1 and P09-GW3 (Grum Dump West)

  - P09-LCD1, P09-LCD4 and P09-LCD6 (Little Creek Dam)
  - P09-VC1 and P09-VC2 (Vangorda Creek)
- Increase frequency of monitoring at selected monitoring wells downgradient of the S-cluster SIS to quarterly (March, June, August, October) (for 2010 only):
  - SRK05-SP4B and SRK05-SP5
  - SIS1, SIS2, SIS3 and SIS4
  - SRK-08-SP7A and SP7B
- Reduce frequency of monitoring from quarterly to bi-annual (May/June and September/October) in the following monitoring wells (on the north side of the Rose Creek valley);
  - P03-06 (all ports)
  - X21A, X21B, X24D
  - P01-03, P05-01 (all ports)
- Discontinue monitoring of groundwater quality in the shallow monitoring wells BH1, BH2, and BH4 screened in outwash sediments below the Zone 2 pit
- Reduce frequency of monitoring in the Upper NFRC and Zone 2 Pit Outwash area from bi-annual to annual (August)

Table 5.1.

Recommended Scope of Groundwater Monitoring in 2010, Faro Mine Site

Well ID	Region	Northing UTM z8 NAD27	Easting 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-SBR1	S-cluster Area			Annual
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 2010, 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 2010, 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
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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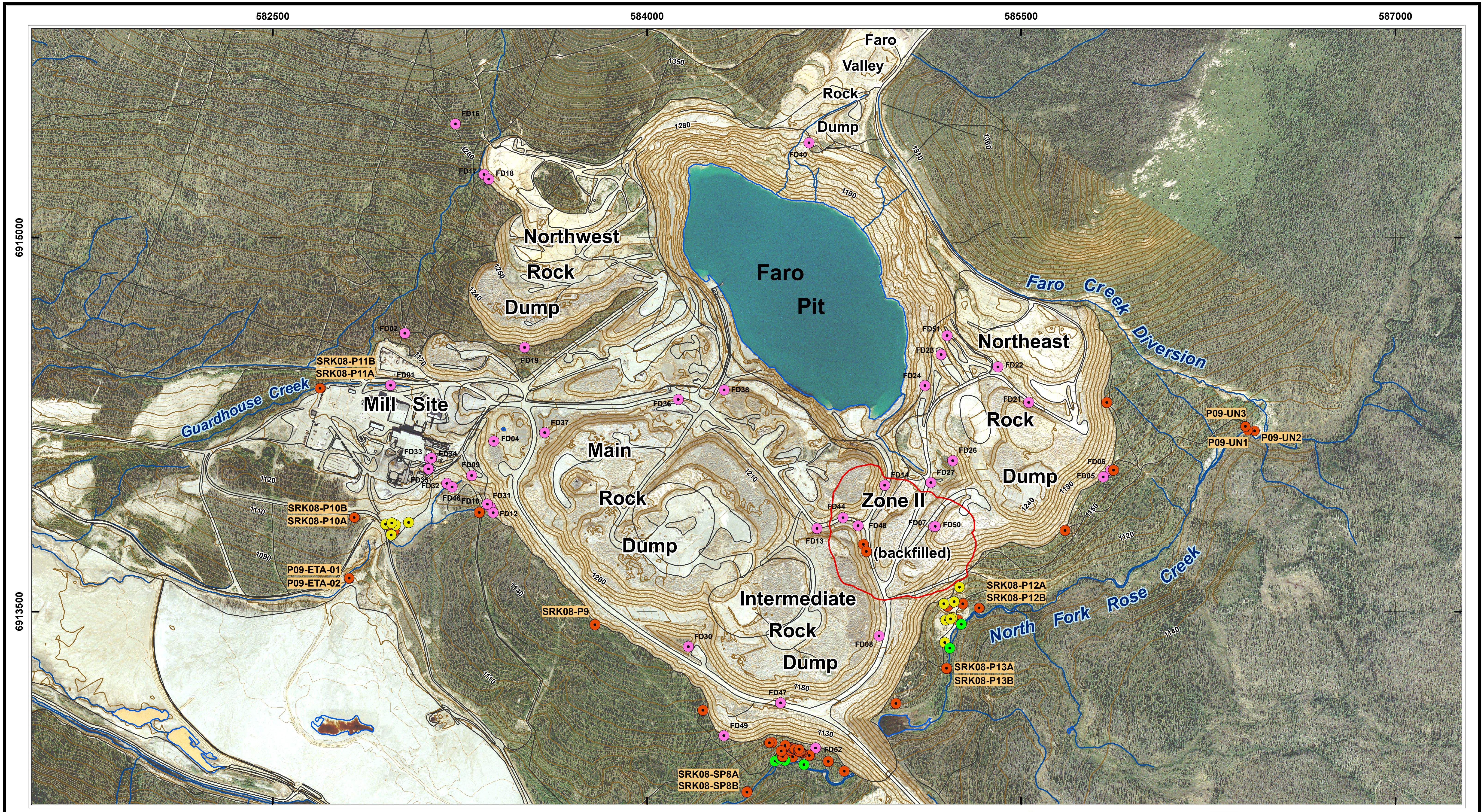
FIGURES



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 27
UNITS: Meters

CONTOUR INTERVAL: 2M

N W E S

Layout of Faro Mine Site

Anvil Range Mining Complex

SCALE

0 250 500 750 1,000 Meters

Yukon Government

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Consulting Geotechnical and Environmental Engineers

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 2-1

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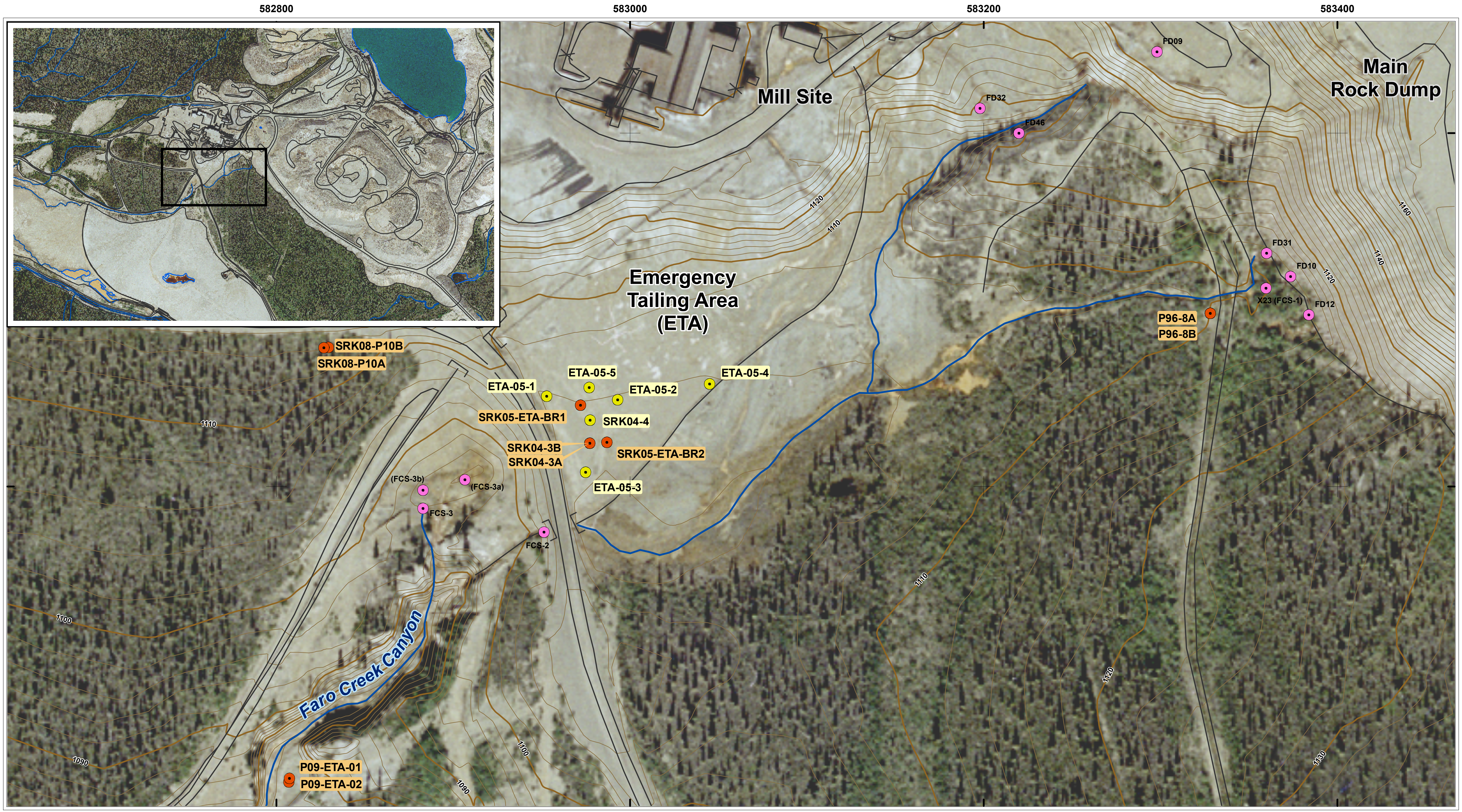

Groundwater Monitoring Wells
ETA Area
Faro Mine Site

LEGEND

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

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

CONTOUR INTERVAL: 2m

N W E S

SCALE
0 25 50 100 150 200 Meters

Yukon Government

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 2-2

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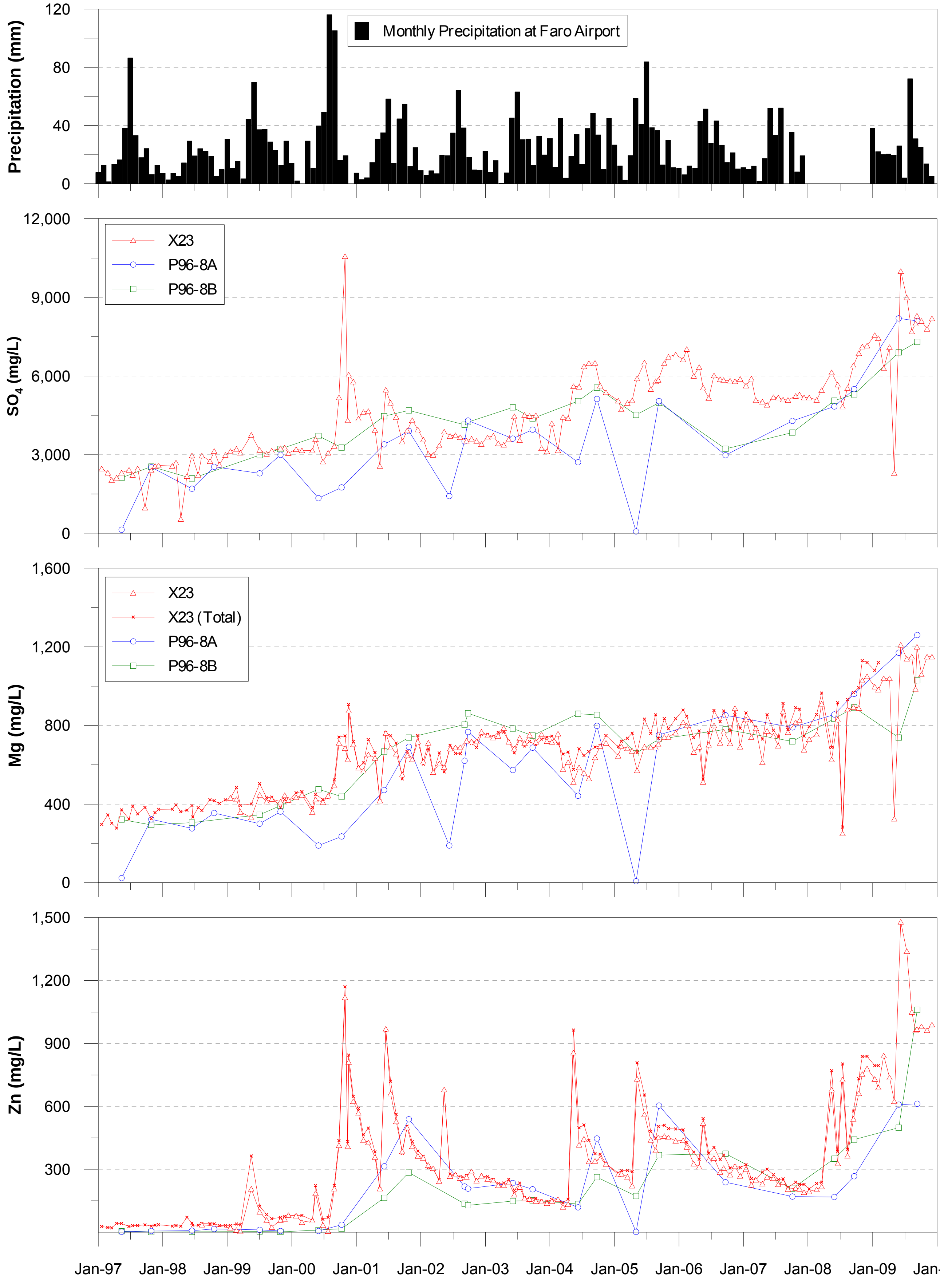


Figure 2-3a. Time trends for SO_4, Mg and Zn at X23 and P96-8A/B

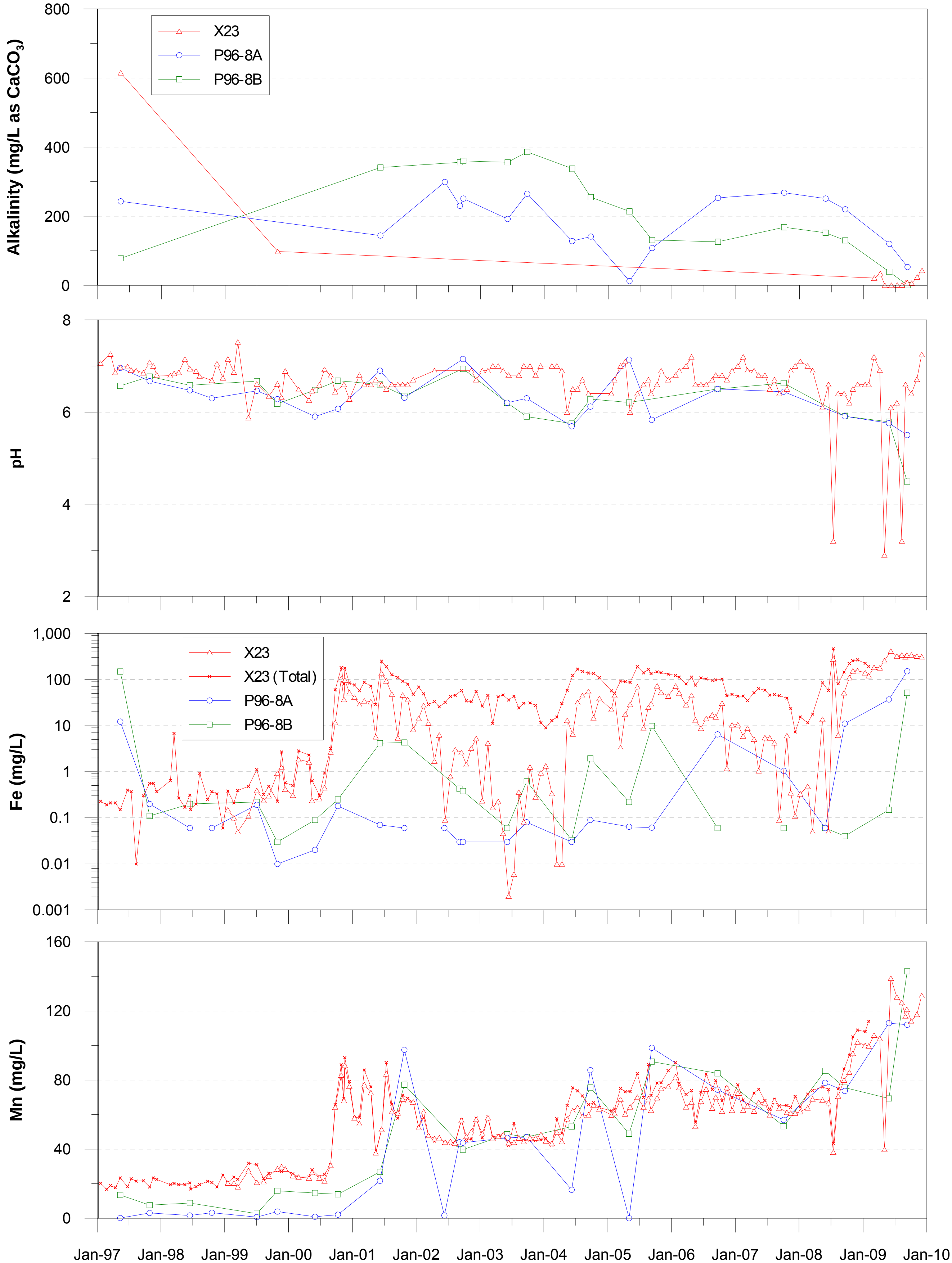


Figure 2-3b. Time trends for alkalinity, pH, Fe and Mn at X23 and P96-8A/B

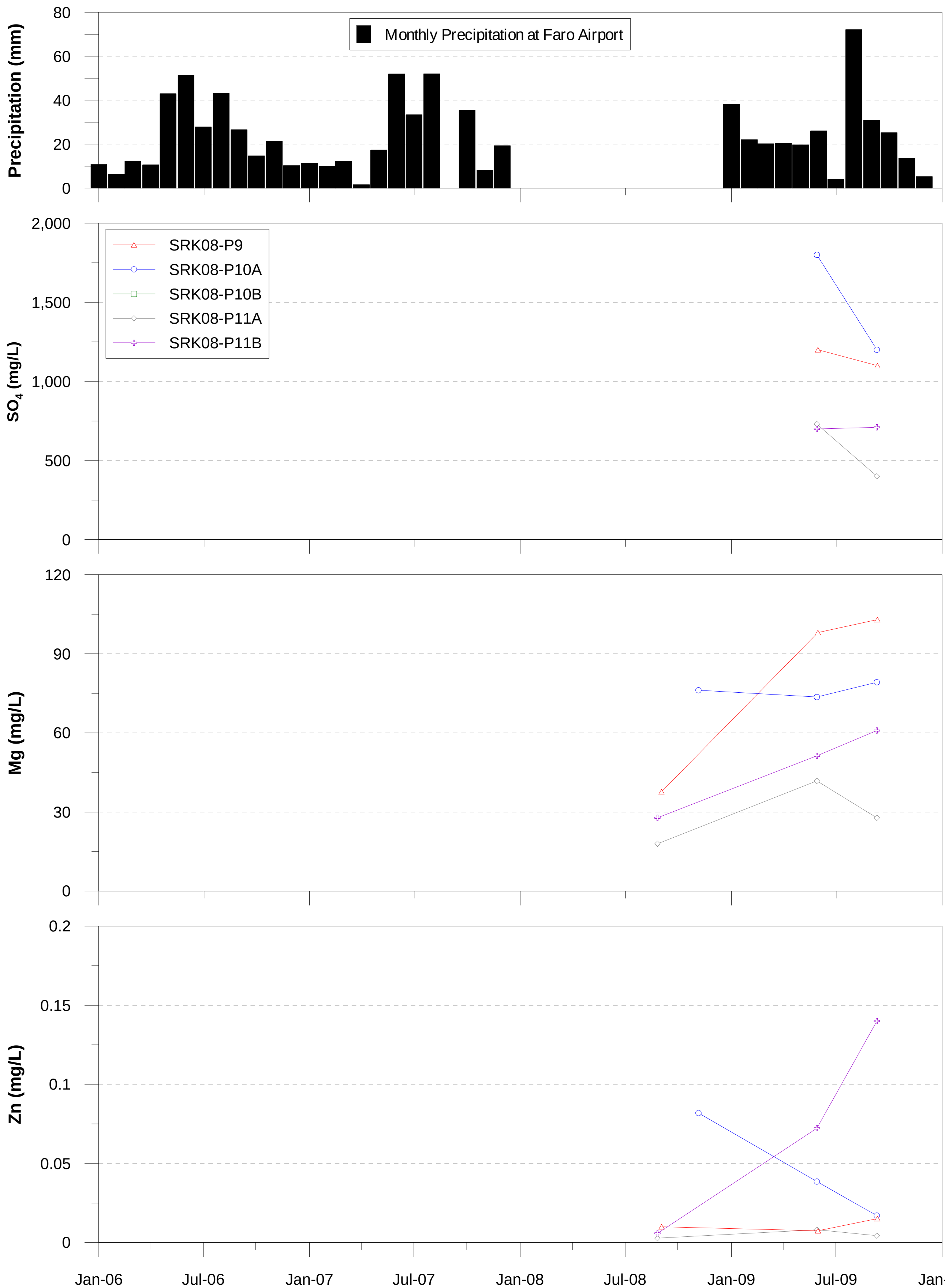


Figure 2-3c. Time trends for SO_4, Mg and Zn in SRK08 wells located in Main Rock Dump and Mill Site areas

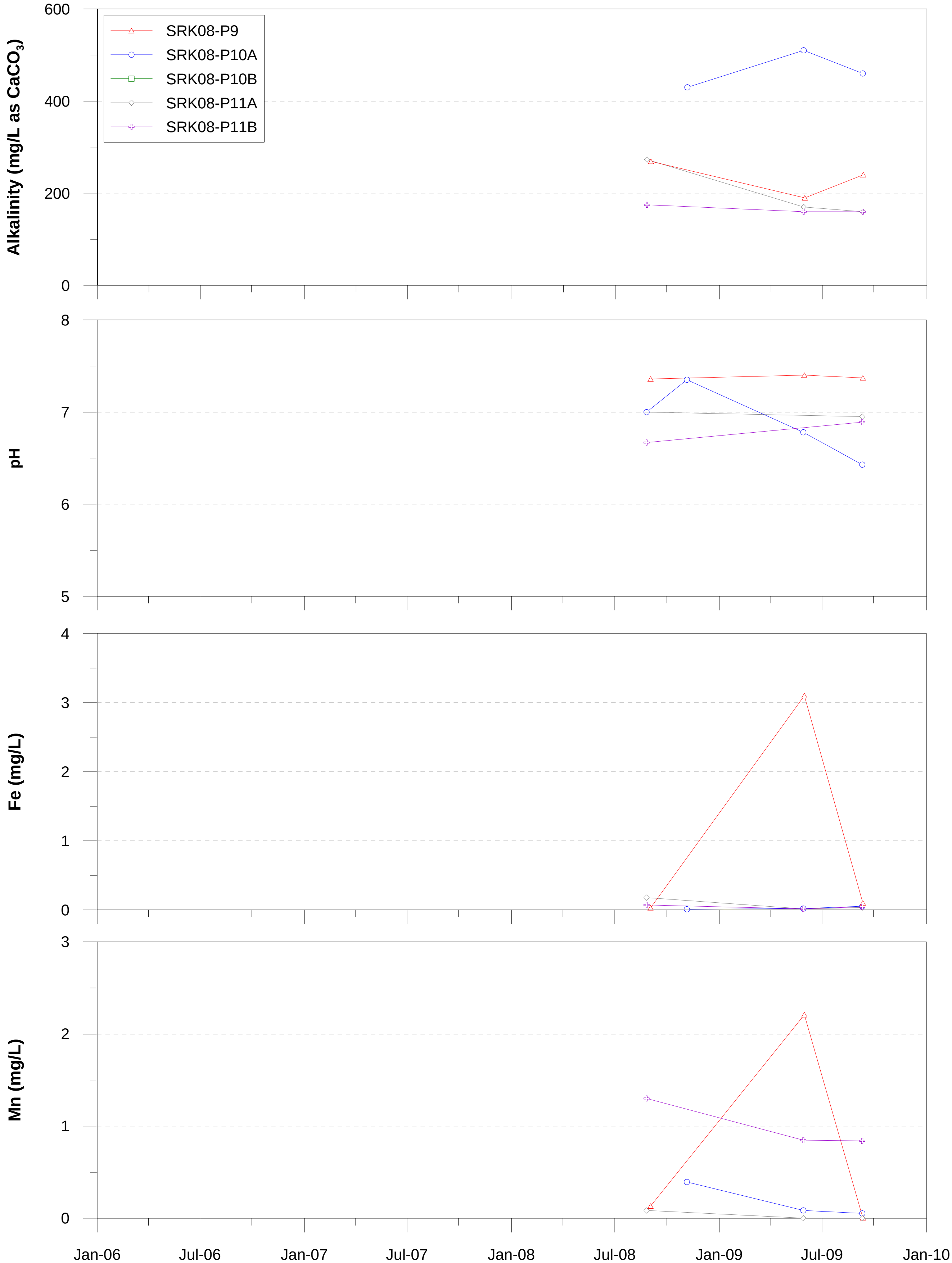


Figure 2-3d. Time trends for alkalinity, pH, Fe and Mn in SRK08 wells located in Main Rock Dump and Mill Site areas

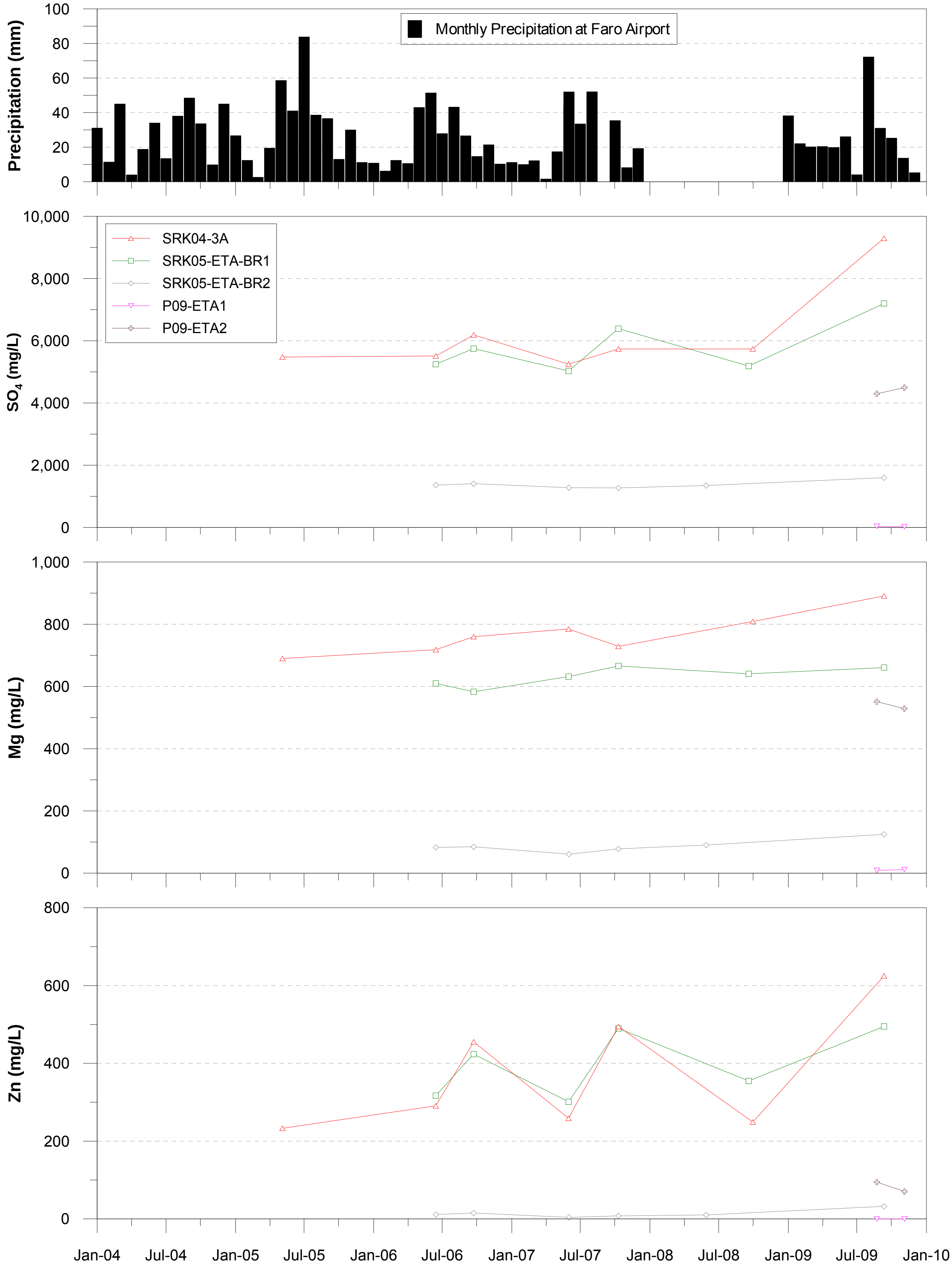


Figure 2-4a. Time trends for SO_4, Mg and Zn in SRK wells in ETA area

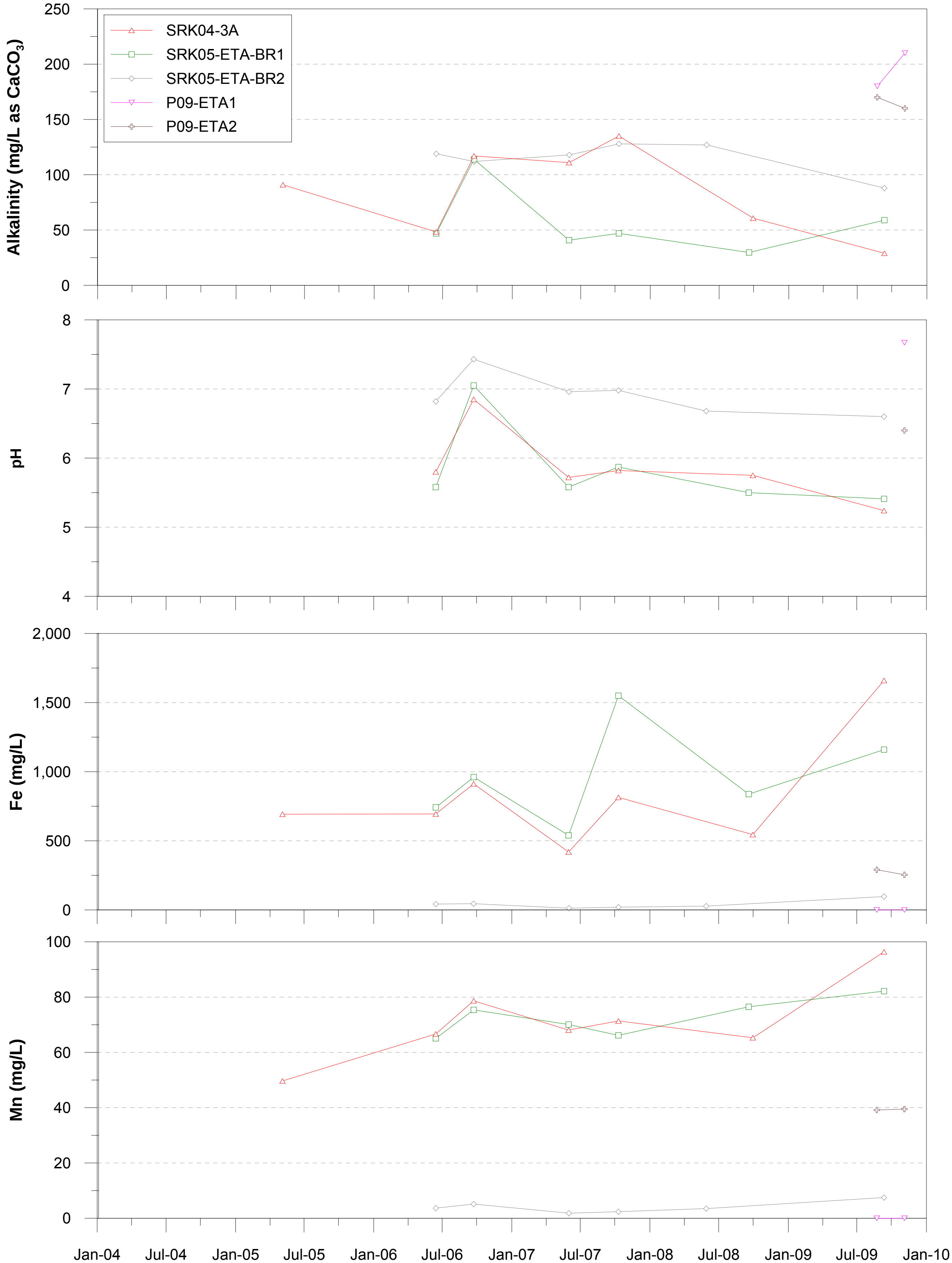
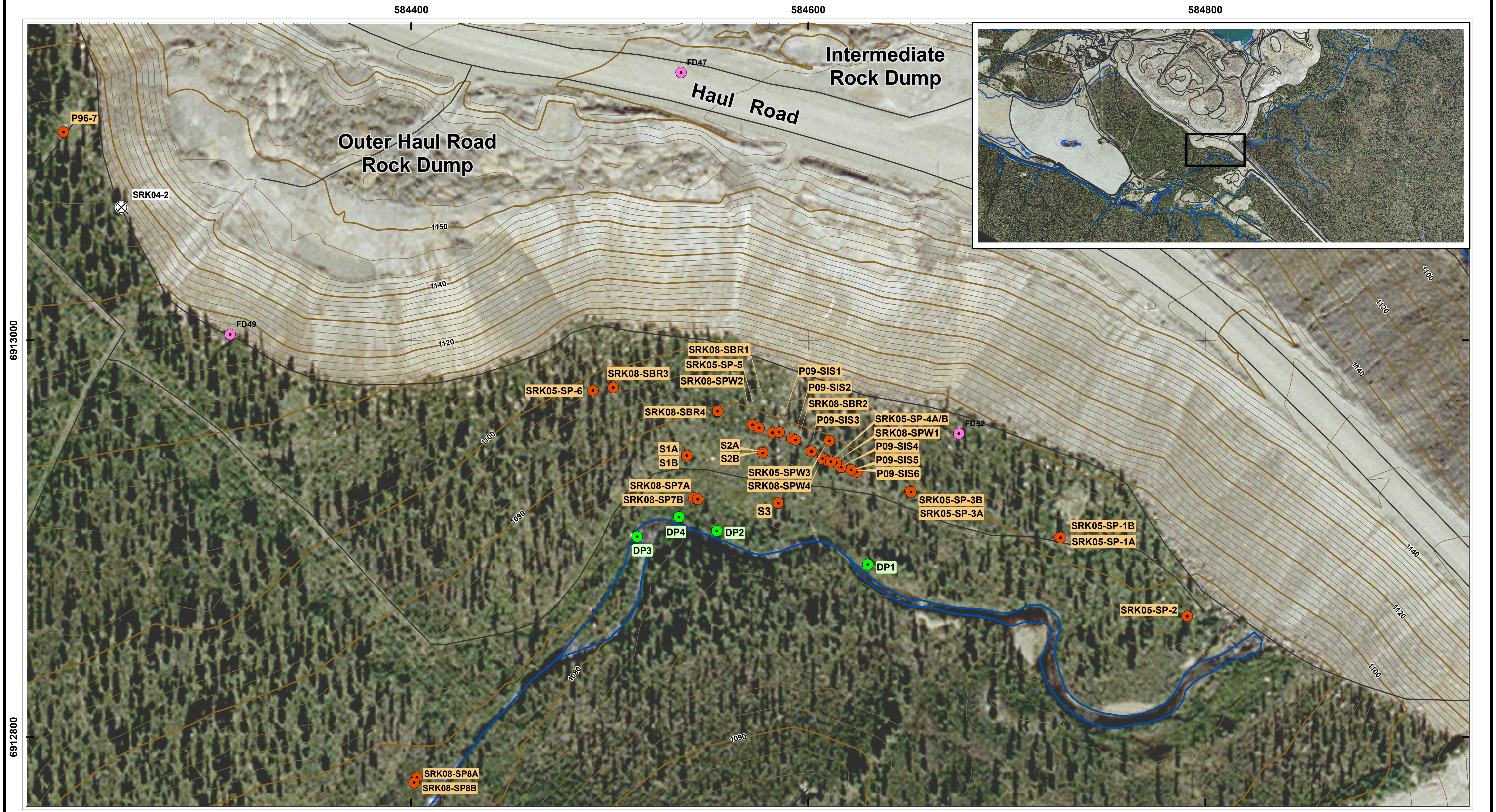


Figure 2-4b. Time trends for alkalinity, pH, Fe and Mn in SRK wells in ETA area



LEGEND

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

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

CONTOUR INTERVAL: 2m

Groundwater Monitoring Wells
S - Cluster Area
Faro Mine Site

SCALE

0 25 50 100 150 200 Meters

Yukon Government

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Consulting Geotechnical and Environmental Engineers

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 2-5

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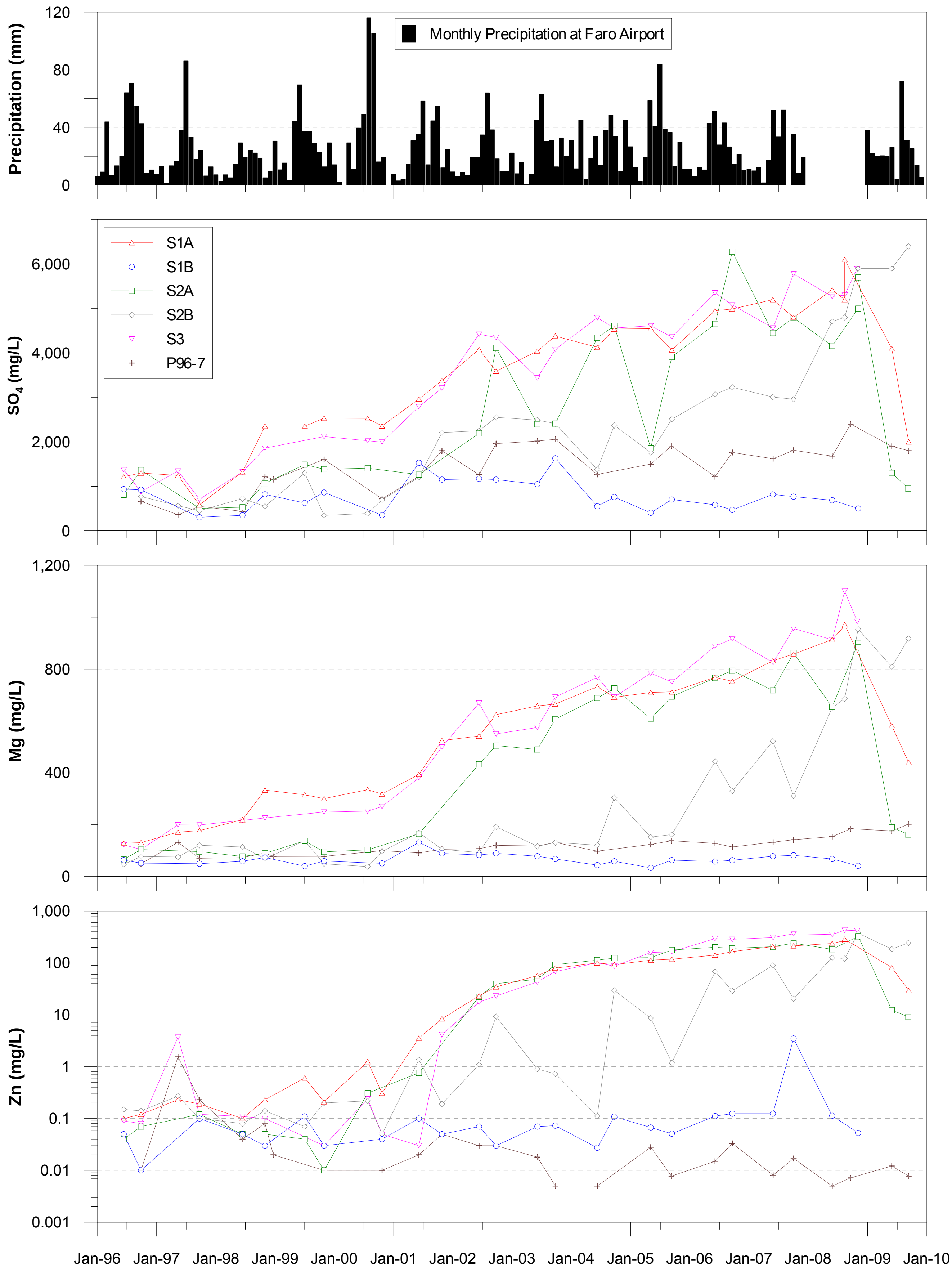


Figure 2-6a. Time Trends for SO_4, Mg and Zn in S-Cluster Wells

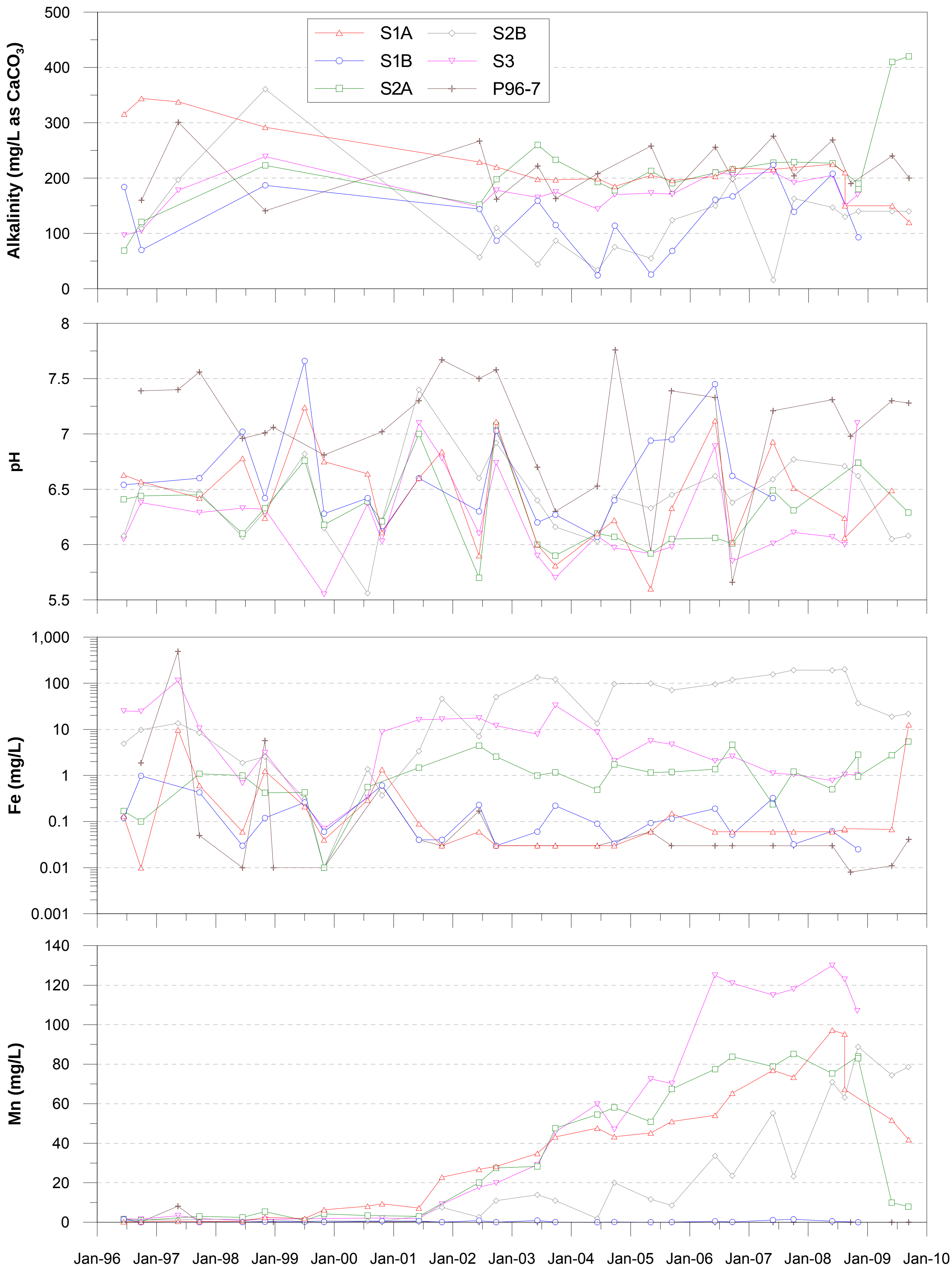


Figure 2-6b. Time trends for alkalinity, pH, Fe and Mn in S-Cluster Wells

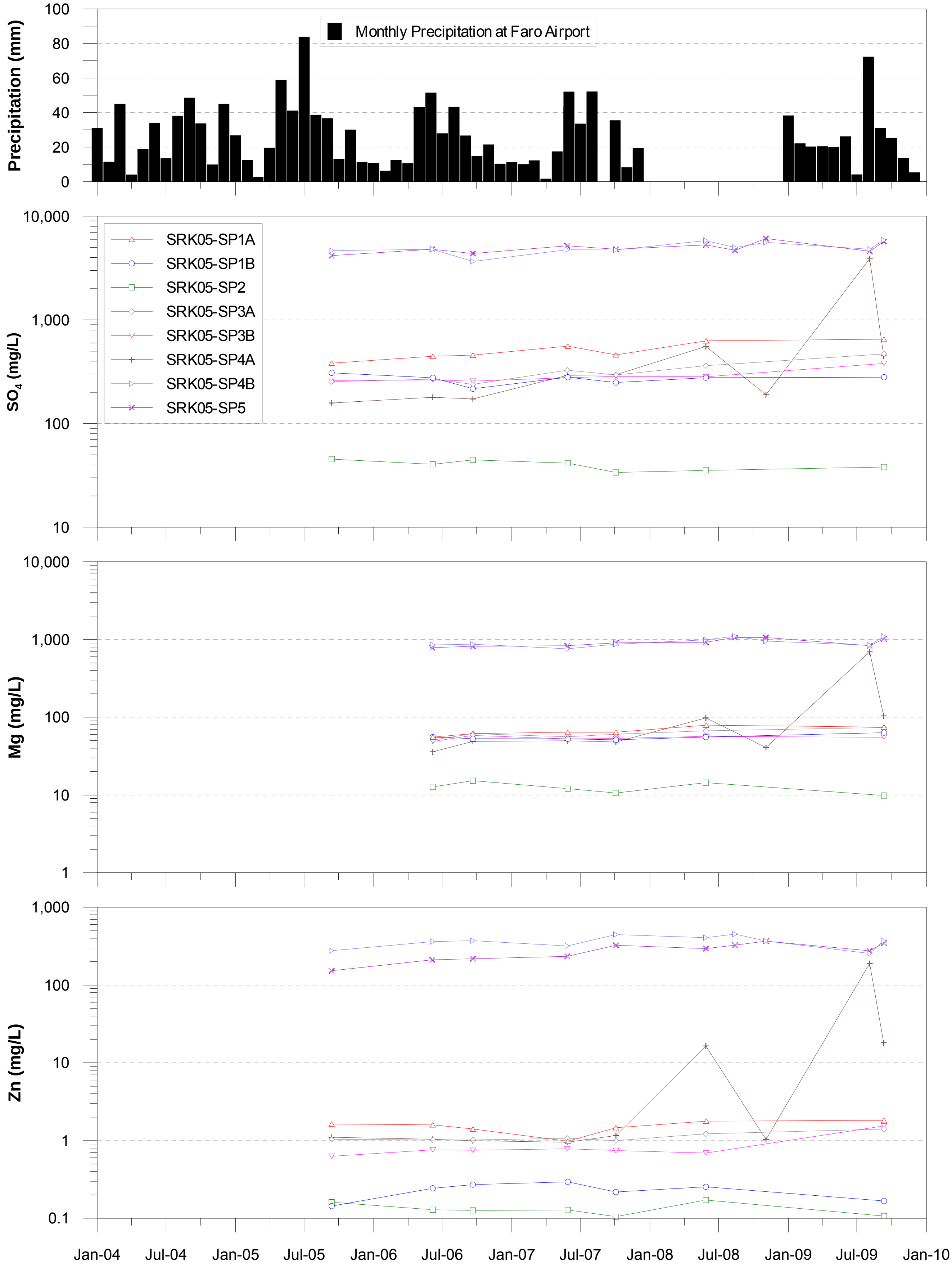


Figure 2-7a. Time trends for SO_4, Mg and Zn in SRK-05 wells in S-Cluster Area

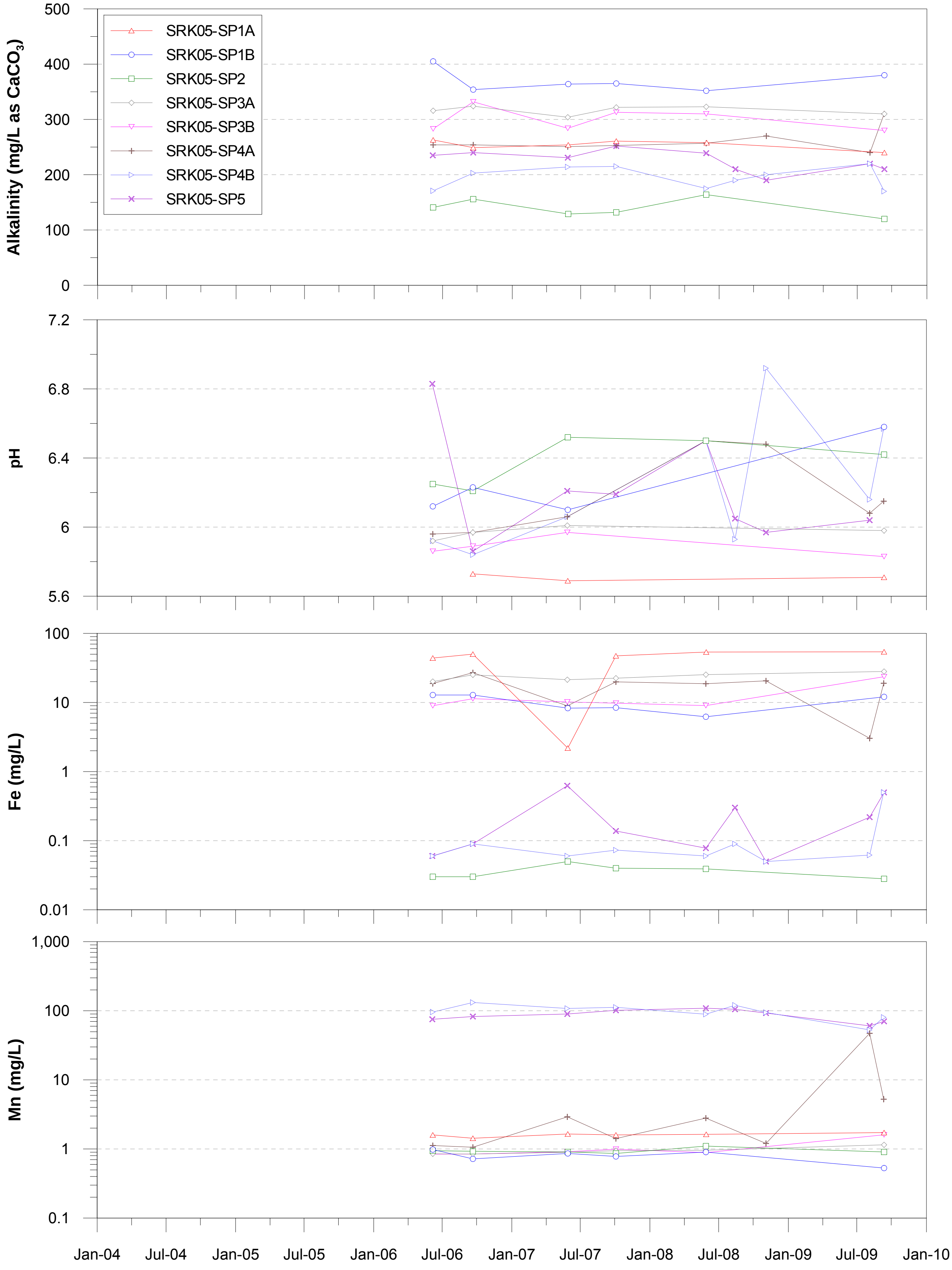


Figure 2-7b. Time trends for alkalinity, pH, Fe and Mn in SRK-05 wells in S-Cluster Area

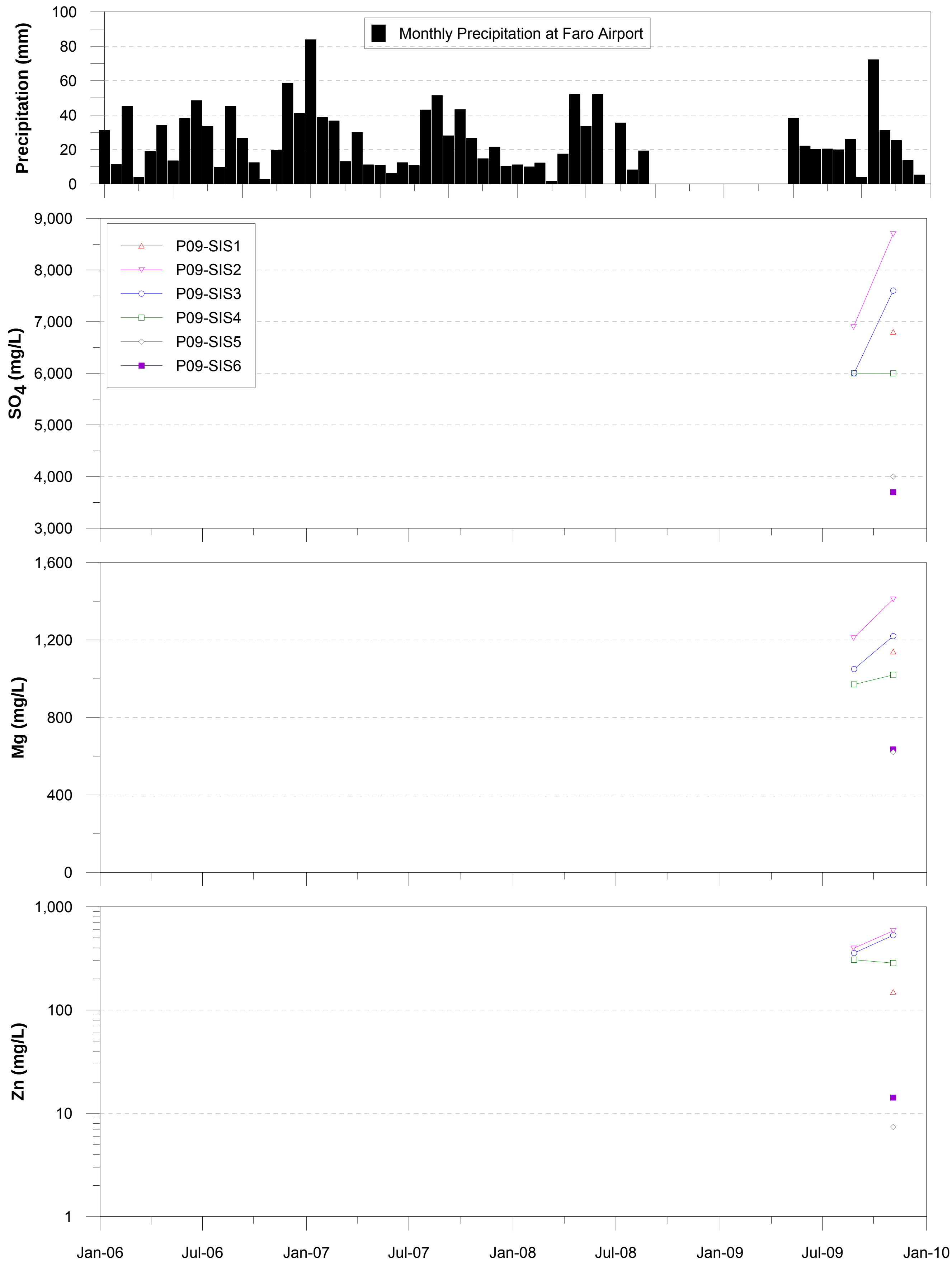


Figure 2-7c. Time trends for SO_4, Mg, Na and Zn in P09-SIS wells, S-Cluster Area

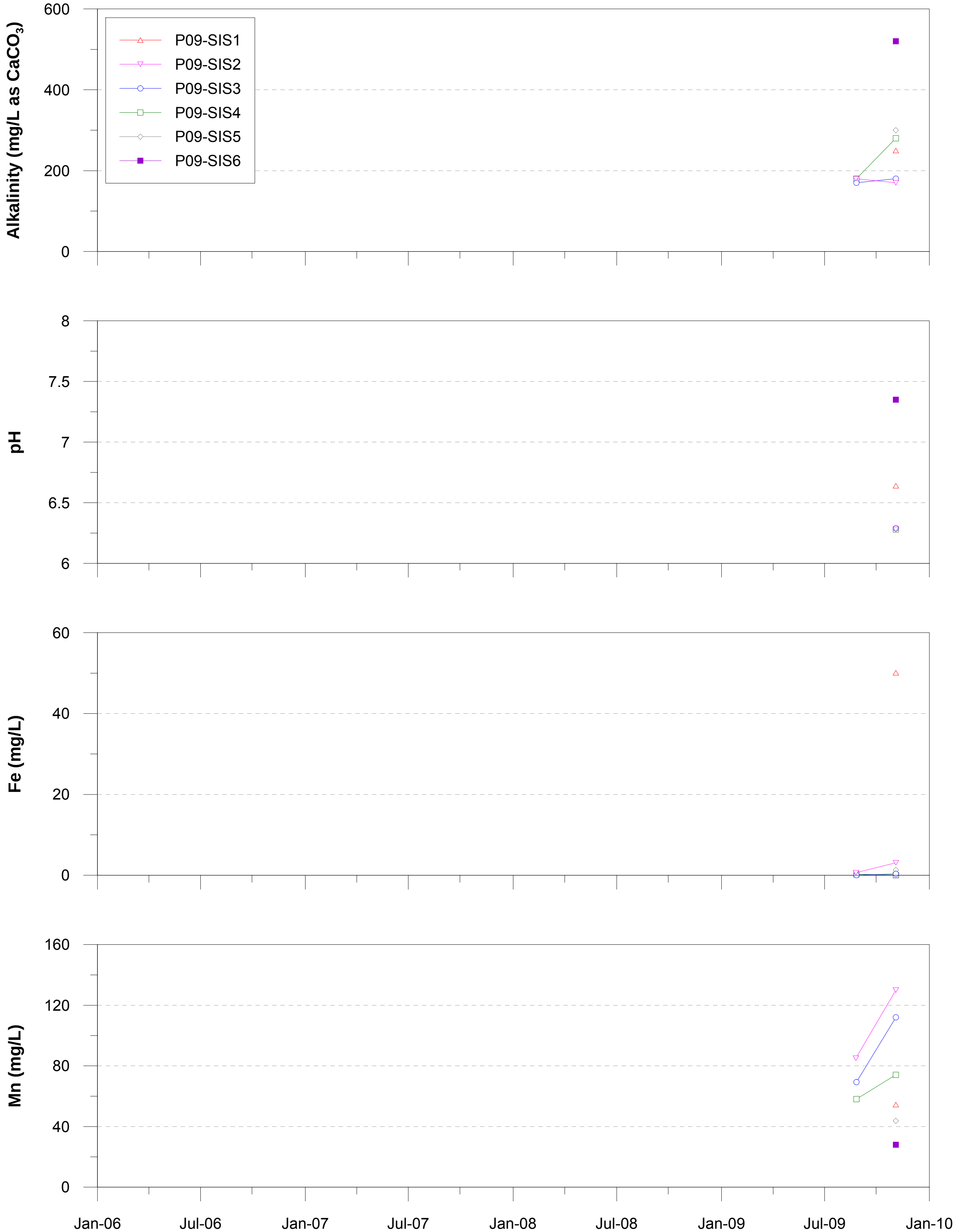


Figure 2-7d. Time trends for alkalinity, pH, Fe and Mn in P09-SIS wells, S-Cluster Area

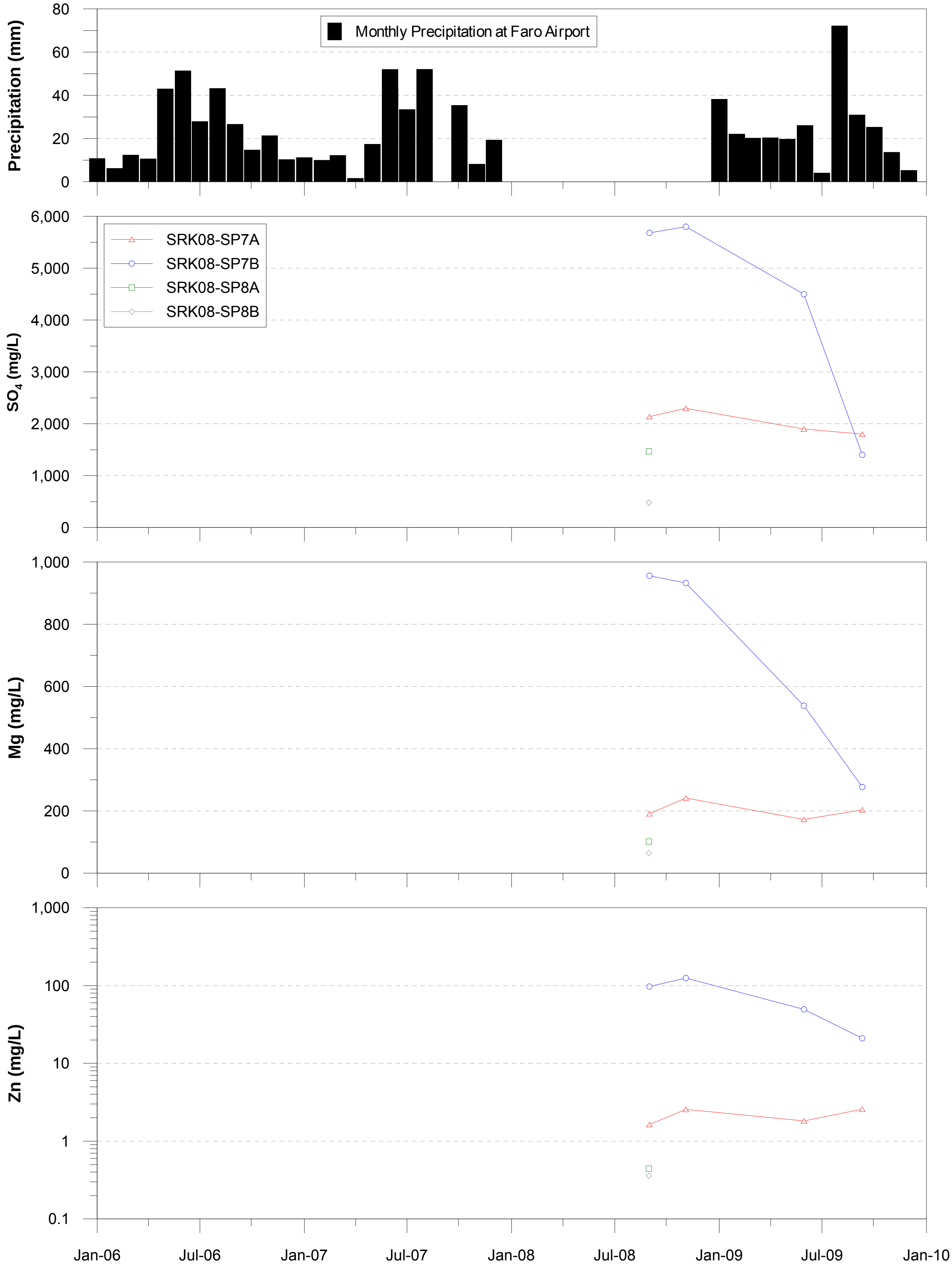


Figure 2-8a. Time trends for SO_4, Mg and Zn in SRK08-SP wells in S-Cluster Area

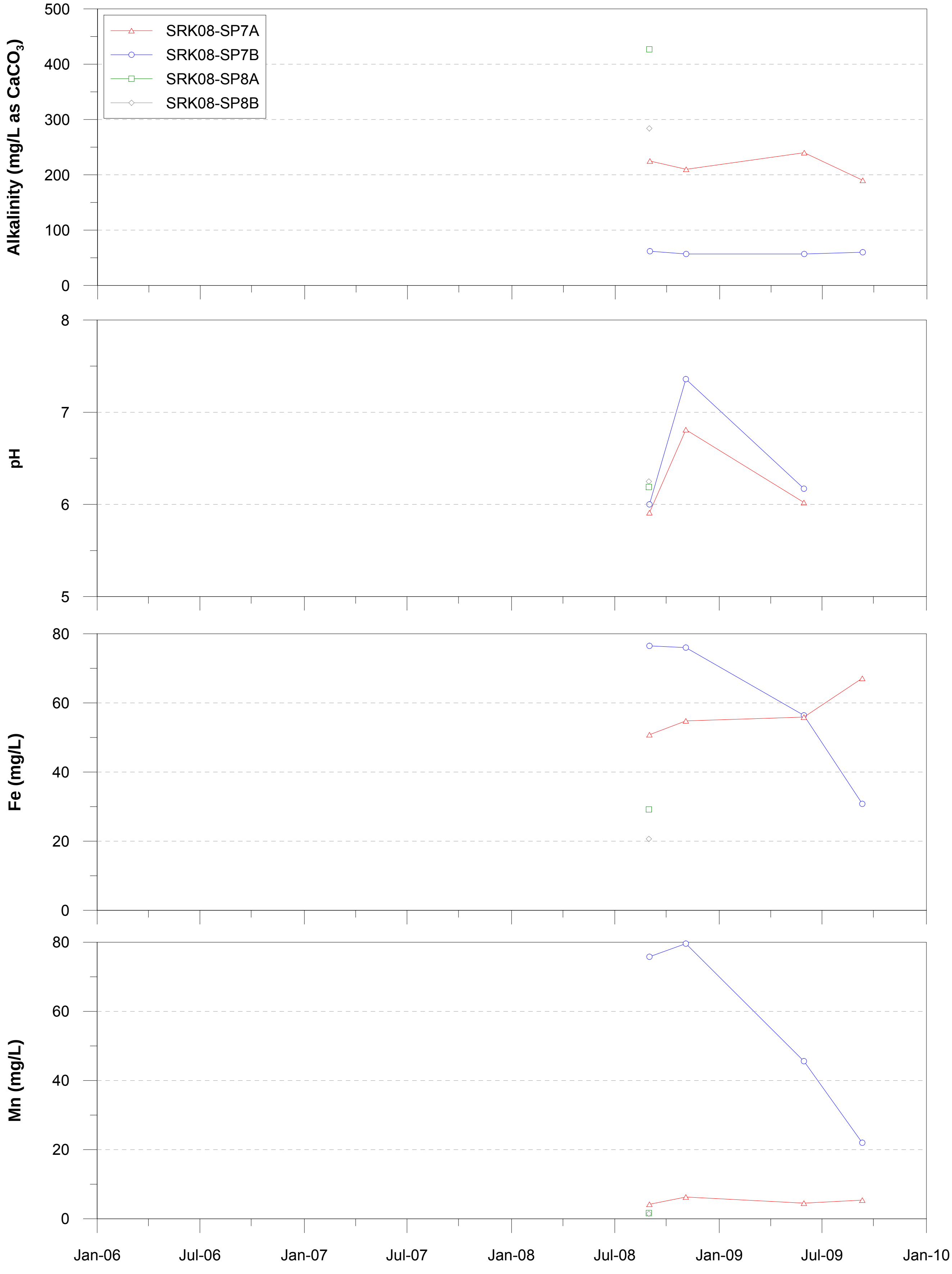


Figure 2-8b. Time trends for alkalinity, pH, Fe and Mn in SRK08-SP wells in S-Cluster Area

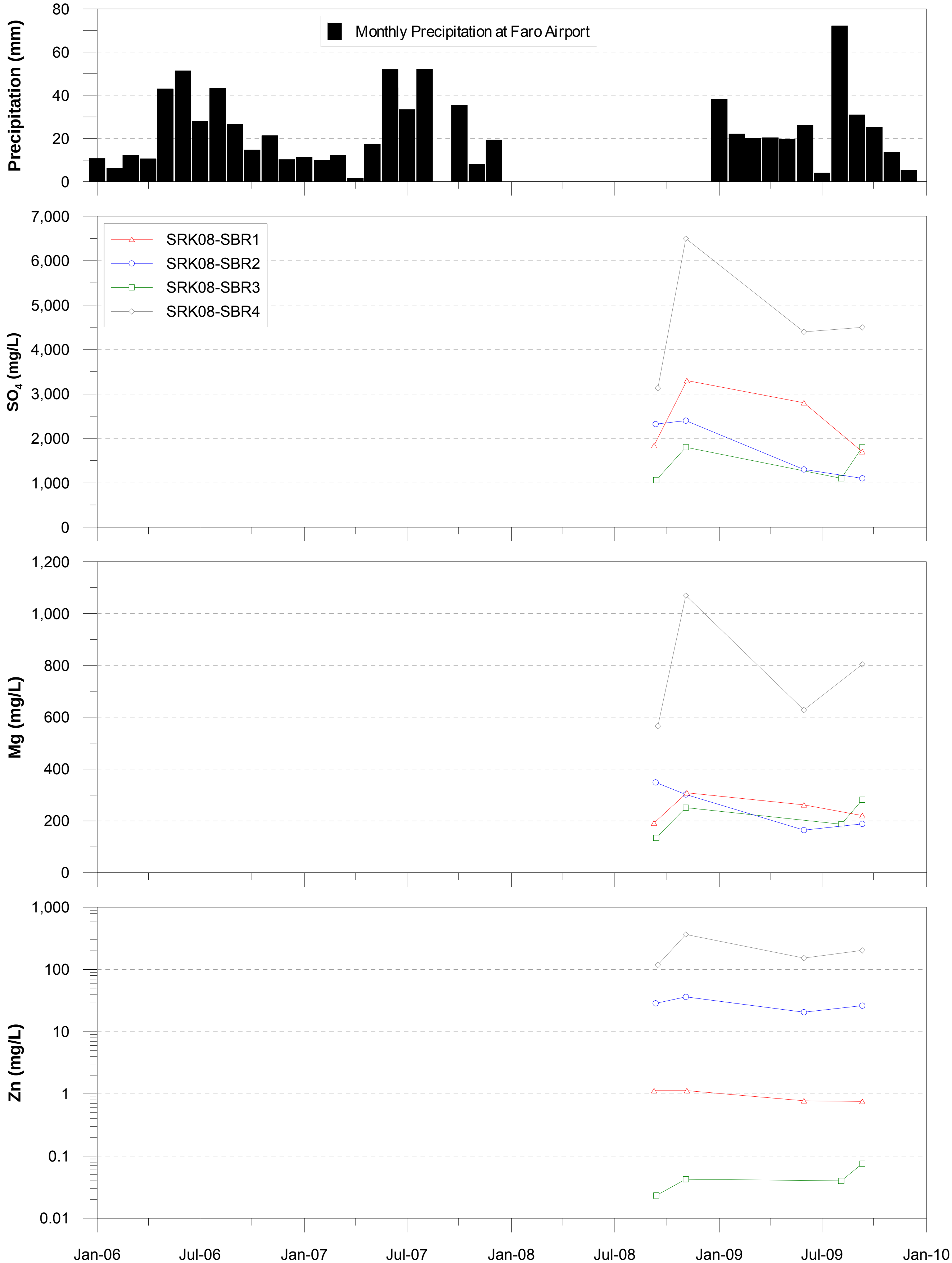


Figure 2-8c. Time trends for SO_4, Mg and Zn in SRK08-SBR wells in S-Cluster Area

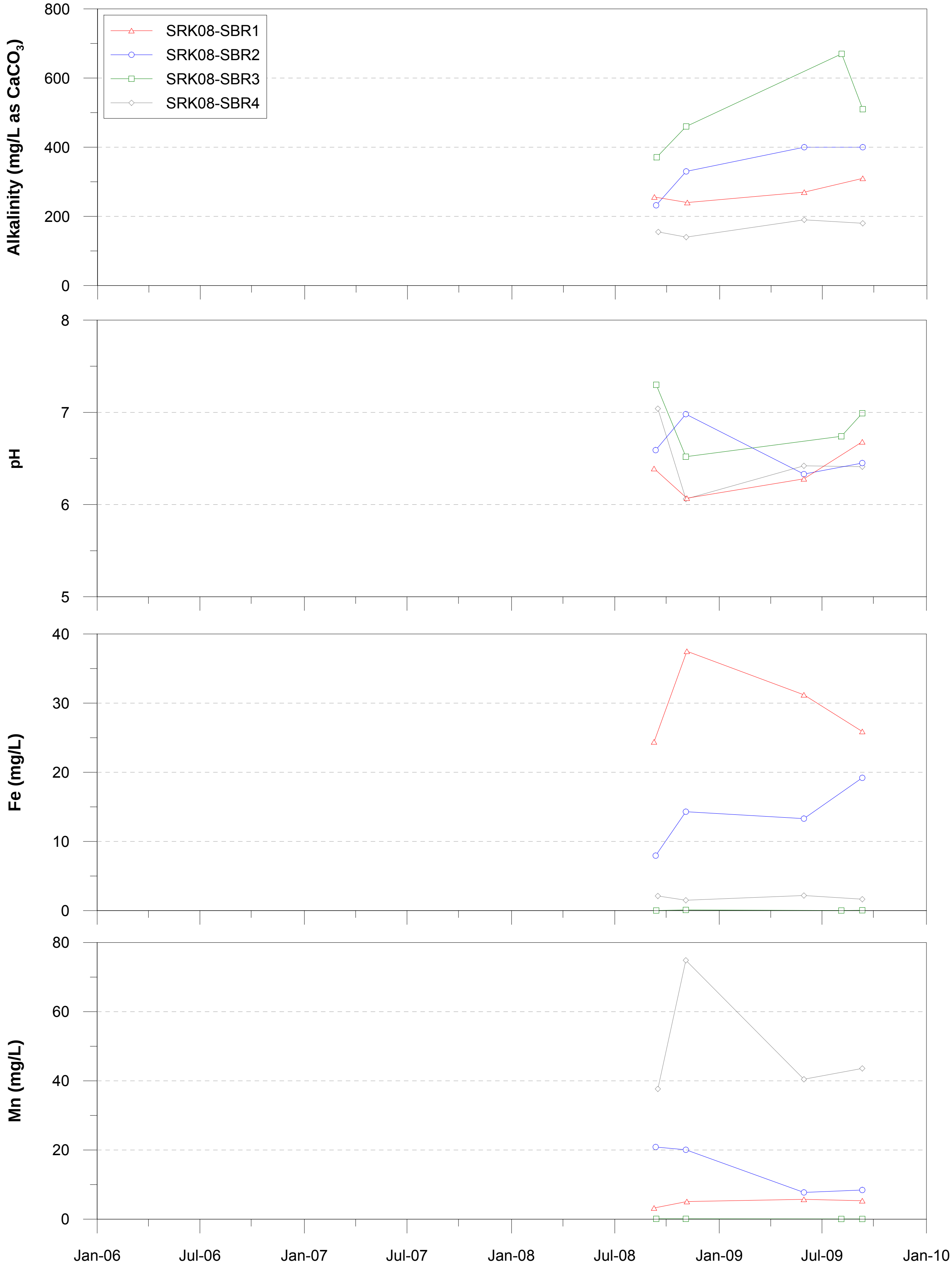
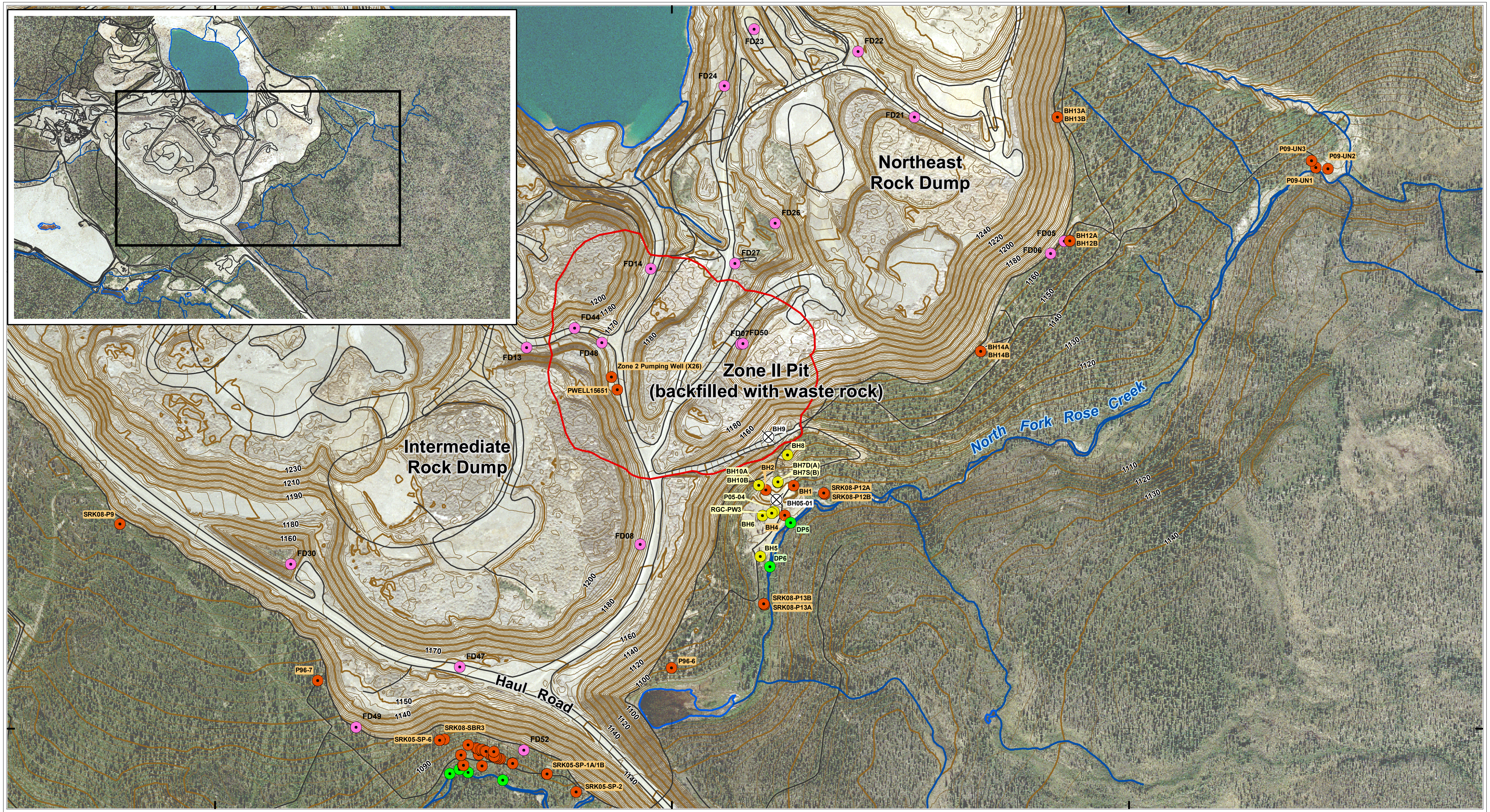


Figure 2-8d. Time trends for alkalinity, pH, Fe and Mn in SRK08-SBR wells in S-Cluster Area



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 27
UNITS: Meters

CONTOUR INTERVAL: 2m

N
W E
S

SCALE

0 150 300 450 600 Meters

Groundwater Monitoring Wells
North Fork Rose Creek Area
Faro Mine Site

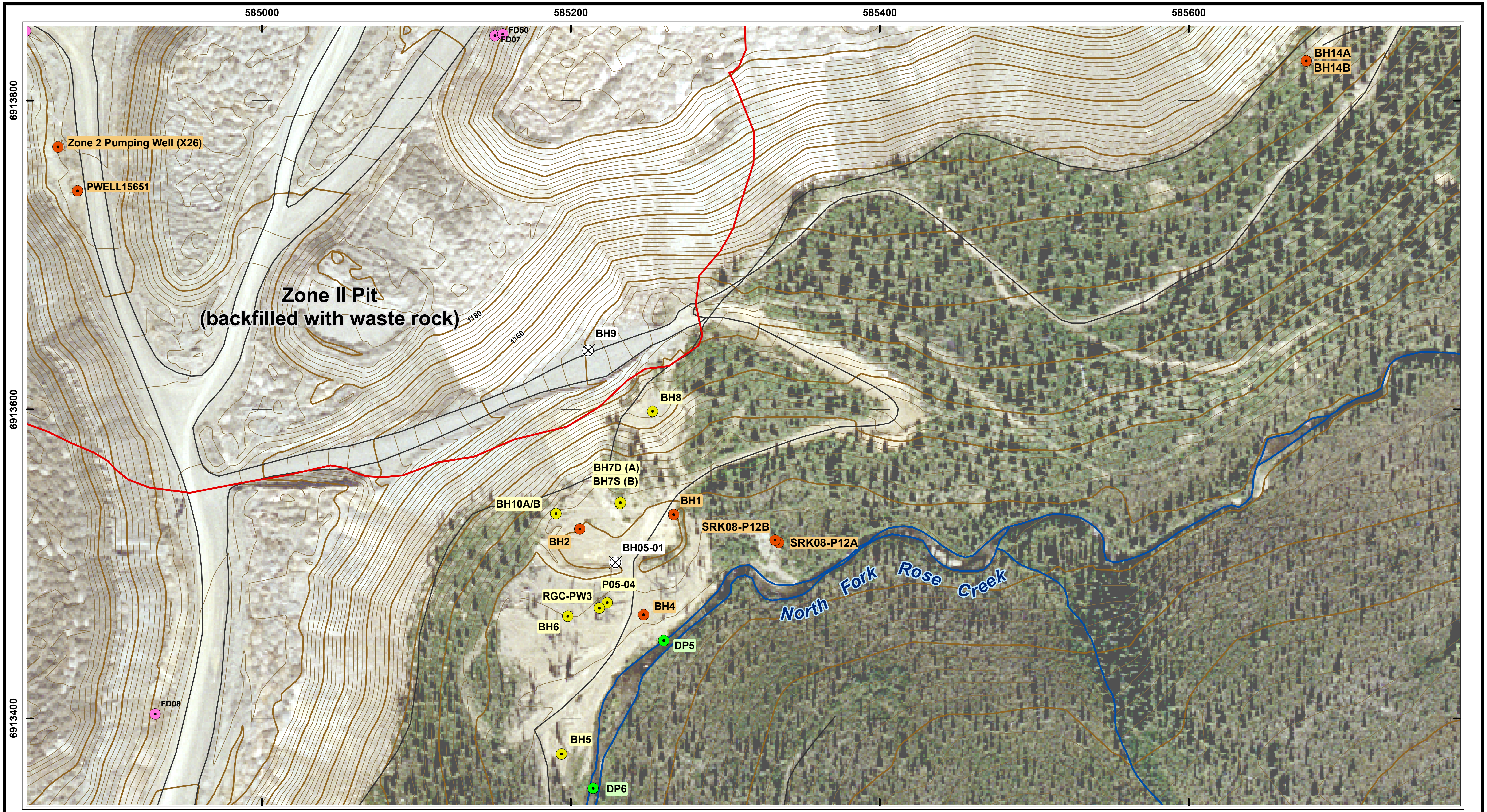
Yukon Government

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FIGURE: 2-9

DATE: 022510
DRAWN BY: OM
FILE: Faro_RoseCreek10.mxd



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 27
UNITS: Meters

CONTOUR INTERVAL: 2m

SCALE
0 25 50 100 150 200 Meters

Groundwater Monitoring Wells
Zone II Pit Outwash Area
Faro Mine Site

Yukon Government

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 2-10

DATE: 022510
DRAWN BY: OM
FILE: Faro_Zone2_area10.mxd

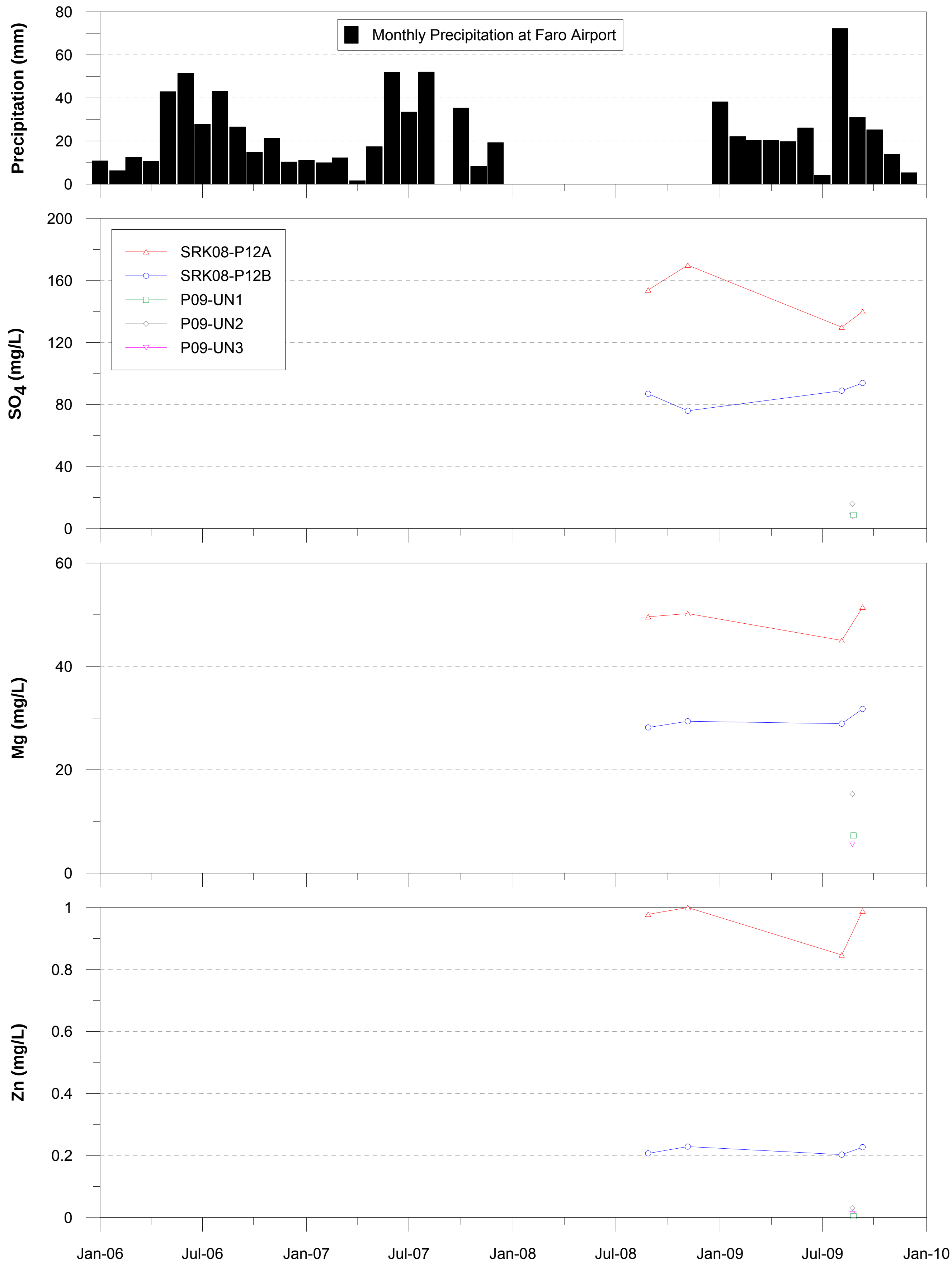


Figure 2-11a. Time trends for SO_4, Mg, Na and Zn in P09-UN and SRK08-P12A/B wells

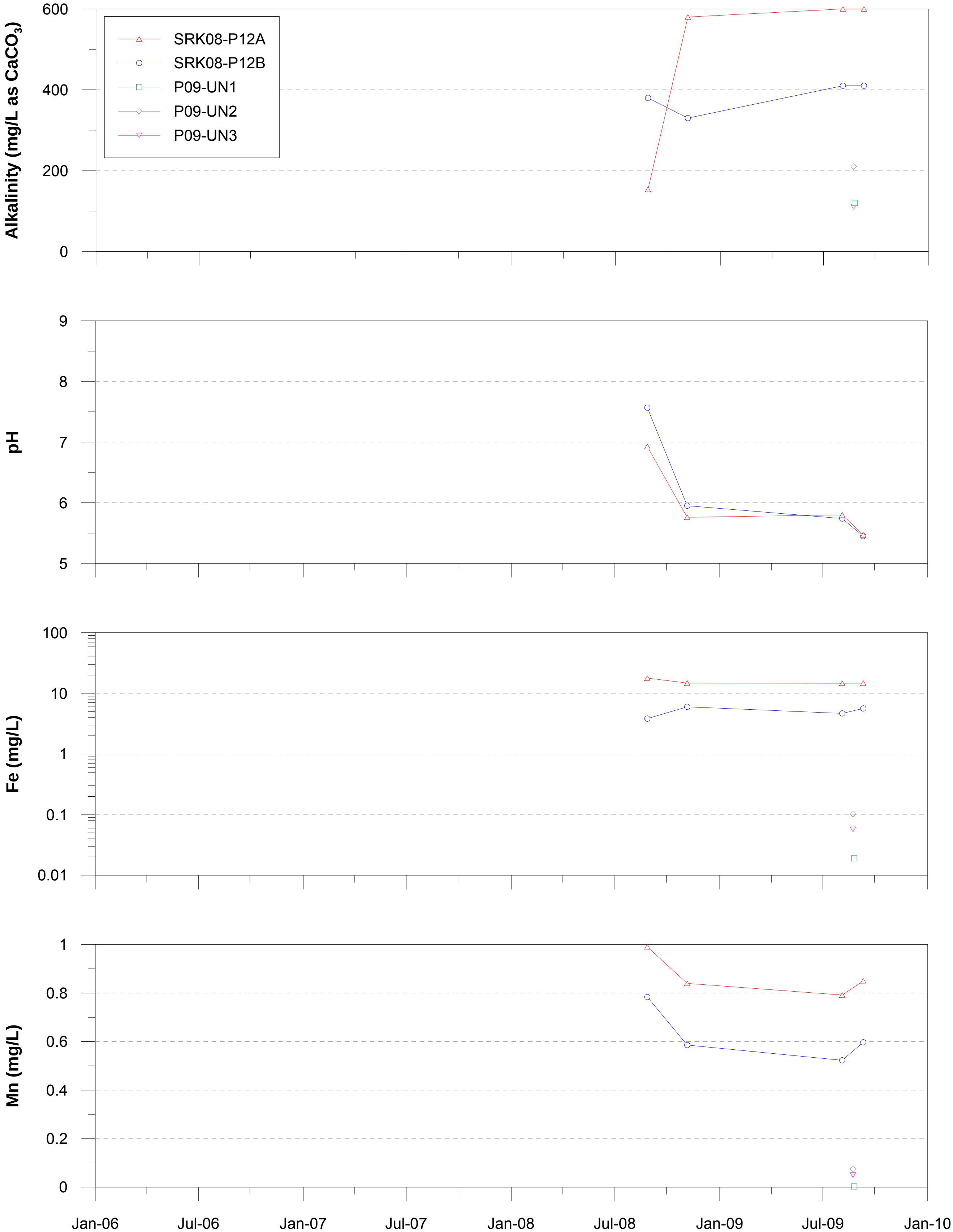


Figure 2-11b. Time trends for Alkalinity, pH, Fe and Mn in P09-UN and SRK08-P12A/B wells

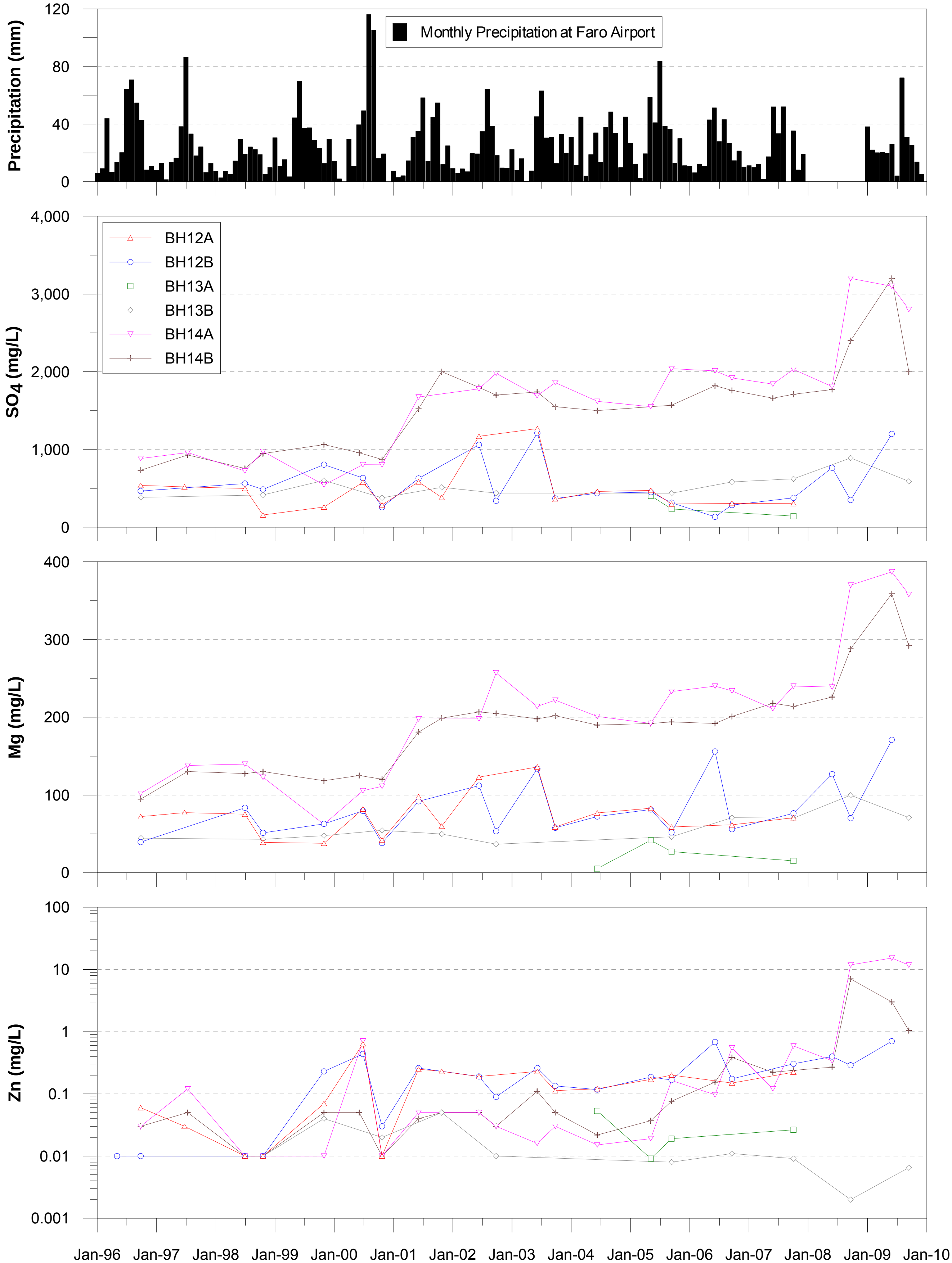


Figure 2-12a. Time trends for SO_4, Mg and Zn in wells at the toe of Northeast Rock Dump

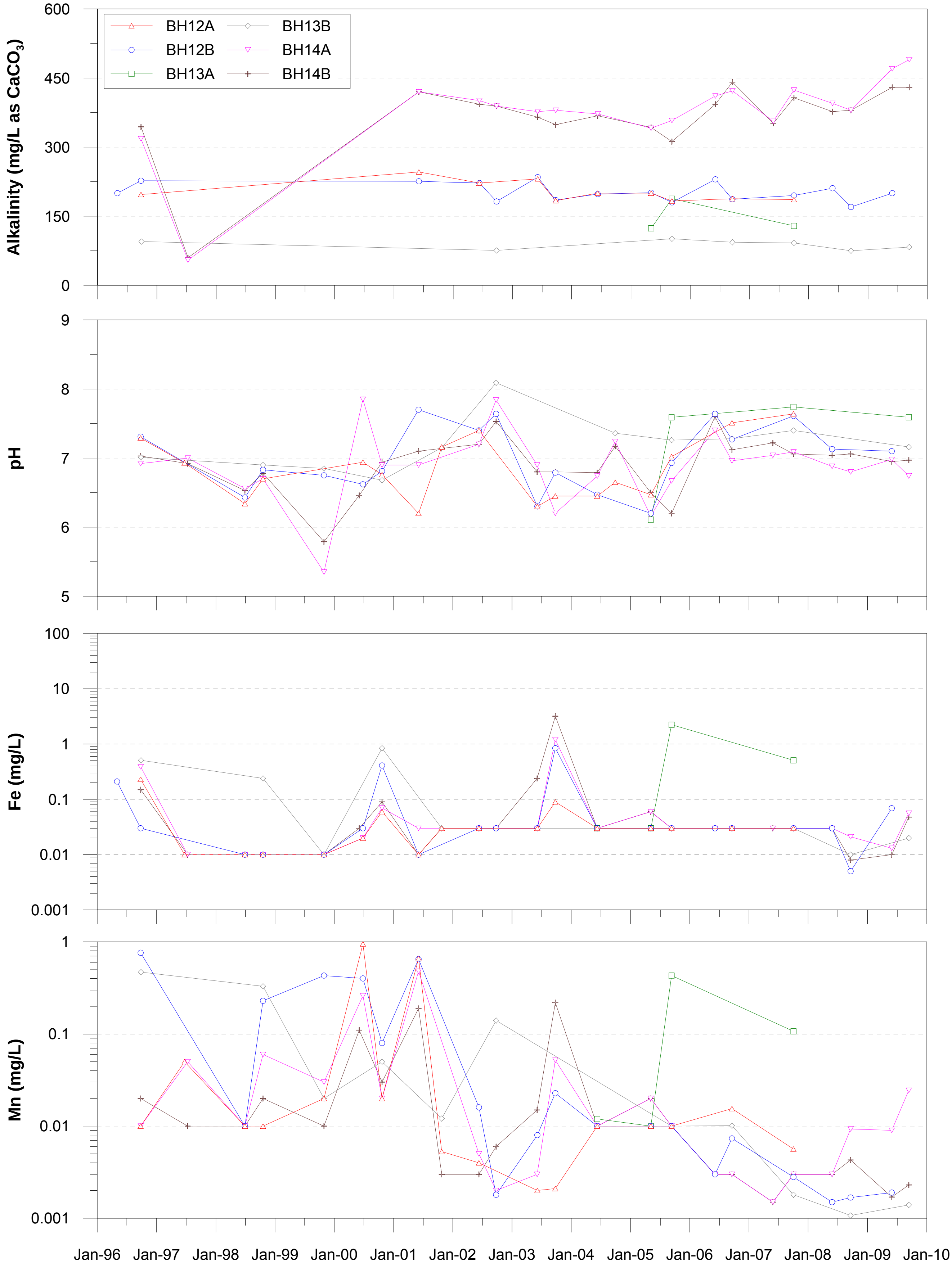


Figure 2-12b. Time trends for alkalinity, pH, Fe and Mn in wells at the toe of Northeast Rock Dump

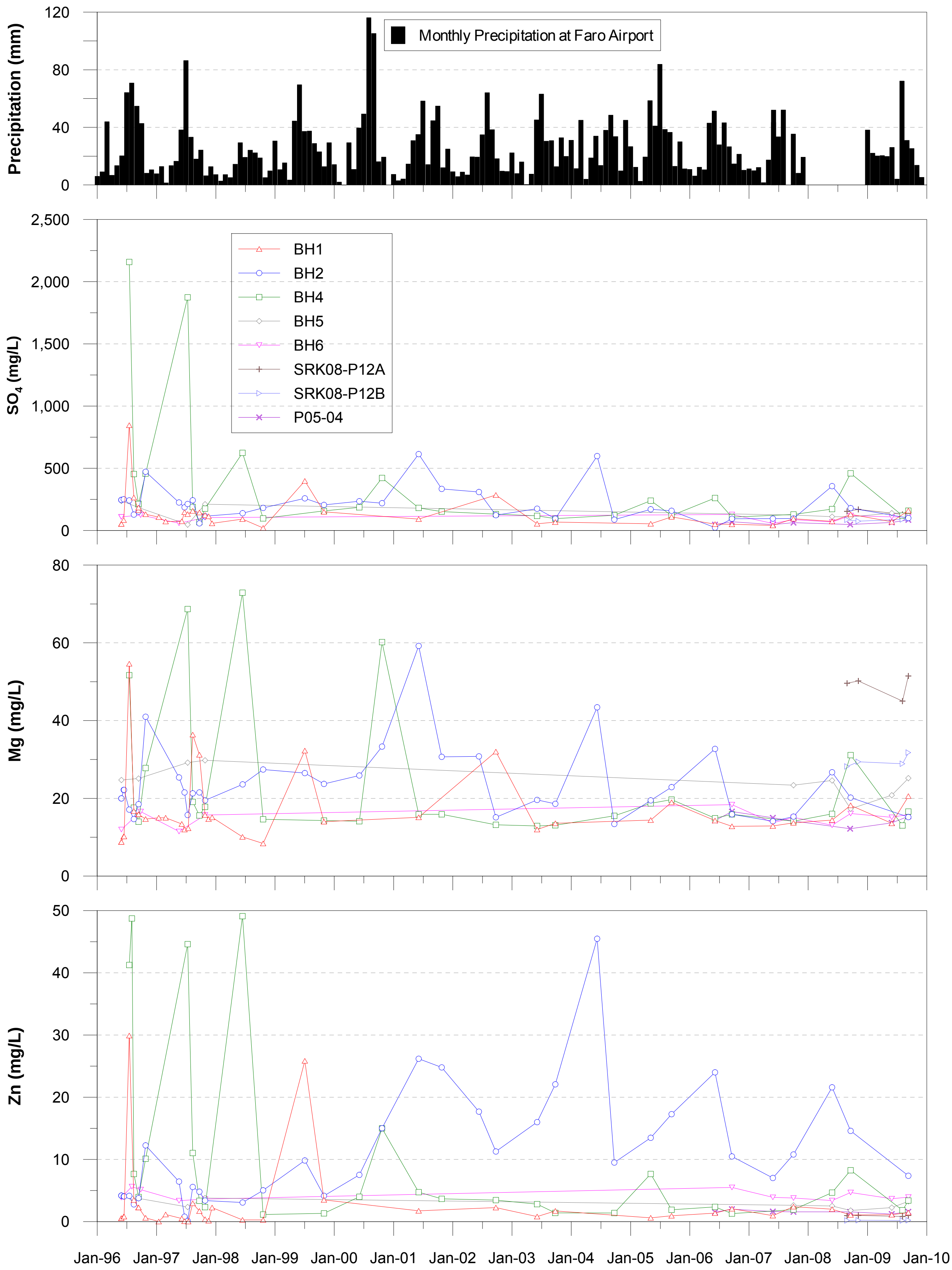


Figure 2-13a. Time trends for SO_4, Mg and Zn for wells in Zone 2 Pit outwash area

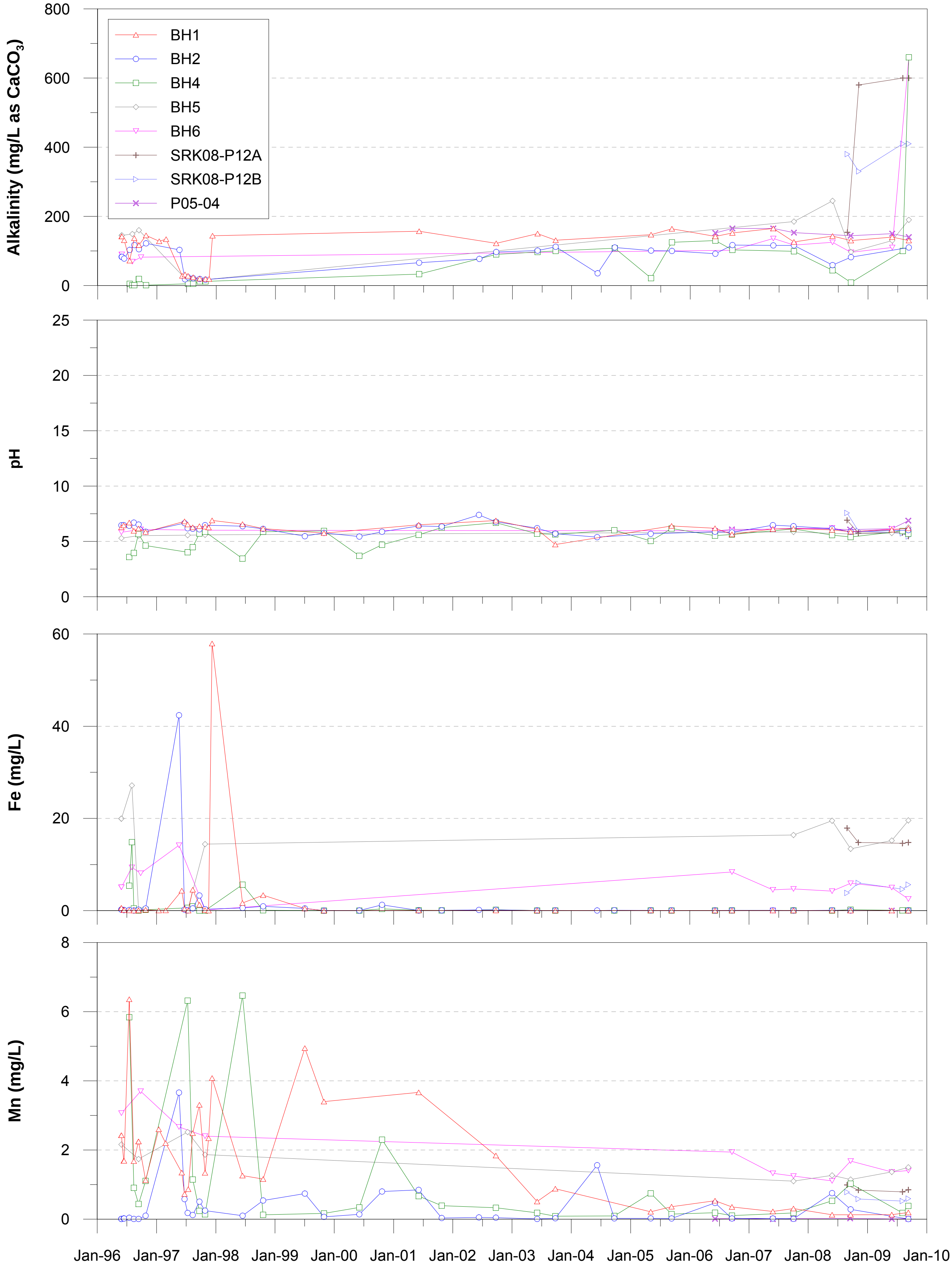


Figure 2-13b. Time trends for alkalinity, pH, Fe and Mn for wells in Zone 2 Pit outwash area

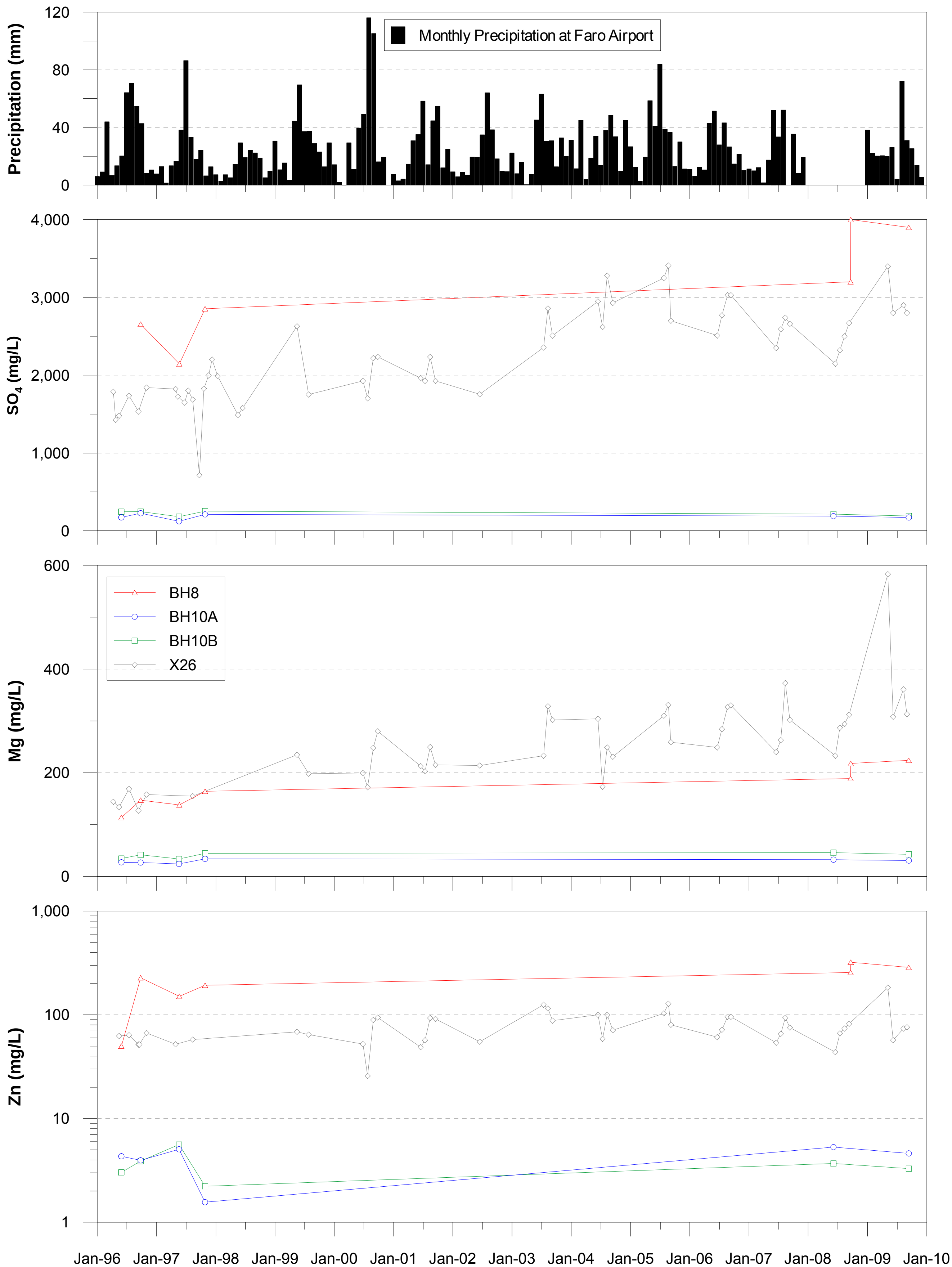


Figure 2-14a. Time trends for SO_4, Mg and Zn for Zone 2 Pit and bedrock wells

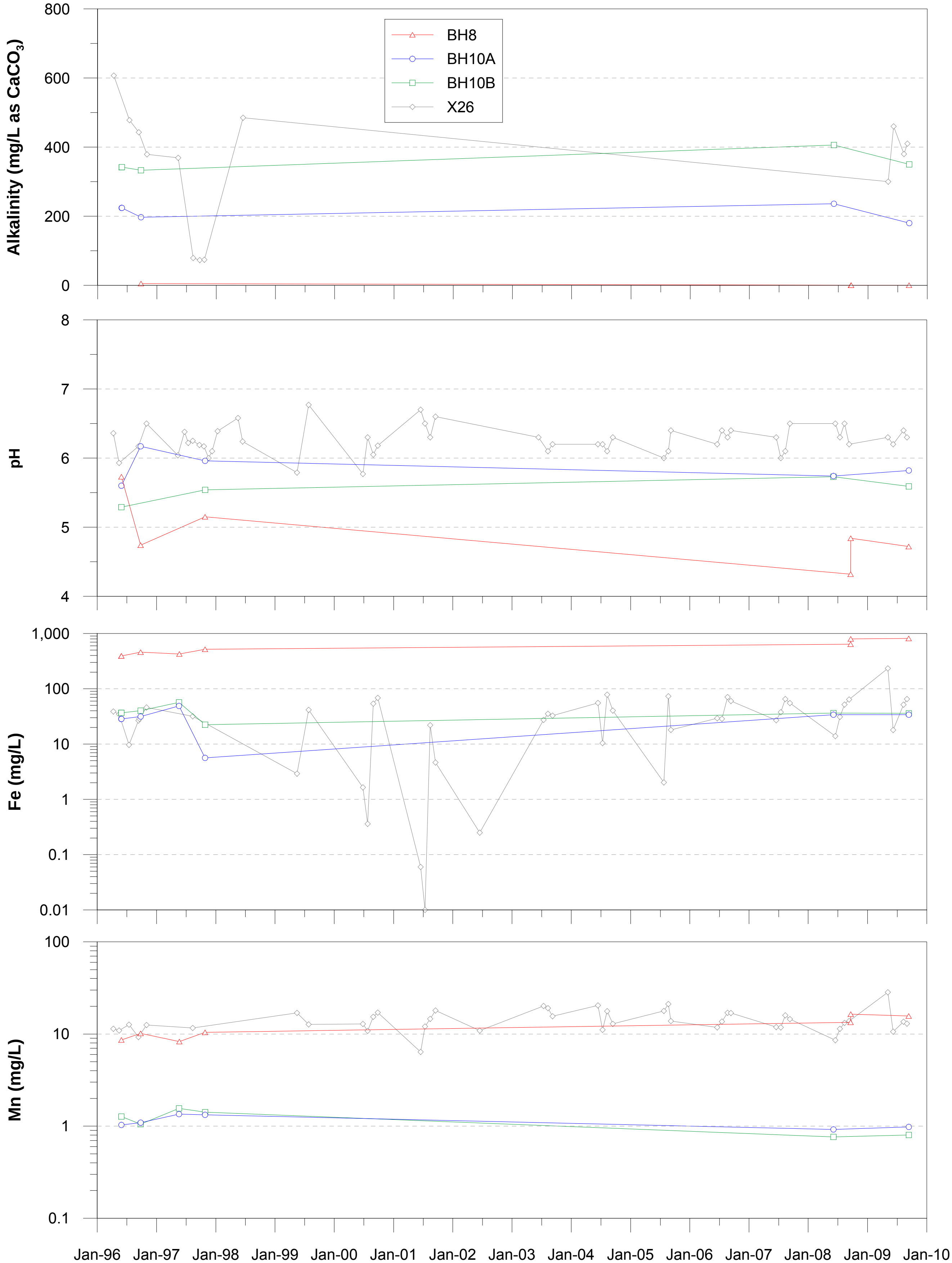


Figure 2-14b. Time trends for alkalinity, pH, Fe and Mn for Zone 2 Pit and bedrock wells

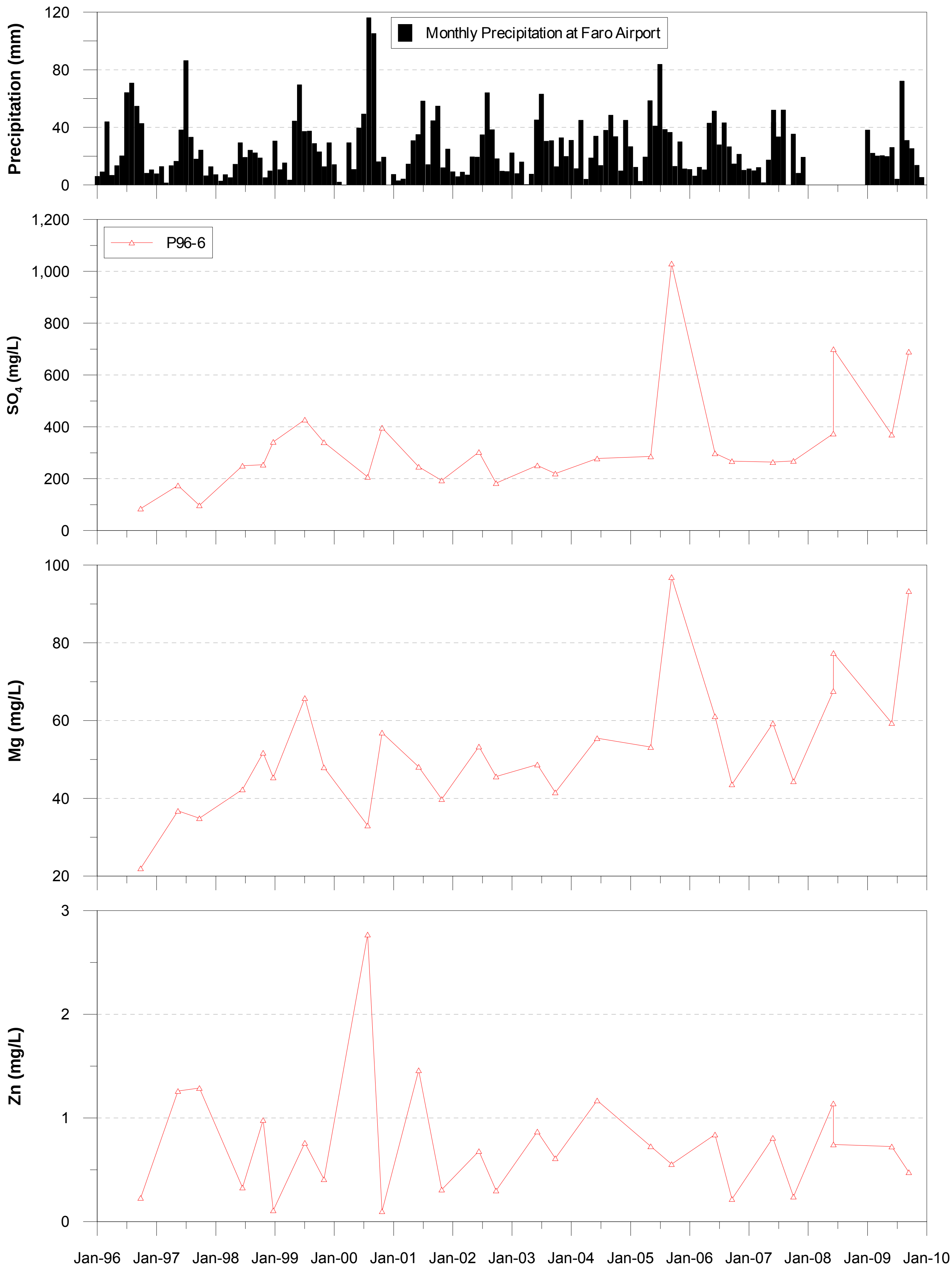


Figure 2-15a. Time trends for SO_4, Mg and Zn in P96-6 at the toe of Intermediate Rock Dump

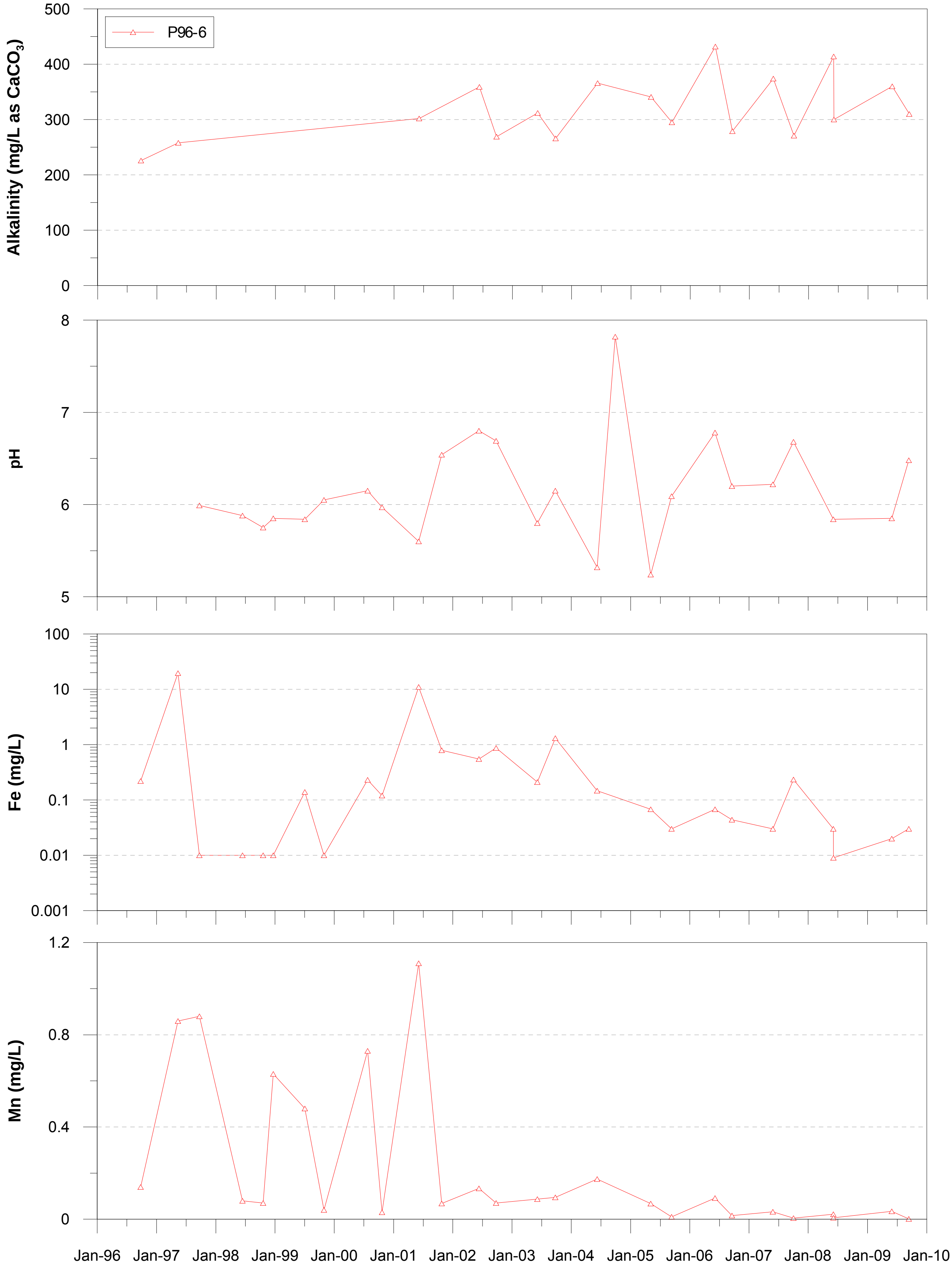
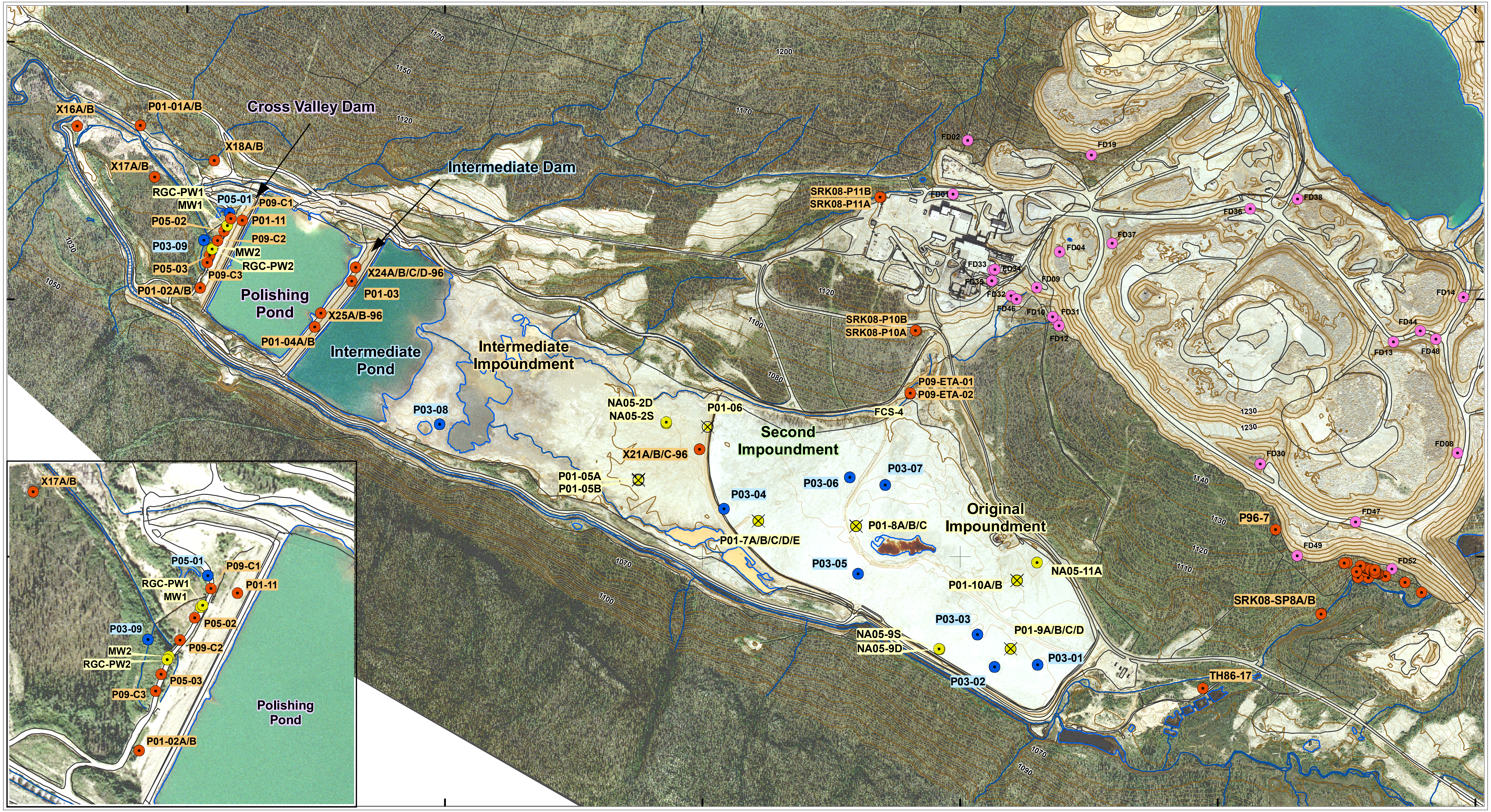


Figure 2-15b. Time trends for alkalinity, pH, Fe and Mn in P96-6 at toe of Intermediate Rock Dump



LEGEND

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

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

CONTOUR INTERVAL: 2M

N
W E
S

Groundwater Monitoring Wells
Rose Creek Tailings Facility
Anvil Range Mining Complex

SCALE

0 375 750 1,125 1,500 Meters

Yukon Government

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 3-1

DATE: 022310
DRAWN BY: OM
FILE: Faro_Tailing_area10.mxd

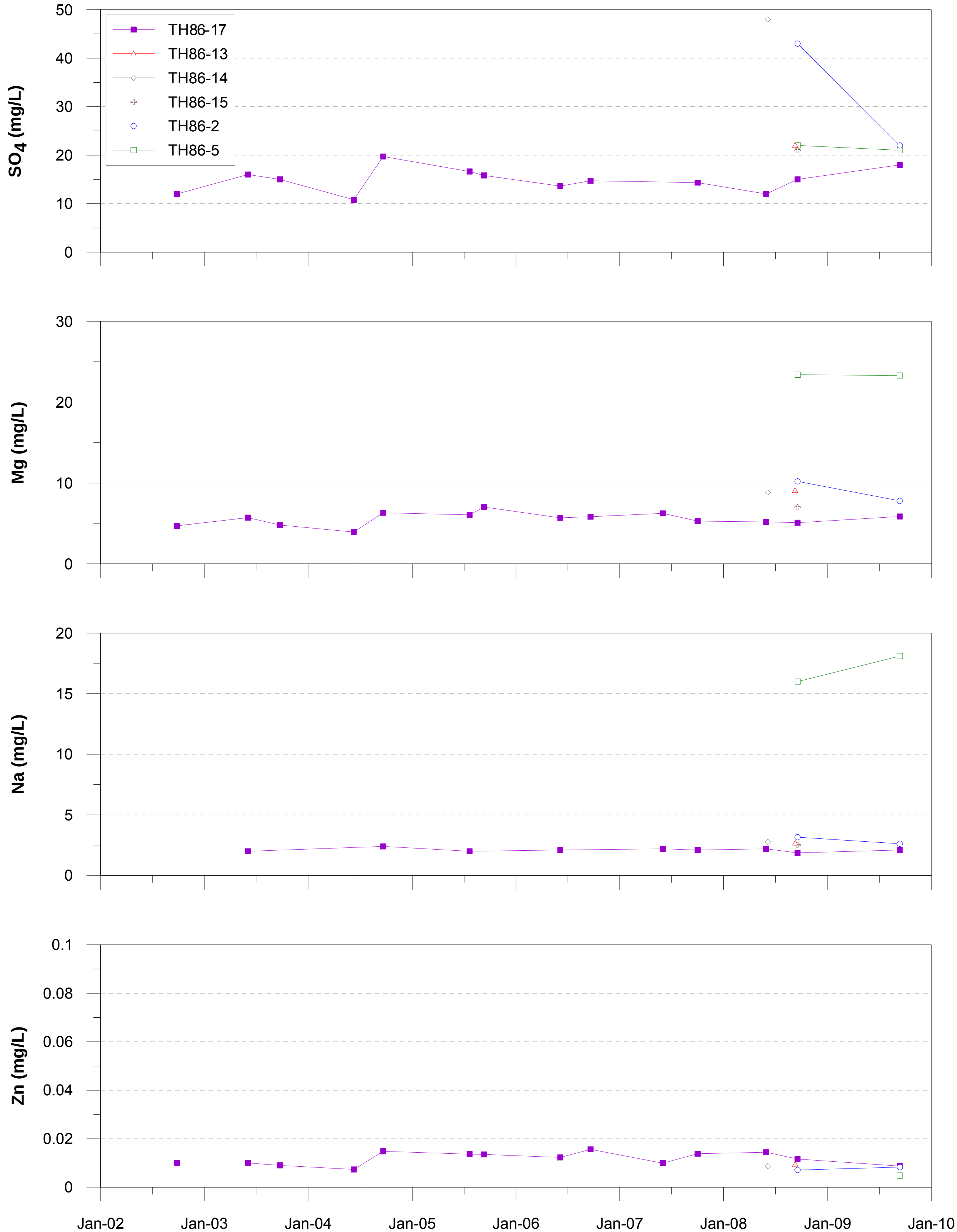


Figure 3-2a. Time trends for SO_4, Mg, Na and Zn in Rose Creek Alluvial Aquifer upgradient of RCTF

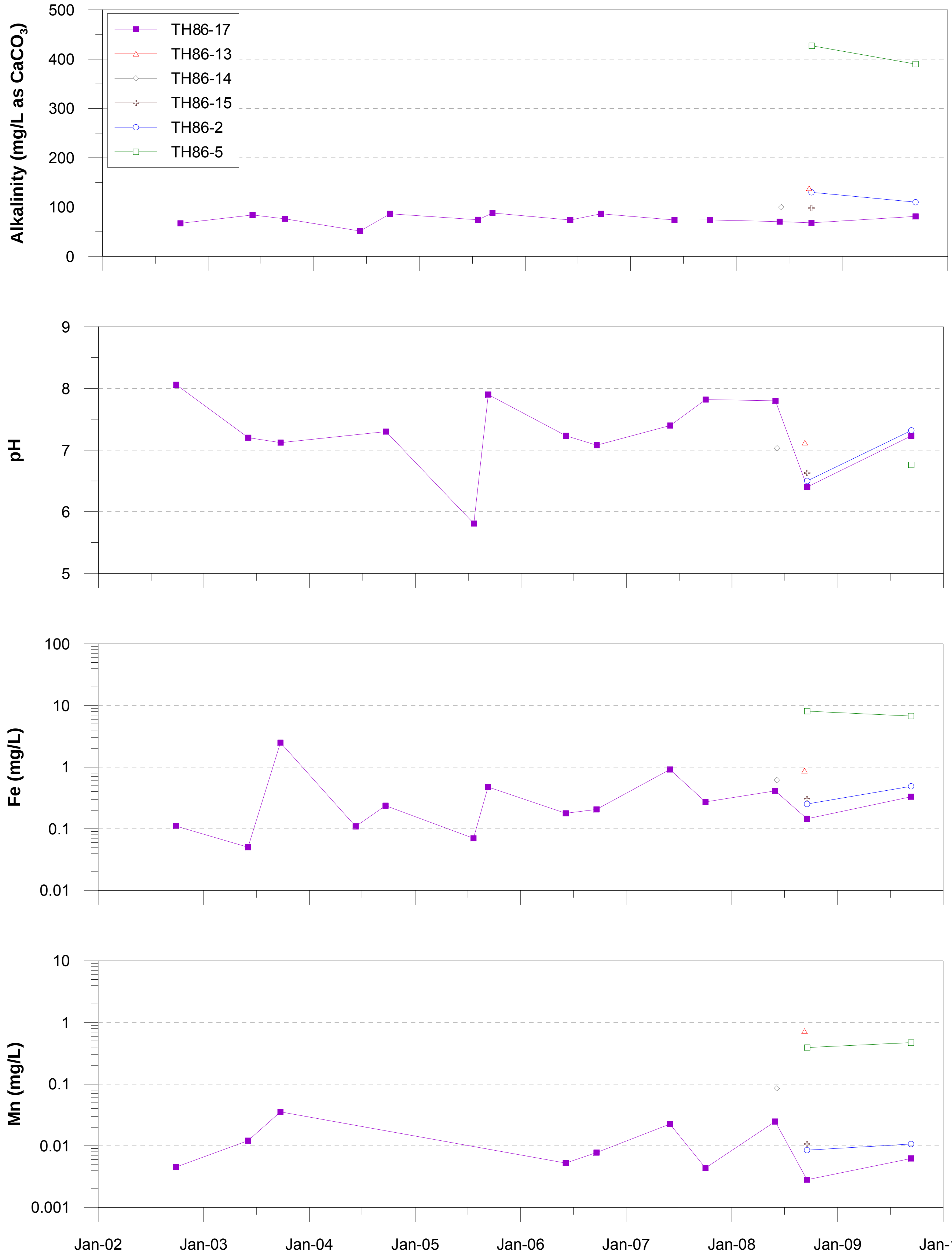


Figure 3-2b. Time trends for alkalinity, pH, Fe and Mn in well Rose Creek Alluvial Aquifer upgradient of RCTF

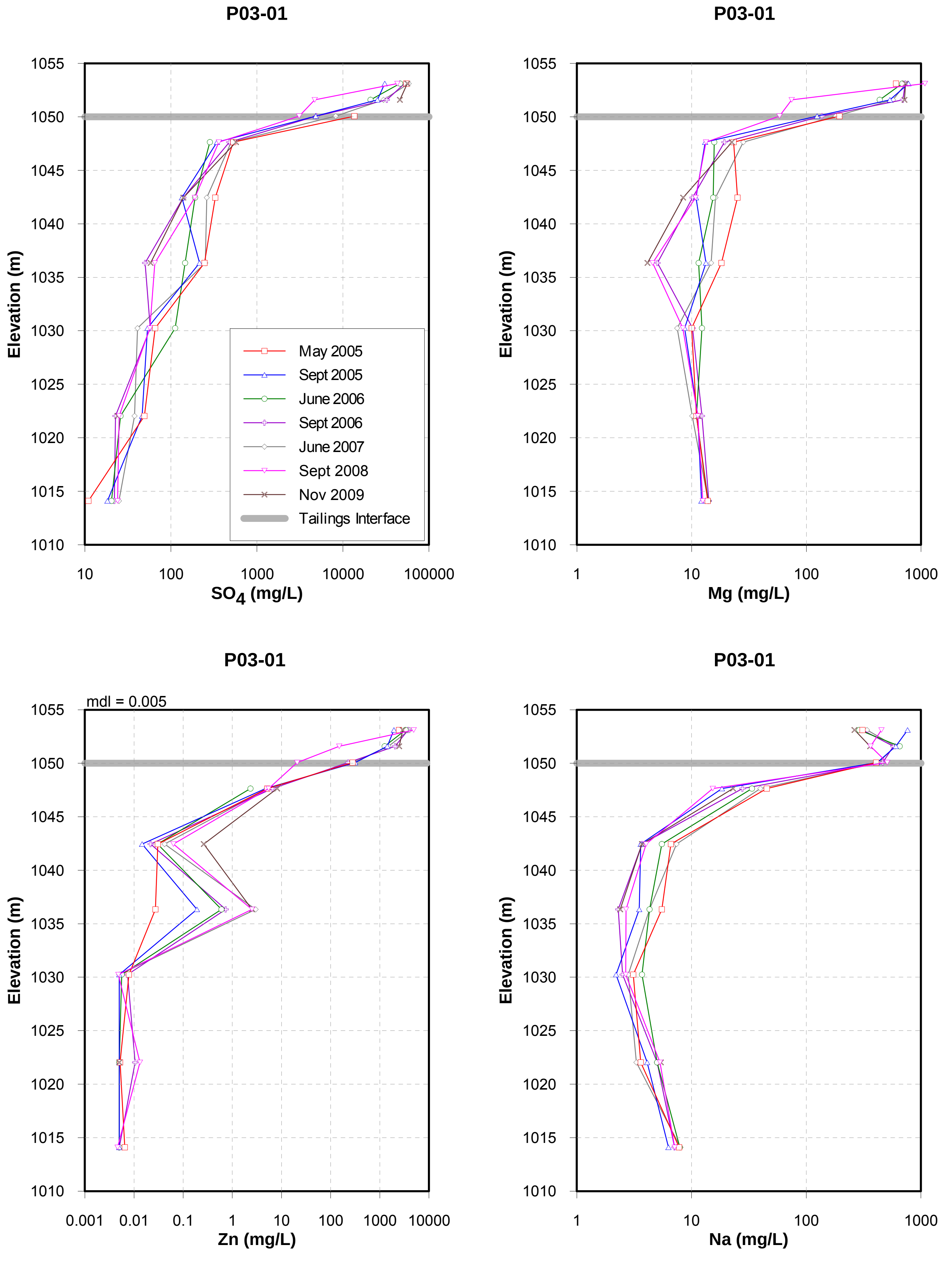


Figure 3-3a. Depth profiles for SO_4, Mg, Zn and Na in P03-01 (Original Impoundment)

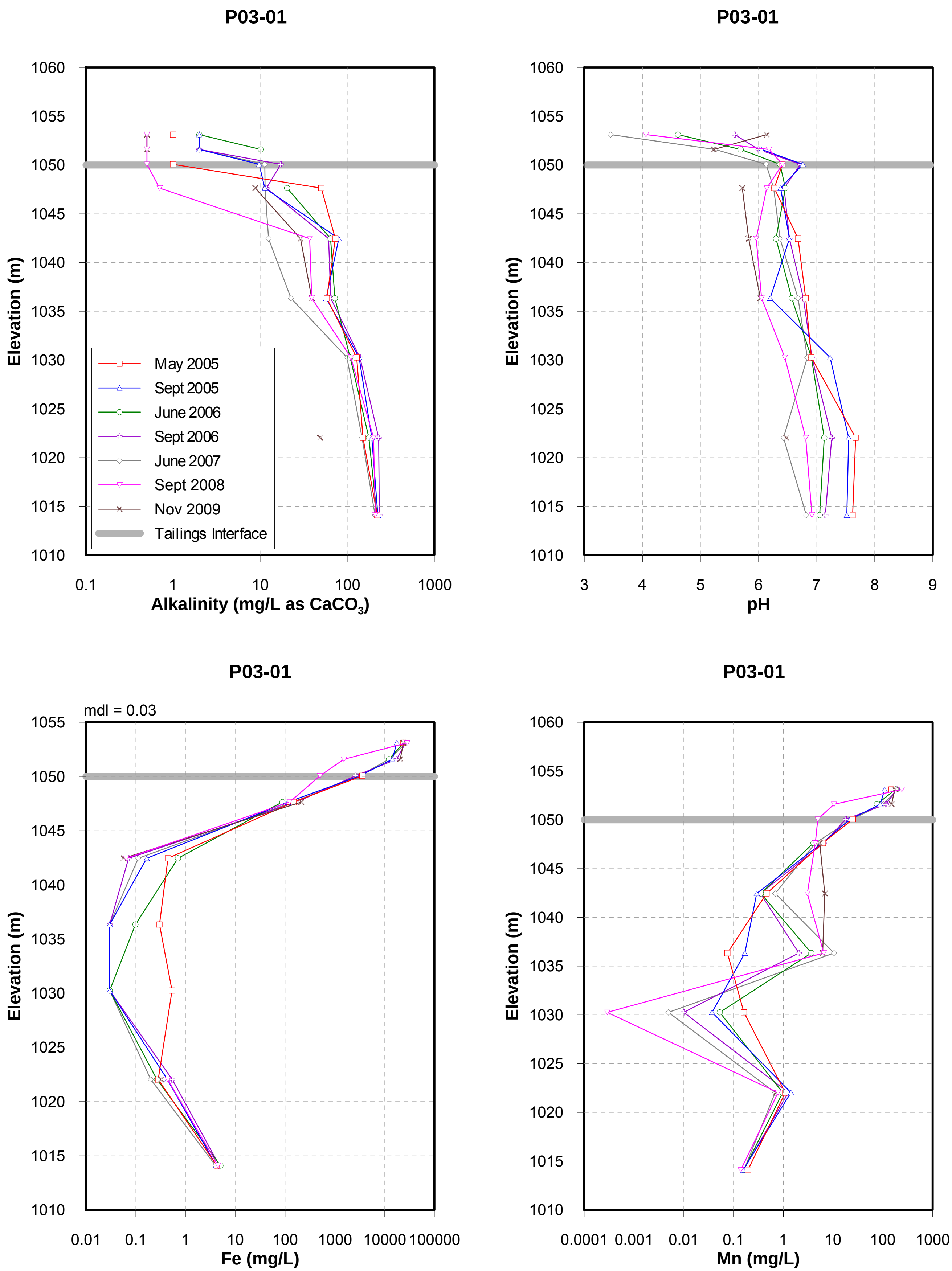


Figure 3-3b. Depth profiles for alkalintiy, pH, Fe and Mn in P03-01 (Original Impoundment)

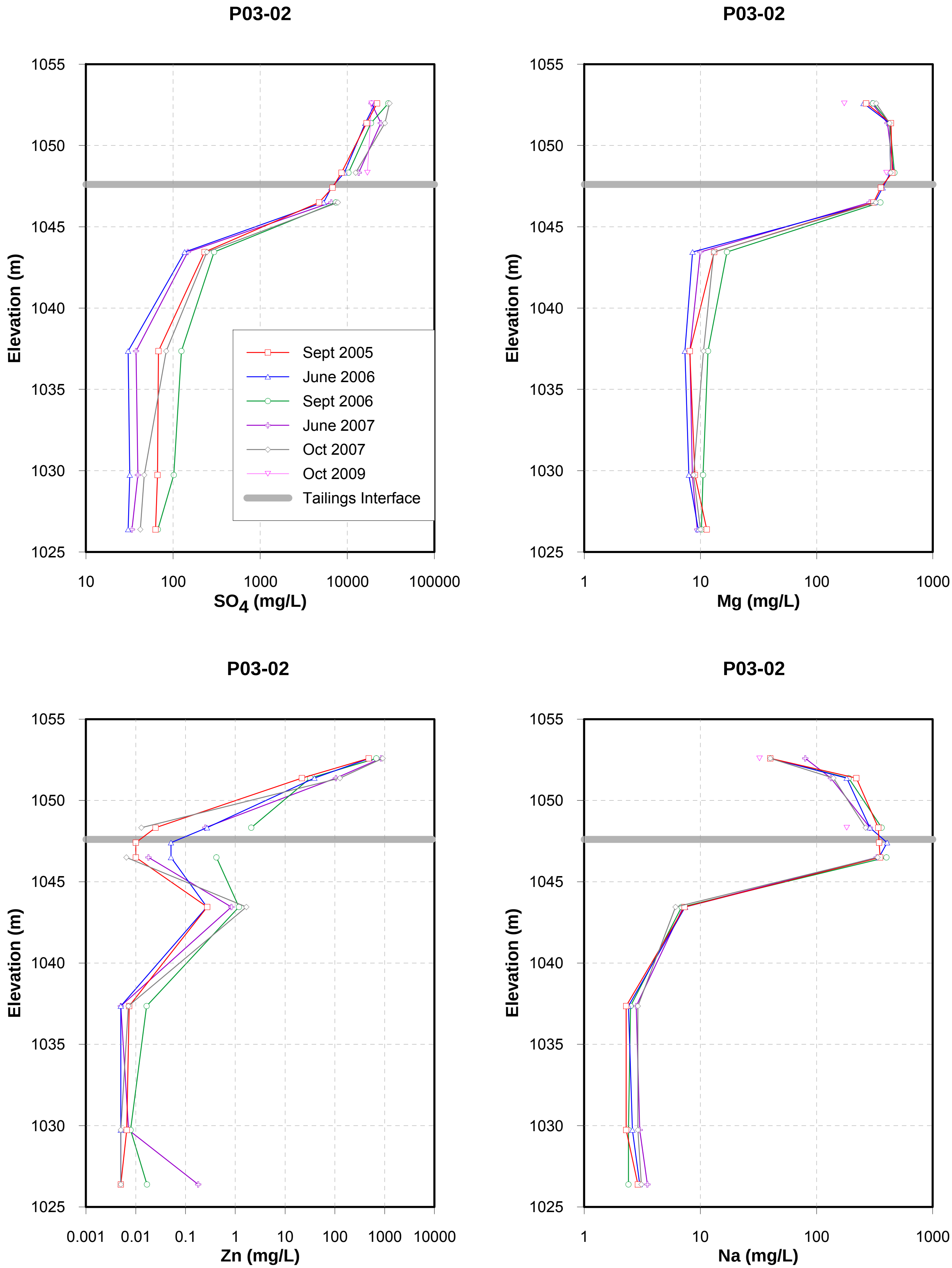


Figure 3-4a. Depth profiles of SO_4, Mg, Zn and Na in P03-02 (Second Impoundment)

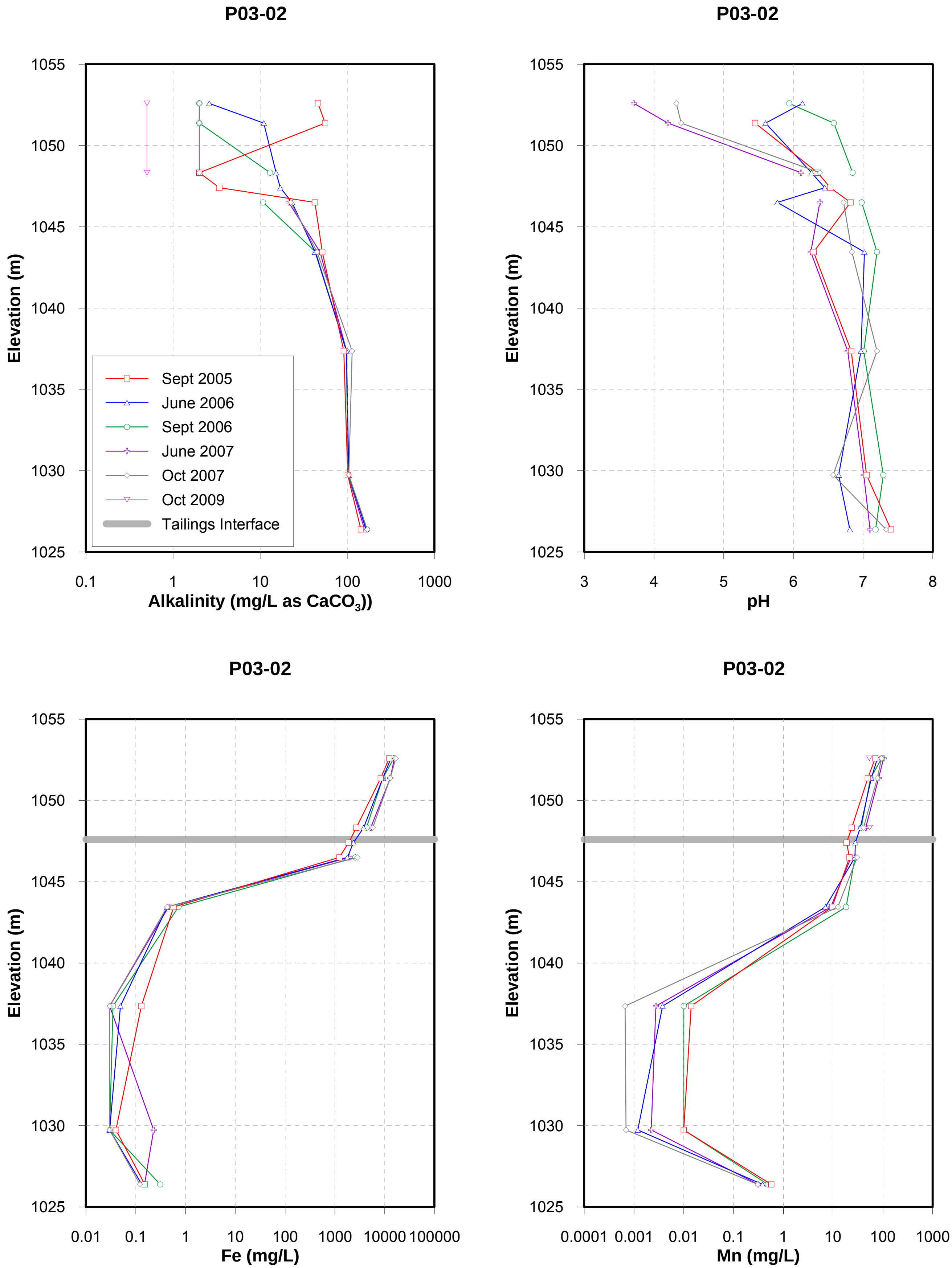


Figure 3-4b. Depth profiles for alkalinity, pH, Fe and Mn in P03-02 (Second Impoundment)

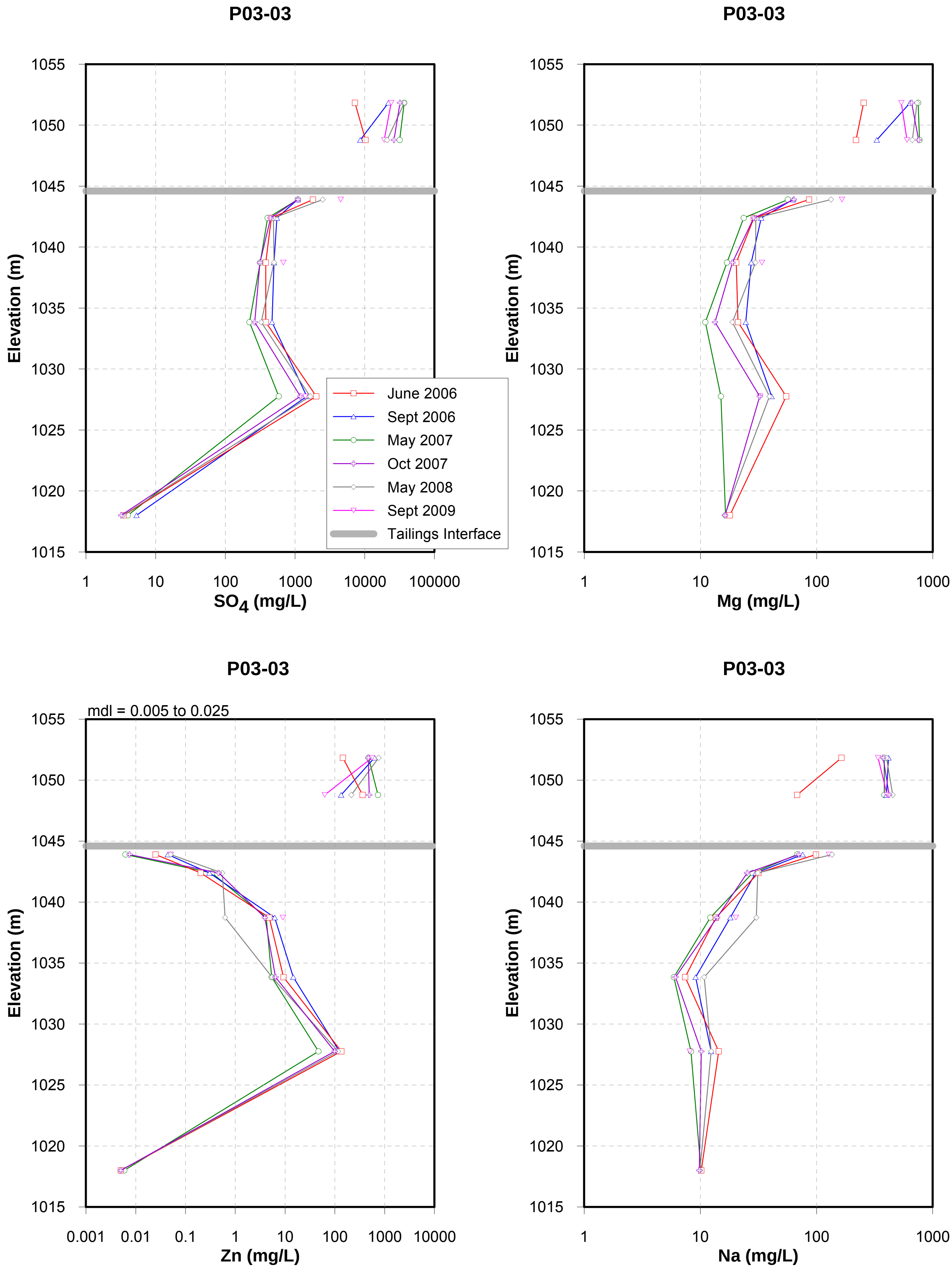


Figure 3-5a. Depth profiles for SO_4, Mg, Zn and Na in P03-03 (Second Impoundment)

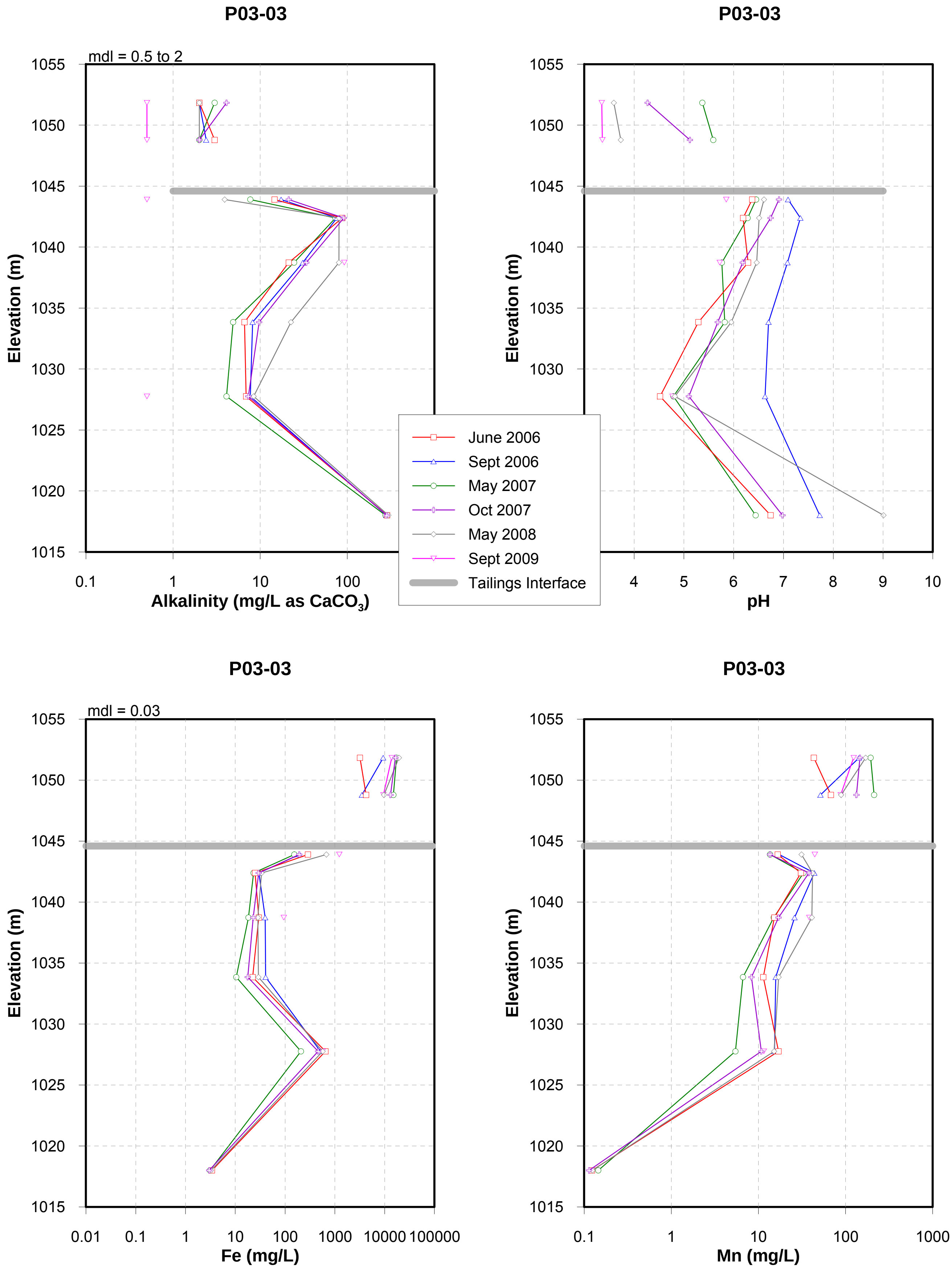


Figure 3-5b. Depth profiles for alkalinity, pH, Fe and Mn in P03-03 (Second Impoundment)

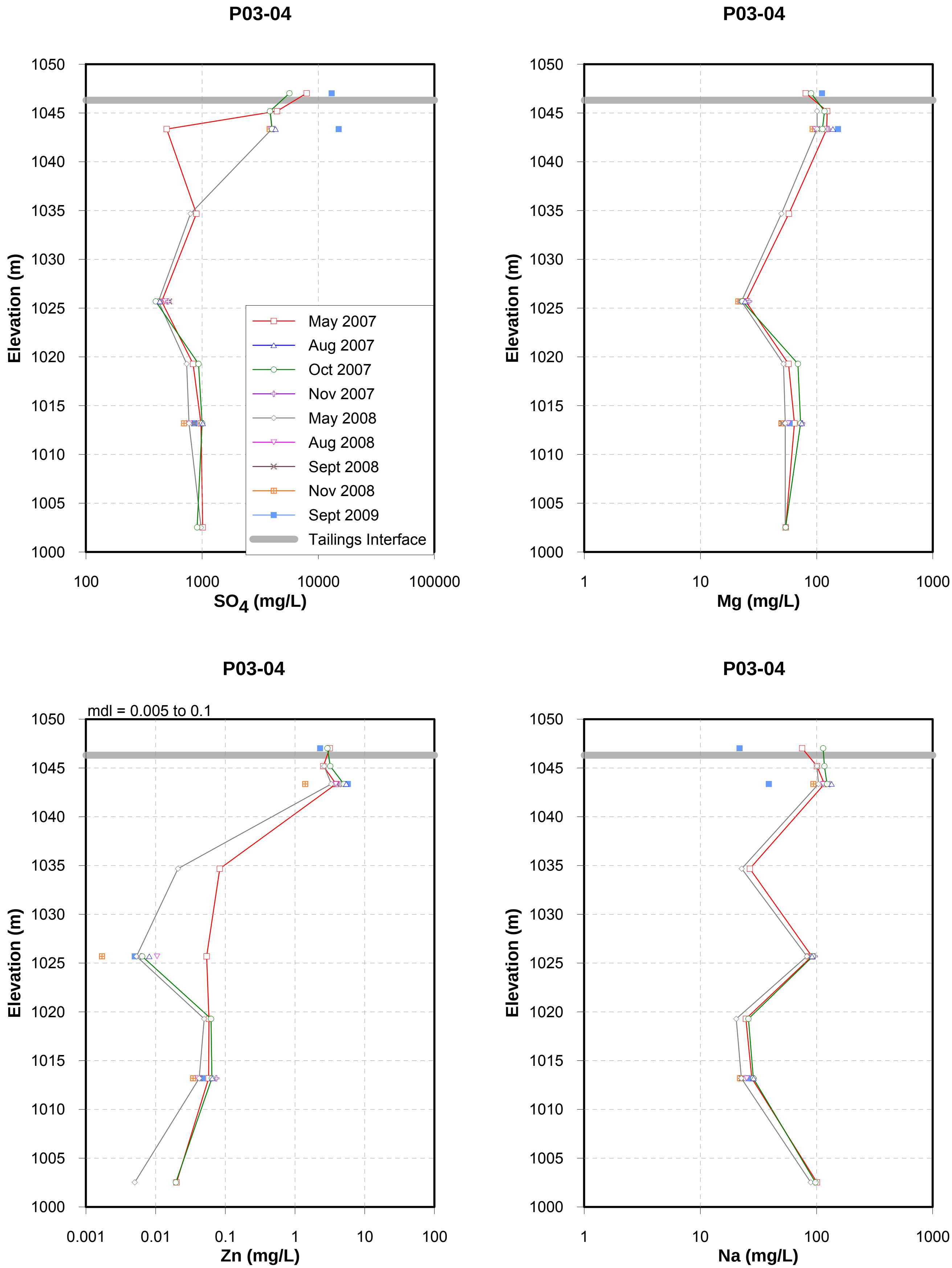


Figure 3-6a. Depth profiles for SO_4, Mg, Zn and Na in P03-04 (Second Impoundment)

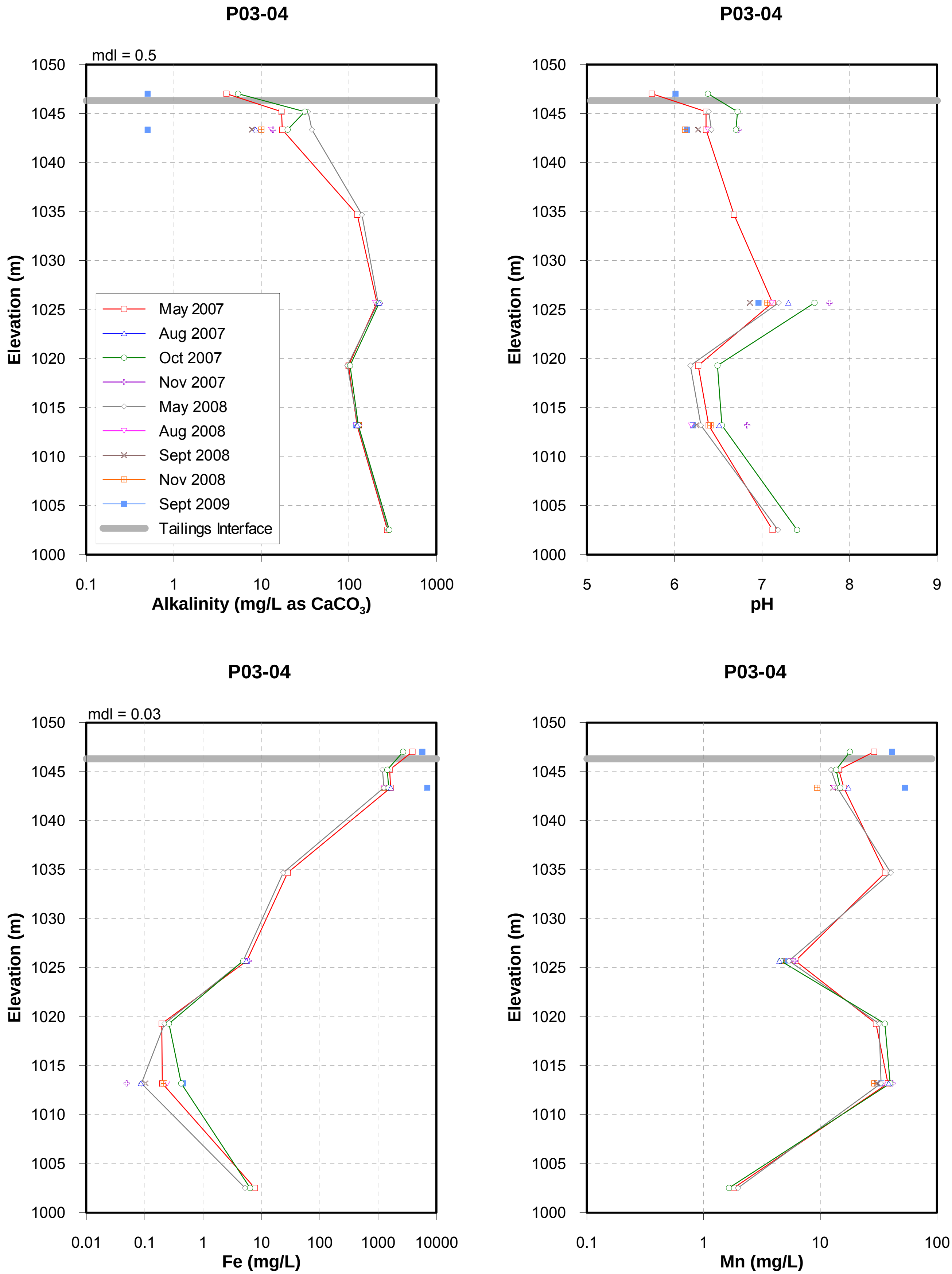


Figure 3-6b. Depth profiles for alkalinity, pH, Fe and Mn in P03-04 (Second Impoundment)

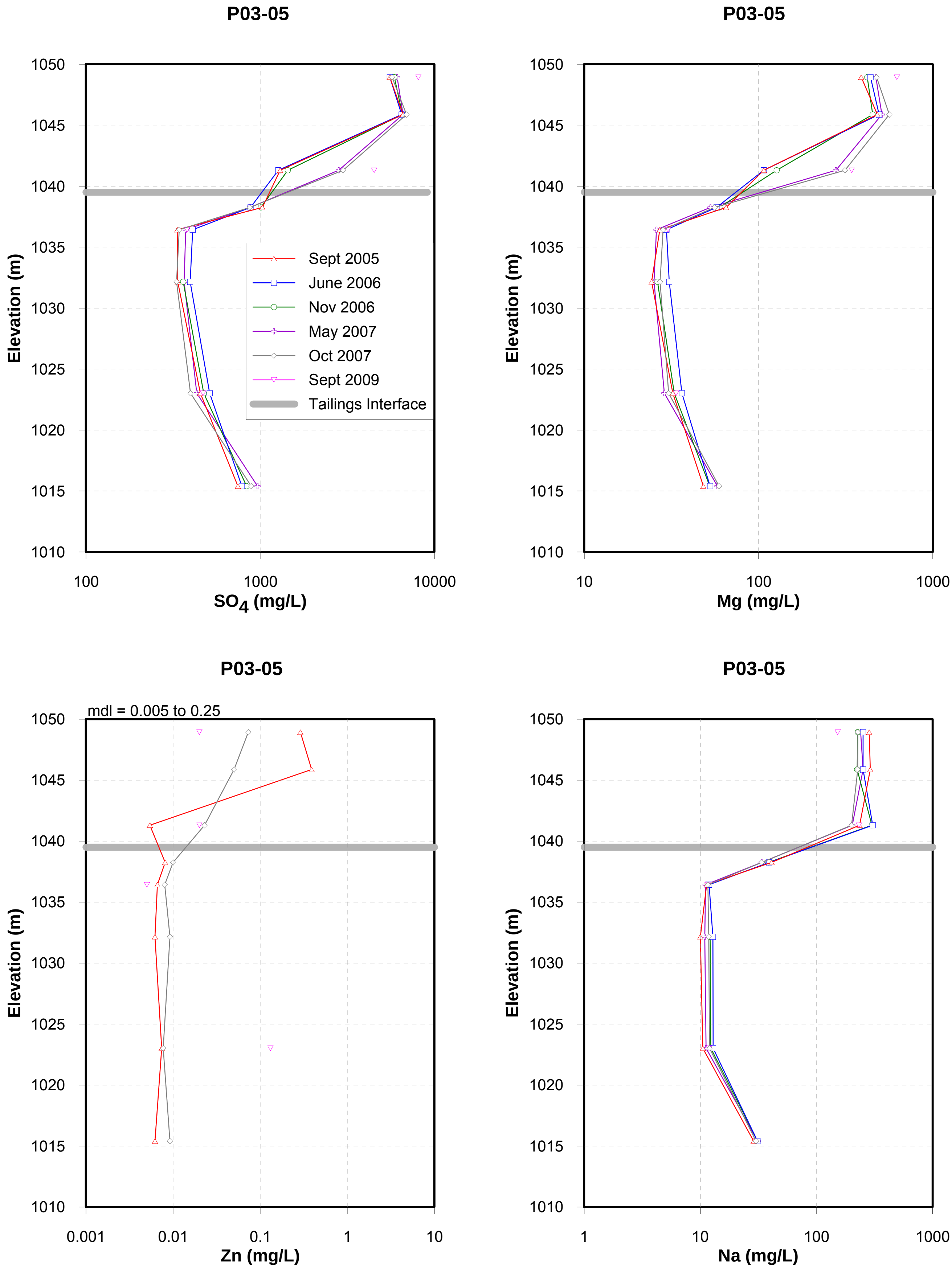


Figure 3-7a. Depth profiles for SO_4, Mg, Zn and Na in P03-05 (Second Impoundment)

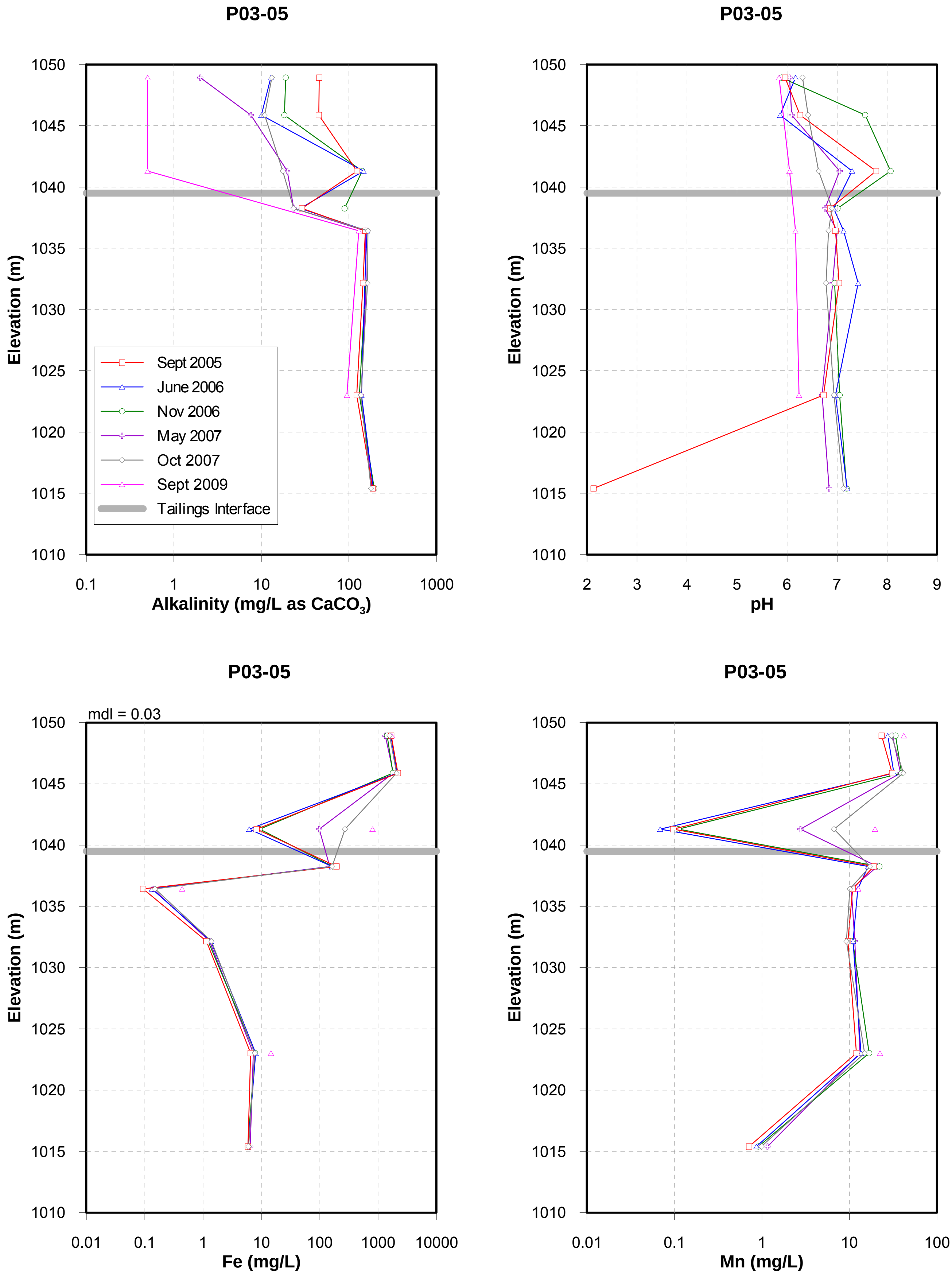


Figure 3-7b. Depth profiles for alkalinity, pH, Fe and Mn in P03-05 (Second Impoundment)

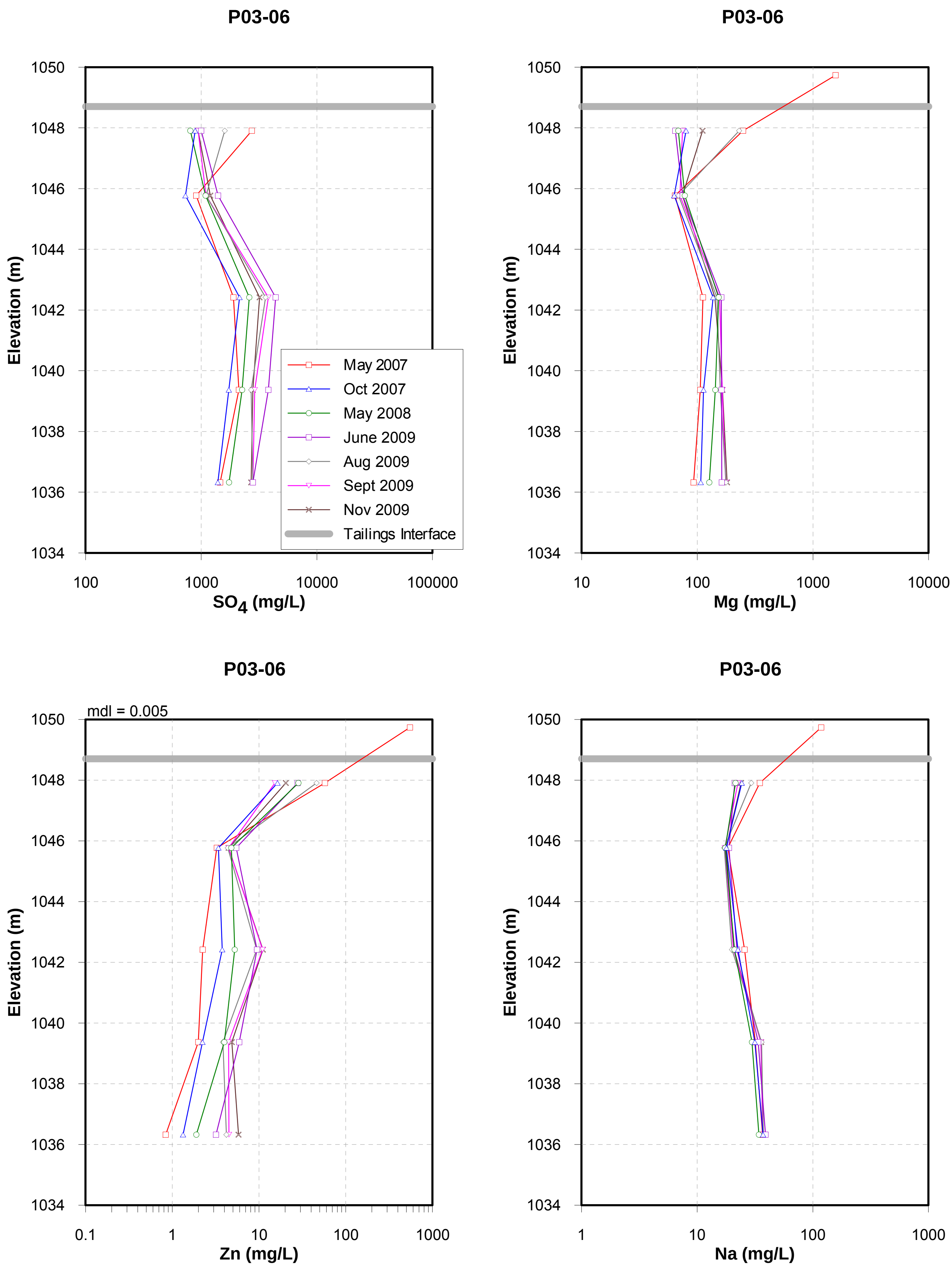


Figure 3-8a. Depth profiles for SO_4, Mg, Zn and Na in P03-06 (Second Impoundment)

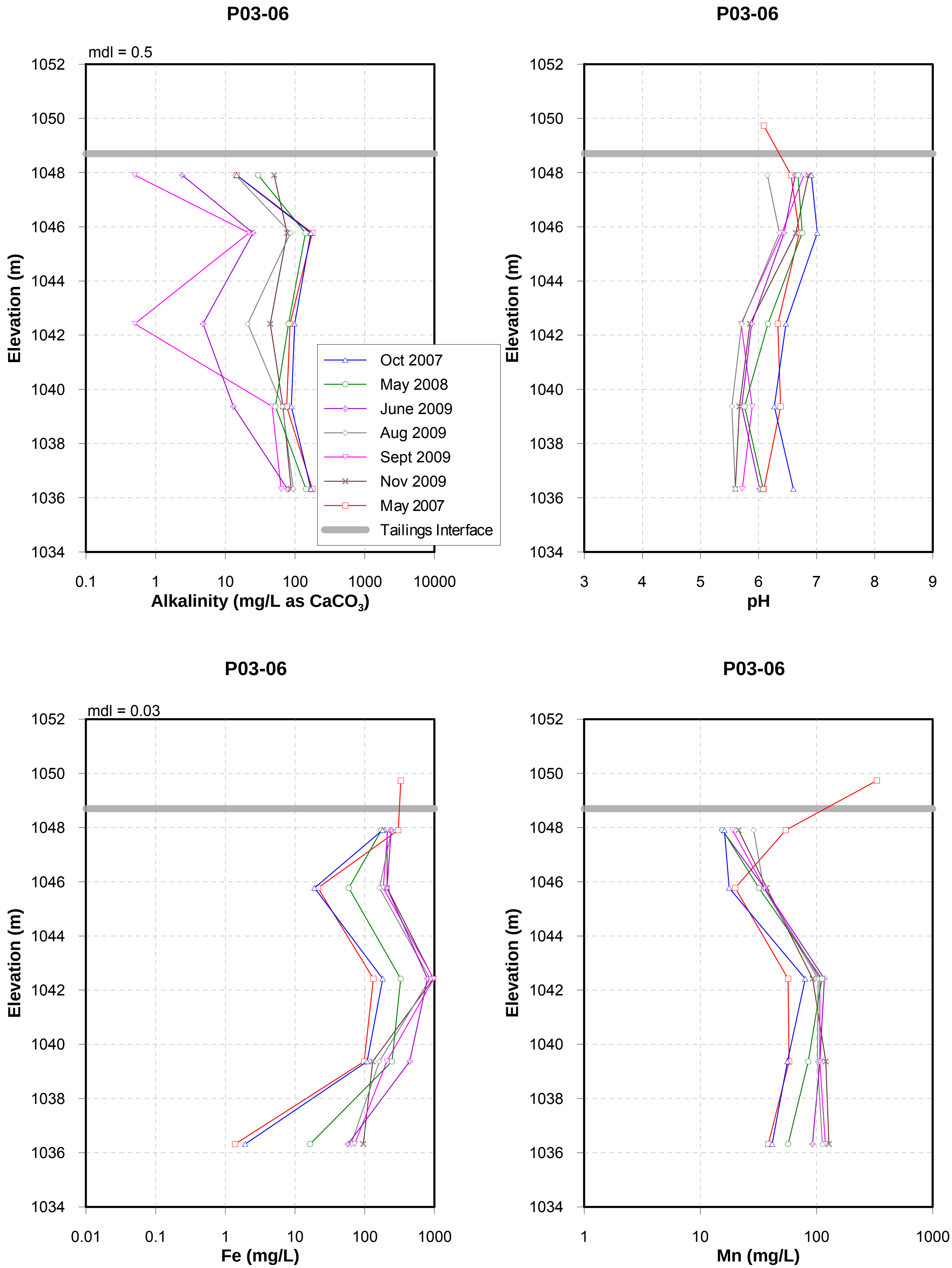


Figure 3-8b. Depth profiles for alkalinity, pH, Fe and Mn in P03-06 (Second Impoundment)

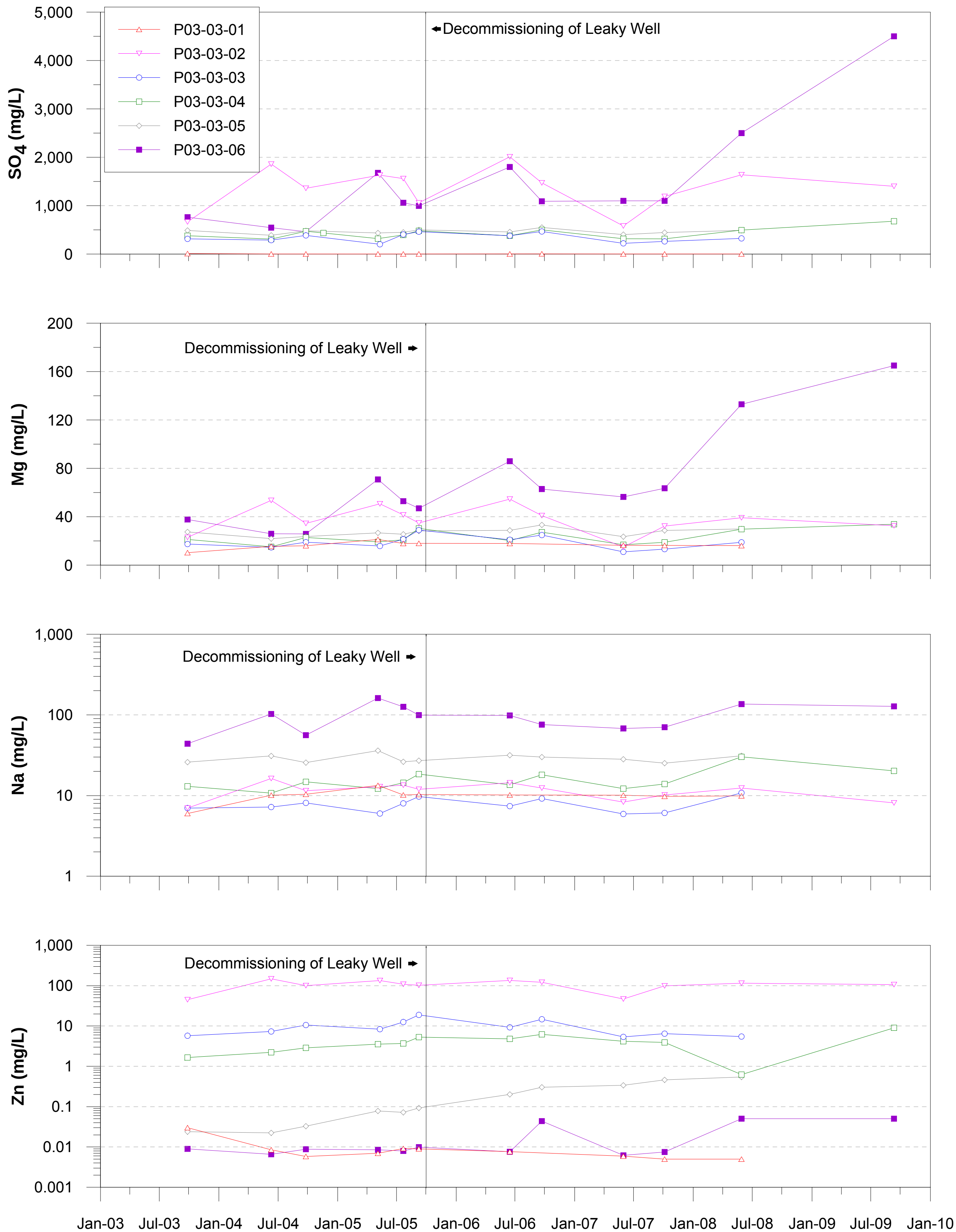


Figure 3-9a. Time trends for SO_4, Mg, Na and Zn in P03-03 (aquifer only)

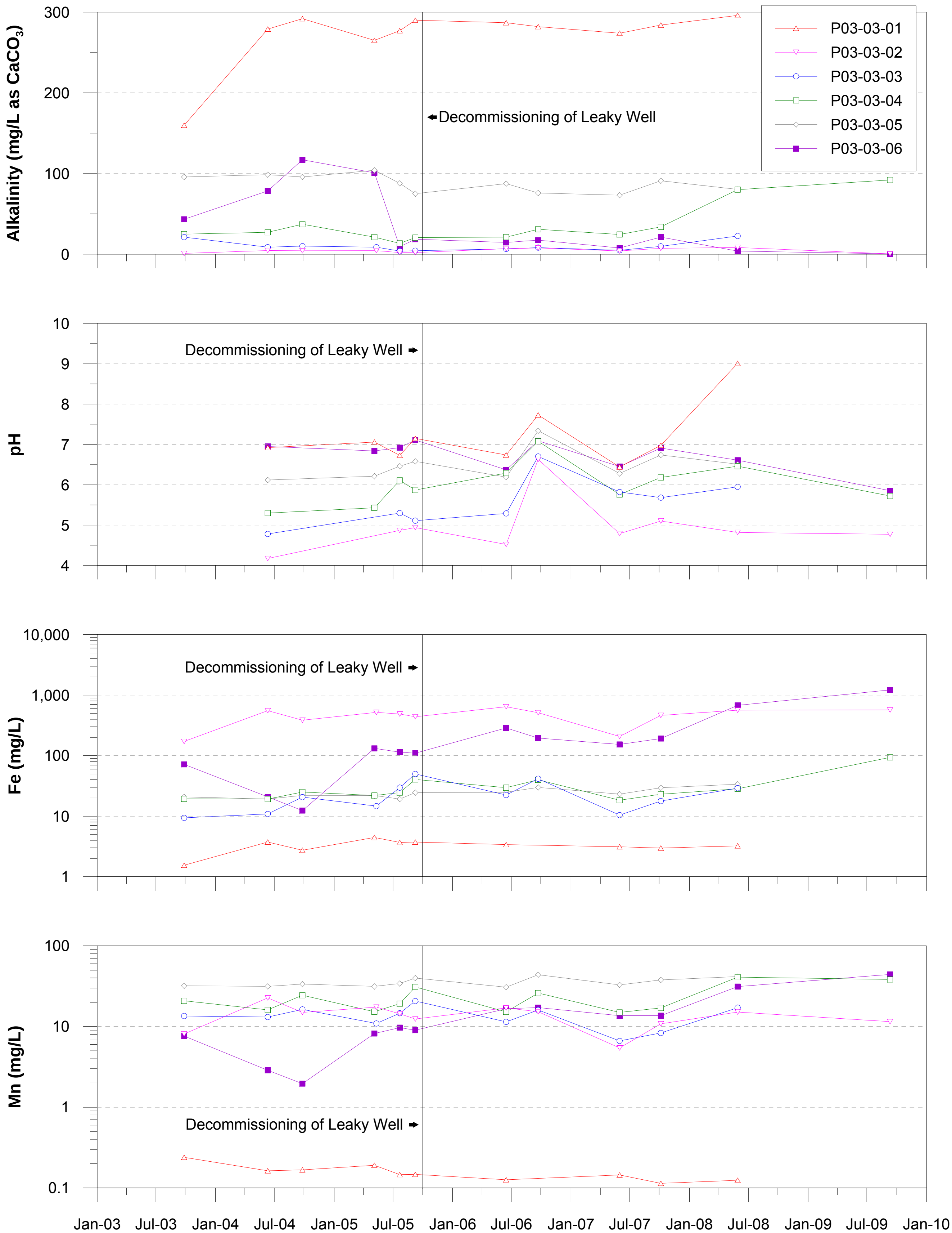


Figure 3-9b. Time trends for alkalinity, pH, Fe and Mn in P03-03 (aquifer only)

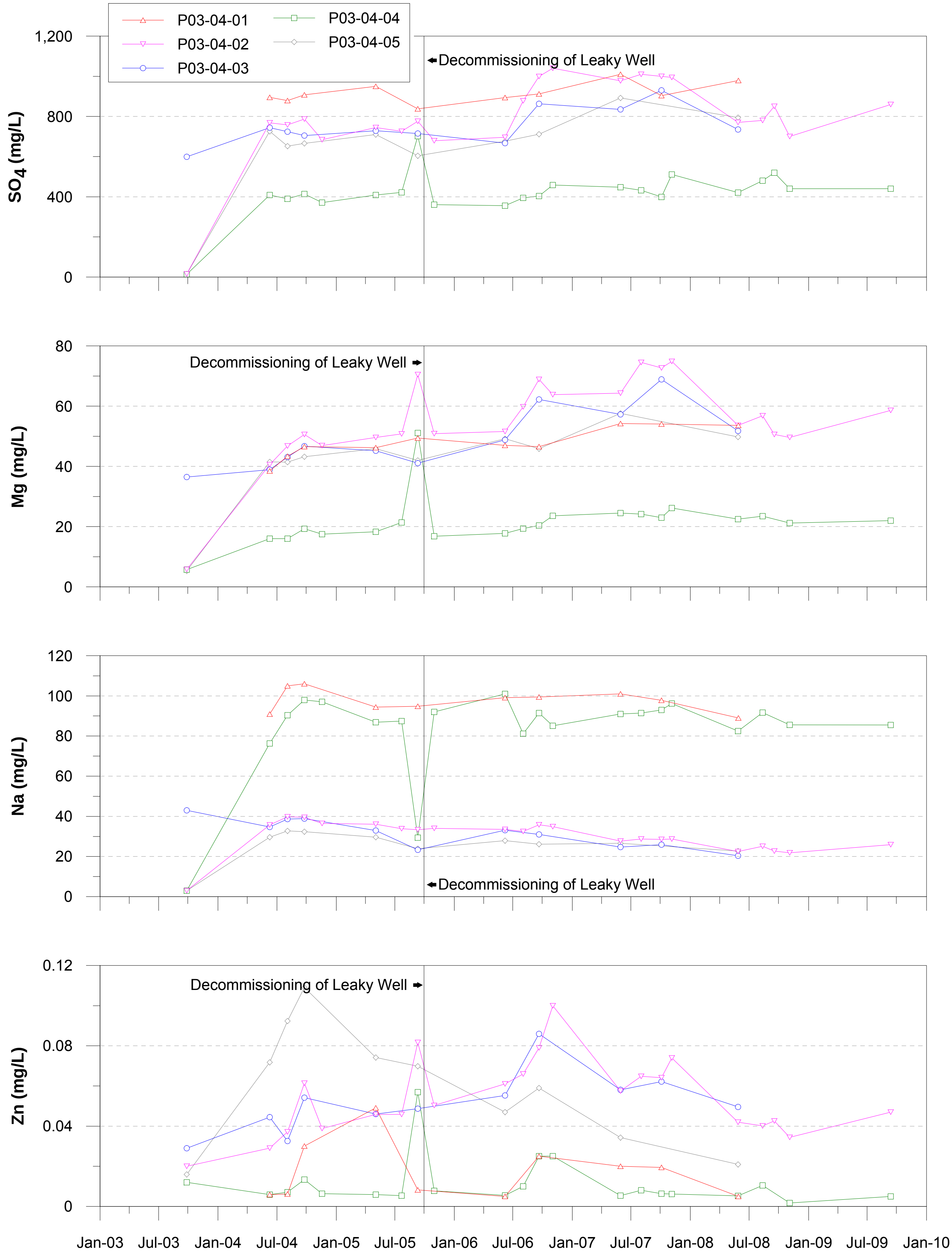


Figure 3-10a. Time trends for SO_4, Mg, Na and Zn in P03-04 (aquifer only)

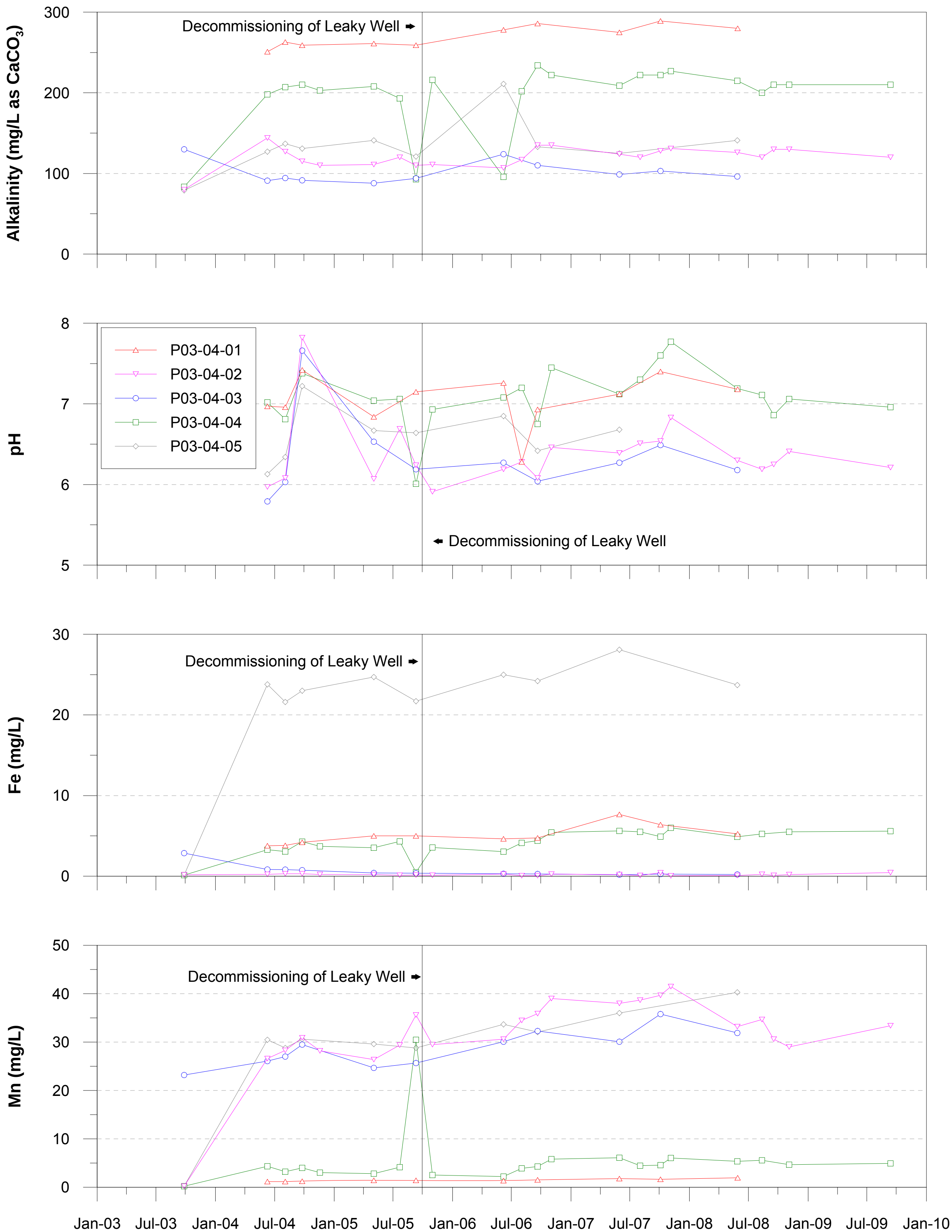


Figure 3-10b. Time trends for alkalinity, pH, Fe and Mn in P03-04 (aquifer only)

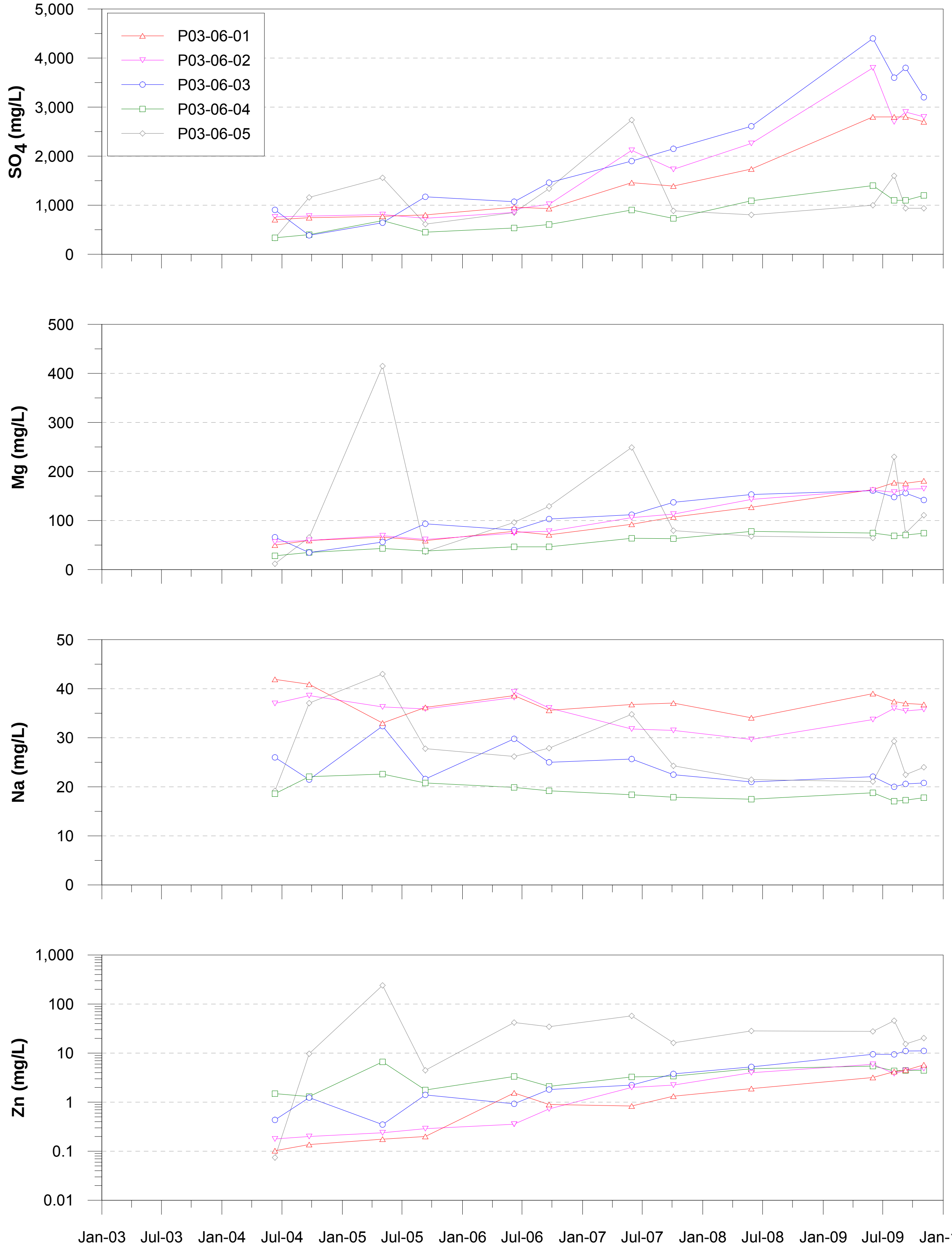


Figure 3-10c. Time trends for SO_4, Mg, Na and Zn in P03-06 (aquifer only)

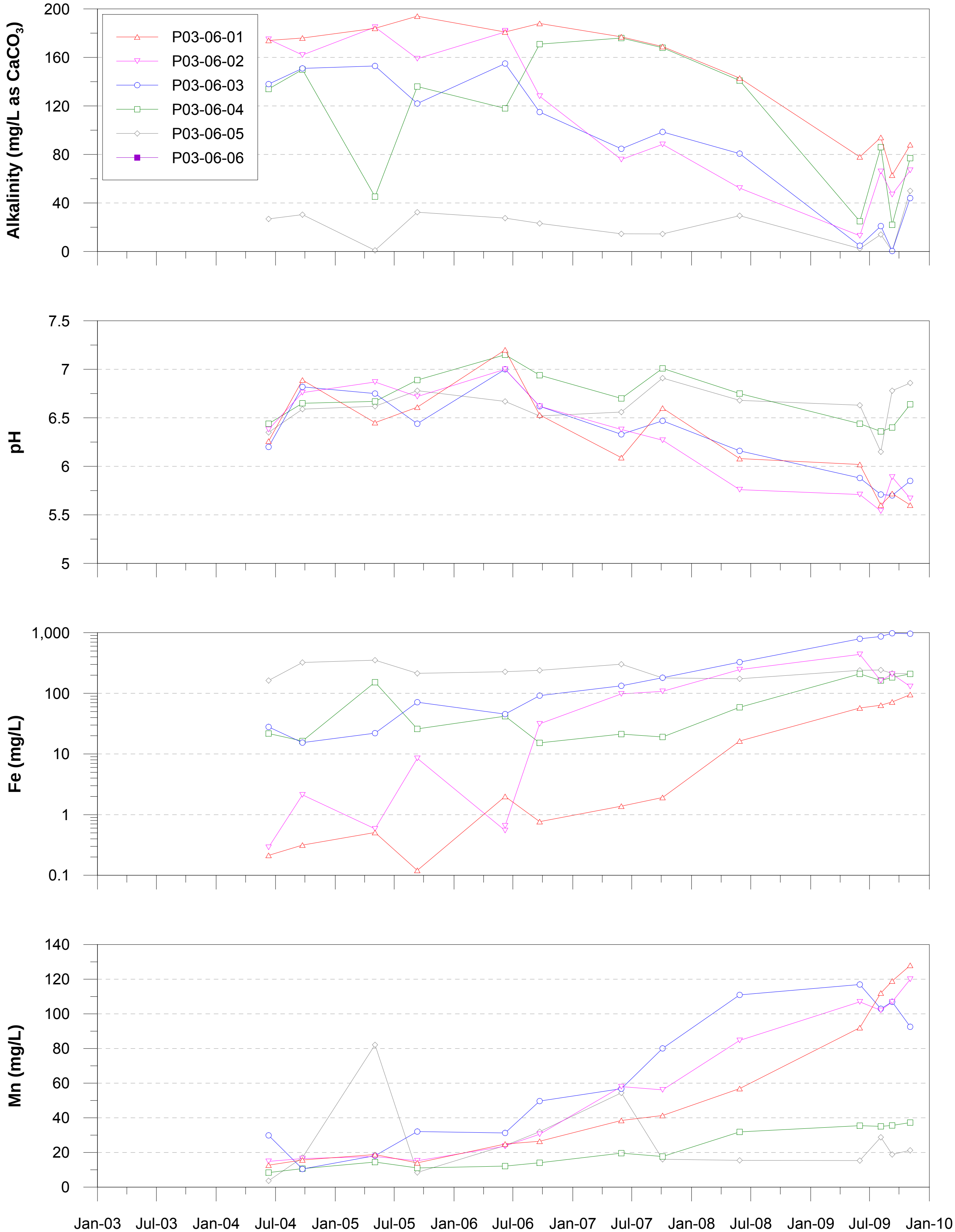


Figure 3-10d. Time trends for alkalinity, pH, Fe and Mn in P03-06 (aquifer only)

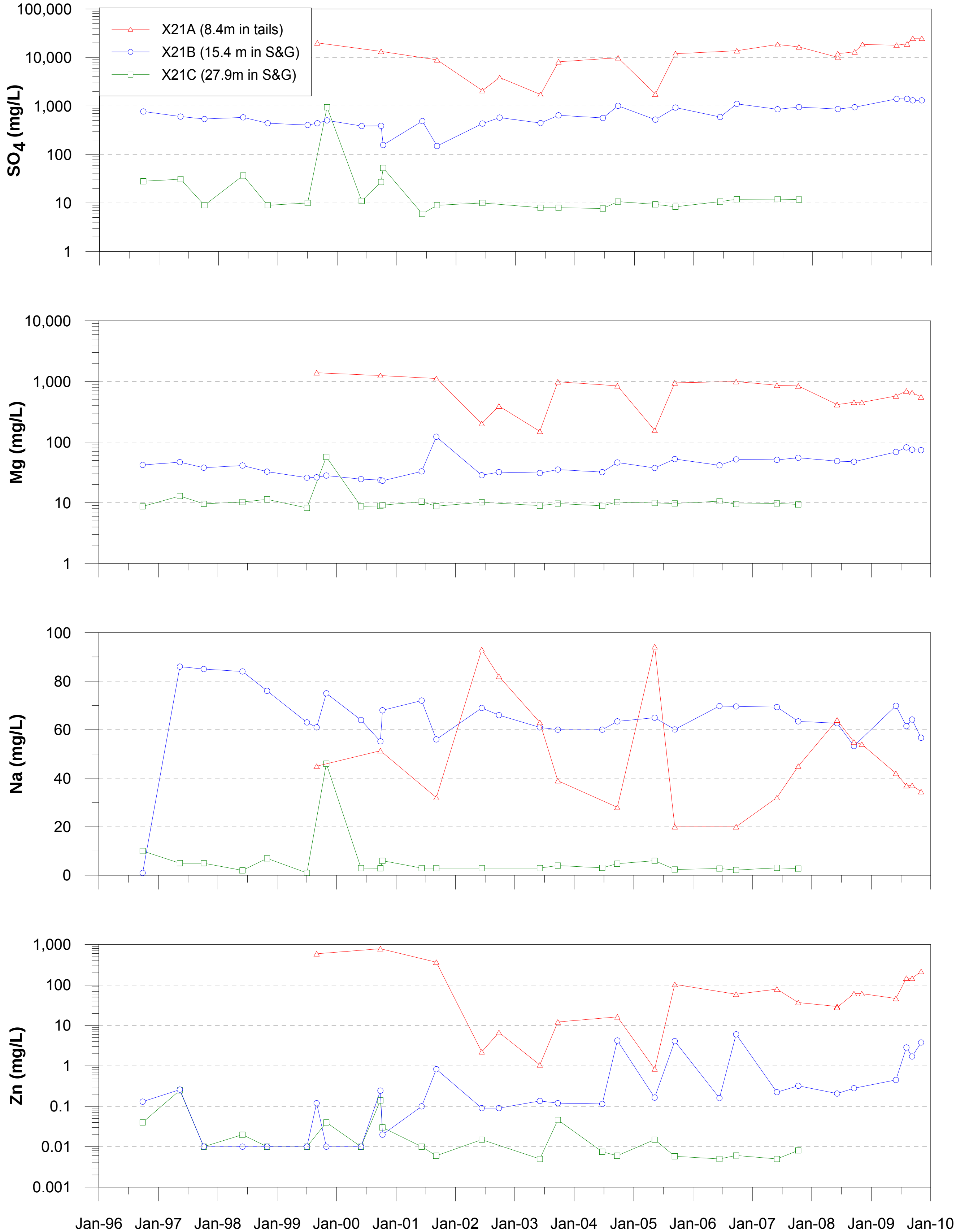


Figure 3-11a. Time trends for SO_4, Mg, Na and Zn in X21(96) (Intermediate Impoundment)

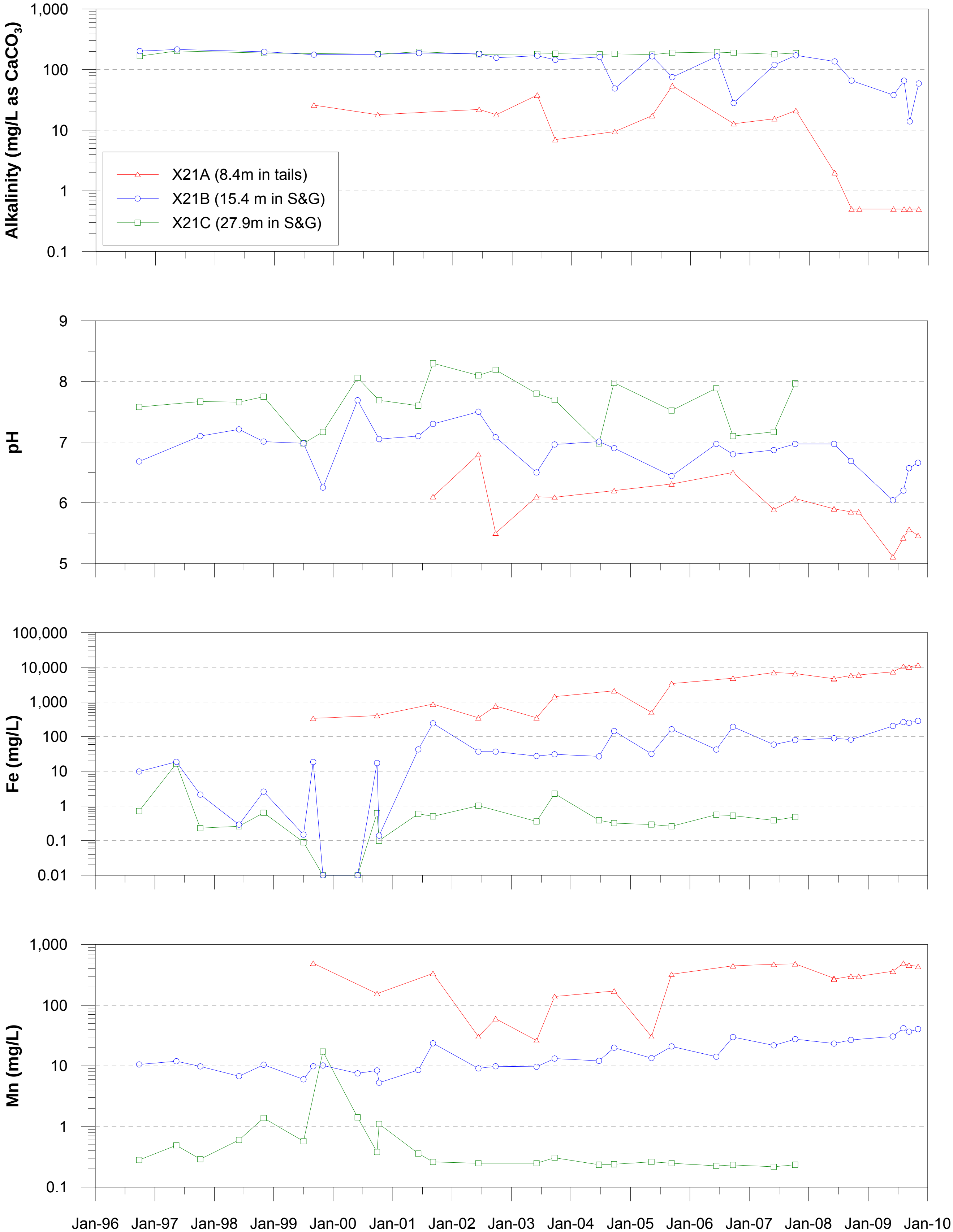


Figure 3-11b. Time trends for alkalinity, pH, Fe and Mn in X21(96) (Intermediate Impoundment)

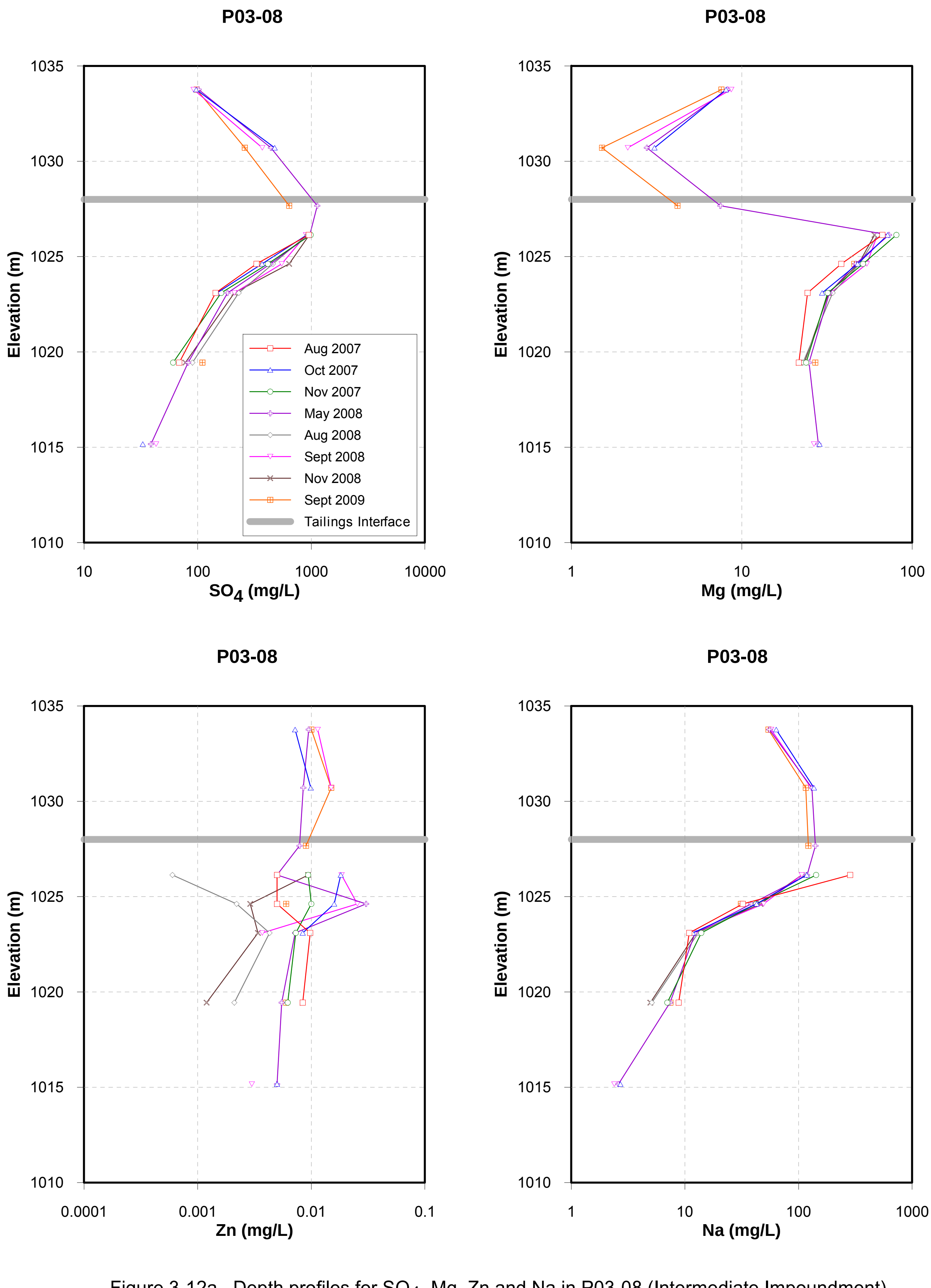


Figure 3-12a. Depth profiles for SO_4, Mg, Zn and Na in P03-08 (Intermediate Impoundment)

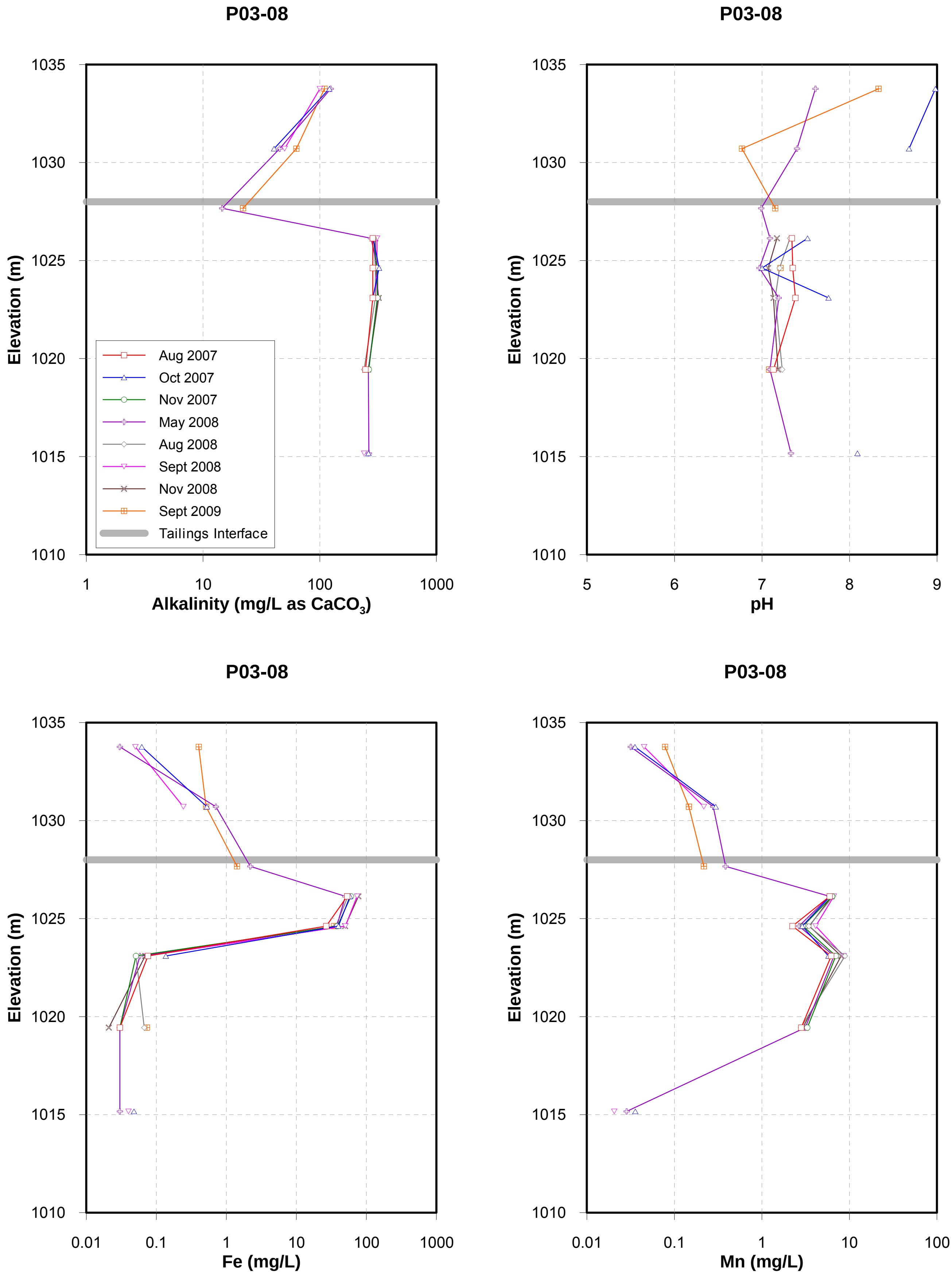


Figure 3-12b. Depth profiles for alkalinity, pH, Fe and Mn in P03-08 (Intermediate Impoundment)

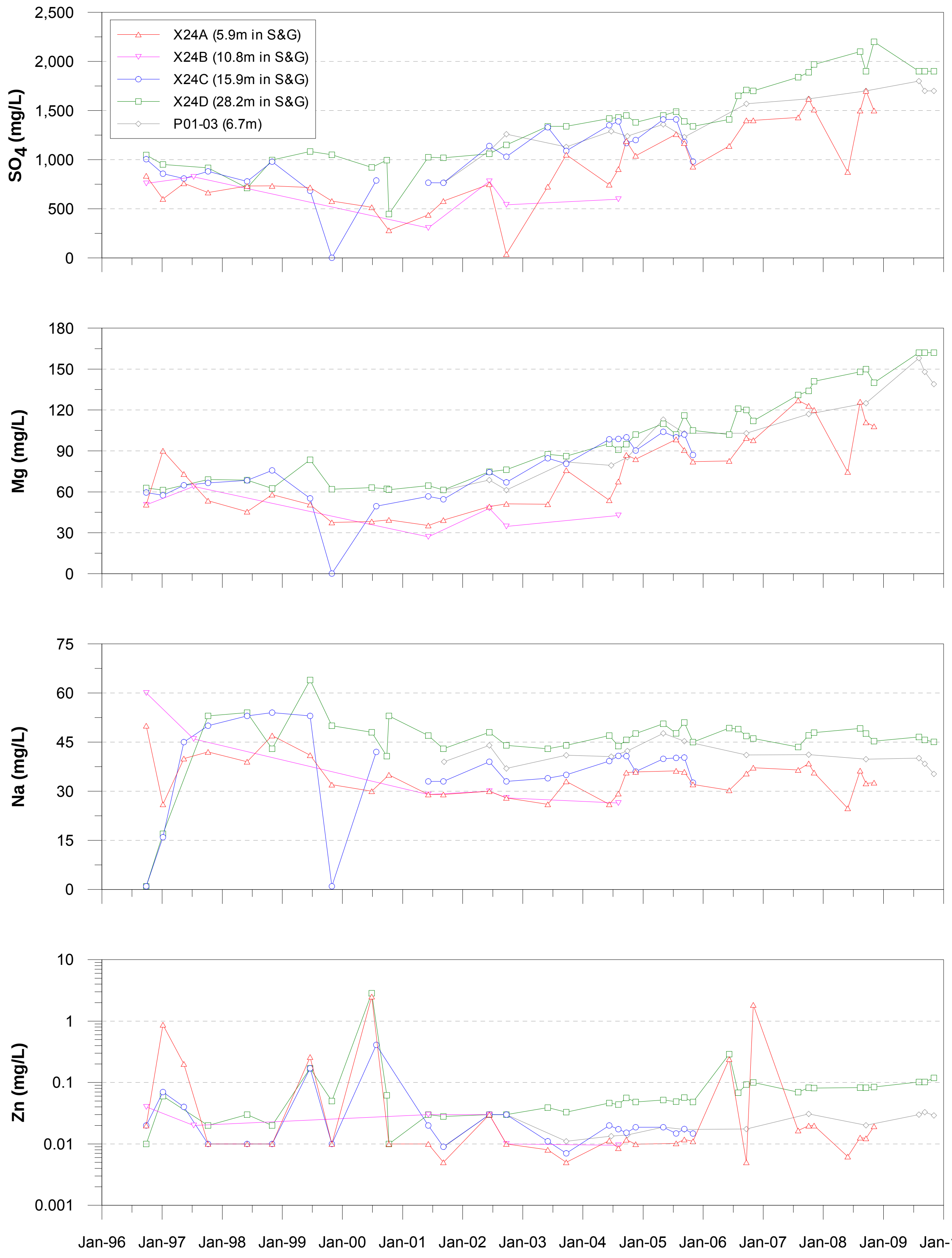


Figure 3-13a. Time trends for SO_4, Mg, Na and Zn in X24(96) and P01-03 (northern side of the Intermediate Dam)

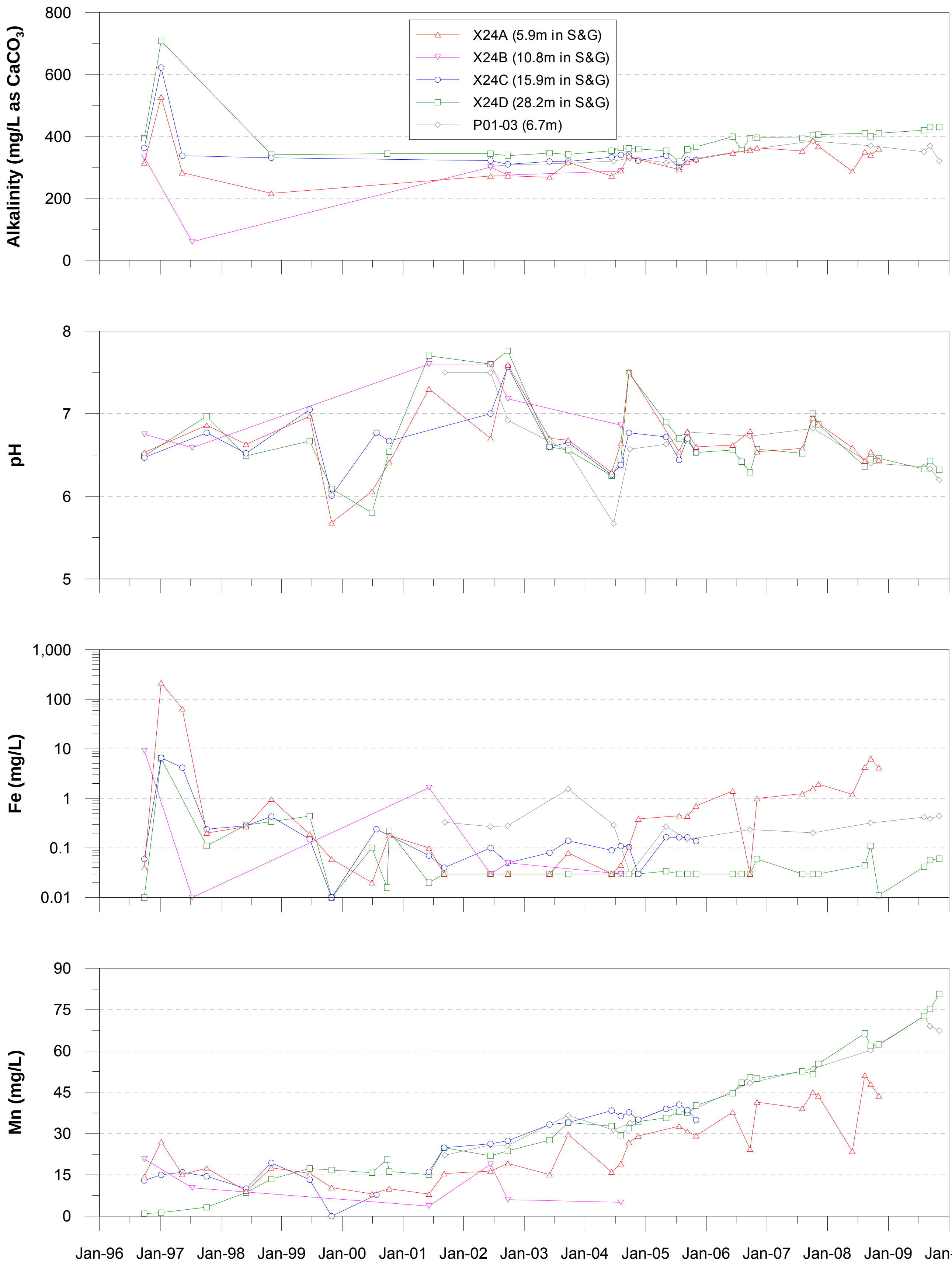


Figure 3-13b. Time trends for alkalinity, pH, Fe and Mn in X24(96) and P01-03 (northern side of the Intermediate Dam)

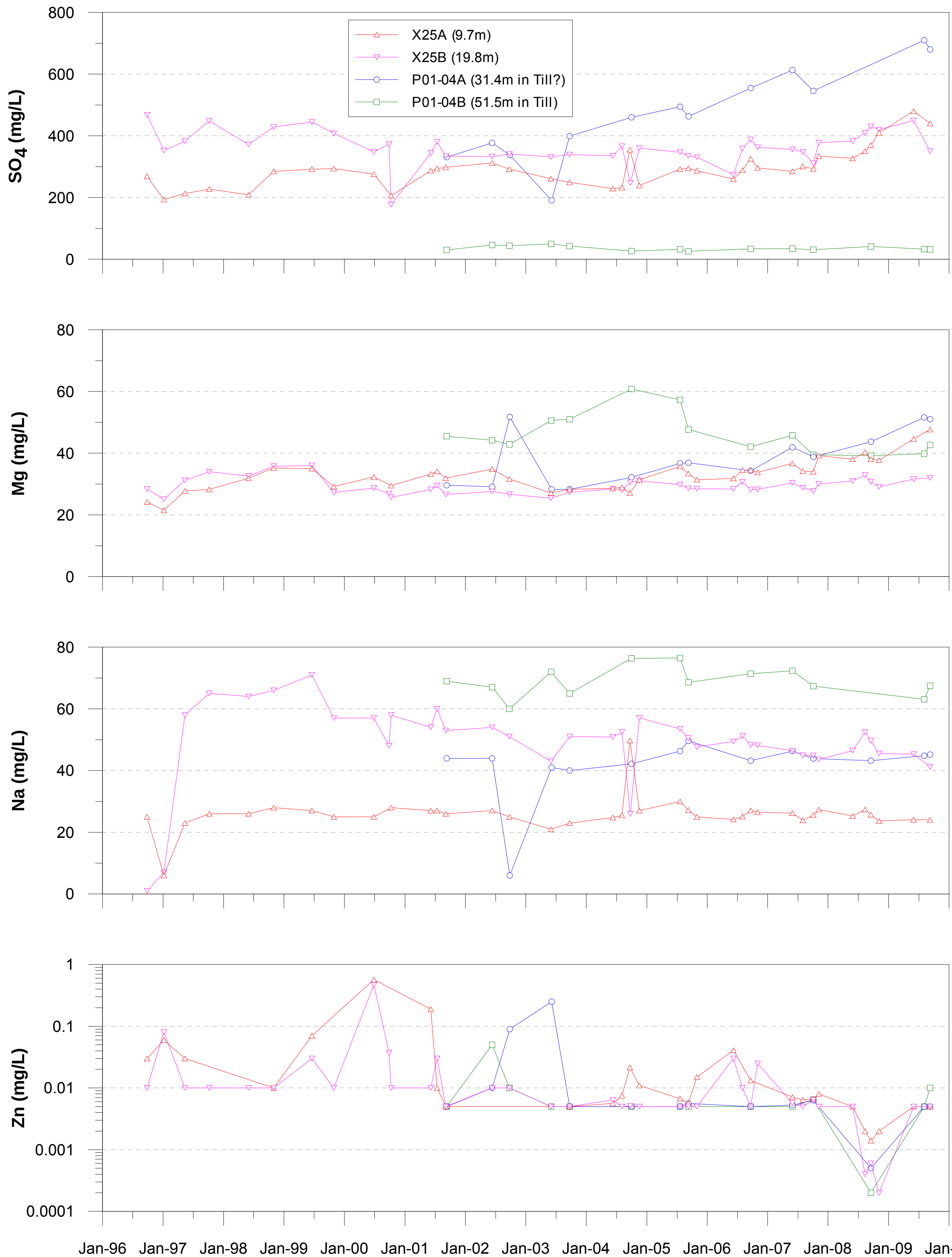


Figure 3-14a. Time trends for SO_4, Mg, Na and Zn in X25(96) and P01-04 (southern side of the Intermediate Dam)

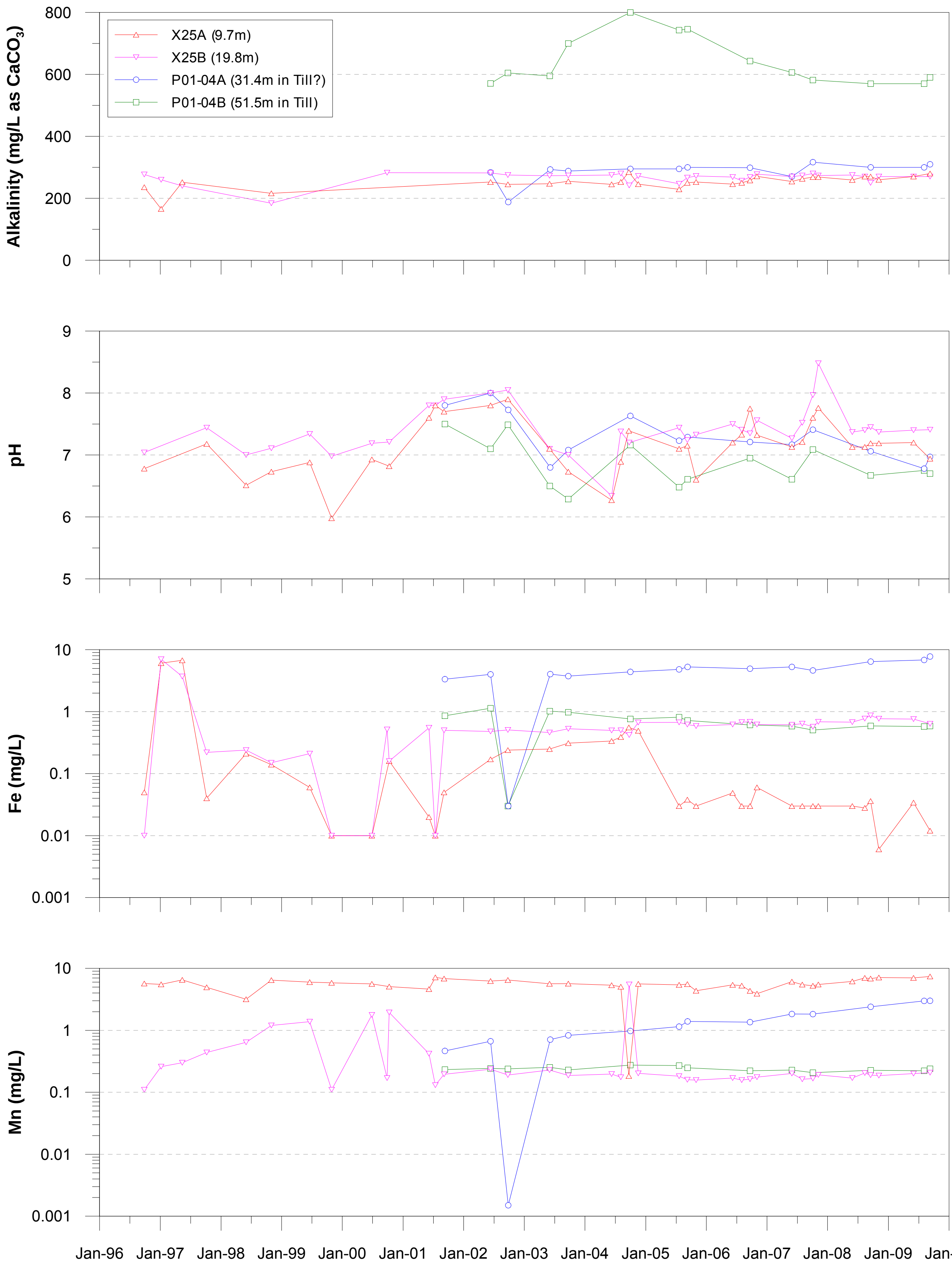


Figure 3-14b. Time trends for alkalinity, pH, Fe and Mn in X25(96) and P01-04 (southern side of the Intermediate Dam)

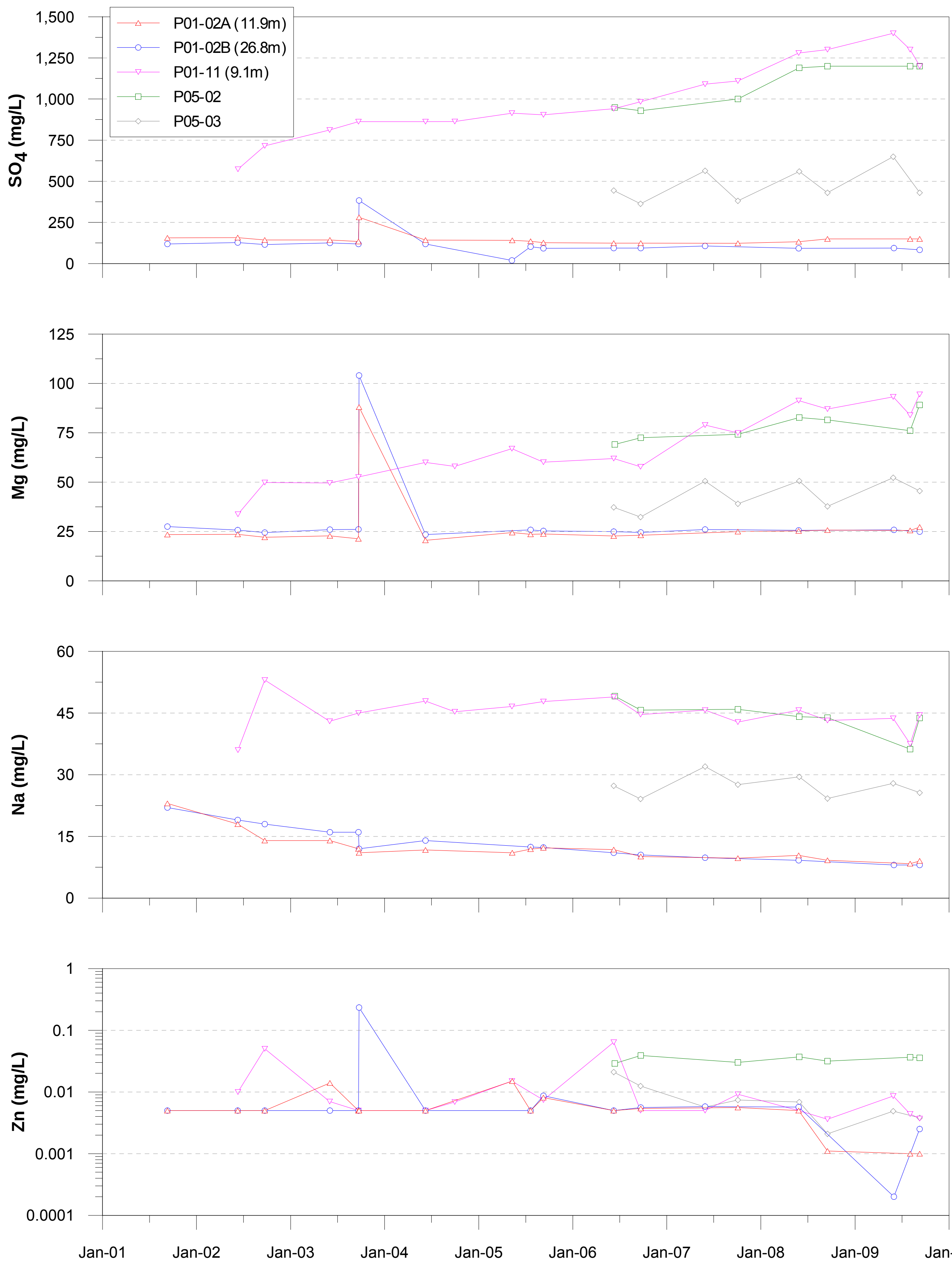


Figure 3-15a. Time trends for SO_4, Mg, Na and Zn in wells along toe of Cross Valley Dam

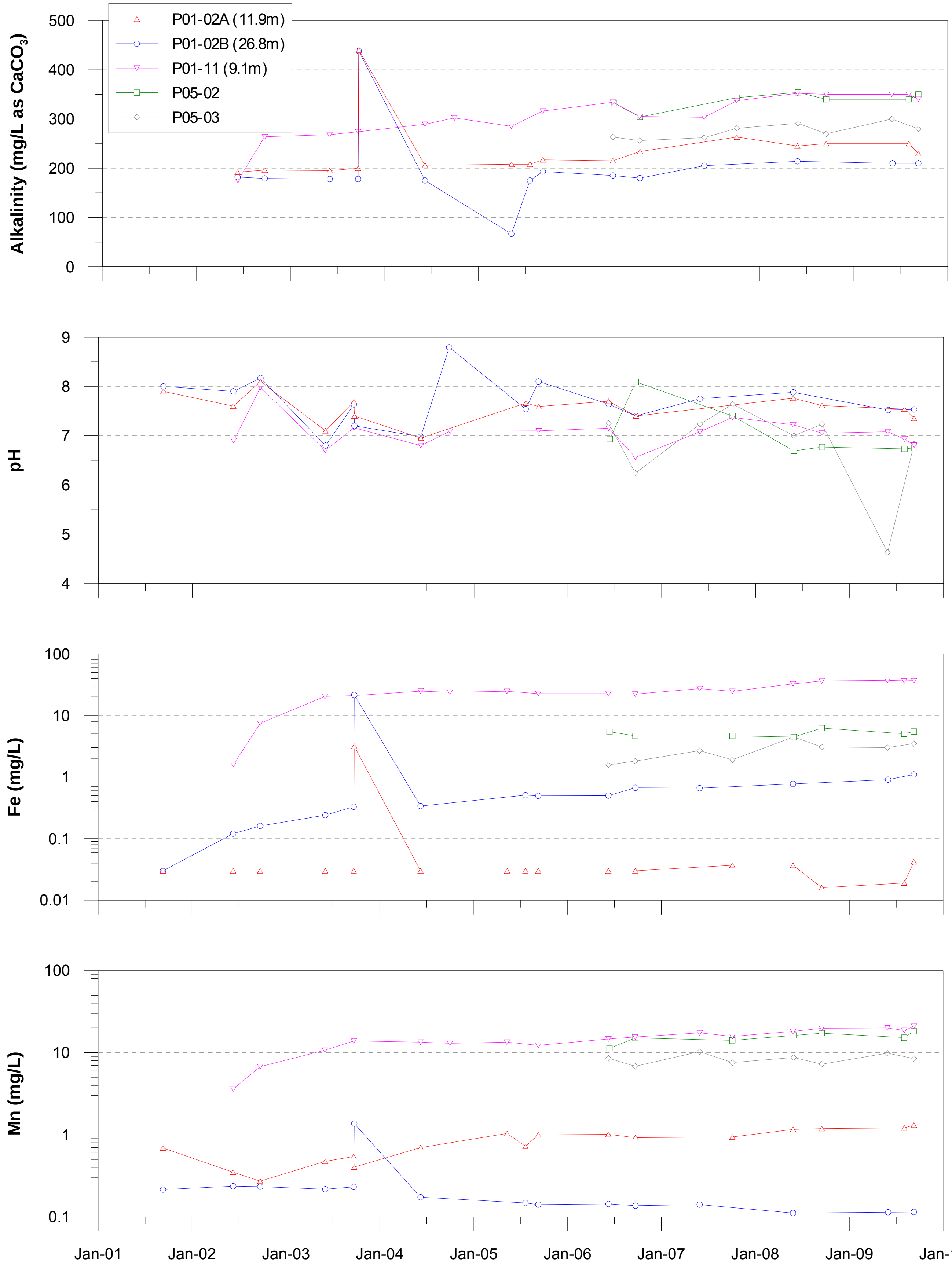


Figure 3-15b. Time trends for alkalinity, pH, Fe and Mn in wells along toe of Cross Valley Dam

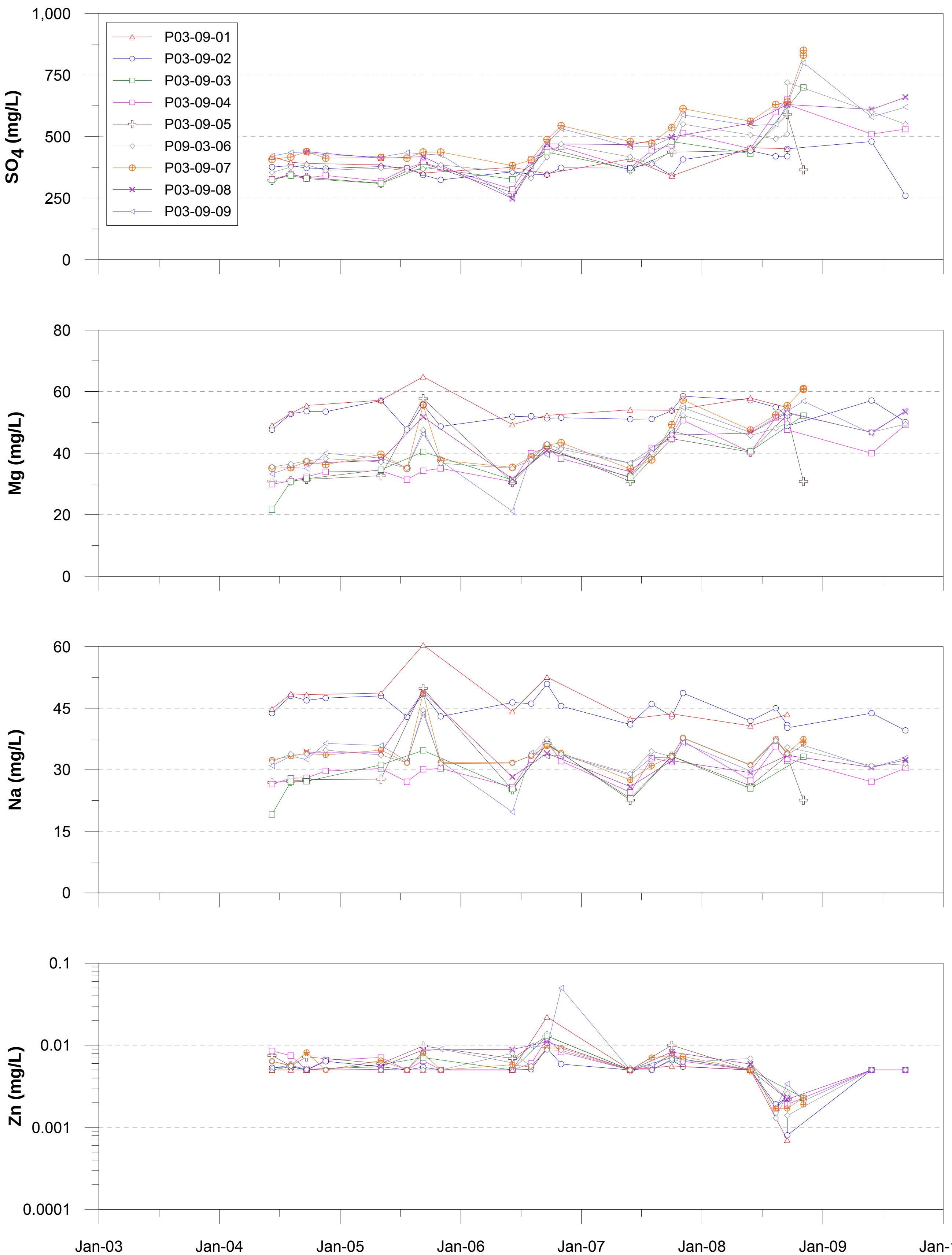


Figure 3-16a. Time trends for SO_4, Mg, Na and Zn in P03-09 (at Cross Valley Dam)

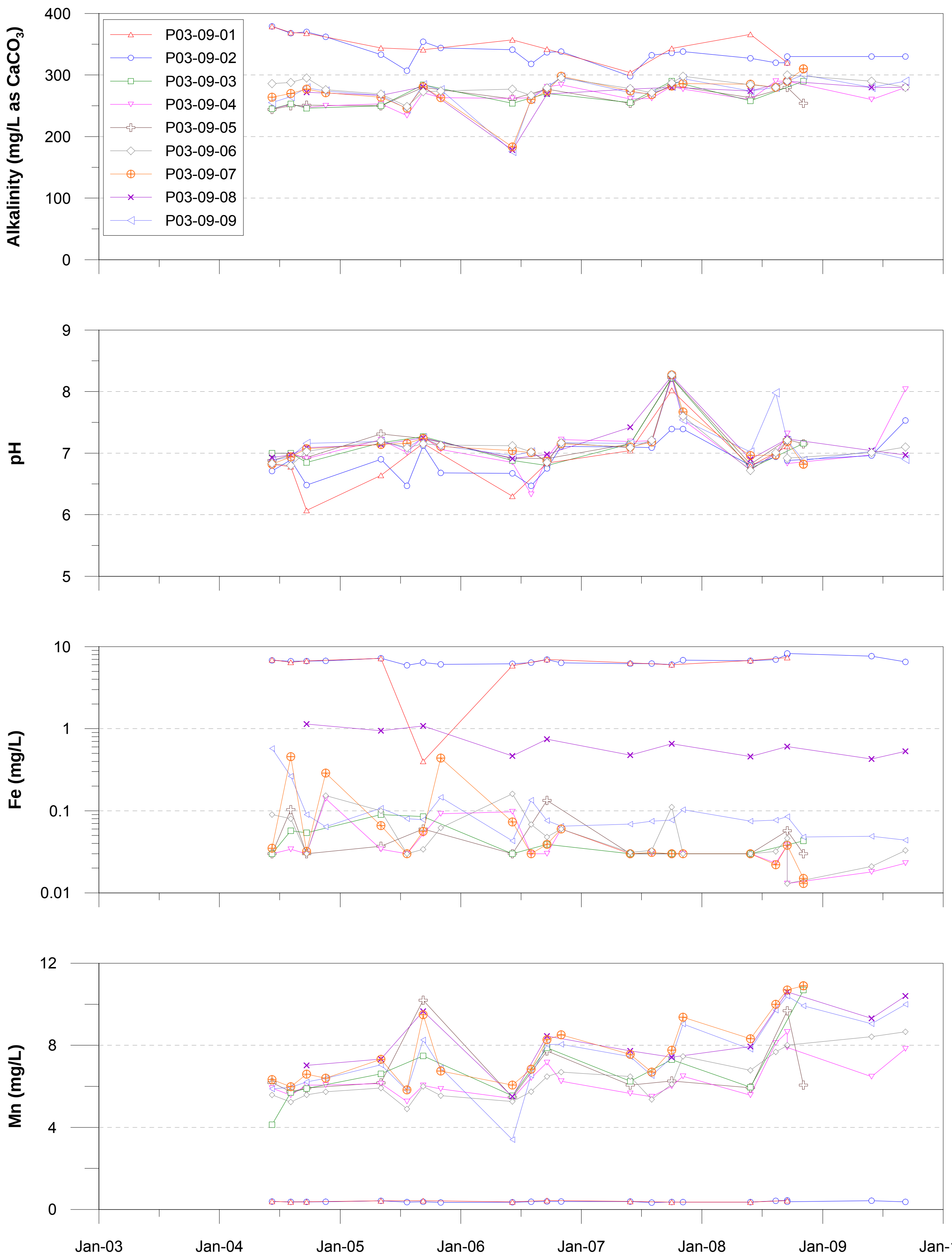


Figure 3-16b. Time trends for alkalinity, pH, Fe and Mn in P03-09 (at Cross Valley Dam)

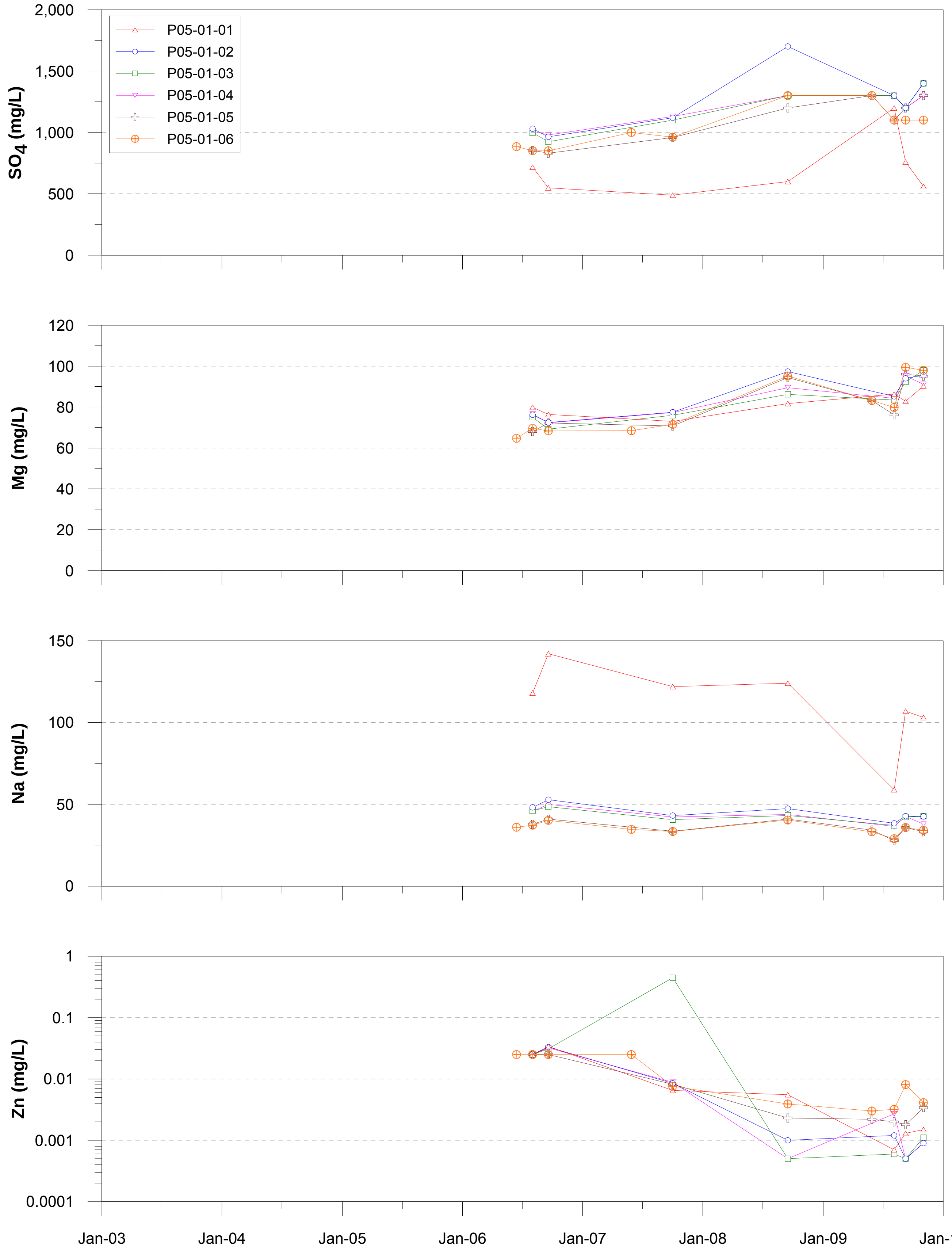


Figure 3-17a. Time trends for SO_4, Mg, Na and Zn in P05-01 (at Cross Valley Dam)

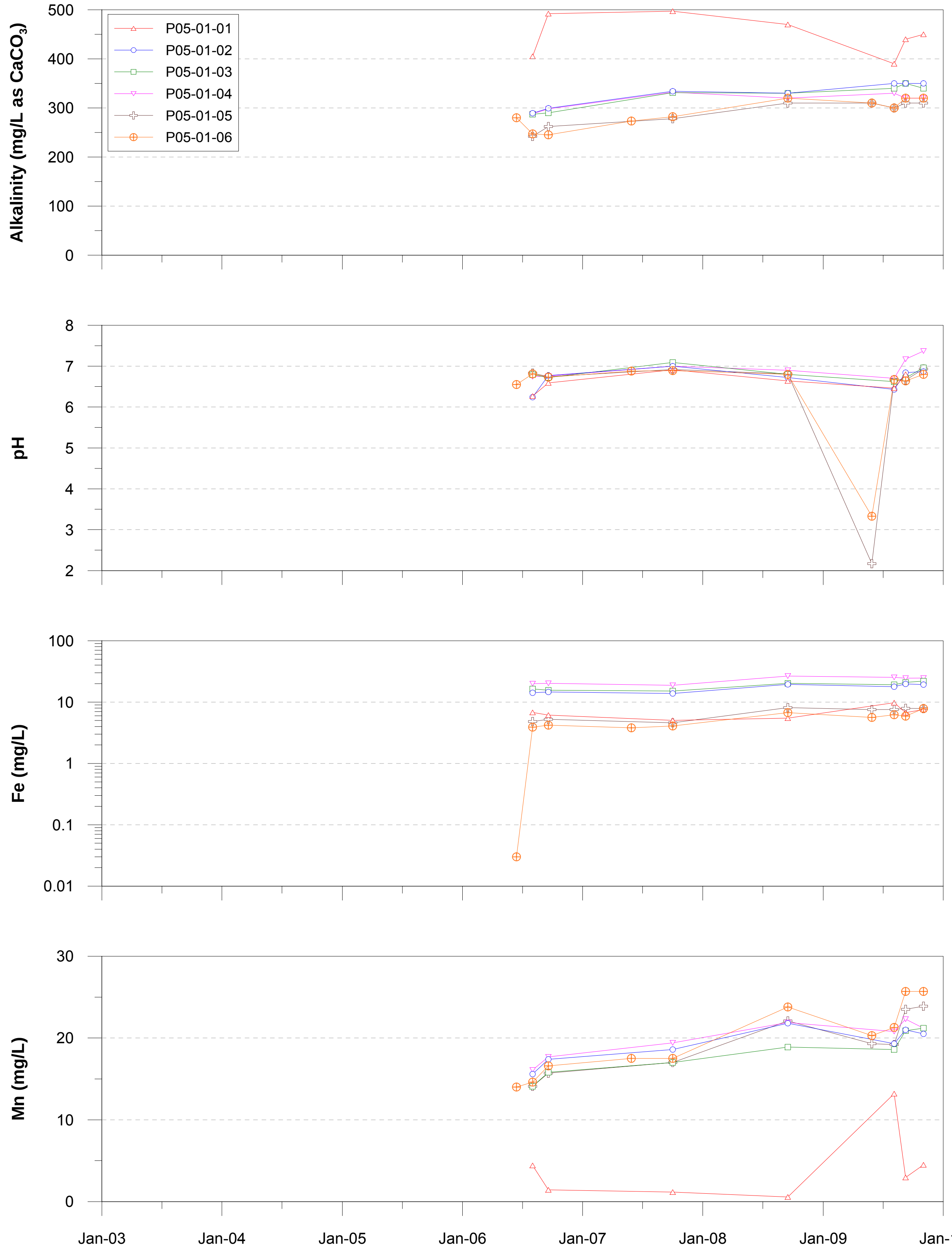


Figure 3-17b. Time trends for alkalinity, pH, Fe and Mn in P05-01 (at Cross Valley Dam)

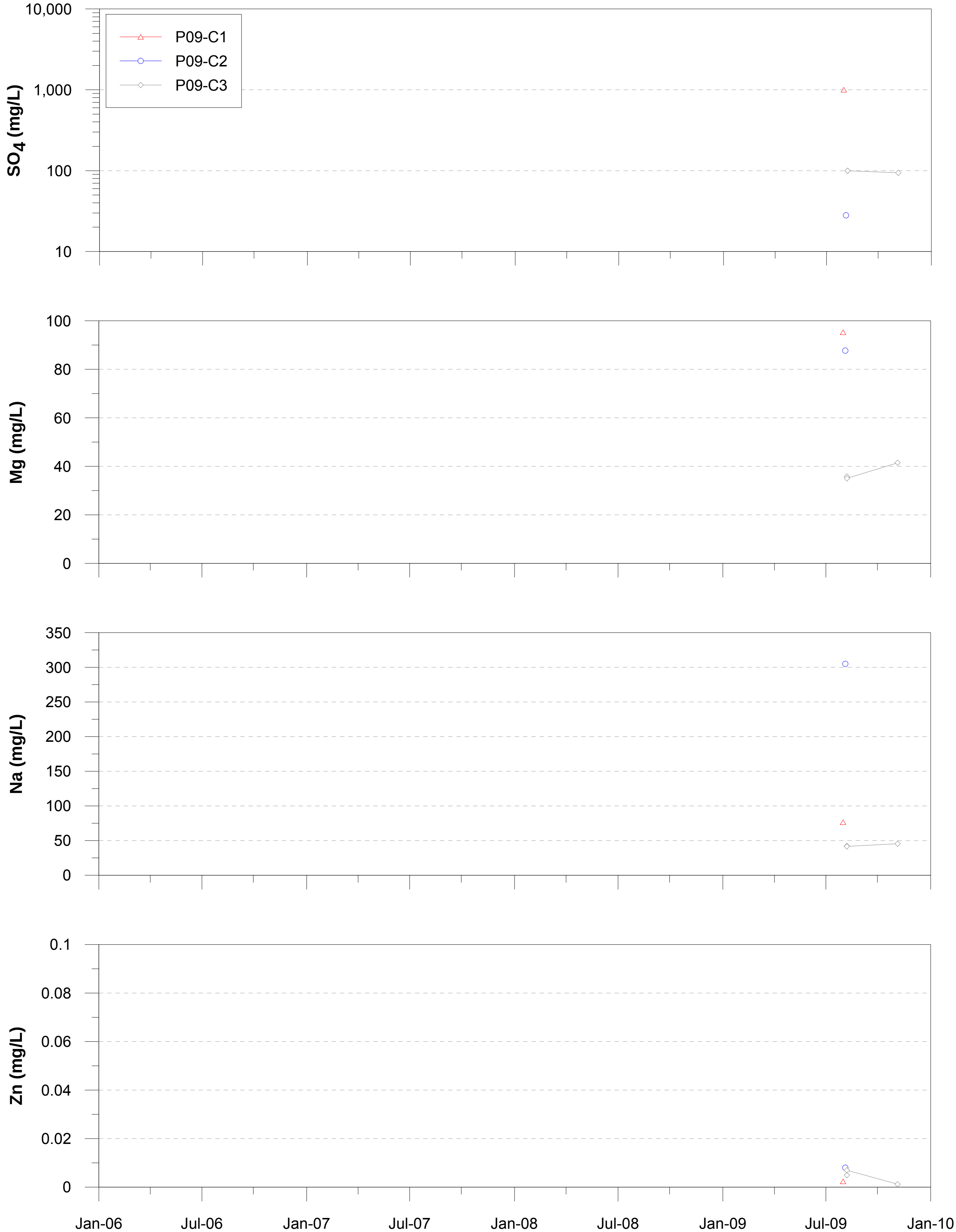


Figure 3-18a. Time trends for SO_4, Mg, Na and Zn in bedrock wells at toe of Cross Valley Dam

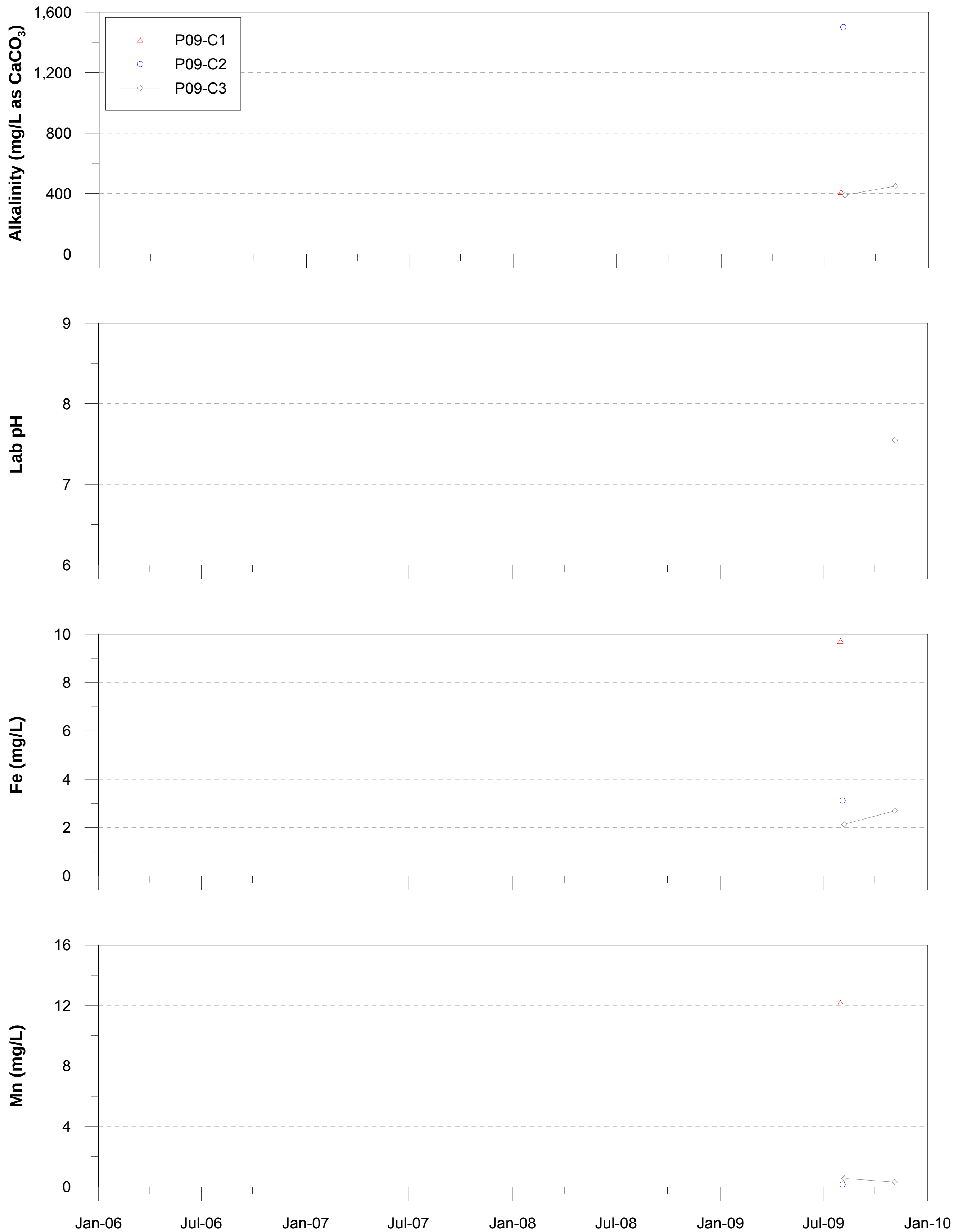


Figure 3-18b. Time trends for alkalinity, pH, Fe and Mn in bedrock wells at toe of Cross Valley Dam

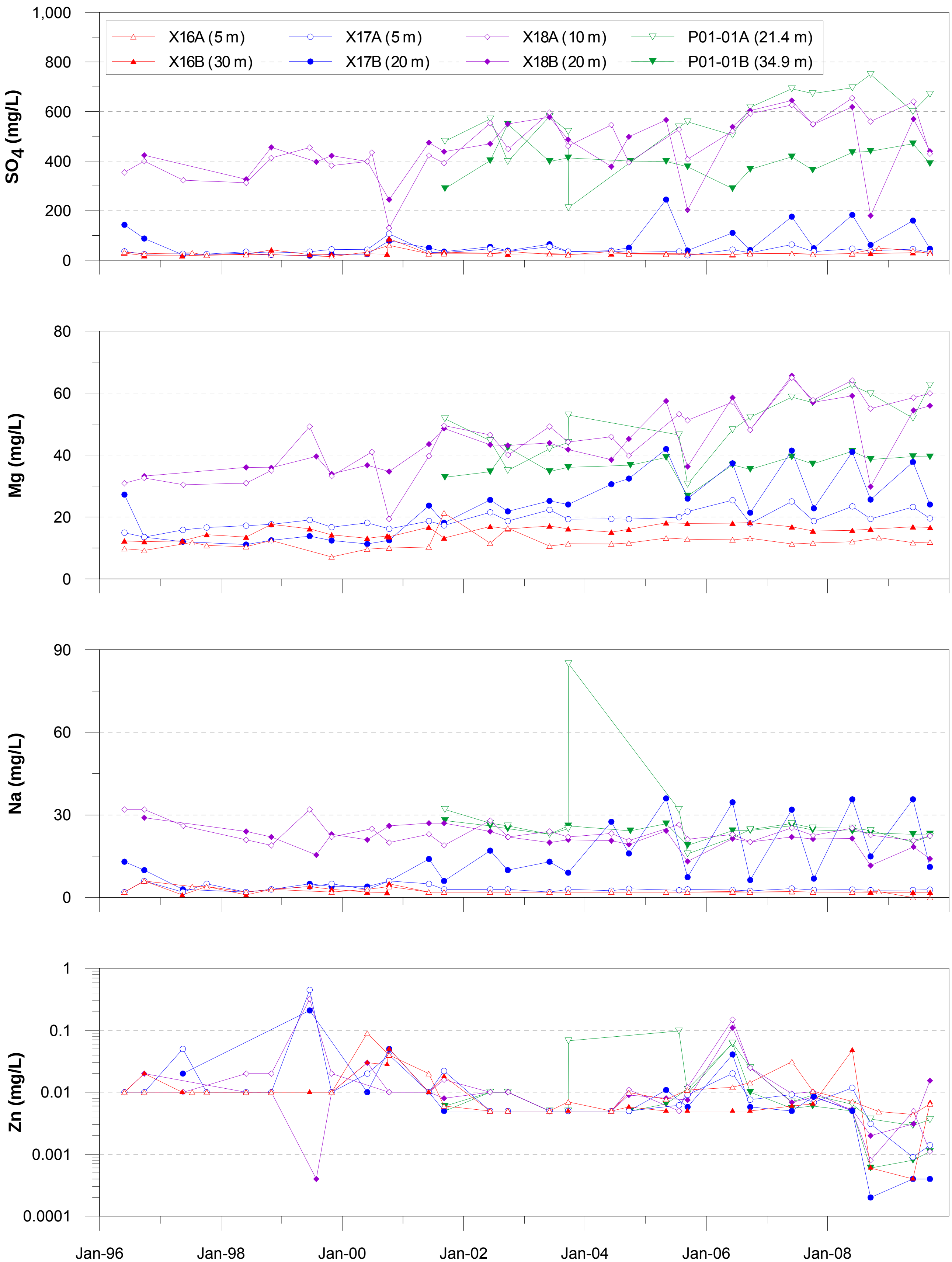


Figure 3-19a. Time trends for SO_4, Mg, Na and Zn in wells down-gradient of Cross Valley Dam

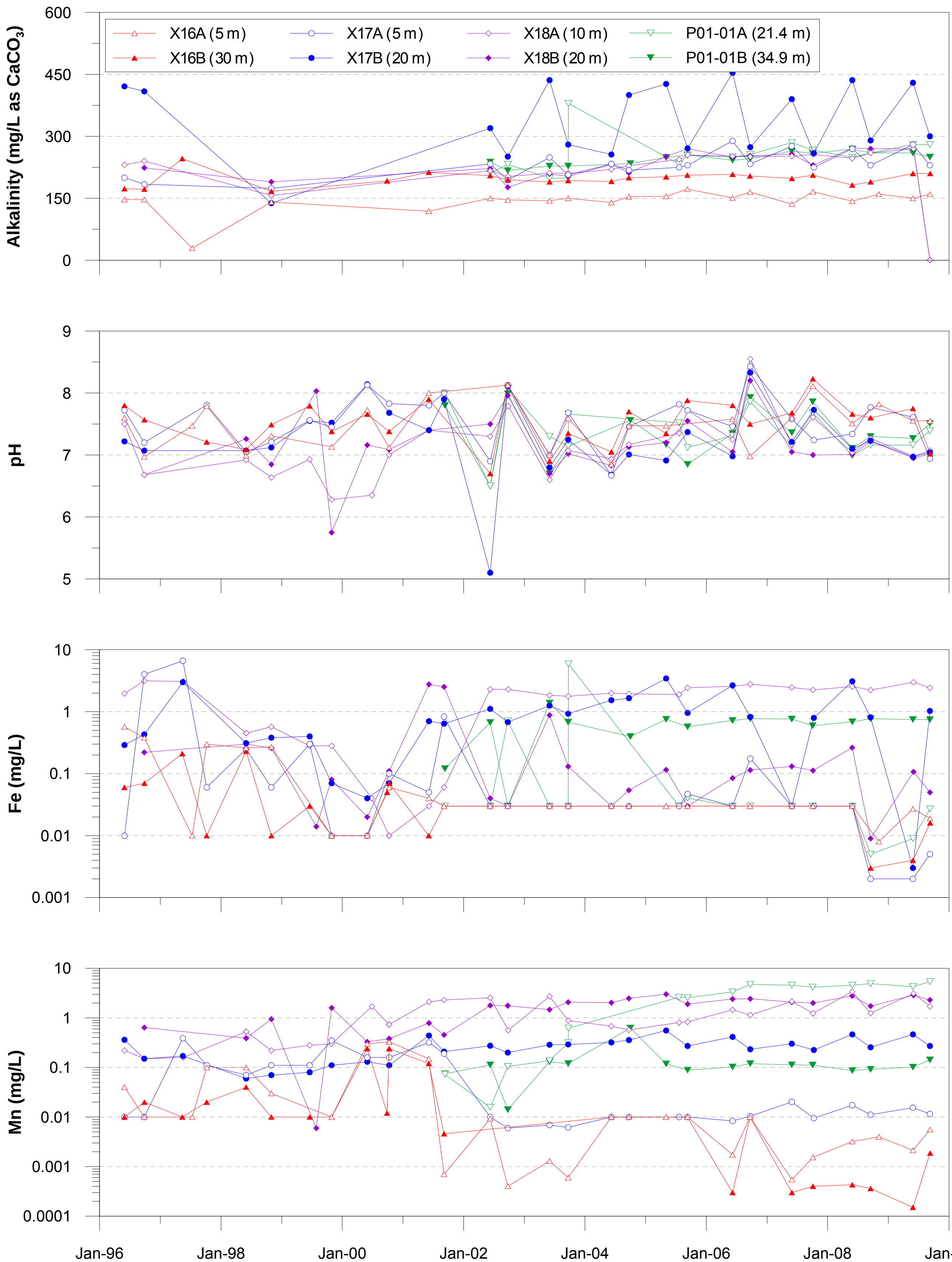
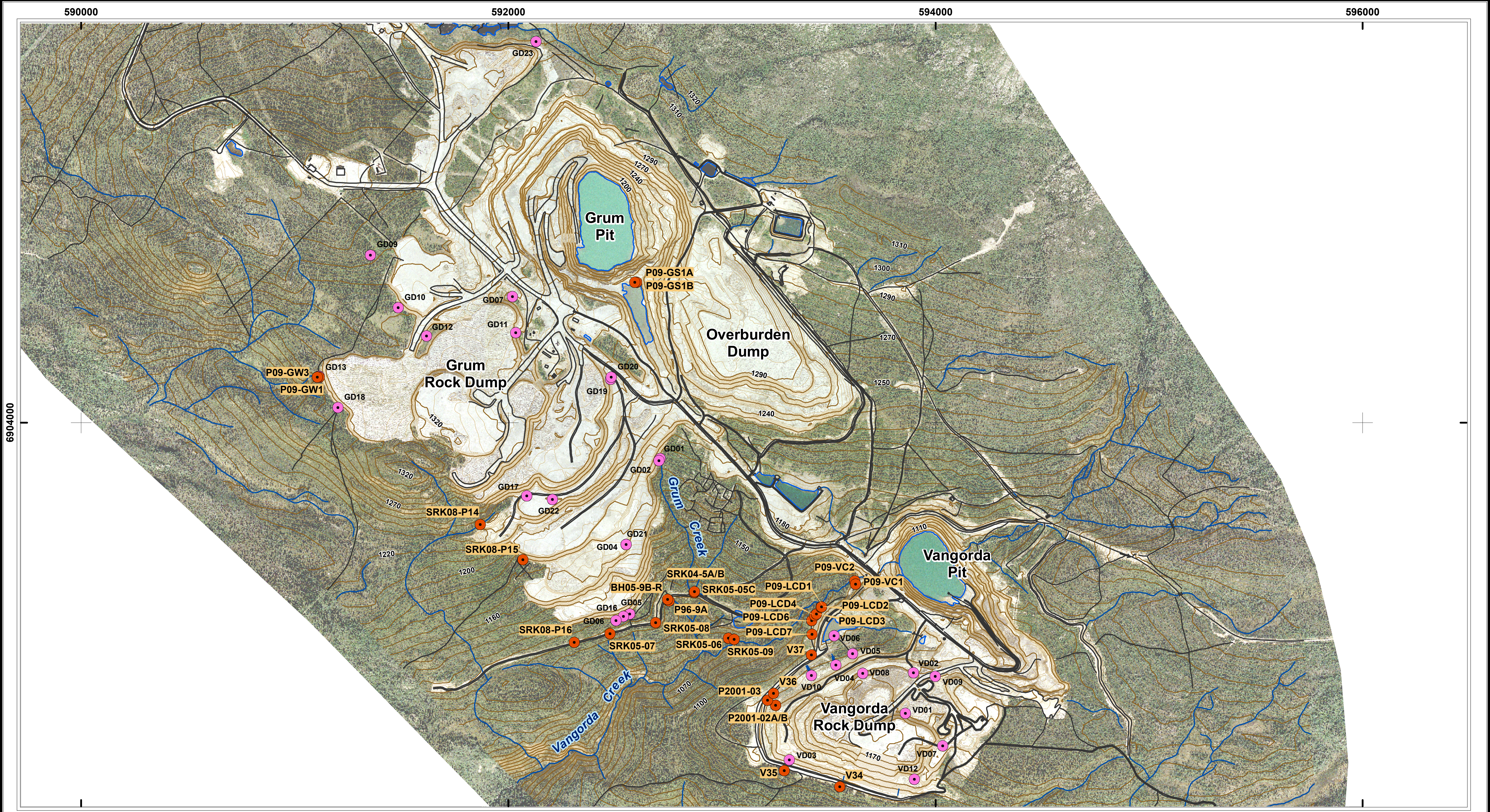


Figure 3-19b. Time trends for alkalinity, pH, Fe and Mn in wells down-gradient of Cross Valley Dam



Layout of Grum & Vangorda Mine Site

Anvil Range Mining Complex

Yukon Government

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FIGURE: 4-1

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

DATE: 022410
DRAWN BY: OM
FILE: Faro_GrumVangorda10.mxd

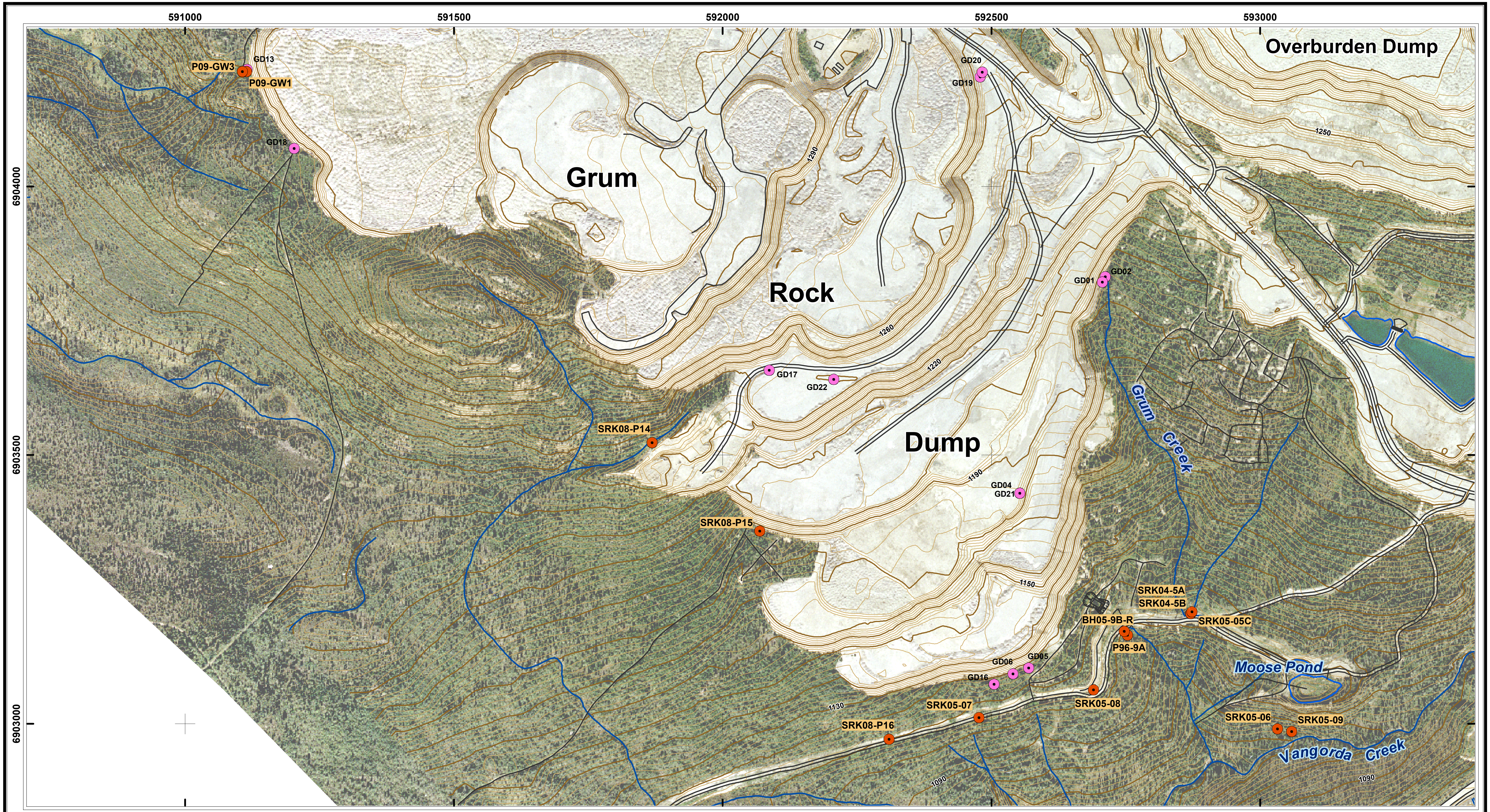
PROJECTION: UTM
ZONE: 8
DATUM: NAD 27
UNITS: Meters

CONTOUR INTERVAL: 2m

N W E S

SCALE
0 375 750 1,125 1,500 Meters

LEGEND
- Monitoring Well
- Seep Monitoring Station



LEGEND

- Monitoring Well
- Seep Monitoring Station

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

CONTOUR INTERVAL: 2m

N W E S
SCALE

Groundwater Monitoring Wells Grum Rock Dump Area

Grum & Vangorda Mine Site

SCALE

0 150 300 450 600 Meters

Yukon Government

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

FIGURE: 4-2

DATE: 022410
DRAWN BY: OM
FILE: Faro_Grum10.mxd

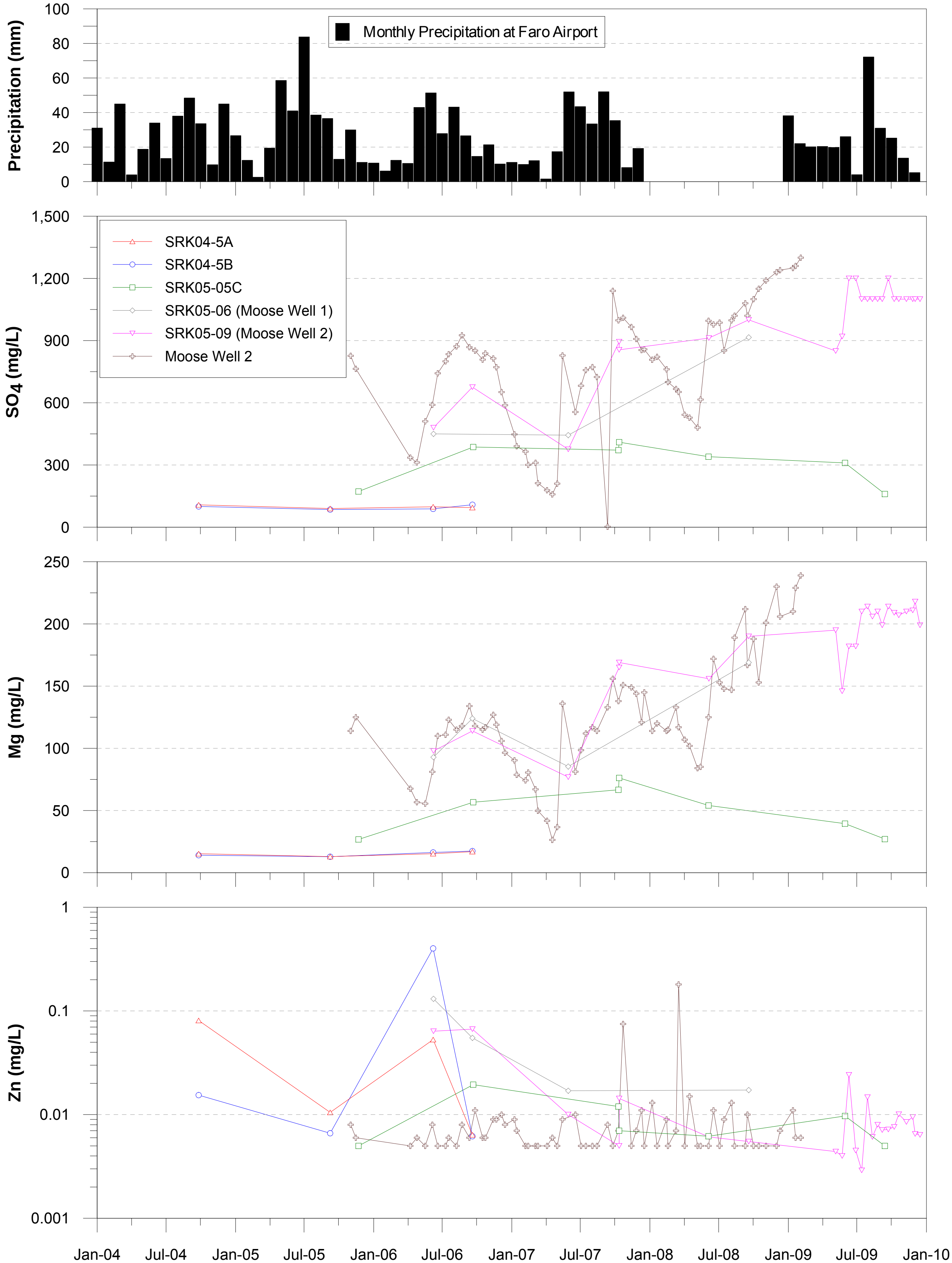


Figure 4-3a. Time trends for SO_4, Mg and Zn in wells in Grum Creek drainage

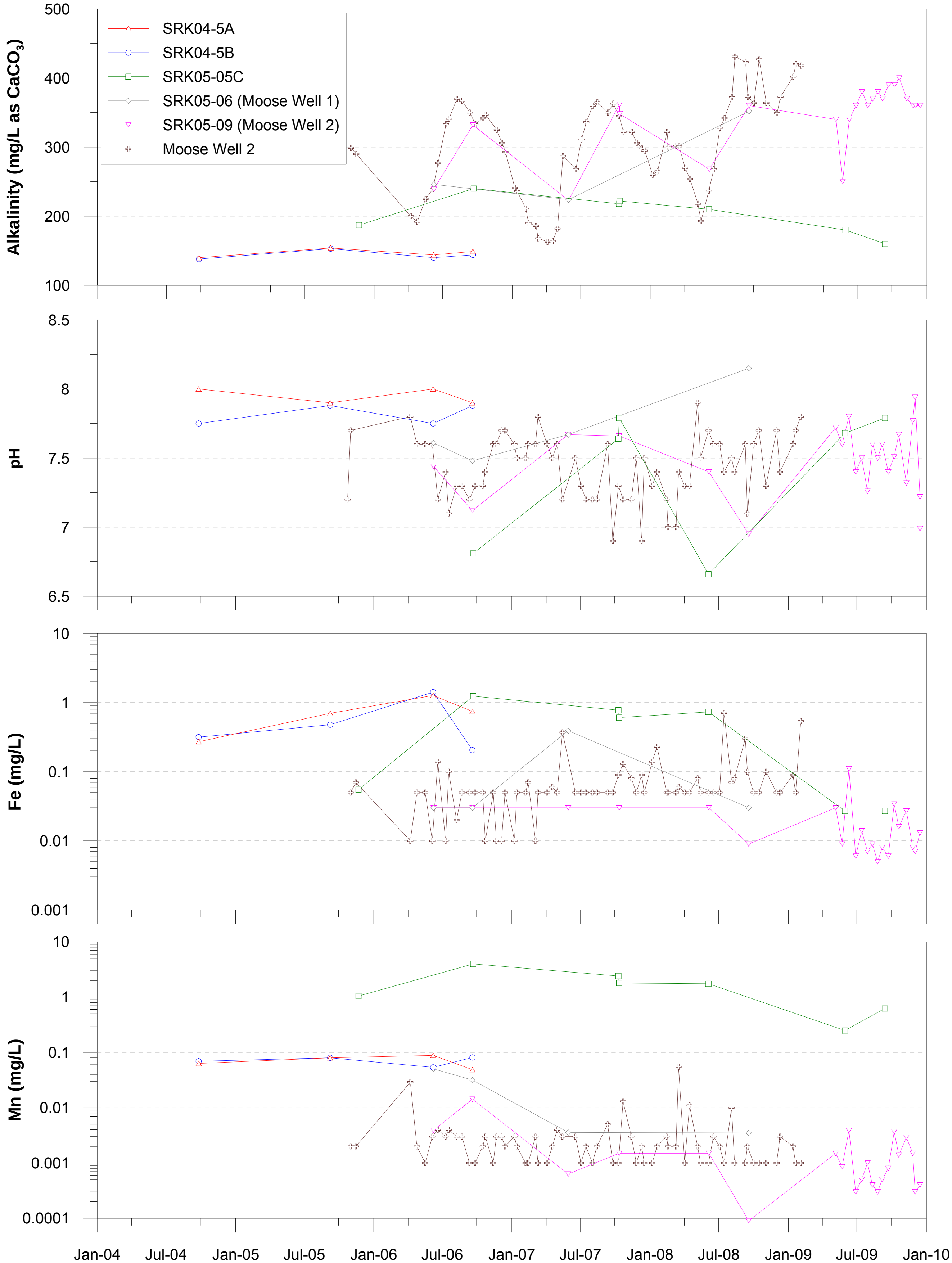


Figure 4-3b. Time trends for alkalinity, pH, Fe and Mn in wells in Grum Creek drainage

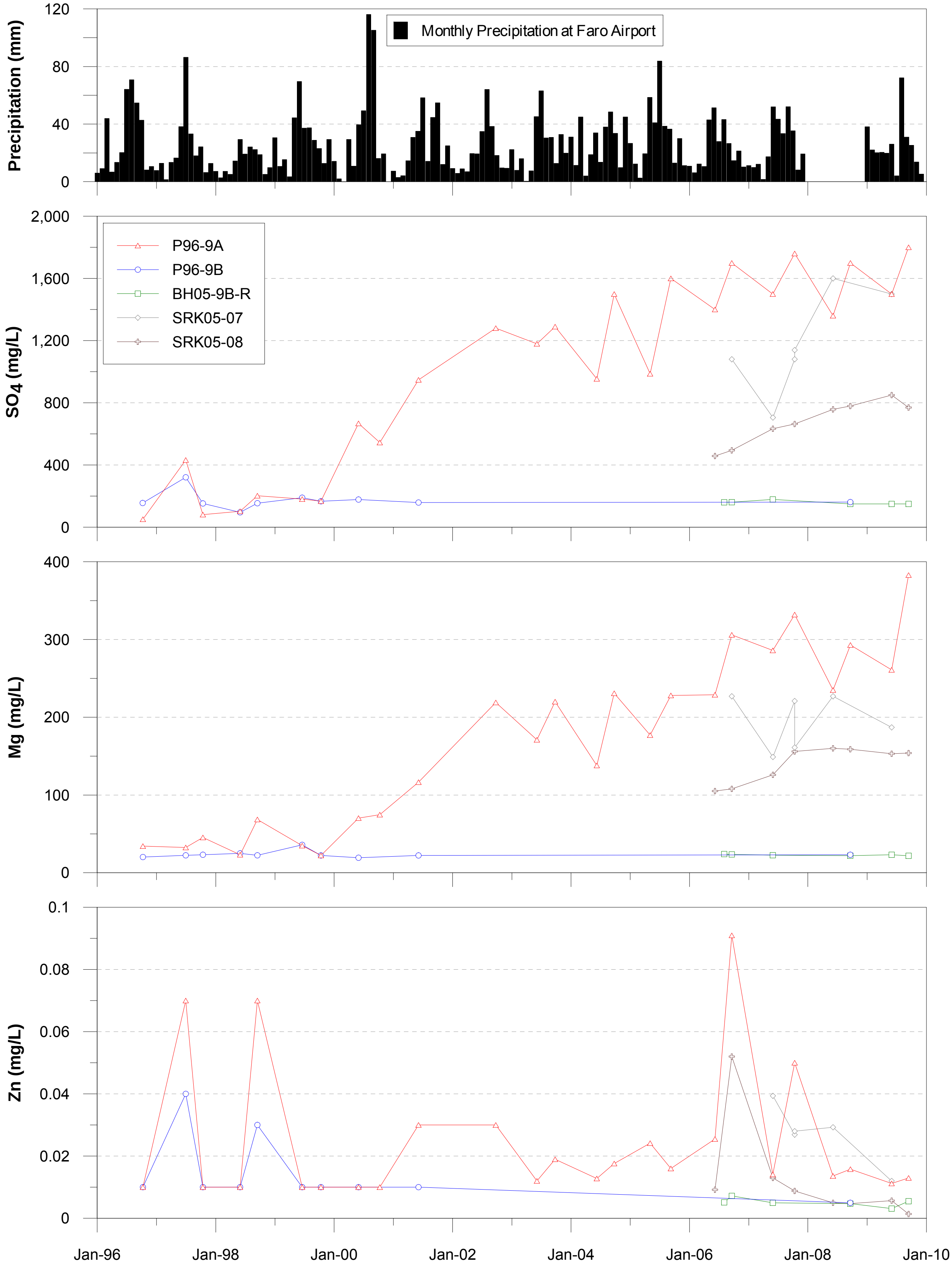


Figure 4-4a. Time trends for SO_4, Mg and Zn in wells located west of Grum Creek

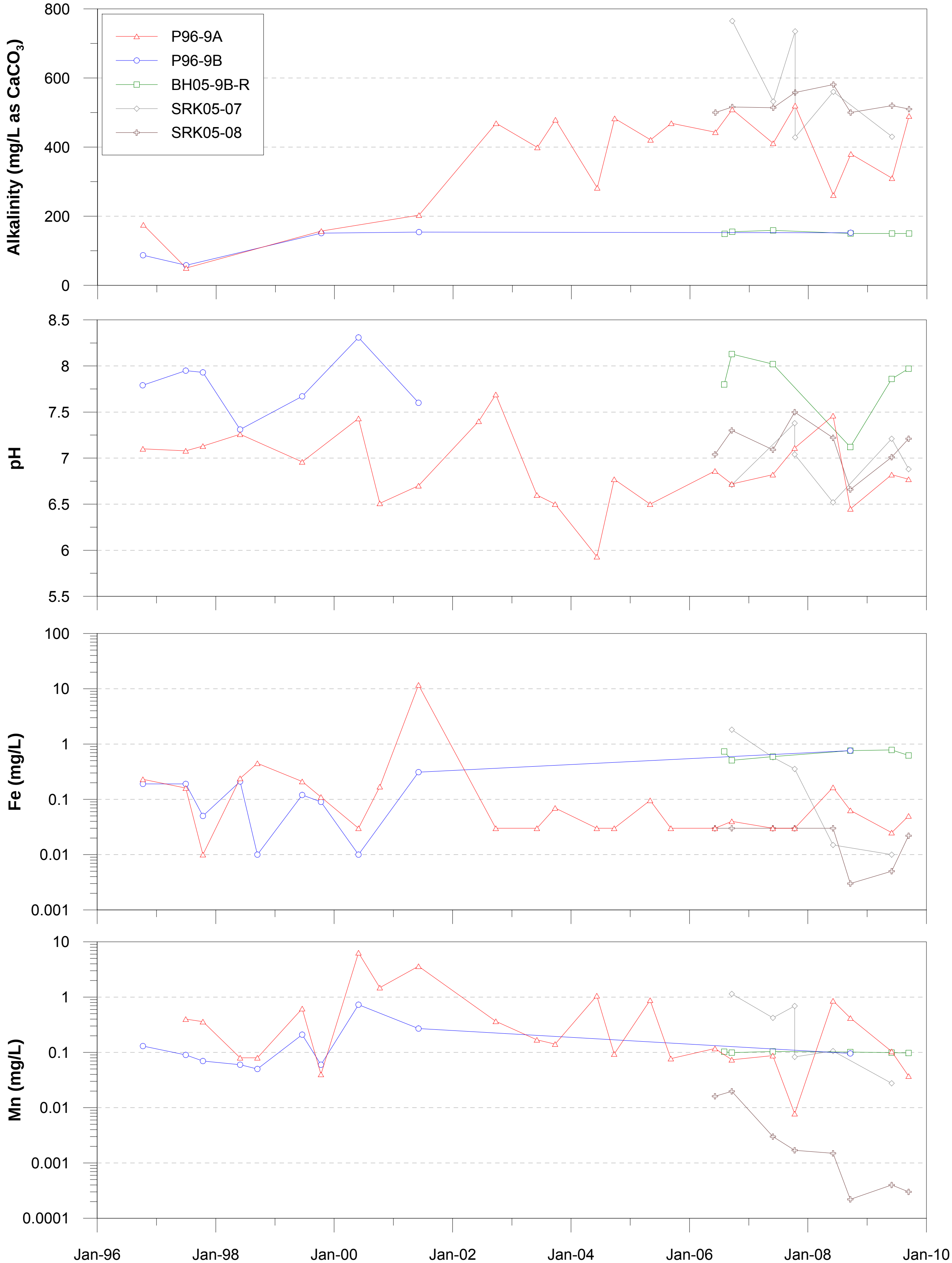


Figure 4-4b. Time trends for alkalinity, pH, Fe and Mn in wells located west of Grum Creek

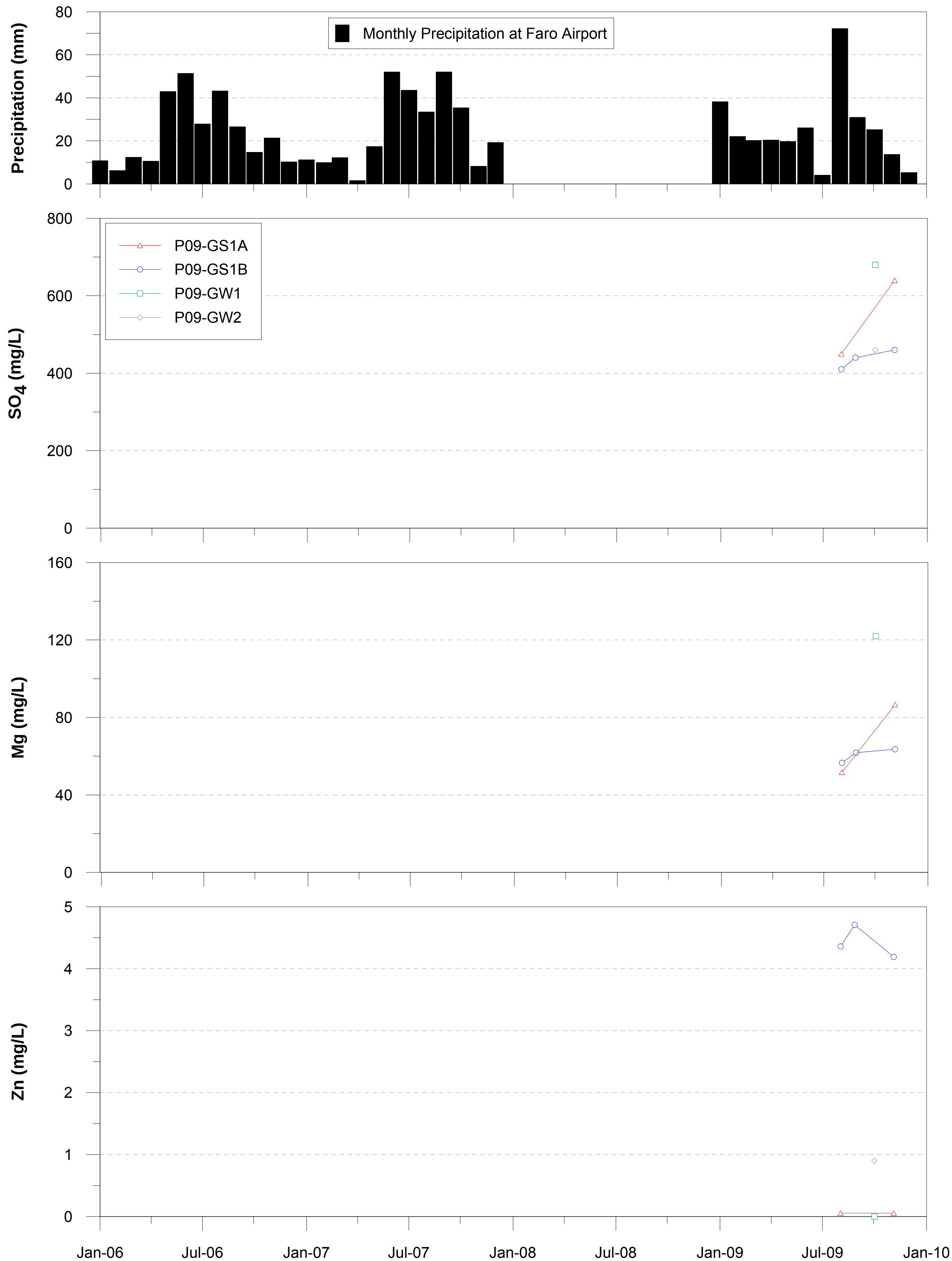


Figure 4-5a. Time trends for SO_4, Mg, Na and Zn in wells located near Grum Slot and west of Grum Dump

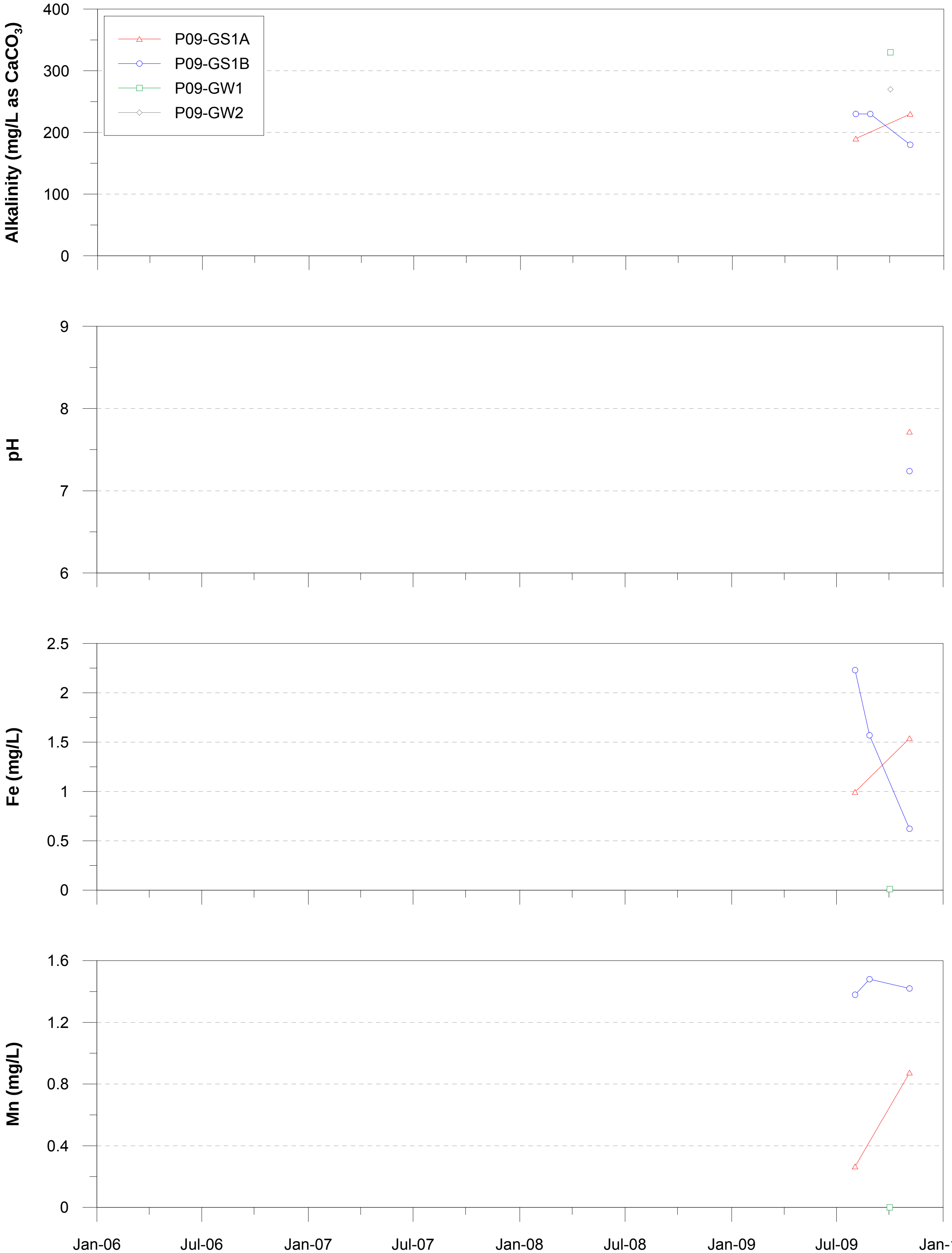


Figure 4-5b. Time trends for alkalinity, pH, Fe and Mn in wells located near Grum Slot and west of Grum Dump

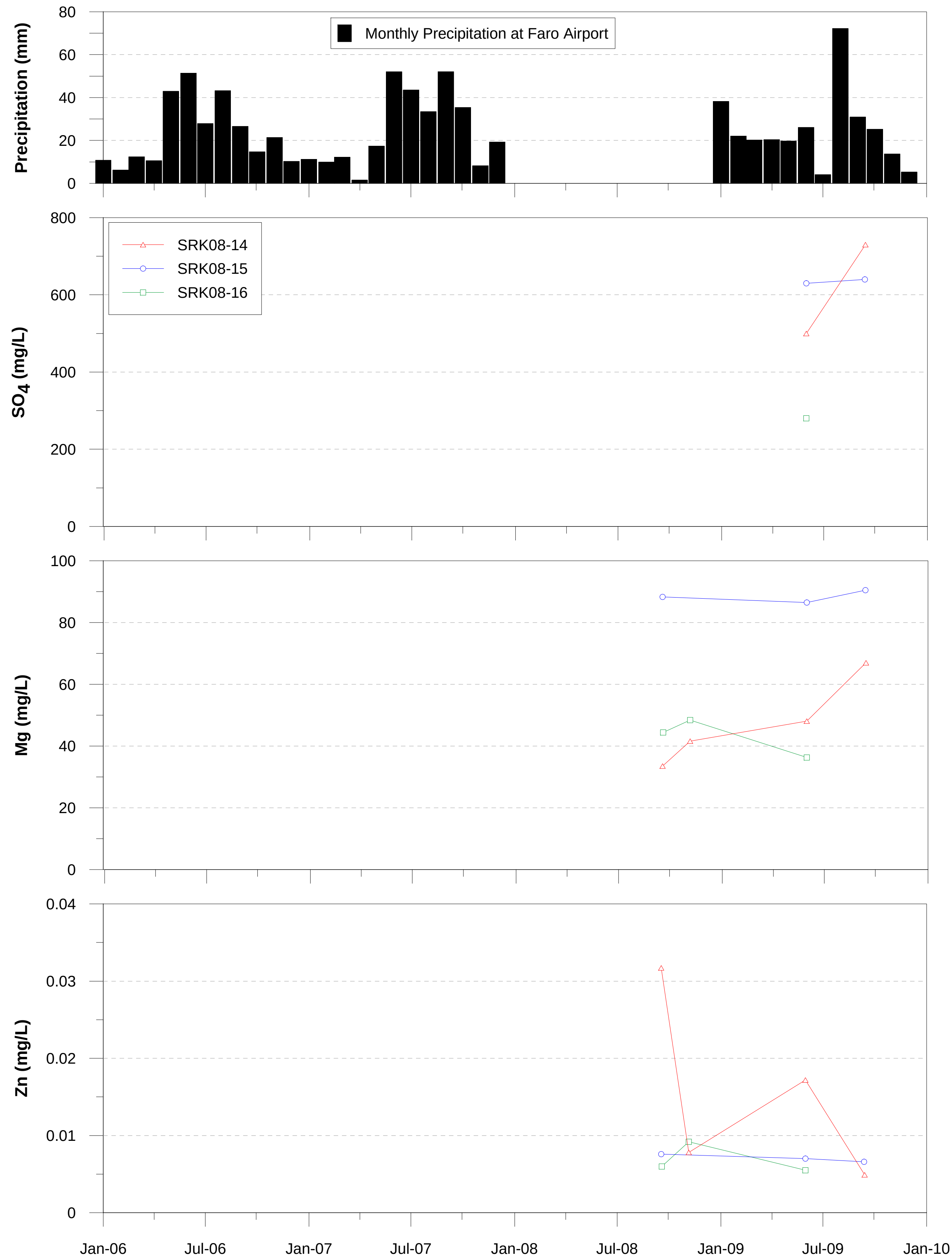


Figure 4-5c. Time trends for SO_4, Mg, Na and Zn in SRK08 wells located southwest of Grum Dump

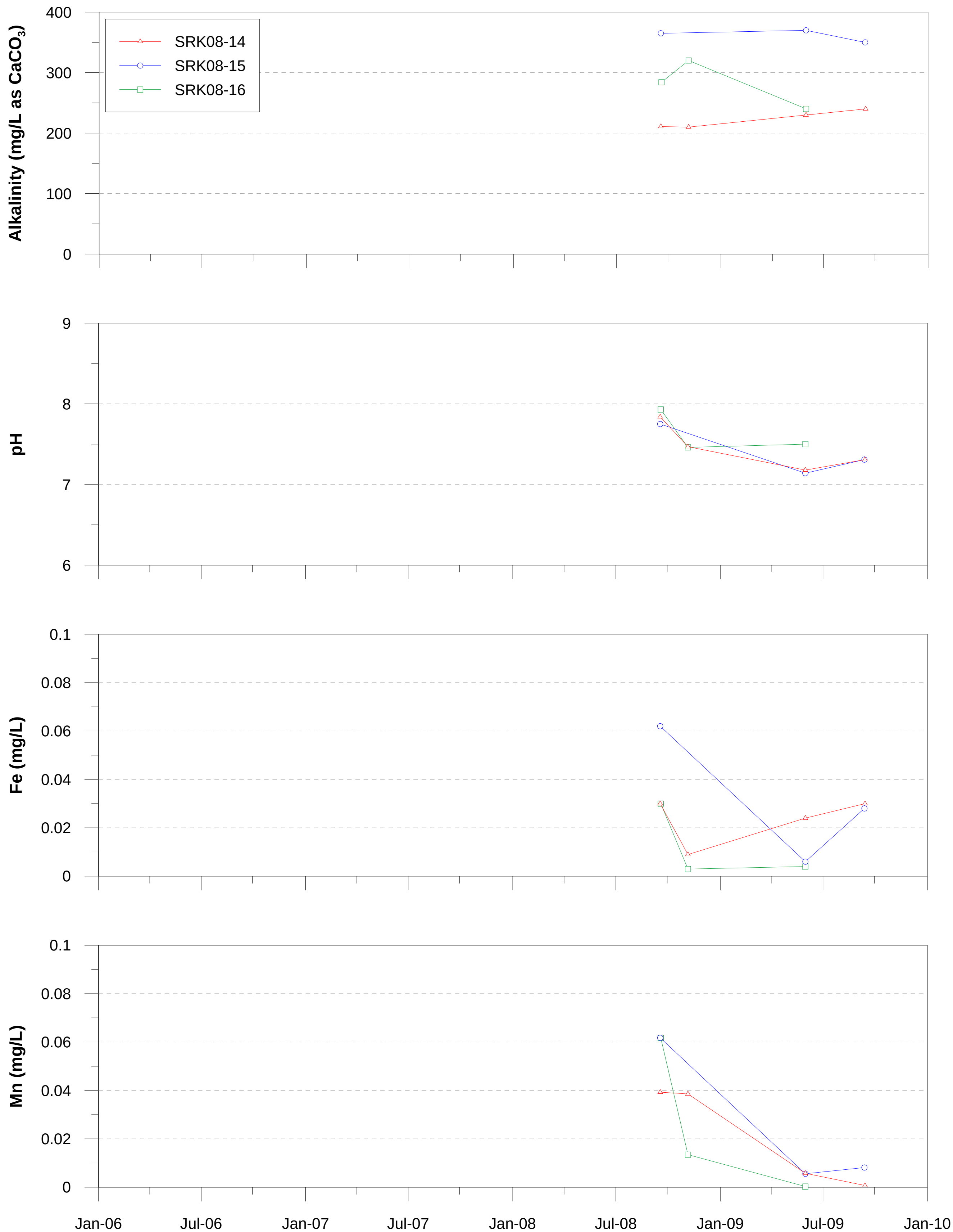
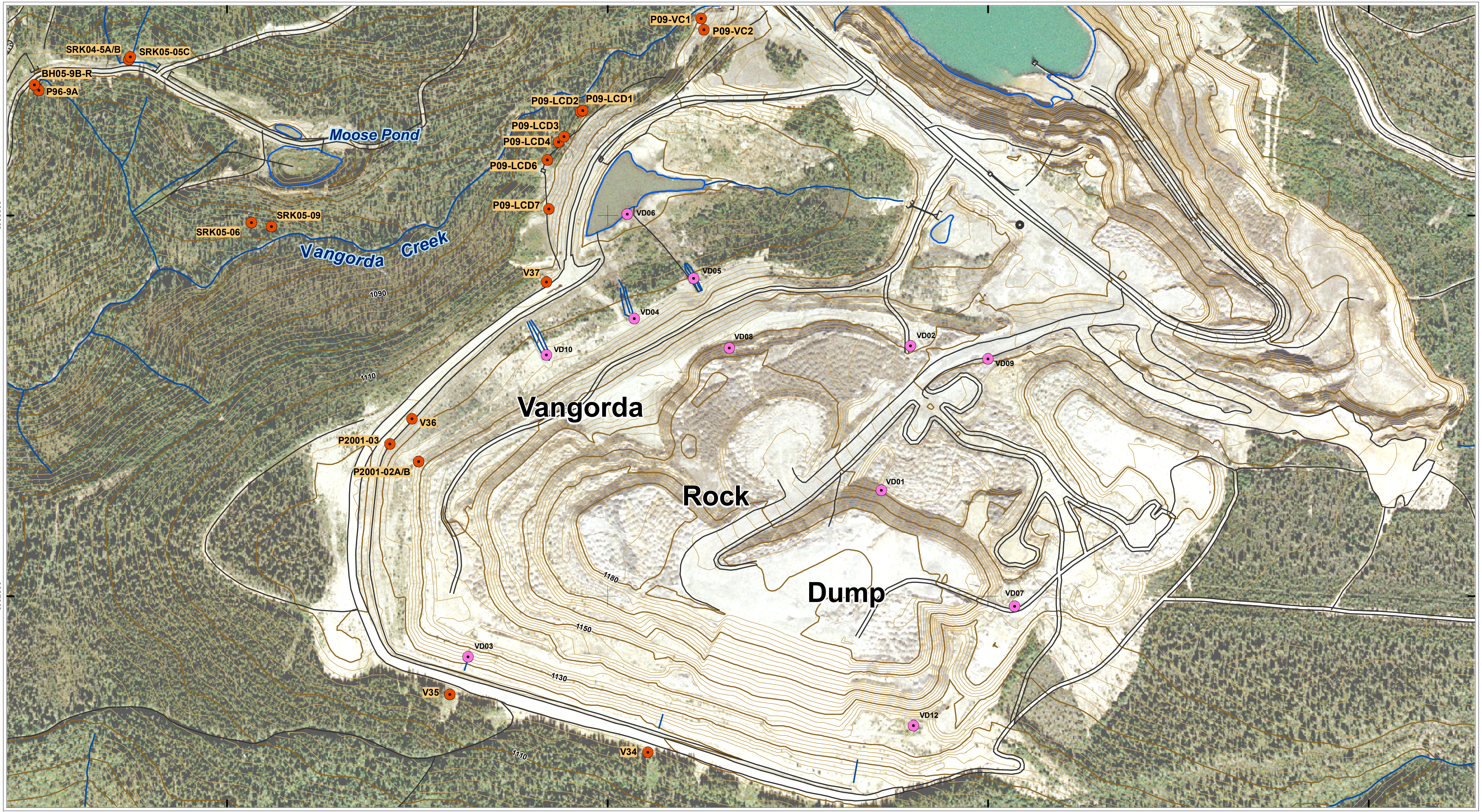


Figure 4-5d. Time trends for alkalinity, pH, Fe and Mn in SRK08 wells located southwest of Grum Dump



LEGEND

- Monitoring Well
- Seep Monitoring Station

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

CONTOUR INTERVAL: 2m

N S E W

Groundwater Monitoring Wells Vangorda Rock Dump Area

Grum & Vangorda Mine Site

SCALE

0 50 100 200 300 400 Meters

Yukon Government

CLIENT: Yukon Government
PROJECT: 2009 ARMC Groundwater Review
REPORT: RGC 118017
LOCATION: Anvil Range Mining Complex,YT, Canada

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FIGURE: 4-6

DATE: 022510
DRAWN BY: OM
FILE: Faro_Vangorda10.mxd

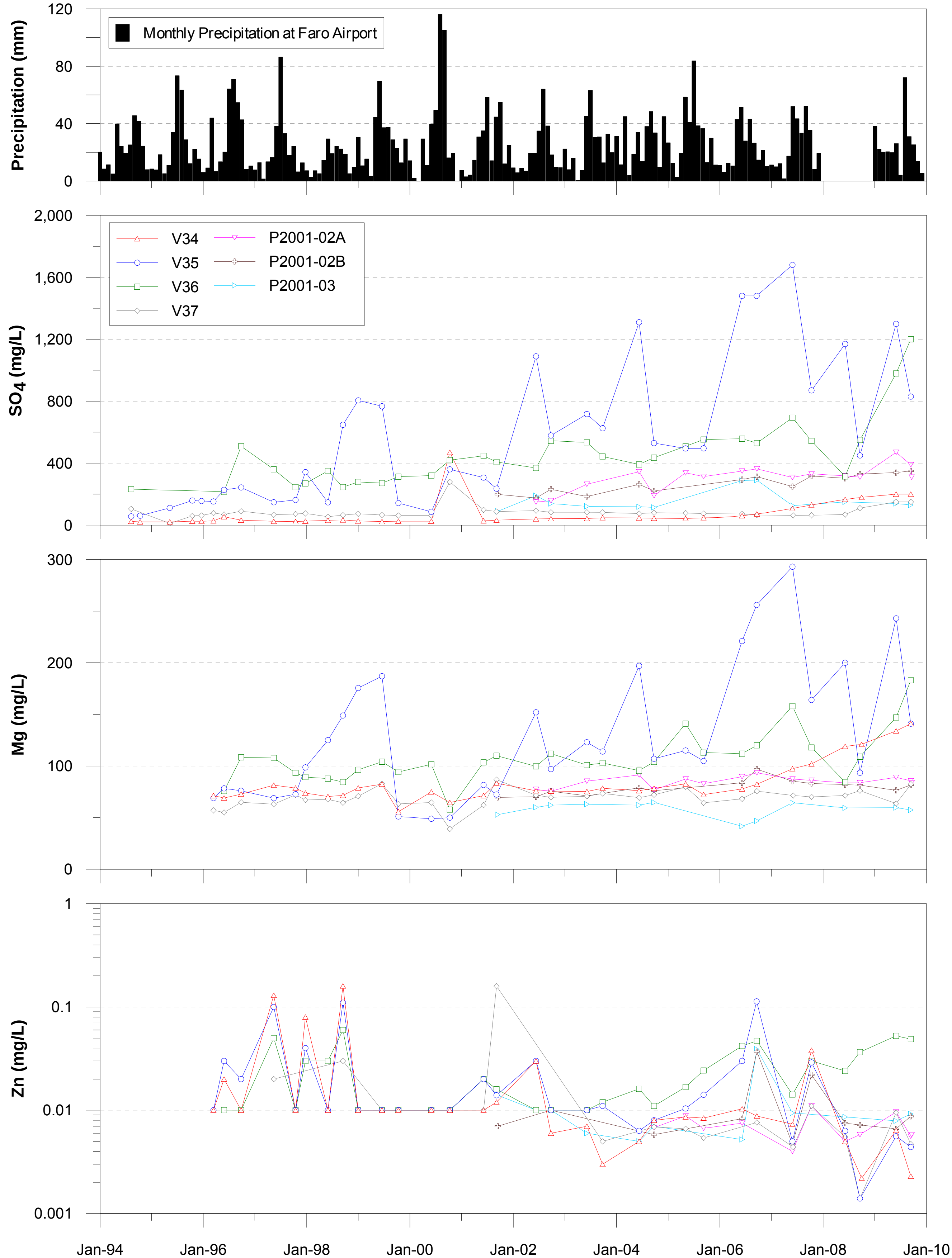


Figure 4-7a. Time trends for SO_4, Mg and Zn in wells downgradient of Vangorda Rock Dump

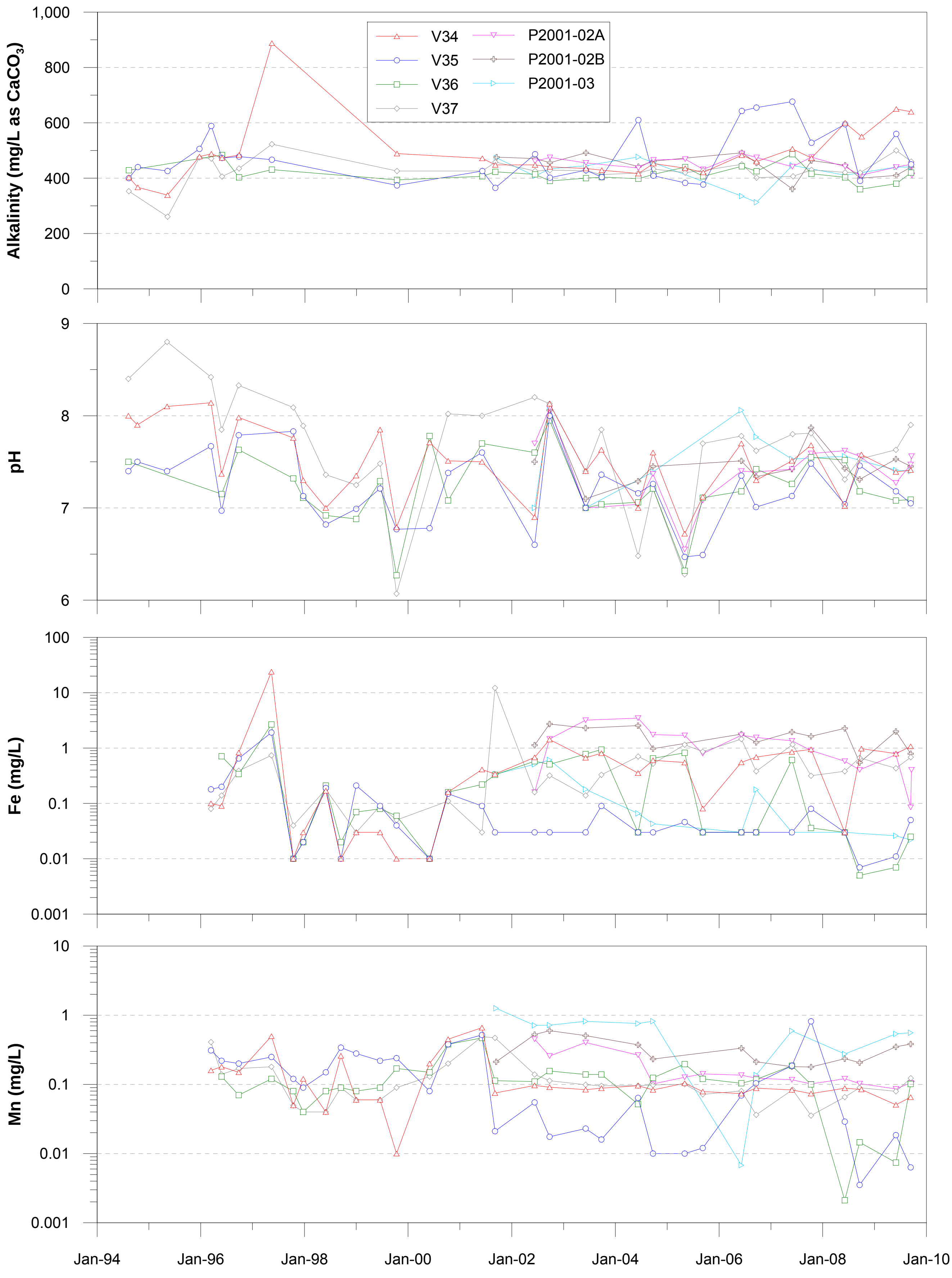


Figure 4-7b. Time trends for alkalinity, pH, Fe and Mn in wells downgradient of Vangorda Rock Dump

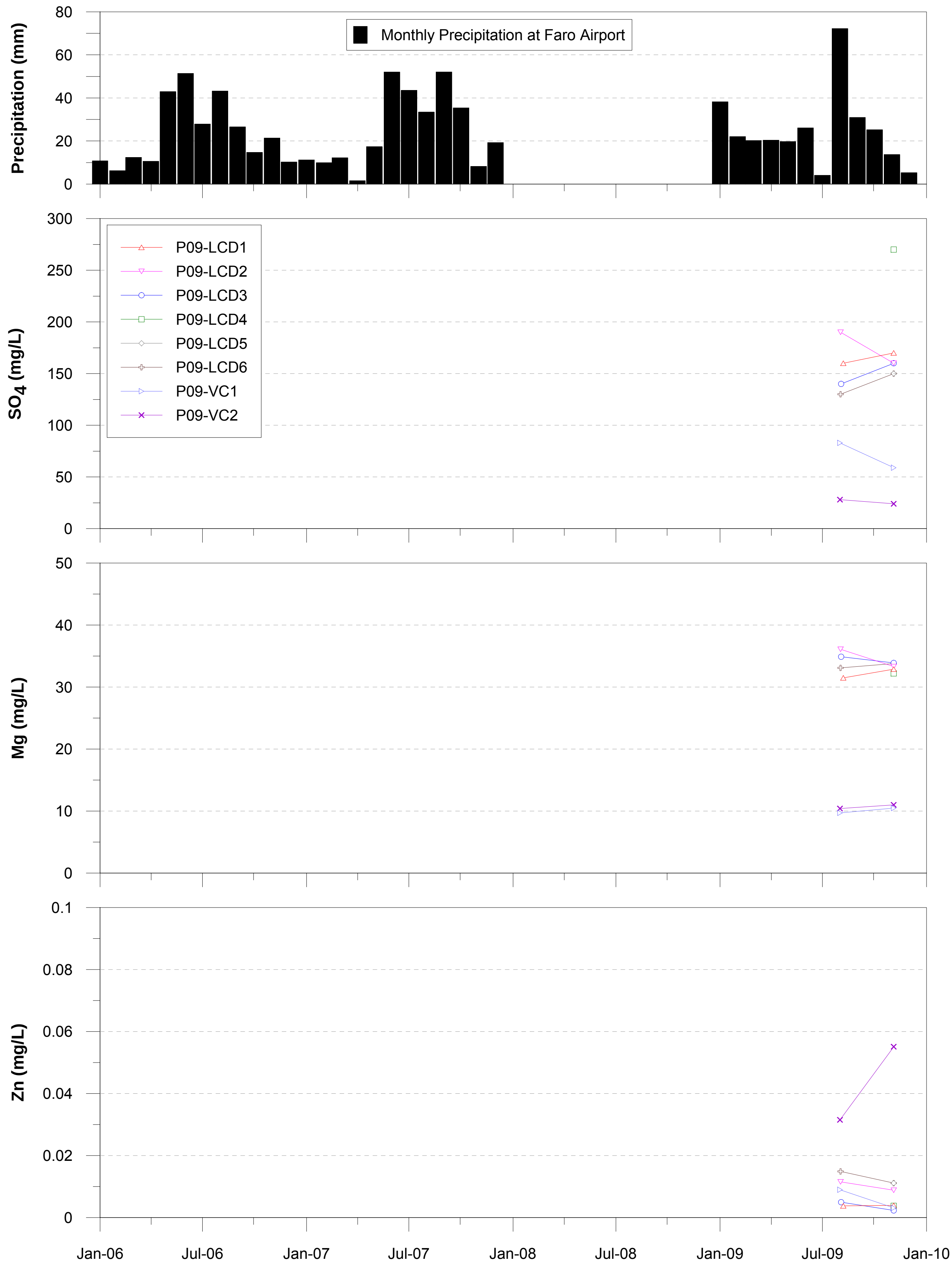


Figure 4-8a. Time trends for SO_4, Mg, Na and Zn in wells near Vangorda Creek and Little Creek Dam

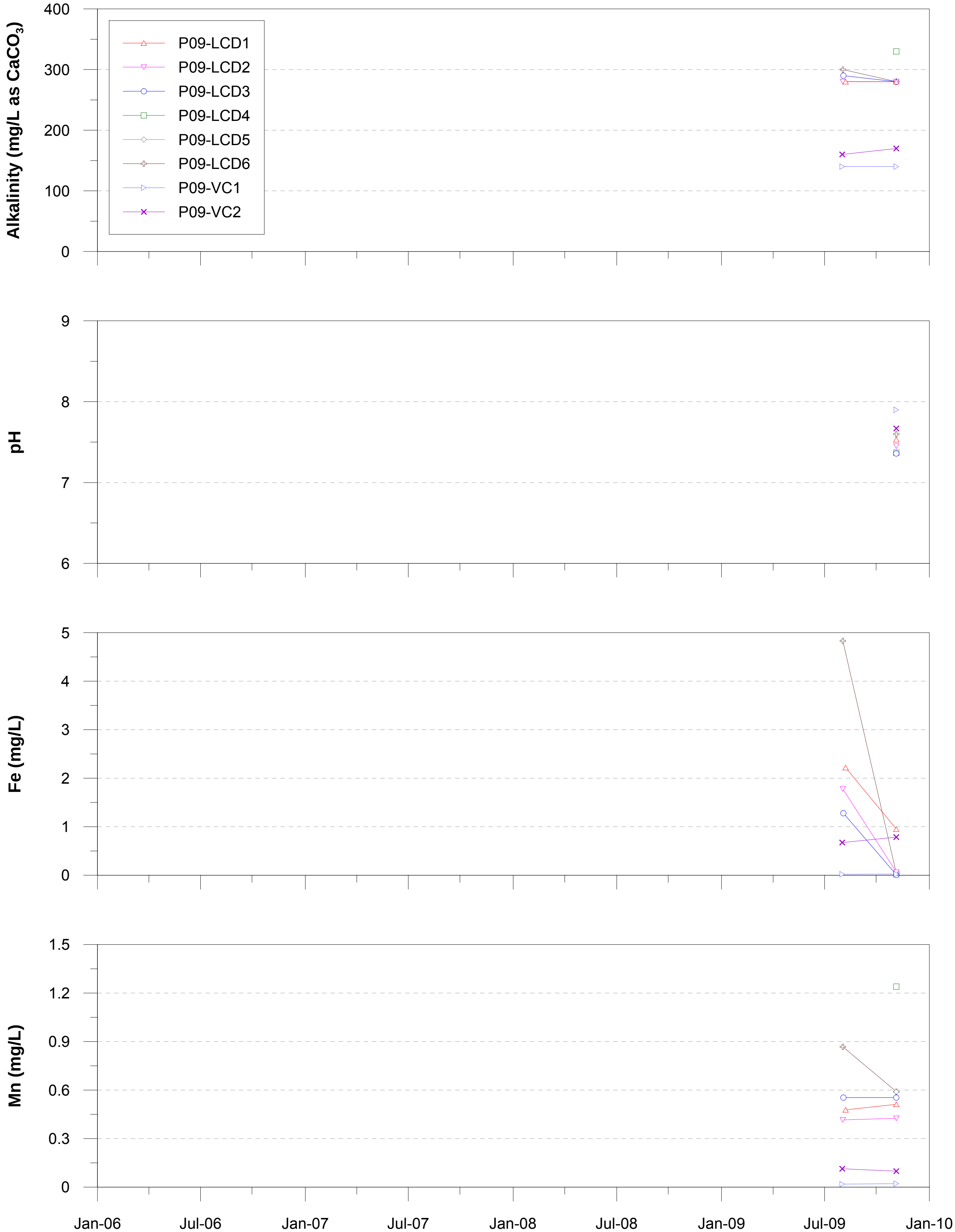


Figure 4-8b. Time trends for alkalinity, pH, Fe and Mn in wells near Vangorda Creek and Little Creek Dam