Robertson GeoConsultants Inc.

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

Memorandum

DATE: July 14, 2004

TO: Daryl Hockley, SRK

CC: Cam Scott, SRK
Valerie Chort, Deloitte Touche

FROM: Christoph Wels, Robertson GeoConsultants Inc.

RE: Initial Review of Groundwater Quality downstream of Faro, Grum and Vangorda WRDs, Yukon Territory

Daryl:

As requested, this memo summarizes the results of my initial (brief) review of the groundwater monitoring data for the Faro, Grum and Vangorda mine sites near the town of Faro, in the Yukon Territory. The groundwater data reviewed cover the observation period from 1996 to early 2004. The primary objective of this review was to assess the requirements for collection of waste rock dump (WRD) seepage at Faro, Grum and/or Vangorda. Preliminary recommendations are also provided for additional fieldwork, which would assist in the evaluation of alternative options for seepage collection at these sites. It should be emphasized that a review of the effects of groundwater seepage on surface water quality was beyond the scope of this review. A review and assessment of potential impacts of groundwater seepage on surface water quality would complement this initial review of seepage water quality presented here.

For the purpose of this review, time trends of sulphate and zinc in shallow groundwater downstream of the WRDs were plotted and evaluated. Sulphate is an early indicator of WRD seepage whereas zinc is a metal of concern at Faro/Grum/Vangorda because it occurs in elevated concentrations in WRD seepage and is mobile under the neutral ("buffered") pH conditions typically encountered at the site.

binder #2

A. Faro Waste Rock Dumps

Groundwater quality is monitored in several monitoring wells located near the toe of the Faro Dumps. Figures 1 to 5 show observed time trends of groundwater quality (sulphate and zinc) in monitoring wells located downgradient of the Faro WRDs. The monthly precipitation (at Faro Airport) and static water levels (expressed as depth to water below top of casing) are shown for comparison. In the following we briefly review the recent monitoring data for the various reaches potentially influenced by seepage from the Faro waste rock dumps.

A.1 Northeast Dumps draining towards North Fork Rose Creek

Monitoring wells in this reach include BH12A/B, BH13A/B and BH14A/B. Two of these wells (BH12A and BH13B) are now frozen and no longer sampled. Groundwater in this area is encountered at shallow depth (2-4m bgs) in shallow overburden and weathered bedrock.

Groundwater in this reach has circum-neutral pH and significant alkalinity (200-400 mg/L). A review of the recent water quality time trends suggests a gradual increase in sulphate concentrations from ~300-500 mg/L (in 1996) to 1200-1700 mg/L (in 2003) in monitoring wells located in this area (Figure 1). The very gradual increase in sulphate concentrations suggests significant dispersion along the flow path. A slow release of sulphate from the NE dumps (compared to other WRD at Faro) may also contribute to the slow increase in sulphate concentrations in the groundwater.

Zinc concentrations are still relatively low (<0.5 mg/L) in all wells in this area suggesting limited release of this metal and/or natural attenuation along the flow path.

While clearly influenced by WRD seepage, seepage interception in this reach may represent a lower priority, considering the (still) relatively low concentrations of dissolved metals and significant distance from the NFRC.

A.2 Zone 2 Pit draining towards North Fork Rose Creek

Monitoring wells in this reach include BH1, 2 and 4. Several other monitoring wells installed in 1994 in this area (BH5, 6, 7 and 8) are no longer monitored. The groundwater table in this area of the mine is only 1-2 meters below ground surface near the North Fork

Rose Creek (at BH1 and 4) but resides at increasingly greater depths towards the Zone 2 Pit (e.g. 4-5m at BH 2 and ~18m at BH8).

The groundwater in this area is slightly to moderately acidic (pH 4.5-6.5) with low to moderate alkalinity (10-100 mg/L). In the past, this area had been significantly affected by at least one historic "spill" from the Zone 2 Pit with highly elevated concentrations of SO4 (up to 9,000 mg/L) and Zinc (~100 mg/L) observed in BH-4 (Figure 2). However, groundwater in this well (and others) has markedly improved over the last 13 years. For example, SO4 and zinc concentrations in BH-4 have declined to ~100 mg/L SO4 and ~3.5 mg/L Zn over the last few years (Figure 2). Groundwater quality in BH1 and BH2 did not show the same historic impact and has remained relatively constant over time. At present groundwater in all three wells is relatively dilute (SO4 ~100-200 mg/L) suggesting no significant on-going seepage from the Zone 2 pit.

However, the residual zinc concentrations in groundwater in this area are still significant (1-3 mg/L at BH1, 3 and 4) and appear to be increasing at BH2 (currently ~10-20 mg/L). Considering the proximity of this shallow groundwater to the NFRC, there is a (small) potential for zinc loading to the NFRC. A more detailed review of the surface water quality data from the NFRC (at stations R8, R9 and R10) would be required to evaluate the potential impact of this source on the NFRC.

The historic variations in groundwater quality (which are still evident today) suggest heterogeneous subsurface conditions and/or variable contaminant sources. The fact that zinc concentrations remain elevated despite the very low sulphate concentrations (relative to Zone 2 pit water and WRD seepage) suggest that there is an in-situ source of zinc in this area. Two potential in-situ sources for zinc leaching may include (i) sediments scoured from a Gossan zone in the early days of mining when the Faro Creek diversion was routed downhill in this area, and (ii) sediments deposited in the "flood plain" during any historic spill(s) from the Zone 2 Pit. The general lack of vegetation in this area supports the hypothesis of sediment deposition in this area. Finally, attenuation of zinc within the local sediments (introduced by any historic "spill(s)") could also explain the very gradual decline in zinc concentrations in local groundwater in this reach.

In my opinion, the local hydrogeological conditions and the source of contamination (e.g. seepage from WRDs and/or Zone 2 pit, leaching or oxidation of in-situ material, desorption of historic zinc, etc.) would have to be studied in more detail in order to evaluate the requirements (and feasibility) of seepage interception along this reach.

Considering the recent improvements in ground water quality, further studies and seepage interception in this area are judged to be of lower priority.

A.3 Intermediate Dump draining towards NFRC (above rock drain)

Only one monitoring well (P96-6) is available along the eastern toe of the Intermediate Dump (draining towards the NFRC). At this location, the overburden soils are relatively thick (>18m) and consist of sandy and silty till with occasional gravel layers. The groundwater encountered at P96-6 (at 18m) is confined in a permeable gravel layer with a piezometric head of 12-13m bgs.

The groundwater in this area is well-buffered with circum-neutral pH (6.0-7.0) and significant alkalinity (200-300 mg/L). Monitoring at this well since 1996 does not show any significant increase in sulphate and/or zinc (Figure 2) suggesting no significant influence of WRD seepage (to date) on the local groundwater quality.

Based on the existing information, this area does not warrant any seepage interception at this time.

A.4 Intermediate Dump draining towards NFRC (below rock drain)

Monitoring wells in this reach include S1A/B, S2A/B and S3, which have been monitored since 1989. In this area, the profile consists of 6-7m of till overlying weathered bedrock (phyllite). The groundwater table in this area of the mine is about 3-4m bgs.

A review of the water quality time trends show a significant increase of sulphate and zinc over time, indicative of a "breakthrough" of neutralized WRD seepage (Figure 3). For example, sulphate in monitoring well S1A (in weathered bedrock) has increased from 140 mg/L in 1989 to 4,400 mg/L in late 2003. Similarly, zinc concentrations have increased from <0.1 mg/L (as recently as 1998) to ~80 mg/L in the most recent survey data available (September 2003). Other metals showing significant increases over the last 5 years include manganese (up to 43 mg/L) and Nickel (1.0 mg/L) (not shown here).

While the alkalinity in this reach has decreased from ~400 mg/L to ~200 mg/L over the last 15 years, the pH of the seepage impacted groundwater has not declined significantly and remains only slightly acidic (6.0-7.0). It is unclear whether these pH conditions reflect neutralization of ARD within the WRD itself or along the flow path.

All five wells in this reach showed similar overall trends, although the timing and magnitude of "breakthrough" of sulphate and zinc varied (Figure 3). Lithology does not appear to be primary factor in controlling the breakthrough of sulphate and zinc. For example, monitoring well S3 (screened in shallow colluvium) showed very similar time trends to those observed in S1A (screened in weathered bedrock). At S2, the breakthrough of sulphate is delayed in both the shallow well (S2A screened in colluvium) and the deeper S2B (screened in weathered bedrock), yet zinc concentrations at S2A are very similar to those observed at S1A and S3. Clearly, there are factors other than lithology influencing solute transport in this area.

A comparison of the breakthrough curves for sulphate and zinc provides insight into the degree of natural attenuation in the local aquifer material. For example, the "mean" breakthrough for sulphate at S1A (screened in weathered bedrock) occurred around 1999 whereas the "mean" breakthrough of zinc occurred about five years later (in 2003). From these observations an approximate "field retardation factor" can be estimated by dividing the mean arrival time (T_{50}) of the reactive solute (zinc) by the mean arrival time of conservative solute (sulphate). Assuming the release of both solutes started in 1990 (end of dumping of Intermediate Dump) we get R= 13yrs/9yrs= ~1.4 for transport in weathered bedrock.

It should be noted that the observed breakthrough curves are not "ideal" which limits the use of a standard retardation approach (which assumes linear soprtion/desoprtion). For example, the breakthrough curve of zinc is much steeper than that of sulphate. In theory, the opposite would be expected with more dispersion ("spreading" around the mean) for the reactive solute than the conservative solute. Consideration should be given to studying the breakthrough curves of sulphate and zinc observed in this reach (and elsewhere at Faro, see below) in more detail to evaluate the attenuation of zinc in the local soils and weathered bedrock. Such an analysis would provide a useful comparison to other attenuation studies currently planned and/or oingoing on the site.

Note that the recent water quality time trends do not yet show a leveling off of the contaminant concentrations. It is therefore possible that the water quality in this reach may further deteriorate over time. In my opinion, the highly elevated concentrations of sulphate, zinc and other metals and proximity to NFRC may require seepage interception in this reach of the Faro mine site. Additional field reconnaissance and hydraulic testing should be carried out in this reach to evaluate the requirements and feasibility of seepage interception. In addition, a detailed assessment of the surface water quality along this reach of NFRC (including a review of historic time trends at X2 and a detailed sampling during baseflow along the reach) should be carried out to evaluate the current impact (if any) of this groundwater seepage on the NFRC.

A review of the pre-mining topography (Figure 4-10 in RGC Report 033001/3) suggests that seepage from the Intermediate Dump (and its "sulphide cell") may also be moving towards Rose Creek along an old drainage channel located further northwest of the "S" well cluster. Again, additional field reconnaissance and potentially additional drilling may be required to evaluate the presence of contaminated seepage in this historic drainage channel.

A.5 Main Dump East draining towards Rose Creek valley

Only one monitoring well (P96-7) is available along the southern toe of the Main Dump (east of the Faro Creek channel). This well is located in a topographic low and was screened across the overburden and in fractured bedrock interface. In this area, the overburden is about 8.0m deep. The groundwater level in P96-7 shows significant seasonal variations, ranging from ~2m bgs to >9m bgs (Figure 3).

Groundwater in this area has a circum-neutral pH (6.5 – 7.5) and moderate alkalinity (150-250 mg/L). Sulphate concentrations in this well showed a gradual increase over the 8 years of monitoring (from ~400 mg/L to ~2,000 mg/L), indicating some influence of WRD seepage from the Main Dump (Figure 3). However, zinc concentrations remained very low (<0.1 mg/L) suggesting limited release and/or natural attenuation of this metal along the flow path.

While clearly influenced by WRD seepage, seepage interception in this reach may represent a lower priority, considering the low concentrations of dissolved metals relative to the neighboring reaches (near "S" cluster and along Faro Creek channel).

A.6 Main Dump West and Northwest Dumps draining into Faro Creek valley

A.6.1 Surface Seepage in Faro Creek Channel (X23)

The main discharge point for seepage from the Main Dump (and Northwest Dumps) is the lower Faro Creek valley. There is sufficient accumulation of dump seepage in this valley to maintain a small, perennial stream, which "daylights" just below the Main Dump near sampling station X23. The water quality of this surface seepage at X23 has been monitored regularly since 1986.

Figure 4 shows the time trends of sulphate, total zinc and total manganese observed in surface seepage at X23 for the entire observation period (1986 – 2004). The monthly precipitation is shown for comparison. Note that sulphate is shown on a linear scale (right axis) while the metals are shown on a log scale (left axis). The monitoring data show a significant increase in contaminant load at X23 over the 18 years of record. Sulphate concentrations increased from ~1,500 mg/L to >4,000 mg/L, with significant spikes (>6,000 mg/L) in recent years (2000 and 2001). The concentrations of manganese and in particular zinc mimic the general trends observed for sulphate, showing a 3-5 fold increase in Mn and a 5-8 fold increase in Zn over the 18 years of record (Figure 4).

The total metal concentrations in WRD seepage at X23 show an even more pronounced increase in 2000 and 2001 than observed for sulphate with peak concentrations reaching ~1,000 mg/L total zinc and ~100 mg/L total manganese (Figure 4). A detailed assessment of these seasonal trends was beyond the scope of this initial review. However, these significant "spikes" in contaminant concentrations could be a result of the "flushing" of stored oxidation products from the WRDs, which are accumulating during "dry" years (e.g. 1998 and 1999) and are then released during subsequent wet years (e.g. 2000).

It should be pointed out that the pH of seepage collected at X23 has remained circum-neutral throughout the 18 years of observation. As a result, concentrations of other metals of concern, which are immobile under neutral pH conditions (e.g. Cu) have remained very low despite the large increase in Mn and Zn. The fact that this "toe seepage" has remained circum-neutral indicates that there is significant buffering capacity within the system. Considering the limited (if any) contact of this seepage with the subsurface soils, it appears likely that the waste rock itself is effectively buffering any ARD produced within the WRDs.

At present, the WRD seepage at X23 is allowed to discharge into the Intermediate Impoundment, and ultimately into the Polishing Pond, where it is treated with lime. However, it is unclear how much of this seepage (and contaminant load) re-infiltrates into the tailings and ultimately enters the groundwater system in the Rose Creek Valley. While detailed loading calculations have not been carried out, reported flow measurements at X23 (ranging from ~2 L/s during baseflow to >15 L/s during snowmelt runoff) suggest that seepage at X23 may represent a significant contaminant load. Hence, from a point-of-view of load reduction, interception and treatment of WRD seepage at X23 may therefore represent a high priority at Faro. In addition, seepage collection at this location should be relatively straightforward thus providing a favorable load reduction relative to the cost of collection. However, the cost of seepage interception would have to be weighted against the "incremental" benefit to the downgradient environment considering the presence of other significant contaminant sources further downstream (e.g. Rose Creek Tailings Facility).

A.6.2 Subsurface seepage in Faro Creek channel

Seepage from the Main Dump (and Northwestern Dumps) also moves within the permeable alluvial sediments of the Faro Creek channel towards the Rose Creek Valley. Two nested piezometers (P96-8A/B) were installed in 1996 in vicinity of X23 to monitor the groundwater quality in this area (RGC, 1996). At this location the alluvial sediments are 8m thick and consist of very permeable sands and gravels overlying phyllite bedrock. The groundwater table in this area is fairly shallow (~1.5-3m bgs) and shows some seasonal fluctuations in response to variations in precipitation (Figure 5).

Figure 5 shows the time trends of groundwater quality observed at P96-8A/B. The surface water quality observed in the Faro Creek channel (X23) is shown for comparison. Both sulphate and zinc show a significant increase over time, similar to the trends observed in the "S series" well cluster downgradient of the Intermediate Dump (Figure 3). Sulphate concentrations increased from ~2,000 mg/L in 1996 to around 4,000 mg/L, whereas zinc increased from ~2 mg/L to >100 mg/L over this 8 year span (Figure 5). The water quality time trends in both wells are remarkably similar to the trends observed in WRD seepage at X23 (except perhaps for peak concentrations observed in surface seepage following storm events) suggesting that all groundwater in this area essentially represents WRD seepage.

As observed elsewhere at the Faro mine site, groundwater in this area still has significant alkalinity 150-350 mg/L and maintains near-neutral pHs (6.0-7.0) suggesting "internal" buffering within the WRD and/or buffering along the flow path (within the alluvial sediments).

Groundwater flowing within the alluvial sediments of the old Faro Creek channel (and potentially in the underlying weathered/fractured bedrock) clearly represents a significant source of sulphate and zinc loading to the downstream environment. However, much, if not most of this subsurface seepage is believed to discharge back to surface further downgradient in the old Faro Creek channel ("water fall"). If this assumption is correct, then most of this seepage also flows into the Intermediate Impoundment and is collected and treated in the Polishing Pond. Nevertheless, there is some potential for re-infiltration of this contaminated water into the tailings and ultimately into the underlying groundwater system in the Rose Creek Valley. Hence consideration should be given to collecting this contaminated seepage either as subsurface flow near X23 and/or as surface flow (combined with surface seepage from X23) before it enters the Intermediate Impoundment. As mentioned earlier, the cost of seepage interception would have to be weighted against the "incremental" benefit to the downgradient environment considering the presence of other large contaminant sources further downstream (e.g. Rose Creek Tailings Facility).

In my opinion, consideration should be given to carrying out additional characterization studies to quantify the seepage rates in this area and to evaluate the feasibility and requirements of seepage interception. These additional studies may include: (i) seismic profiling of the Faro Creek Channel near X23, (ii) hydraulic testing in this area (slug testing and potentially pump testing), and (iii) drilling into bedrock to determine the presence (quantity and quality) of groundwater below the alluvial sediments. Prior to starting any field investigation, detailed flow measurements should be carried out along the Faro Creek channel (between X23 and discharge into the Intermediate Impoundment) to quantify the amount of subsurface seepage discharging back to surface along this reach.

A.6.3 Potential Seepage from Faro Pit

The potential for seepage from the Faro Pit towards the old Faro Creek channel (at X23 and P96-8A/B) was also evaluated as part of this review. The Faro Pit received tailings until the end of mining operations in 1996 and has since been allowed to further reflood to a water level of 1140-1145 m amsl. Given this significant rise in water level there is a possibility that water from the open pit could flow towards X23 either in (potentially fractured) bedrock and/or unconsolidated material (alluvial sediments and/or mine waste)

However, our data review suggests that seepage of the Faro Pit towards the Faro Creek channel is unlikely to be a significant factor for two reasons. First, the water level in the Faro Pit has been maintained at least 15m below the topographic low in the bedrock surface (3,800 ft amsl or 1158.2 m amsl) along the Faro Creek channel reported in SRK (1991) and cited in BGC (2003). In other words, seepage from the Faro Pit towards X23 would be limited to flow in deeper bedrock (primarily along potential fractures). This scenario is unlikely to result in a significant increase in seepage flows (and/or increase in contaminant concentrations) at X23.

Second, concentrations of sulphate, Zn and other metals are significantly lower in the Faro Pit (~500 mg/L SO4 and 10-20 mg/L zinc) than in WRD seepage at X23. Based on this observation, one might expect, that significant seepage from the Faro Pit would result in a decrease of contaminant concentrations (dilution) at X23 rather than the observed recent increase in contaminants of concern (Figure 5).

In summary, it appears unlikely that seepage from the Faro Pit contributes significantly to the seepage and contaminant load observed at the toe of the Main Dump in the old Faro Creek channel. However, seepage from the Faro Pit along the Faro Creek channel towards X23 could potentially become an issue if the pit water level was allowed to rise. In my opinion, consideration should therefore be given to carrying out additional studies to evaluate the potential for seepage from the Faro Pit. These studies may include (i) drilling and hydraulic testing in the Faro Creek channel (south of the Faro Pit) to define the subsurface conditions (depth to bedrock, permeability of alluvial sediments and underlying fractured bedrock), (ii) installation of monitoring wells in this area to monitor groundwater levels and groundwater quality, and (iii) seismic surveys across the Faro Creek channel (between Faro Pit and X23) to better define the bedrock topography.

A.7 Northwest Dumps draining towards Guardhouse Creek

No monitoring wells are available in the Guardhouse Creek sub-watershed downgradient of the Northwest Dumps. The only information on subsurface conditions and seepage water quality was obtained in a test pit program carried out in 1992 (SRK, 1992). Water quality analyses on seepage samples collected in shallow test pits during this study suggested no significant impact of WRD seepage.

Based on the (limited) information available, it appears that this area of the Faro mine site receives very little seepage from the WRDs and does not contribute significant contaminant loads to Guardhouse Creek and/or Rose Creek valley. In my opinion, seepage interception in this area represents a low priority.

B. Grum and Vangorda Waste Rock Dumps

Groundwater quality is monitored in several monitoring wells located near the toe of the Grum and Vangorda waste rock dumps. Figures 6 and 7 show observed time trends of groundwater quality (sulphate and zinc) in monitoring wells located downgradient of the Grum and Vangorda WRDs, respectively. The monthly precipitation (at Faro Airport) and static water levels (expressed as depth to water) are shown for comparison. In the following we briefly review the recent monitoring data for the various reaches downgradient of the Grum and Vangorda WRDs.

B.1 Grum Dump draining southeast

A set of two nested piezometers (P96-9A/B) were installed in 1996 in a tributary to Grum Creek, which drains the central portion of the Grum Dump, to monitor the groundwater quality in this area (RGC, 1996). At this location the overburden soils were relatively thick with phyllite bedrock encountered at a depth of ~18m.

The shallow piezometer (P96-9A) was screened in alluvial sands and gravels and the deeper piezometer (P96-9B) was screened in sands and gravels confined by low permeability till. The water level in the upper (unconfined) aquifer is about 5m bgs and appears to be hydraulically connected to the creek. The lower (confined) aquifer is artesian.

A review of the time trends in P96-9A/B indicates that seepage from the Grum dump has had a much smaller impact (thus far) on local groundwater than observed at Faro. For example, sulphate concentrations in the shallow groundwater have only started to increase over the last four years, from ~50 mg/L in 1996 to ~1250 mg/L in 2003 (Figure 6). Zinc concentrations in the shallow groundwater are still very low (~0.01 mg/L). The deeper, confined aquifer has maintained low sulphate concentrations (~150 mg/L) at least until 2001 the last date of monitoring (It is my understanding that this well has been damaged and is no longer monitored).

A recent water quality survey of seeps on Grum dump (SRK, 2003) indicated average sulphate and zinc concentrations in the southeastern part of Grum Dump of ~1100 mg/L SO_4 and 3.0 mg/L Zn. The observed sulphate concentrations in seeps from Grum Dump (along the toe) are very similar to those observed in the shallow groundwater, suggesting that shallow groundwater is comprised primarily of WRD seepage with little dilution from precipitation and/or regional groundwater. The lower zinc concentrations observed in shallow groundwater suggest that zinc is attenuated in the overburden soils along the flow path.

The seep survey also indicated that seepage from the southeastern part of Grum Dump has significant higher alkalinity (~500 mg/L) than the natural groundwater. As a result shallow groundwater has also shown an increase in alkalinity from ~50-150 mg/L in 1996/97 to ~450 mg/L in 2003.

While the lack of any increase in sulphate and alkalinity in the deeper aquifer clearly indicates no significant influence of WRD seepage to date, an eventual "breakthrough" of WRD seepage in this aquifer cannot be ruled out. We therefore recommend that monitoring at P96-9B be reinitiated (this may require rehabilitation and/or redrilling of this monitoring well.

Based on the above discussion we tentatively conclude that shallow groundwater along the southeast slopes below Grum Dump represents primarily seepage from Grum Dump with limited dilution from recharge and/or regional groundwater. Hence the future groundwater quality in this area will depend to a large extent on the evolution of ARD within the Grum Dump (and the Sulphide Cell in particular). In my opinion, seepage interception in this reach of Grum Dump may not be a high priority today but may be required in the future to protect Vangorda Creek.

It should be noted that the number of monitoring wells are very limited in this area. Additional hydrogeological characterization work (drilling, well installation and hydraulic testing) would be required to evaluate the feasibility and requirements of seepage interception in this reach.

B.2 Grum Dump draining southwest

No monitoring wells were available to evaluate the groundwater quality to the southwest of the Grum Dump. According to a recent seep survey (SRK, 2003), most seeps in this area have low sulphate (<500 mg/L) and very low zinc concentrations (<0.03 mg/L), representative of drainage from the calcareous phyllites and till dumped in the northwest draining portion of the Grum Dump.

Based on this (very limited) information, groundwater quality to the southwest of Grum Dump can be expected to show very little, if any, influence of WRD seepage. This area likely represents a low priority for seepage interception.

B.3 Potential Seepage from Grum Pit

The Grum pit was excavated into the historic channel of Grum Creek, which is believed to contain permeable alluvial sediments and could potentially provide a path of preferred seepage from a partially reflooded Grum Pit. A detailed review of the seepage potential was beyond the scope of this initial review. However, we noted that the current Grum pit water level (~1185.4m amsl) was similar to the approximate elevation (~1184m amsl) of seep sampling location SRK-GD-01, i.e. where seepage in Grum Greek first emerges. In other words, the pit water level is sufficiently high to potentially induce seepage from Grum Pit towards Grum Creek. No detailed pit water level records were available to evaluate the historic (and most recent) time trends of filling of Grum Pit.

Water quality monitoring in the Grum Pit show a gradual increase in sulphate and zinc over time (not shown). However, sulphate concentrations are still significantly lower (currently ~500 mg/L) than those observed at the most upgradient seep in Grum Creek (1200-1320 mg/L SO4 at seep SRK-GD-01) indicating that Grum pit water could not be the source of this seepage. Nevertheless, this does not rule out the potential for <u>future</u> seepage towards Grum Creek, in particular if the pit water level is allowed to rise over time. Whether such seepage would result in significant contaminant loading to Grum Creek would depend on the future pit water quality and the degree of natural attenuation along the flow path.

In my opinion, the potential for seepage from Grum Pit should be evaluated further in a desktop study, which should include a review of all existing information on the depth and nature of the overburden material in vicinity of the historic Grum Creek channel (drill logs, bedrock mapping, pit wall mapping) and review of the water balance for the Grum Pit. Additional fieldwork (drilling, seismic survey etc) may only be required if this review indicates that there is potential for significant seepage from Grum Pit towards Grum Creek.

B.3 Vangorda Dump draining towards Dixon Creek

Monitoring wells in this reach include V34 (GW94-01) and V35 (GW94-02), which have been monitored since 1994. Overburden soils to the south of Vangorda Dump consist of highly compacted, silty glacial till of relatively low permeability. The thickness of the overburden ranges from ~12m at V34 to >18m at V35. Groundwater levels in this area lie about 5-9 m bgs (Figure 7).

The water quality in V34 is believed to be typical of background groundwater in the calcareous till of the area, with slightly alkaline pH (7.5-8.0), high alkalinity (~400 mg/L), low sulphate (~40 mg/L) and very low metals including zinc (~0.01 mg/L). There has been no change in water quality over the last 10 years of monitoring except for a single "spike" in sulphate concentrations in October 2000 (Figure 7). (This outlier appears to be the result of a sampling and/or analytical error). Based on this data it appears that V34 does not receive significant seepage from the Vangorda WRD, potentially due to preferred groundwater flow in a more westerly direction towards Vangorda Creek.

In contrast, groundwater quality in V35 shows some (very limited) influence of WRD seepage, as evidenced by the gradual increase in sulphate over the last 10 years of monitoring, with peak concentrations in the range of 750-1,000 mg/L (Figure 7). As might be expected at this early stage of contaminant breakthrough, Zn concentrations are still very low (0.01-0.1 mg/L) in V35. Note, that the observed concentrations of sulphate and zinc are still much lower than in WRD seepage observed at the toe of Vangorda Dump, with SO4 as high as 20,000-30,000 mg/L and zinc concentrations in the range of ~25-7,000 mg/L (SRK, 2003). Clearly, any seepage from the WRD is currently significantly diluted and/or attenuated in the local groundwater system.

In my opinion, seepage interception along the southeast side of Vangorda Dump is not a high priority at this stage. The primary reason for the limited influence of WRD seepage on groundwater quality to date is likely the relatively low permeability of the till underlying the Vangorda WRD which limits seepage into the groundwater system.

However, it should be recognized that ARD evolution in the Vangorda Dump is well advanced (with acidic conditions in parts of the dump and very high sulphate and zinc concentrations). Hence, any seepage from the Vangorda Dump would have a very high potential of impacting the local groundwater in the long-term. It may therefore be prudent to carry out additional studies in this area at some point in the future to get a better understanding of the local hydrogeology and groundwater flow paths.

B.4 Vangorda Dump draining towards Vangorda Creek

Monitoring wells in this reach include V36 (GW94-03), V37 (GW94-04), V38 (GW94-05), P01-01, P01-02A/B and P01-03. V36 to V38 have been monitored since 1994. The "P2001" series of wells were only completed in 2001. The overburden in this area also consists primarily of highly compacted, silty glacial till of relatively low permeability. However, the thickness of the overburden thickens considerably towards Vangorda Creek (e.g. >35m at V38). (Note: the drill logs of the "P2001" series of wells were not available for this review). The groundwater levels in this area vary from ~4m bgs at P01-02A/B (likely confined) to >30m bgs at P01-03.

The groundwater quality in most of the wells in this reach is representative of, or at least close to background, with slightly alkaline pH (7.5-8.0), high alkalinity (~400 mg/L), low sulphate (~50-150 mg/L) and very low metals including zinc (<0.01 mg/L). Only monitoring well V36 (GW01-03) appears to show early signs of WRD seepage with a gradual increase in sulphate over the last 5 years (Figure 7). Again, there has been no increase in zinc thus far which is consistent with observations elsewhere at Grum and Vangorda.

In general, the local groundwater in this reach shows very little impact from WRD seepage, which might be expected considering the nature of the overburden (tight silty till), the depth to groundwater and the potential presence of permafrost. Hence, seepage interception along this side of Vangorda Dump is, in my opinion, a low priority at this stage. However, as mentioned previously, it may be prudent to study the local groundwater conditions in vicinity of the Vangorda Dump in more detail to evaluate the potential for future impacts on the local groundwater system.

An assessment of seepage from the partially flooded Vangorda Pit was beyond the scope of this review. However, it is my understanding that the water level in the Vangorda Pit is kept below the contact between the till and the bedrock suggesting that seepage in the more permeable alluvial sediments in the historic Vangorda Creek channel cannot occur.

C. Preliminary Recommendations for 2004-2005 Field Work

It is my understanding that provisions have been made for additional field investigations (to be carried out in 2004-2005), which may be required to develop seepage collection systems at the toe of Faro and Grum waste rock dumps. The five principal field activities that may be carried out to determine the requirements and feasibility of seepage collection in various reaches of the Faro and Vangorda Plateau mine sites include:

- Test pitting;
- Seismic Profiling;
- Drilling and Well Installation; and
- Hydraulic Testing

Some of this fieldwork has already been carried out in various parts of the site and/or is not required in certain parts of these sites (where the effect of WRD seepage on groundwater quality is still limited to date). In the following, I briefly summarize the objectives of these activities and provide recommendations as to where specifically these field activities might be required. It is acknowledged that budgetary, logistical and/or time constraints may prevent the implementation of all recommendations provided herein. Therefore, the various recommendations have been assigned a priority index ranging from "high", over "medium" to "low". This prioritization is primarily based on my assessment of the magnitude and timing of contaminant migration and its potential impact on nearby surface water. The cost of collection and treatment in a given area was not used as a criterion.

Table 1 summarizes the recommendations and my weighting with respect to their priority. This table should assist the project team in selecting the most appropriate set of field activities to be carried out in 2004. It should be emphasized that the recommendations listed in Table 1 only address seepage issues downgradient of the WRDs. Groundwater contamination issues at other parts of the Anvil Range Mining Complex (e.g. Rose Creek Tailings Facility) are not addressed in this memorandum.

C.1 Test Pitting

Test pitting can be used to characterize the shallow overburden (maximum 3-4m depth) and determine the depth to bedrock (where overburden is very shallow). In my opinion, test pitting is only of limited value because groundwater in many parts of the site resides at depths greater than 3-4m bgs and/or groundwater flow may occur primarily in the weathered bedrock. Test pitting may be useful, however, as a first screening tool to site locations for future drilling and/or seismic profiling (see below).

Table 1. Priority listing of recommended hydrogeological field studies.

Project Area	Test Pitting	Seismic Survey	Drilling & Well Installation	Hydraulic Testing
Faro				
Northeast Dumps towards NFRC	N/R	N/R	N/R	N/R
Zone 2 Pit towards NFRC	L	N/R	L	L
Intermediate Dump towards NFRC	N/R	N/R	N/R	N/R
Intermediate Dump towards Rose Crk	L	H	M	H
Main Dump East towards Rose Crk Valley	L	N/R	N/R	N/R
Main Dump West & NW Dumps towards old Faro Creek channel	N/R	H	H	H
Old Faro Creek Channel (near pit)	N/R	M	M	M
NW Dumps towards Guardhouse Crk	L	N/R	N/R	N/R
Grum				
Grum Dump towards southeast	L	M	M	M
Grum Dump towards southwest	N/R	N/R	N/R	N/R
Grum Creek drainage channel (near pit)	N/R	L	L	L
Vangorda				
Vangorda Dump towards Dixon Crk	N/R	N/R	N/R	N/R
Vangorda Dump towards Vangorda Crk	N/R	N/R	N/R	N/R
Vangorda Creek channel (near pit)	N/R	N/R	L	N/R

Legend:

H	High Priority
M	Medium Priority
L	Low Priority
N/R	not required at this stage

In my opinion, consideration should be given to use test pitting in the following areas:

- In the "floodplain" below Zone 2 pit (Faro) to obtain samples of in-situ material (for geochemical testing);
- South of the Intermediate Dump to guide in the siting of a seismic profile line and drilling locations;
- South of the Main Dump (East) to better characterize subsurface conditions and shallow groundwater quality;
- Downgradient of the Northwest Dumps (in the Guardhouse Creek area) to better characterize subsurface conditions and shallow groundwater quality; and
- Southeast of the Grum Dump to determine the extent of valley fill and to assist in the siting of a seismic profile line and drilling locations.

In general, test pitting is considered a lower priority compared to other required field activities (see Table 1 for ranking of priority).

C2. Seismic Surveys

Seismic surveys provide information about the groundwater table and the depth to bedrock along a survey line. This method is considered relatively cost-effective and provides valuable information for estimating seepage flows and siting drilling locations (e.g. in the center of a valley).

Consideration should be given to carrying out seismic surveys along the following profiles:

- Along the southern toe of the Intermediate Dump (near the "S" cluster of wells);
- Across the old Faro Creek channel (near X23);
- Across the old Faro Creek channel (near Faro Pit);
- Along the southeastern slope below Grum Dump (including Grum Creek valley)
- Across the old Grum Creek valley (near Grum Pit);

The priority for each of the recommended profiles is summarized in Table 1. The exact transect lines for these seismic surveys would have to be confirmed during a field reconnaissance.

C.3 Drilling & Well Installation

Drilling provides an opportunity to evaluate the subsurface conditions in overburden and underlying bedrock. The borehole can be used for hydraulic testing (in particular in bedrock) and for the installation of monitoring wells and/or pumping wells.

The following scope of drilling and well installation is recommended for the 2004/2005 field investigation:

- 1 borehole in the "floodplain" below Zone 2 pit (Faro); this borehole should be completed as a pumping well (4" screened in alluvial sediments) to allow pump testing of this area;
- 1 borehole to the NW of the "S" well cluster (near the southern toe of the Intermediate Dump); this borehole should be completed with 2 nested piezometers (2" each) screened in overburden and weathered bedrock, respectively;

- 2 boreholes in the old Faro Creek channel (near X23); 1 borehole should be completed as a monitoring well (2" screened in weathered bedrock) and the other as a pumping well (4" screened in alluvial sediments);
- 1 borehole in the old Faro Creek channel (near Faro Pit); this borehole should be advanced at least 20m into "tight" bedrock to assess fracturing and to allow packer testing; the borehole should be completed with 2 nested piezometers (2" each) screened in alluvial sediments and weathered (or fractured) bedrock, respectively;
- 2 boreholes downgradient (southeast) of Grum Dump, one adjacent to Grum Creek and a second borehole to the west of P96-09; each borehole should be completed with 2 nested piezometers (2" each) screened in overburden and weathered bedrock, respectively;
- 1 borehole in the old Grum Creek channel (between Grum Pit and seep site "SRK-GD-01"); this borehole should be advanced at least 20m into "tight" bedrock to assess fracturing and to allow packer testing; the borehole should be completed with 2 nested piezometers (2" each) screened in alluvial sediments and weathered (or fractured) bedrock, respectively;

Table 1 shows my assessment of the priority of drilling/well installation for the different sites. In my opinion, the high priority sites are required and the medium priority sites should also be drilled as part of the 2004/2005 field investigations, if the budget allows. The low priority sites are optional and could be drilled at a later stage if there are budgetary or logistical constraints.

Drilling should be carried out using an air rotary/hammer rig with ODEX type casing advance (6"- 8" OD) or a SONIC drill rig with 6" casing advance. Depending on access conditions, a track-mounted rig may be required for some sites. All boreholes should be drilled with air as a drilling fluid to detect water-bearing units.

Water level and water quality monitoring in the proposed nested piezometers would provide insight into the impact of WRD seepage (and/or pit seepage) in those areas of interest. In addition, all proposed wells should be used for hydraulic testing, i.e. to perform pump tests and/or slug tests (see below).

C.4 Hydraulic Testing

Hydraulic testing provides insight into the hydraulic properties of the aquifer units and therefore allows an assessment of seepage rates required for assessing the requirements and feasibility of seepage interception.

Consideration should be given to carrying out the following hydraulic tests:

- a constant discharge pump test in the "floodplain" below Zone 2 pit (Faro) using the proposed pumping well (or any other suitable 4" well); such a pump test would provide information about the hydraulic conductivity of the local sediments, the degree of heterogeneity within these sediments, and the interaction of the shallow groundwater with NFRC;
- slug tests in all existing and proposed piezometers of the "S" well cluster (near the southern toe of the Intermediate Dump);
- a constant discharge pump test in the old Faro Creek channel (near X23) using the proposed pumping well; such a pump test would provide information about the hydraulic conductivity of the local sediments and test the feasibility of an active interception system in this area; in addition, slug tests should be carried out in all existing and proposed piezometers in this area;
- packer testing in the proposed borehole to be drilled into bedrock near the Faro Pit; in addition, slug tests should be carried out in the two proposed piezometers in the same borehole;
- slug tests in the proposed piezometers downgradient (southeast) of Grum Dump;
- packer testing in the proposed borehole to be drilled into bedrock near the Grum Pit; in addition, slug tests should be carried out in the two proposed piezometers in the same borehole.

The pumping rate and duration of the CD pump tests will have to be determined based on a review of the available hydraulic data and will have to take into account the requirements for collection and/or disposal of pumped groundwater. It is imperative that both **drawdown and recovery data** be collected in the pumping well and the near-by monitoring wells as part of the pump test. An automated data acquisition system (using pressure transducers) should be used, where possible, for collection of water levels during drawdown and recovery. Manual water levels should also be taken as a back-up.

Slug tests should include falling head and rising head tests on all tested piezometers. The use of a downhole datalogger (e.g. Solinst Levelogger or equivalent) is highly recommended for more permeable aquifer units.

Table 1 shows my assessment of the priority of hydraulic testing for the different sites. In my opinion, the high priority sites are required and the medium priority sites should also be tested if budget and time allows.

D. Closing Comments

It should be emphasized that this review focused primarily on groundwater quality and did not include a detailed review of all previous hydrogeological studies and borehole logs. As such the author had to rely on his knowledge of local site conditions acquired during preparation of the ICAP in 1995-1996. A more detailed review of all previous hydrogeological studies (in particular borehole logs and hydraulic testing data) and a site reconnaissance should be carried out in order to assess the requirements and feasibility of seepage interception at Faro and Grum/Vangorda.

Furthermore, a review of the effects of groundwater seepage on surface water quality was beyond the scope of this review. A review of recent trends in surface water quality (in particular along the North Fork of Rose Creek) would complement this initial review of seepage water quality presented here.

In my view, the need for seepage interception at Faro, Grum and Vangorda should consider the likely contaminant load associated with seepage in a given reach and its potential impact on the receiving surface water. The results of the proposed 2004 field investigation would provide a sound basis for carrying out such an analysis.

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

ROBERTSON GEOCONSULTANTS INC.

Christoph Wels, Ph.D.
Senior Hydrogeologist

Att. 7 figures in separate pdf file

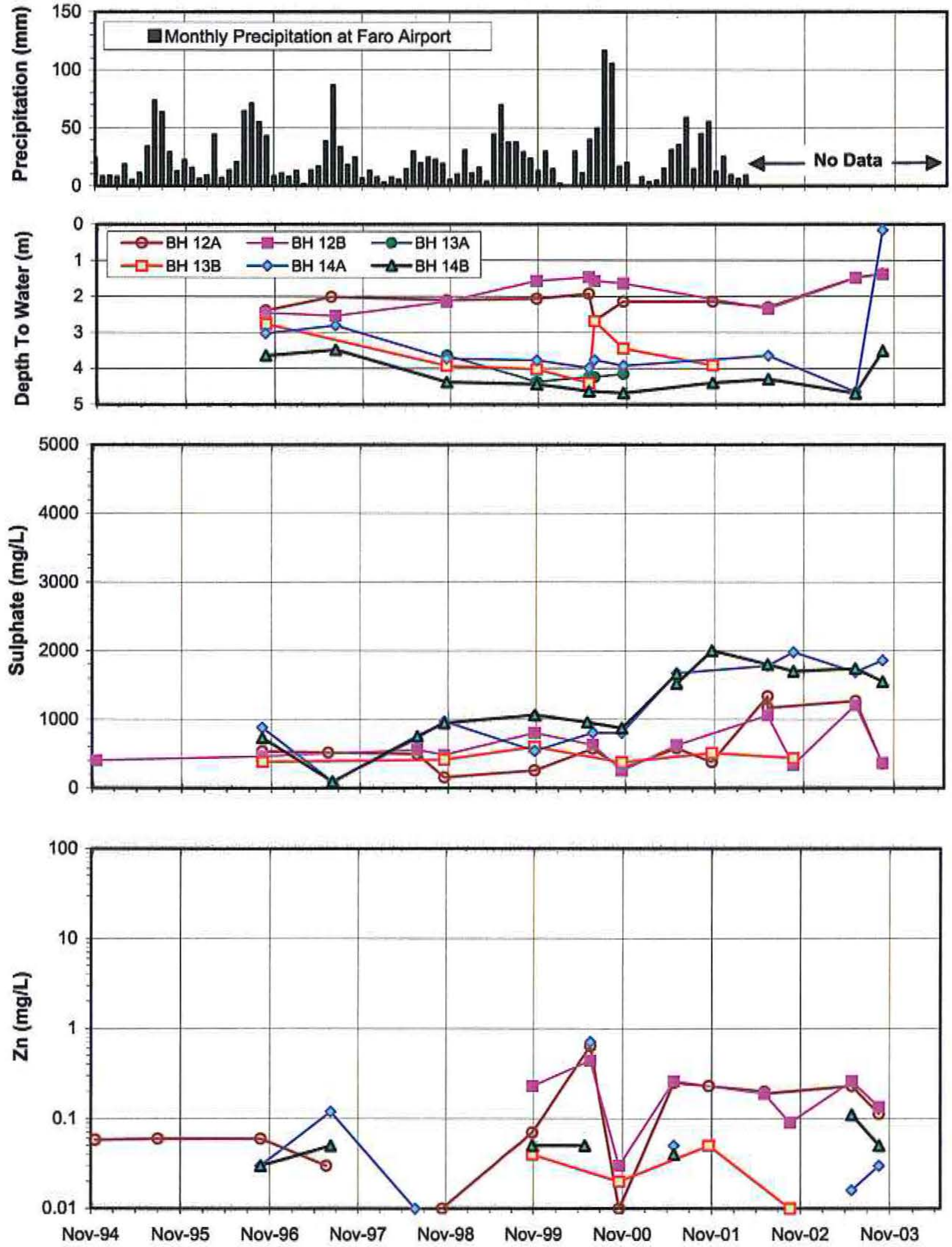

Figure 1. Groundwater quality downgradient of Northeast Dumps (towards NFRC).

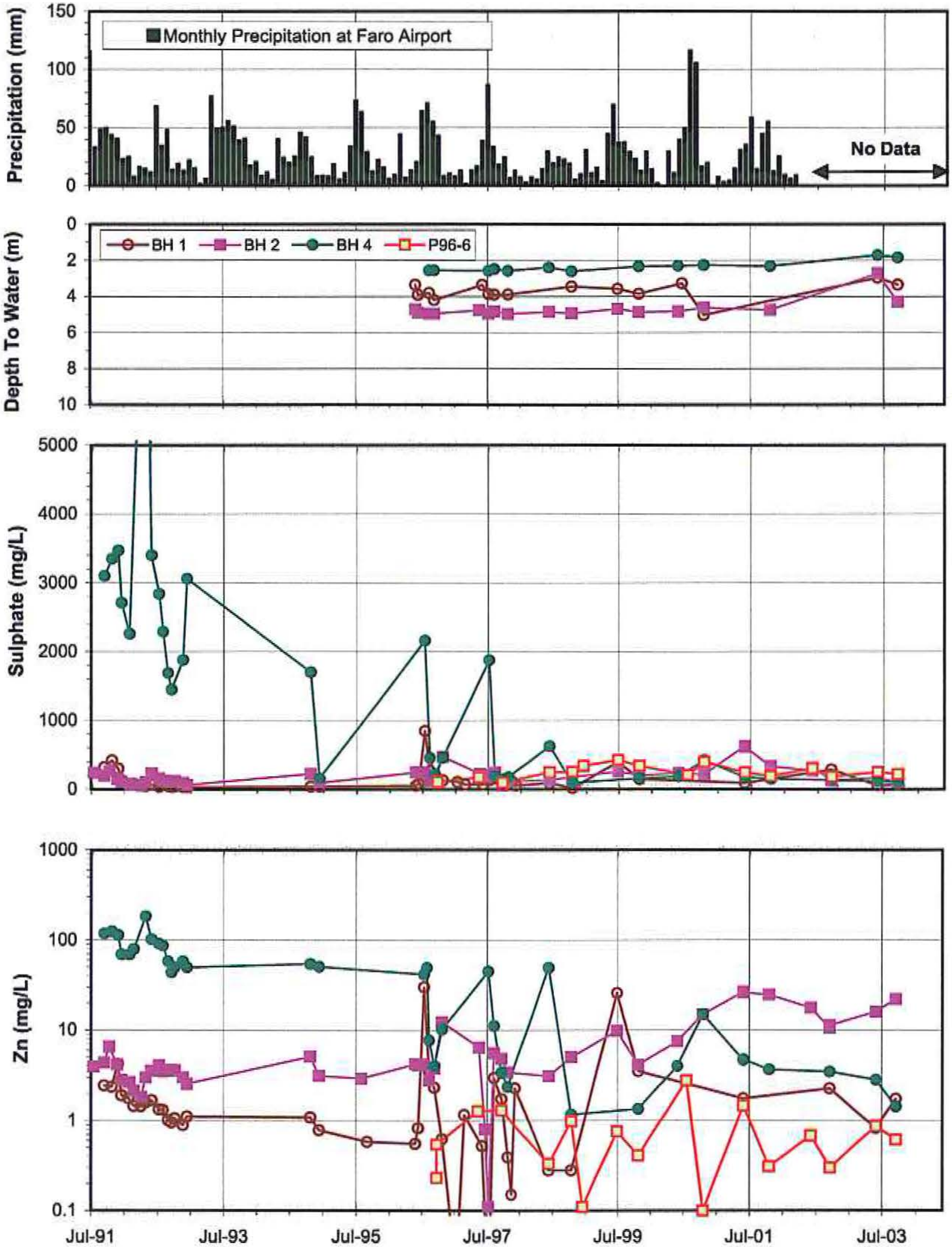

Figure 2. Groundwater quality downgradient of Zone 2 Pit and Intermediate Dumps (towards NFRC above rock drain).

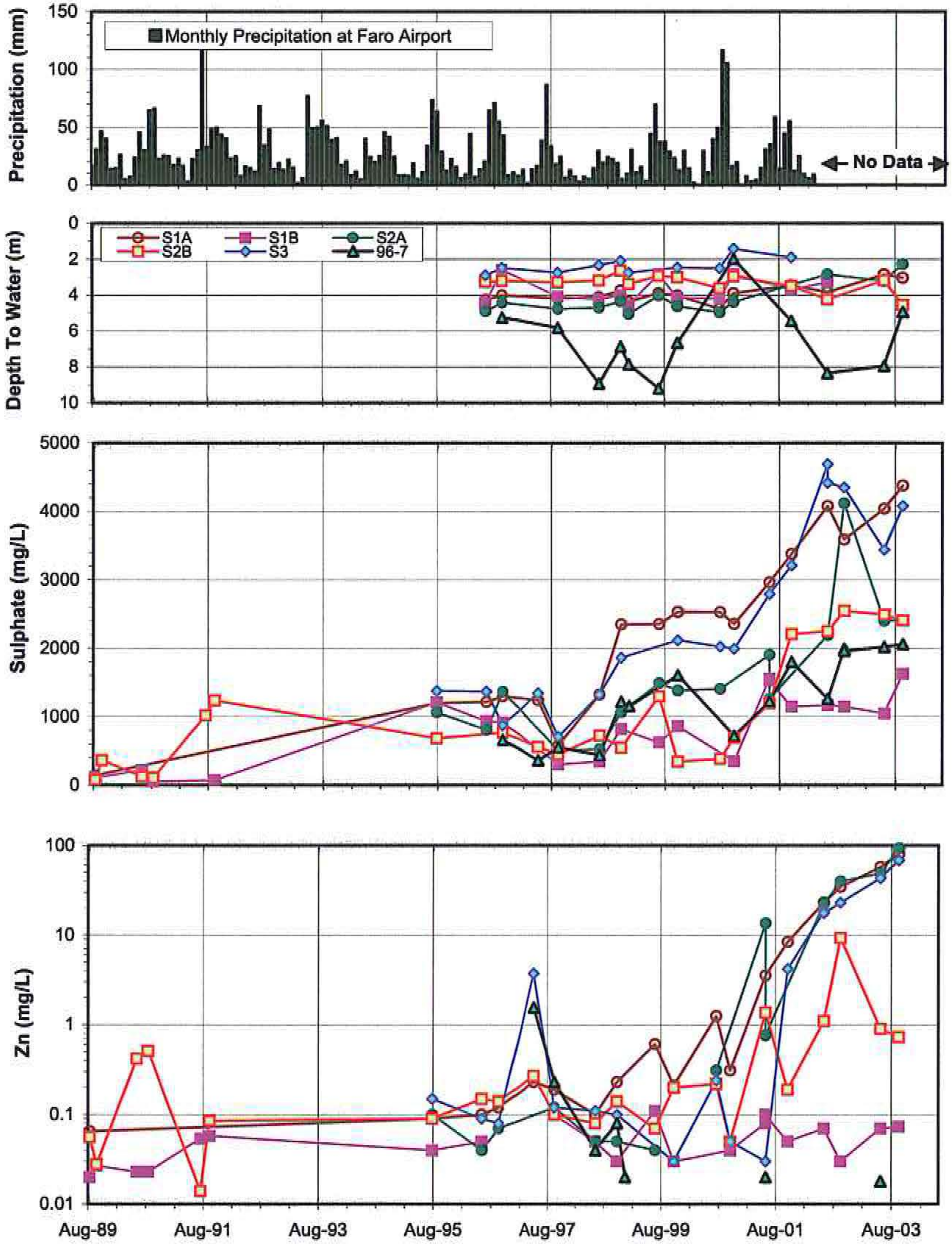

Figure 3. Groundwater quality downgradient of Intermediate Dump (towards NFRC below rock drain).

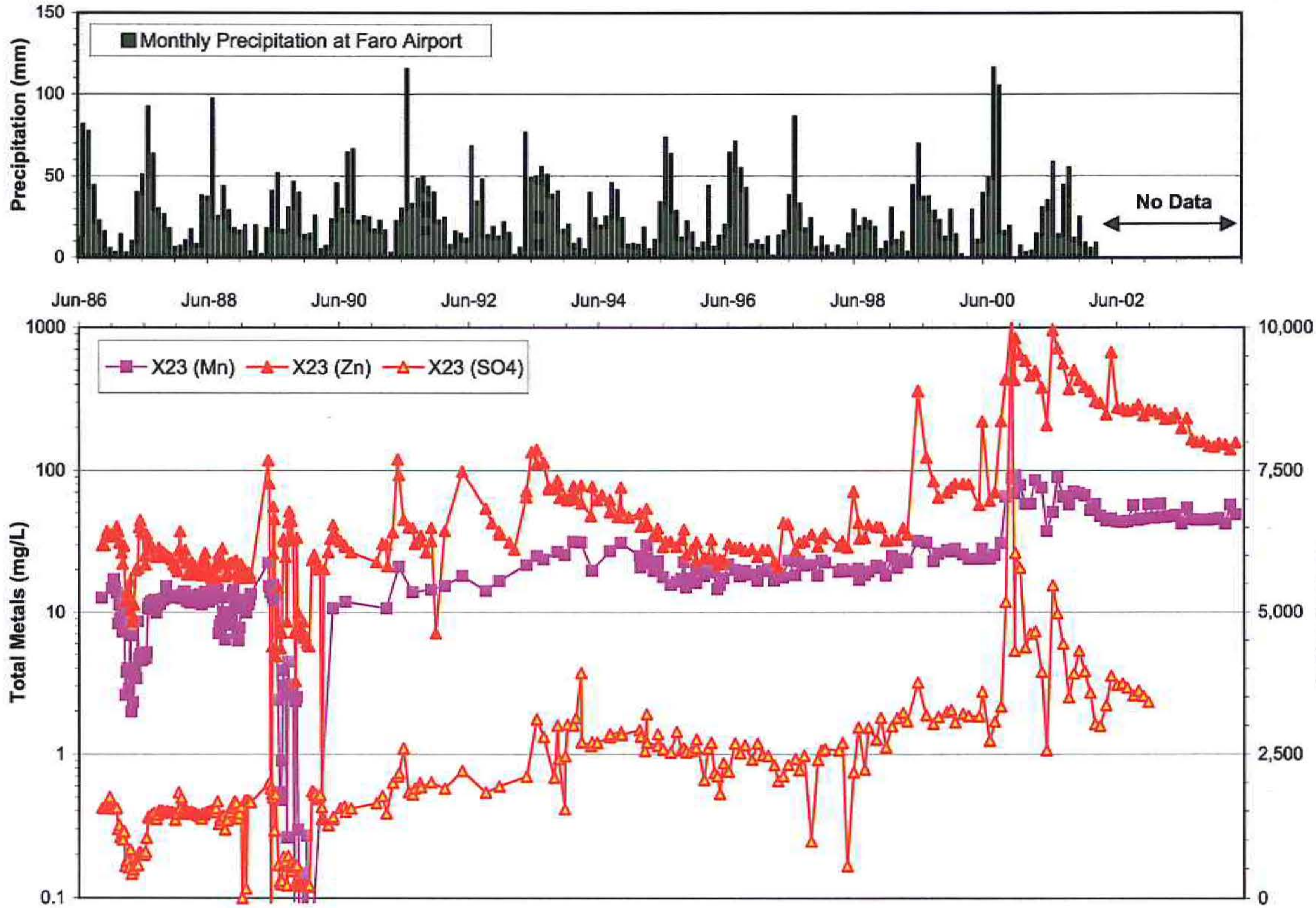

Figure 4. Time trends of sulphate, total zinc and total manganese in toe seepage at X23 (1986-2004).

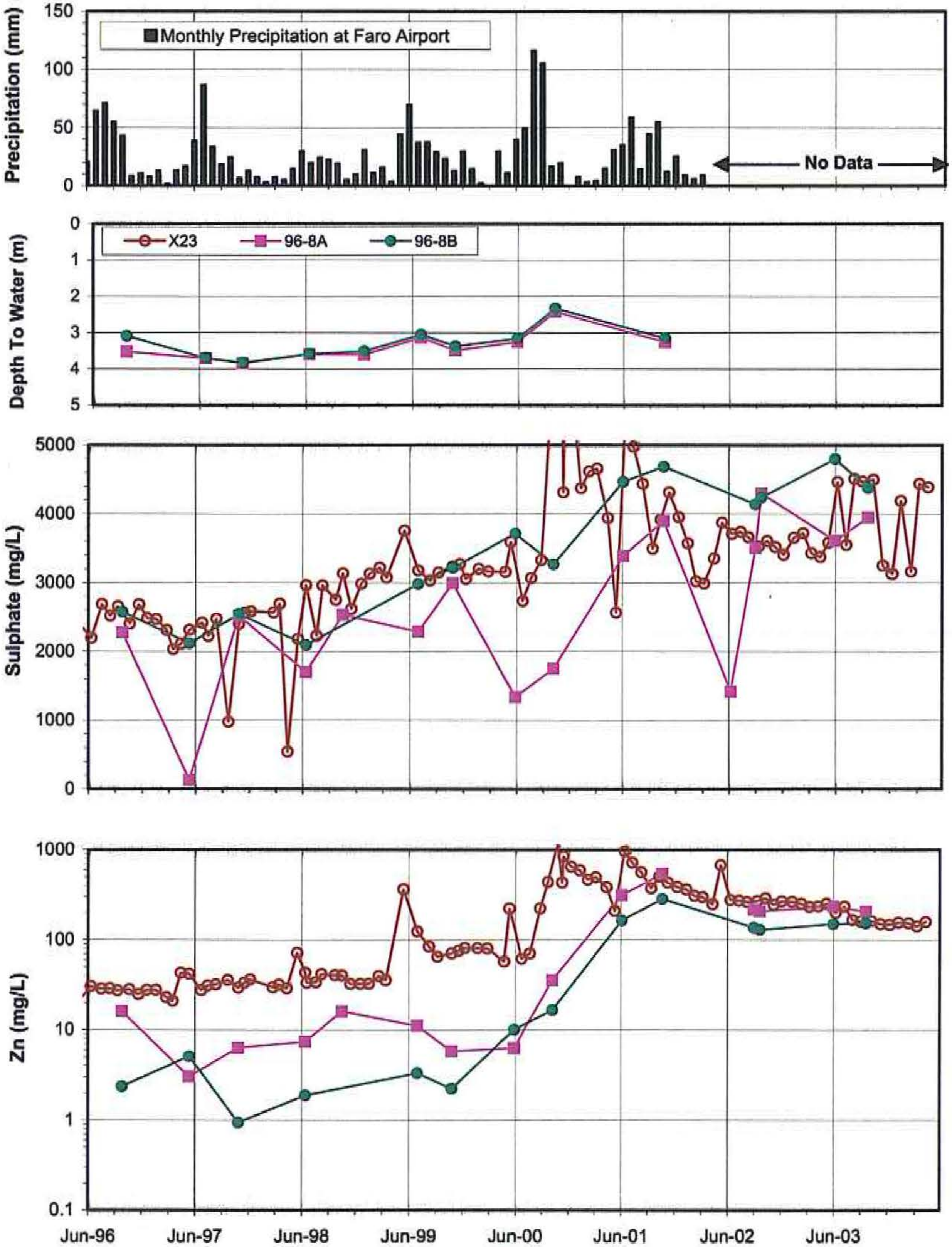

Figure 5. Water quality in surface seepage (X23) and subsurface seepage (P96-8A/B) downgradient of Main Dump (in old Faro Creek channel).

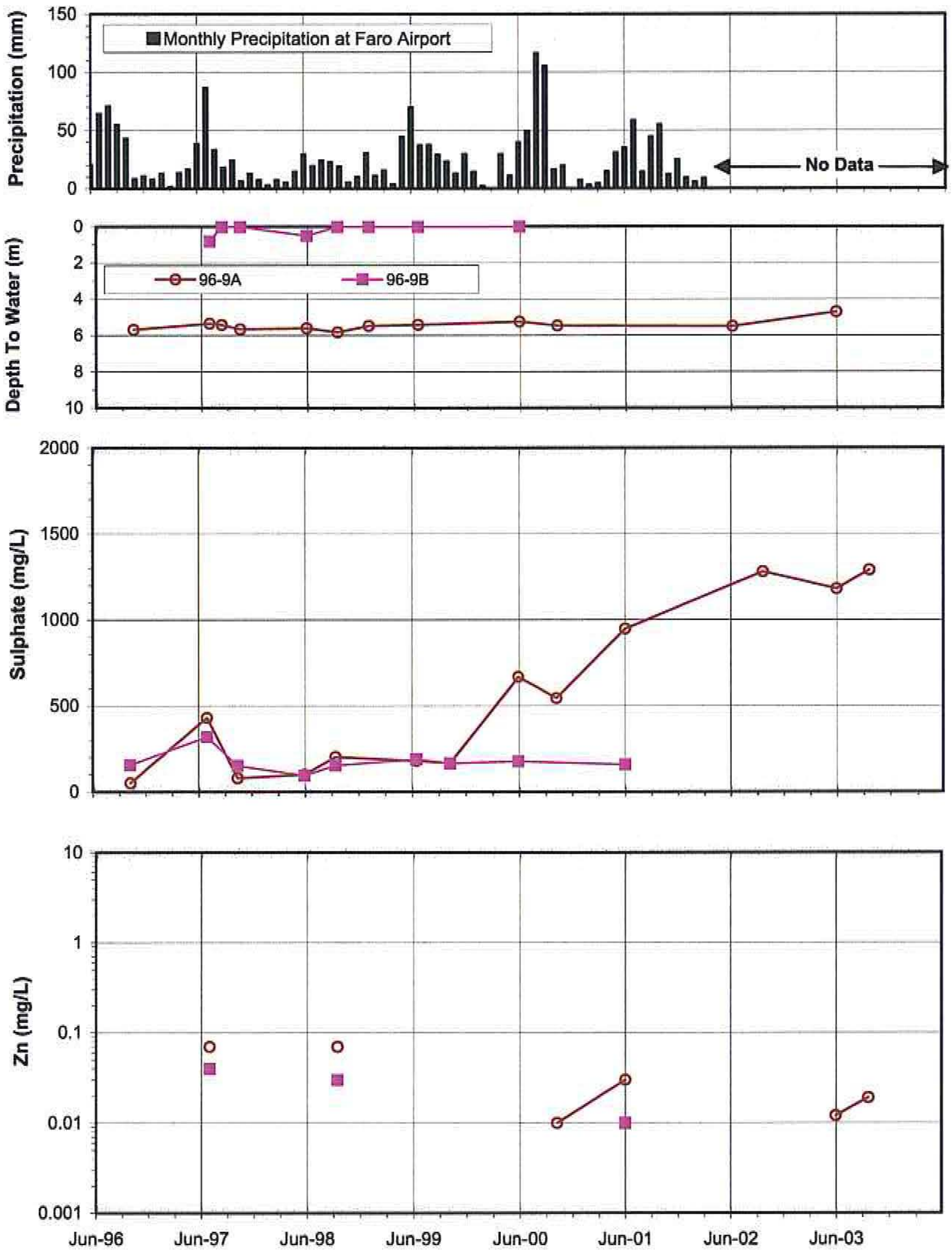

Figure 6. Groundwater quality downgradient of Grum Dump .

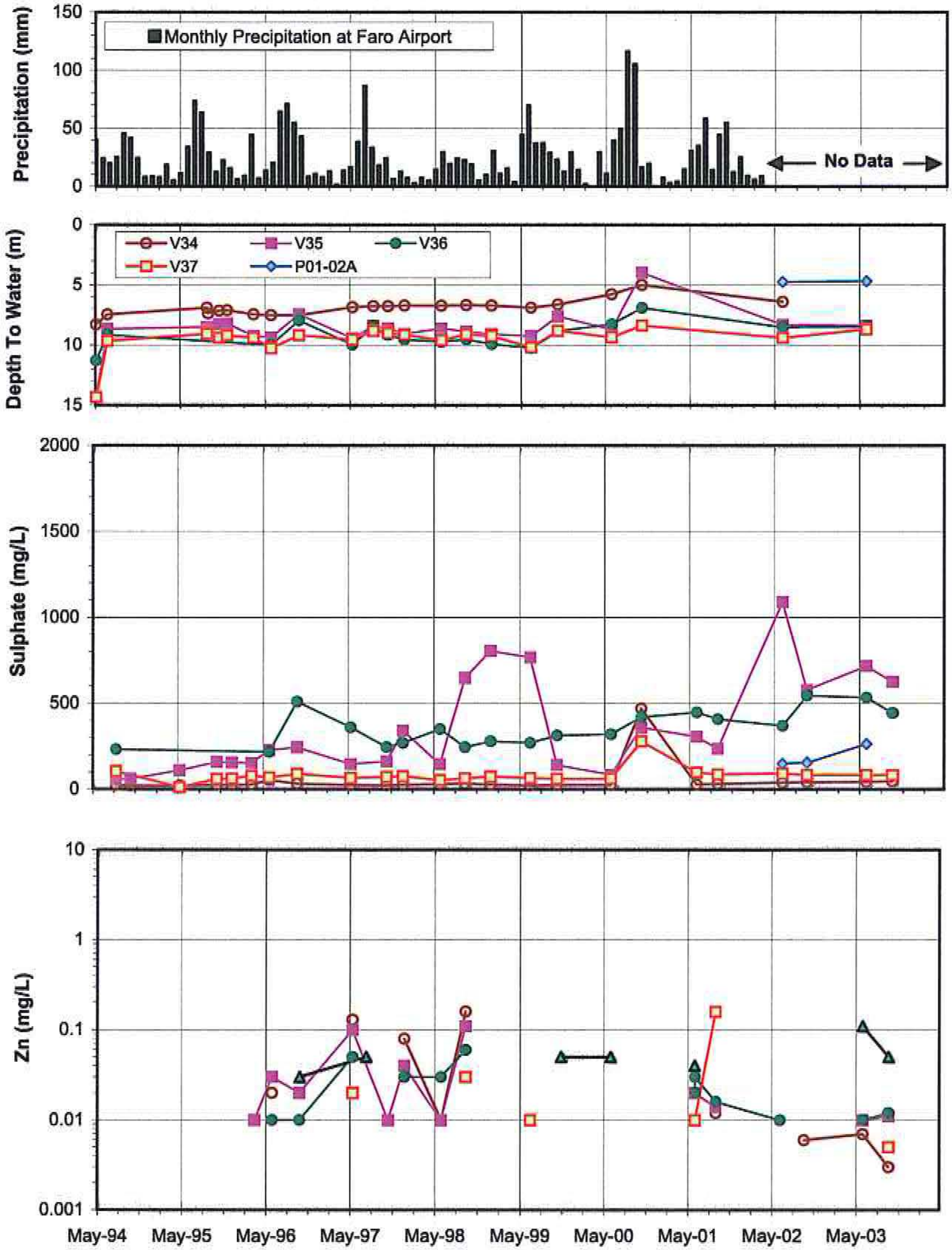

Figure 7. Groundwater quality downgradient of Vangorda Dump.