2011 S-wells Performance Review FINAL

Report Prepared for

Yukon Government

Report Prepared by

SRK Consulting (Canada) Inc.

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Executive Summary

SRK Consulting (Canada) Inc. (SRK) was requested by Kaori Torigai of the Faro Project Execution Team, Government of Yukon (YG), to conduct a performance review of the Faro Mine S-wells seepage interception system (SIS).

The scope of work included review of the S-wells system operation in terms of hydraulic performance (water level distributions) and down gradient water quality; identification of potential inefficiencies or issues with the system as well as recommendations for improvements; an evaluation of whether pumping well PW1 should be operated or not; providing comments on the pipeline scaling precipitation issues, if not related to PW1; and estimation of the total load of zinc and sulphate contaminants reporting to Faro Pit in 2010.

The conclusions and observations made for the S-wells review are presented below.

Hydraulic Performance

- ***The PW3 sump water level is achieving the performance objective of being drawn down to the base of the Shallow Aquifer.***
- PW2 and PW3 pumping rates appear sufficient to achieve the water level performance objective.
- Assessment of PW2 pump physical condition is not possible (i.e., whether or not the pump has to work increasingly hard over time to maintain the recorded rates).
- PW3 performance has deteriorated somewhat over time, probably related to pipe scaling.
- It may be possible to operate PW2 at a higher rate, but this may jeopardize the ability of PW3 to maintain the 1083 masl water level during times of the year when the SIS utilizes the 2-inch pipeline, due to pipeline pressure rating limitations.
- Manual water levels at monitoring wells SIS1 to SIS4 suggest that the interceptor trench is typically achieving the performance objective of drawing down the water level below the base of the Shallow Aquifer.
- Manual water levels at monitoring wells SIS5 and SIS6 suggest that the permeable units in which these monitoring wells are completed are not being as effectively intercepted as units monitored by SIS1 to SIS4.
- ***Continuous monitoring of water levels within the SIS monitoring wells should be modified to provide improved confidence of performance over time.***

Water Quality and WQ Parameter Loadings

- The SIS effectively reduced zinc concentrations in the NFRC in 2010. However, the operation of the SIS appeared to have only a minor effect on sulphate concentrations as measured at X2.
- Zinc was expected to be the dominant signature of seepage from the S-wells area into the NFRC; the average zinc concentration in PW3 was 22,000 times greater than the average zinc concentration in NFRC.
- In 2010, loadings of zinc and sulphate pumped to Faro Pit from PW3 were approximately 25 tonnes and 360 tonnes, respectively. Approximately 78,000 m^3 of water was pumped from the SIS to Faro Pit in 2010.
- A comparison of the zinc loadings extracted from PW3 in 2009 and 2010 to zinc loadings present in NFRC in 2008, 2009 and 2010 suggests that a large portion of the loadings extracted would not have reported directly to NFRC. Rather, the seepage may have followed a flow path below the creek and/or loadings may have become attenuated in the organic material in the subsurface.
- The water quality data from the NFRC suggests that sulphate and manganese may be present at elevated concentrations downstream of SC-3 and that this source, which could be a

continuation of the plume from the S-wells area, may in part be the cause of the increase in sulphate concentrations observed at X2. A load balance on SP8B monitoring well water located near SC-4 indicates that impacted groundwater in this area may contribute to loadings observed at X2.

- ***The operation of PW1 appears to be of negligible or no benefit in terms of mitigating water quality effects in NFRC; therefore, reactivating of the well is not recommended.***

Pipeline Scaling

- PW3 discharge pressure and flow data (at 100% VFD speed) indicate that the 2 inch pipeline may gradually be accumulating ferric scale.

The following recommendations were made based on the findings in the S-wells review.

Recommendations for system operation:

- The PID controller parameter setting should be evaluated to reduce the response time of the VFD operating the PW3 pump to water level variations (i.e. speed up how quickly it responds).
- Current operational methods appear to work as intended. No additional changes to the existing operation are required.

Recommendations to address pipeline scaling:

- Pipeline pressure appears to be slowly increasing maximum pump speed (VFD = 100%). Further scaling will result in further pipeline pressure increase and, consequently, reduced pumping rate. CAUTION: *the pipeline pressure relief valve should be checked regularly to confirm that it functions properly. As the pipeline pressure increases, the proper operation of that valve becomes more important.*
- If feasible, the 4 inch pipeline should be used whenever possible (during non-freezing conditions) to reduce exposure of the 2 inch line to ferric precipitation. ***THIS SHOULD BE STARTED IMMEDIATELY TO ALLOW ASSESSMENT OF THE 2-INCH LINE.***
- Easily accessible pipe fittings should be disassembled and cleaned.
- If feasible, the 2 inch pipeline should be jetted or ‘pigged’.

Recommendations for monitoring:

- Sampling at the following stations should continue according to the current schedule:
  - PW1, PW2 and PW3;
  - SC-1, SC-2, SC-3, SC-4 and X2;
  - SIS1 to SIS6; and
  - Sampling at other groundwater monitoring wells.
- Flow measurements and sampling of all NFRC surface water stations should continue on the same schedule.
- ***A staff gauge or other fixed point should be installed in the NFRC down gradient of the SIS, surveyed and measurements taken on a monthly basis, to provide better control on NFRC water level elevation.***
- Monitoring points should be installed within the interceptor trench, as per the original design.
- ***The c-can data logging system should be reprogrammed to include VFD frequency and pressure to allow ongoing assessment of the performance of the PW3 pump.***
- ***Data loggers should be installed in SIS1 to SIS6 and SRK05-SP4b to a depth just above the bottom of each monitoring well. Loggers should be set to record on an hourly basis.***
- ***A data logger should be installed in SRK05-SP5 to allow direct assessment of PW2 hydraulic performance.***

Recommendations for Interceptor Trench Modifications:

Effectiveness of the interceptor trench in the vicinity of SIS-5 and SIS-6 is uncertain due to limited data. Monitoring at these locations should be continued, if possible, to allow assessment of system performance in this specific area. While interceptor trench modifications in this area are not specifically recommended at this time, additional monitoring may indicate bypass in the area of the eastern interceptor trench extension. The necessity and utility of interceptor trench modifications in this area (i.e., deepening) should be assessed as part of future performance reviews.

The observed groundwater sulphate concentrations at monitoring wells down gradient of the SIS and sulphate loading to the NFRC in the general area of these monitoring wells, suggest that a sulphate plume exists under and discharges to the creek. This groundwater does not appear to be a source of significant zinc loading to the NFRC. Therefore, monitoring of NFRC water quality should be continued to determine if sulphate (and zinc) loading changes over the next couple of winter seasons, but no additional remedial action is considered necessary at this time.

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1 Introduction and Scope of Report

SRK Consulting (Canada) Inc. (SRK) was requested by Kaori Torigai of the Faro Project Execution Team, Government of Yukon (YG), to conduct a performance review of the Faro Mine S-wells seepage interception system (SIS).

The scope of work as agreed to in Yukon Government contract number C00009470 included:

- Review of the S-wells system operation in terms of hydraulic performance (water level distributions) and down-gradient water quality;
- Identify inefficiencies or issues with the system and provide recommendations for improvements;
- Determine whether pumping well PW1 should be operated or not;
- Provide overall comments on the pipeline scaling precipitation issues, if not related to PW1;and
- Estimate total load of contaminants of concern and volumes going to Faro pit for the last year.

This report presents findings and conclusions for each of these points, as well as recommendations for future system operation and monitoring.

A site location map is shown on Figure 1-1 including the layout of the SIS and monitoring points.

2 Background

When poor groundwater quality was identified in the S-wells (or S-cluster) area in 2004 as part of a review of groundwater quality (RGC, 2004), it was recognized that some level of remediation would likely be required to protect water in the nearby North Fork of Rose Creek (NFRC) from zinc loading. During the 2007 and 2008 winter low-flow periods, zinc concentrations in the NFRC increased (+/-0.1 mg/l), relative to summer periods. Multiple field investigations were completed to characterize the groundwater system and develop options for seepage interception (SRK, 2006a, 2009a). A primary conclusion of these investigations was the presence of two aquifers, the shallow and deep aquifers, both of which indicated deteriorated water quality resulting from waste rock dump (WRD) seepage, with dissolved zinc concentrations as high as 400 mg/L.

During the 2008/2009 winter season, a SIS was constructed in the S-wells area to intercept seepage from WRDs prior to reaching the NFRC. The SIS has two interception components: two pumping wells within the Deep Aquifer (SRK08-SPW1 and SRK08-SPW2, henceforth called PW1 and PW2, respectively) and a relatively shallow rock-filled interceptor trench incorporating a 2.1 m diameter central sump (SRK08-SPW3, henceforth called PW3) cross-cutting the Shallow Aquifer. Water from the two Deep Aquifer pumping wells is directed to the sump, from which both the Deep Aquifer contribution and water intercepted from the Shallow Aquifer is pumped to the Faro Pit. Data loggers within the PW3/sump control housing (the sea-can) record flow rates, cumulative pumped volumes and water levels. Details on the design and implementation of this SIS were presented in SRK, 2009b.

During the 2009 freshet, seeps emanating from the toe of the Intermediate waste rock dump were observed at locations uphill of the SIS. Flow was running along the ground surface, bypassing the SIS and entering the marshy ground adjacent to the NFRC. Samples of these seeps indicated zinc concentrations in the 6 to 59 mg/L range. During the 2009 summer season, under the guidance of YG, Denison Environmental Services (DES), the site care and maintenance contractor constructed a rock drain from the toe of the Intermediate waste rock dump to the SIS collector trench to intercept waste rock dump toe seepage surface runoff that was bypassing the SIS.

Following the 2009 freshet, performance to date was reviewed. In July 2009, a summary of SIS performance was presented to YG by the Faro Technical Advisory Team (TAT). Key findings were as follows:

- The SIS was intercepting a significant metal load from waste rock dump seepage.
- The SIS pipeline pressure capacity was insufficient to handle relatively large freshet flow volumes.
- The SIS sump pump was not deep enough to provide the required drawdown, (i.e. relative to the base of the Shallow Aquifer).
- The SIS interceptor trench should be extended further to the east.
- Variations in generator-based power supply were causing problems with the Scada system (data logger) and, possibly, pump performance.
- Oxidation of flows contributed by PW1 were believed to be causing build-up of iron oxide precipitate in the pipeline, to the Faro Pit, which was gradually reducing the flow capacity of this pipeline.

Options for increasing the SIS sump pump flow capacity; including modifications to the existing pipeline, deepening of the interceptor trench itself or lowering the sump pump were presented. In September 2009, SRK provided design options, construction planning and implementation of construction activities under project management by DES and review by YG (SRK, 2010a). Hatch Engineering provided pipeline and plumbing modification designs. Modifications included:

- Eastward extension of the interceptor trench by approximately 25m.
- Deepening of the PW3 sump by 2.0m and the PW3 pump by 1.8m (the modified operating drawdown level was 1082.6 masl).
- The PW1 and PW2 discharge pipes were extended to have the discharge point below the working water level within the sump.
- A second, larger diameter (4-inch), parallel pipeline was installed to accommodate freshet flow.
- Pipeline discharge points were extended into the Faro Pit Lake to an approximate depth of 30m below pit lake water level.

Upon completion of modifications, a performance review was conducted to assess improvements. The following points were noted:

- The minimum sump water level declined from about 1084.7 masl to about 1083.3 masl following deepening of the sump.
- Following construction of the eastern trench extension, water levels further declined to between 1082.6 masl and 1083.4 masl, which is close to the base of the shallow aquifer.

Even with deepening of the sump, the minimum working water level could not be lowered below that of the NFRC (e.g., 1082.4 masl on June 8, 2009) due to physical limitations: the base of the shallow aquifer (i.e., 1083.3 masl) appears to be at a higher elevation than the NFRC water level; the internal sump water level cannot be maintained below the elevation of the NFRC immediately down gradient, nor below any areas downstream of the SIS. This limitation was recognized during the SIS modification design discussions with YG and the TAT, and the objective of SIS modifications was defined as lowering the water level as much below the base of the Shallow Aquifer as possible. These conclusions were presented in two letters to YG (Appendix C of SRK, 2010a).

As of the last review of NFRC water quality (SRK 2010), it remained difficult to ascertain how effective the SIS has been at reducing loading to the creek. This was primarily a result of the relatively short period of time that had passed since the system was installed. NFRC zinc concentrations during the winter low flow period were less than for previous years, but observation of concentrations during additional low flow periods was required before conclusions could be drawn with confidence.

3 Available Data

3.1 Water Levels and Flows

Water level and flow data for the S-wells review were supplied by YG and DES and included:

- Water level for PW1, PW2 and PW3 – continuous data from February 2009 to May 2011.
- Pumping rate data for PW1, PW2 and PW3 – continuous data from February 2009 to May 2011.
- Manual water levels in wells SIS-1 through SIS-6 and SRK05-SP4b.
- Continuous water level data for SIS-2, -3 and -4, SRK05-SP4b and the steel drive-point located up gradient of the SIS.

3.2 Water Quality

Water quality data supplied by YG and DES included a complete historical record for all groundwater monitoring wells in the S-wells system and surface water quality data for stations on the NFRC. Specific records included:

- Water quality for PW1, PW2 and PW3 discharge – April 2009 to December 2010.
- Water quality for SIS 1- 6 – November 2009 to November 2010.
- Water quality for other groundwater monitoring wells – various periods.
- Laboratory analysis and photographs of scale materials from within the PW3 pipeline – August 2009.

4 Review of System Performance

4.1 Hydraulics

One of the key design functions of the SIS was interception of a significant percentage, if not all, of the groundwater flow within the shallow aquifer. The SIS design incorporated two elements to this objective:

1. The interceptor trench was excavated to the interpreted base of the shallow aquifer, with the sump base and pump at an elevation below that of the Shallow Aquifer (and preferably the NFRC water level as measured directly down gradient of the SIS), and
2. The interceptor trench was backfilled with clean, coarse waste rock to provide a relatively high hydraulic conductivity pathway in which water would flow freely and easily towards the main sump (PW3).

During design and installation, it became apparent that the base of the Shallow Aquifer appeared to be slightly higher than the NFRC water level, thus achieving drawdown below the NFRC water level was not physically possible. The modified objective was to draw down the trench water level as much as possible, in an effort to reduce the hydraulic gradient towards the NFRC.

To assess whether or not drawdown was occurring across the entire trench, the original design incorporated two monitoring points within the trench itself, towards the ends, monitoring of which would allow direct assessment of this hydraulic performance; those monitoring points were not installed and, instead, observations at monitoring wells immediately down gradient of the trench are relied upon. Within the trench, water levels within the sump, labelled as PW3, are the only records available.

Monitoring wells SIS-1 to SIS-6 were installed immediately down gradient of the SIS in 2009 (SRK, 2010b). SRK05-SP4b is also screened within the Shallow Aquifer immediately down gradient of the SIS.

The two Deep Aquifer pumping wells, PW1 and PW2, were installed in 2008 as part of an investigation aimed at providing additional information for use in designing a SIS. These two wells were subsequently put into operation as interception wells.

Numerous observation wells were completed in the Deep Aquifer in close proximity to these pumping wells. SRK05-SP4a is located adjacent to PW1. SRK05-SP5, SRK08-SBR1 and SRK08-SBR2 are located in close proximity to PW2. Completion details for these monitoring wells can be found in SRK, 2009a. Unfortunately, none of these monitoring wells are currently used for monitoring pumping well performance. Therefore, it is not possible to assess physical performance of these wells, or whether or not the pumping well screens themselves are becoming plugged or corroded over time.

4.1.1 Hydraulic Data and Trends

Figure 4-1 shows a record of daily average pumping rate for each of the three pumping wells, PW1, PW2 and PW3. Pumping rate at PW3 is controlled by a variable frequency drive and level transducer to maintain a sump water level approximately 0.10 meters above the top of the pump. Pumping rates for PW1 and PW2 are manually controlled.

In 2009, severe scaling was observed in the pipes from the S-well pumping system. The cause of the scaling was thought to be dissolved iron in the water extracted from PW1. On February 28, 2010 pumping from PW1 was stopped in an attempt to reduce the formation of iron scale in the SIS. The well remained inactive for the remainder of 2010. Pipe scaling is discussed further in Section 4.3.

PW2 averaged about 1.0 L/s until February 2010, when the rate was increased to about 1.3 L/s to make up for flow lost when PW1 was shut off.

The pumping rate at PW2 has been relatively constant. Manual adjustments are understood to have been made, which influence the rate trend; details on all of these adjustments are not available. The highest long term rate of about 1.4 L/s occurred during June to September in 2010.

The pumping rate at PW2 has varied between about 1.0 L/s and 1.3 L/s, with occasional periods in the 1.4 L/s range. The pumping rate at PW2 is manually controlled to provide make-up water to the PW3 sump. Pumping rate data suggest that the PW2 pump continues to operate within the required range.

The pumping rate at PW3 shows significantly more variation. PW3 pumping rate is governed by the rate of pumping from PW1 and PW2, from direct contributions to PW3 and by the control strategy used to maintain a low water level in PW3. Highest pumping rates occur during the spring freshet when average daily pumping rates can be as high as 5.7 L/s. During freshet, the larger 4-inch pipeline must be utilized due to the limited capacity of the 2-inch pipeline. During other times of the year the pumping rate varies between about 2.0 to 2.3 L/s, which is within the operating range of the 2-inch pipeline.

Figure 4-2 shows water levels for the three pumping wells. The water level within the PW3 sump has remained steady at approximately 1083 masl, consistent with the level observed following deepening of the sump and re-setting of the pump to a greater depth. The level remains slightly higher than the NFRC (1082.4 as measured in June 2009) but below the base of the Shallow Aquifer (1083.3 masl).

Higher sump water levels were observed over short periods. Figure 4-3 shows that the majority of the high water level events in PW3 are associated with an increase in the pumping rate and hence an increase in inflow to PW3 as a result of precipitation or snowmelt events. During the high water level events the pump in PW3 ramps up in response to the increasing water level. The maximum flow rate delivered by the PW3 pump was between 2.5 and 2.7 L/s during the winter, summer and fall seasons when the 2 inch pipeline was in use. During spring freshet, the un-insulated 4 inch pipeline was used, which allowed flows of up to 5.7 L/s.

A closer look at Figure 4-3 shows that the pump in PW3 responds relatively slowly to changes in water levels. For example, during the high water level event on 25 February 2010 the pumped ramped up, peaked and then ramped down over a period of 4 days. Much tighter water level control can be achieved by adjusting the proportional, integral and derivative (PID) controller parameters such that ramp-up and ramp-down occurs over a few hours rather than days. This measure is likely to eliminate the majority of fluctuations in the PW3 water level.

For a few days during the peak freshet flow (May 6 to 9, 2011) the inflow to PW3 appeared to exceed the capacity of the pump. Reconfiguration of the piping to allow parallel operation of the 2 inch and 4 inch lines may alleviate the capacity limitation. However, elevated water level in PW3 for a short period is unlikely to affect the overall performance of the S-well SIS.

Water levels for the Shallow Aquifer monitoring wells are shown in Figure 4-4. Soon after PW3 was set to a lower depth as part of system modifications in December 2009, it appears that either the water levels dropped below the transducers or the transducers ran out of memory, thus no record is available after that time. The transducers are understood to not have been reset to greater depth following lowering of the PW3 pump. That said, the available record does indicate that lowering of the PW3 pump did lead to lowering of water levels below the entire length of the interceptor trench. This is interpreted to indicate that either the interceptor trench is acting as designed from a hydraulic perspective (i.e., drawdown within the trench was approximately equal along its entire length) or that the permeable units in which the monitoring wells are screened are hydraulically connected to the trench.

Manual water level measurements have been periodically recorded in these monitoring wells and are tabulated in Table 4-1.

Table 4-1 Shallow Aquifer Monitoring Well Manual Water Level Measurements

		Depth to Water (m below TOC)								
	Bottom of Well (m below TOC)	25-Aug-09	26-Aug-09	27-Aug-09	04-Jan-10	09-Jun-10	24-Jul-10	13-Sep-10	02-Nov-10	01-Feb-11
SIS1	7.27	4.340				5.378	5.026	5.441	5.204	5.495
SIS2	6.48	3.340				4.343	3.646	5.343	4.291	4.540
SIS3	4.73	2.700				4.221	3.956	4.221	4.227	4.335
SIS4	4.73	2.990				4.31	3.852	4.221	4.312	4.420
SIS5	4.68		2.730			3.936		3.746		4.065
SIS6	5.50			2.990		3.524				3.893
SP4b					4.700	4.425		4.352		4.670

		Water Elevation (m.a.s.l)								
	Stick-up Elev (masl)	25-Aug-09	26-Aug-09	27-Aug-09	04-Jan-10	09-Jun-10	24-Jul-10	13-Sep-10	02-Nov-10	01-Feb-11
SIS1	1087.59	1083.250				1082.212	*1082.564*	1082.149	1082.386	1082.095
SIS2	1087.39	1084.050				*1083.047*	1083.744	1082.047	*1083.099*	*1082.850*
SIS3	1087.36	1084.660				*1083.139*	1083.404	*1083.139*	*1083.133*	*1083.025*
SIS4	1087.55	1084.560				*1083.240*	1083.698	1083.329	*1083.238*	*1083.130*
SIS5	1087.49		1084.760			1083.554		1083.744		1083.425
SIS6	1087.39			1084.400		1083.866				1083.497
SP4b	1087.42	1087.420			1082.72	*1082.995*		*1083.068*		*1082.750*

Shaded cells indicate potentially erroneous water levels lower than the NFRC (1082.4 masl) or may be affected by PW2 operation.

Cells with values in italics only indicate water levels below the base of the Shallow Aquifer (1083.3 masl)

Locations of monitoring wells are shown on Figure 1-1. The following observations can be made:

- From June 2010 onwards, water levels in SIS1 to SIS4 and SP4b were typically below the base of the Shallow Aquifer.
- In July 2010, water levels at only SIS1 were below the base of the Shallow Aquifer Water levels at SIS2 to SIS4 were slightly above the base of the Shallow Aquifer. This time coincides with a short period when the PW3 sump water level was high because of an increase in inflows (precipitation).
- Water levels at SIS5 and SIS6 have remained above the base of the Shallow Aquifer. These two monitoring wells are down gradient of the eastern extension of the SIS interceptor trench.

Water level in SIS1, and on one occasion at SIS2, appears to have been below the level of the NFRC (as measured in June 2009). Note that the reported levels at SIS1 are below that of the sump water level (~1083). Considering the location of SIS1 (to the west of the SIS trench and in closer proximity to PW2), it is possible that continued pumping of PW2 (at depth) has also resulted in a drawdown in the Shallow Aquifer in the vicinity of SIS1. There is insufficient data available to assess this hypothesis; water level data from SRK05-SP5 is required. Manual water level measurements, while only indicative of water level at the time of measurement, suggest that water levels down gradient of the main SIS trench are typically within the performance objective target (i.e., at or below the base of the Shallow Aquifer). However, the area immediately downgradient of the eastern extension of the interceptor trench are not achieving this objective. The majority of down gradient water levels appear to be highly influenced by sump water level, as would be expected. It is possible that hydraulic efficiency of the eastern interceptor trench extension is not as high as that of the main trench, or that the small permeable lenses in which SIS5 and SIS6 are completed are not effectively connected to the interceptor trenches at all. This could be indicative of SIS by-pass.

4.2 Water Quality and WQ Parameter Loadings

Effects of seepage from the Faro waste rock dumps on the water quality in North Fork of Rose Creek (NFRC) are described in the following sections. Additional information concerning effects of seepage from the S-wells area is available in *2010 Annual Review Adaptive Management Plan Faro Mine Complex* (Denison 2011) and in *2010 Groundwater Quality Review Anvil Range Mining Complex, Yukon Territory* (Robertson GeoConsultants Inc., 2011).

The purpose of the S-wells pumping system is to intercept ARD impacted seepage flowing from the Faro waste rock dump and to pump the water to Faro Pit. The interception and collection of seepage will prevent loadings of water quality parameters of concern (zinc and sulphate) from reporting to downstream aquifers and the NFRC.

4.2.1 Water Quality Trends: Pumping Wells

Figure 4-5 through 4-7 show zinc, sulphate and iron concentrations in pumping wells PW1, PW2 and PW3 from April 2009 to November 2010.

Zinc concentrations in PW2 decreased gradually from approximately 300 mg/L in April 2009 to 150 mg/L in November 2010. Concentrations in PW3 varied between 200 and 500 mg/L in 2009 and 2010 with a decreasing trend towards 300 mg/L in the second half of 2010. A spike in zinc concentrations in PW1 was observed between September 2009 and February 2010. Outside of this period, concentrations remained steady and low (between 1.2 and 1.8 mg/L).

Sulphate concentrations in the three wells follow the trends observed for zinc. Sulphate in PW2 showed a decreasing trend from approximately 5000 to 2800 mg/L while concentrations in PW3 ranged between 3000 and 7000 mg/L, trending towards 4500 mg/L in the second half of 2010. Aside from a spike in the winter of 2009/2010, the sulphate concentrations in PW1 have decreased marginally from approximately 400 to 300 mg/L.

Figure 4-7 shows that concentrations of dissolved iron in PW1 ranged between 20 and 28 mg/L in 2009 and 2010. The dissolved iron in PW1 was suspected of causing ferric scaling in the dewatering pipeline and pumping from the well was therefore discontinued in 2010. Iron concentrations in PW2 and PW3 were generally less than 10 mg/L in 2010 but showed an increasing trend. The increased iron loadings to the two wells could accelerate the formation of ferric scaling in the transfer pipeline and should continue to be monitored. Pipeline scaling is discussed further Section 4.3.

The composition of water in PW1 is evidently distinctly different from water collected in PW2 and PW3. This indicates poor connectivity between PW1 and PW2/PW3, which is corroborated by the lack of draw-down of PW1 by the dewatering of PW2 (Figure 4-2).

4.2.2 Water Quality Trends: Monitoring Wells Downstream of SIS

The water quality in wells located down-gradient from the SIS was monitored in 2009 and 2010. Monitoring well locations are shown on Figure 1-1. For this review, a sub-set of monitoring wells was assessed:

- SIS-1, SIS-2, SIS-3 (2009 and 2010).
- SIS-4 and SIS-5 (2009 only).
- SRK08-SP7A, -SP7B, -SP8A and SP8B (2008 through 2011).

For a complete review of groundwater quality, refer to *2010 Groundwater Quality Review Anvil Range Mining Complex, Yukon Territory* (Robertson GeoConsultants Inc., 2011).

Figure 4-8 and 4-9 shows concentrations of dissolved zinc and sulphate in the SIS wells. Concentrations of zinc and sulphate in SIS-2 and SIS-3 were relatively constant in 2009 and 2010 with the exception of a spike in May 2010. The three data points available for SIS-1 show a concentration increase followed by a decrease for zinc and sulphate. Concentrations of both species in the three monitoring wells were generally higher than in PW2 and PW3.

As shown in Figure 1-1, the SIS wells are located adjacent and down-gradient of the SIS trench. As discussed in Section 4.1.1 the water level in SIS-1, SIS-2 and SIS-3 were generally below or equal to the water level in PW3, except for the month of July, 2010. With the exception of SIS1, and possibly SIS2, SIS water level data generally indicate a gradient towards the PW3 sump and/or interceptor trench (water levels are higher in the SIS wells than the interceptor trench). As the PW3 water level remains slightly above that of the NFRC, a gradient also exists from the SIS wells towards the NFRC. The area between the SIS and the NFRC likely retains a volume of impacted water not being actively drawn back towards the SIS. This “stagnant” water, if not receiving additional inputs from WRD seepage, could be expected to show relatively stable concentration trends, as observed.

Insufficient data are available to assess water quality trends at SIS-5 and SIS-6.

Figure 4-10 through 4-12 show zinc, sulphate and manganese concentrations in monitoring wells SRK08-SP7A, -SP7B, -SP8A and SP8B (2008 to 2011). Wells SP7A and SP7B are located approximately 50 m down-gradient of the SIS. In 2008, water in the shallow well, SP7B (screen at

5 to 8 m below ground surface), was significantly impacted by ARD, while the deep well, SP7A (screen at 14 to 17m below ground surface) was only lightly impacted. Concentrations of zinc, sulphate and manganese decreased significantly in the shallow well (SP7B) after the SIS began operating in 2009. The improvement in water quality in SP7B continued until August 2010 and remained steady thereafter. The parameter concentrations in the deep well (SP7A) decreased gradually by about 50% over the same period.

A review of water quality trends in monitoring wells S1A, S2A and S2B are included in RGC (2011). These wells are located between 10 and 30 m down-gradient from the SIS. Wells S1A and S2A (9 to 12 m deep) exhibited the same trend as was observed for well SP7B: increasing concentrations until 2009 and then steeply declining trends thereafter. In contrast, zinc and sulphate concentrations in S2B (4 to 7 m deep) continued to increase after 2009.

The monitoring results from SP7, S1A and S2A provide a clear indications that loadings intercepted by PW2 and PW3 are mitigating the effects of ARD on groundwater in the S-wells area. At the same time, the increasing concentrations in S2B suggest that some portion of the flow at the interface between the shallow and deep aquifers bypasses the S-wells SIS. However, the observed reduction in dissolved zinc concentrations in the NFRC suggests that flows bypassing the SIS has a minor or negligible effect on the water quality in the creek.

SP8A (screen at 8 to 11 m below ground surface) and SP8B (screen at 3 to 6 m below ground surface) are located approximately 275 m down-gradient from the SIS and approximately 20 m west of the NFRC. Concentrations of zinc, sulphate and manganese in the wells are considerably greater than in the NFRC (Zn: 1.4 to 1.8 mg/L, SO42-: 500 to 1100 mg/L, Mn2+: 1.5 to 1.8 mg/L). However, parameter concentrations in the two wells have essentially remained constant between 2008 and 2011.

SP7a & 7b and SP8a & 8b were installed in 2008. At that time, it was hypothesized that the observed concentrations indicated the presence of a plume extending underneath the NFRC from the S-wells area. The observed concentration trends at these wells do not contradict this hypothesis. Additional monitoring over time will provide evidence as to whether or not the S-wells SIS has affected movement of this plume.

4.2.3 Water Quality Trends: NFRC

The SIS was designed to intercept seepage from the Faro waste rock dump and thereby mitigate potential water quality effects in the NFRC. Figure 4-13 and 4-14 show measured concentrations of zinc and sulphate at station X2 between 2003 and 2010. Station X2 is one of the compliance points on the NFRC and is located approximately 600 m downstream of the S-wells area.

Zinc concentrations at station X2 began increasing in the winter of 2005/2006 and showed a generally increasing trend through the winter of 2008/2009.However, zinc concentrations were reduced substantially at station X2 in the winter of 2009/2010, presumably as a result of the operation of the SIS. Meanwhile, sulphate concentrations at station X2 increased marginally between 2003 and 2009 with only a minor reduction in concentrations in the winter of 2009/2010 (Figure 4-14).

4.2.4 Seepage Signature in NFRC

Figure 4-15 shows a comparison of flow rates measured in 2010 at four stations along the NFRC (SC-1, SC-2, SC-4 and X2) with the rate of pumping from PW3. Between April and November 2010, the flow rate in the NFRC was measured between ~200 L/s and ~2500 L/s. Flow measurements for the winter season were not reported. The average monthly pumping rate from PW3 in 2010 varied between 2.1 and 2.7 L/s. The total volume pumped to Faro Pit from the S-wells SIS was 71,680 m^3. For the period of record, the flow in NFRC was between 100 and 1000 times greater than flow pumped from PW3.

In order to assess the potential effect of impacted seepage from the S-wells area on NFRC water quality, the concentrations of water quality parameters in PW3 were compared to concentrations measured at station X2.

Figure 4-16 shows ratios of average parameter concentrations measured in PW3 and X2 (i.e. $[Zn^{2+}]$PW3/$[Zn^{2+}]$X2). The ratios indicate which parameters are likely to be signatures of seepage in NFRC. Zinc concentrations in PW3 water are on average 22,000 times greater than zinc concentrations measured at station X2; concentrations of manganese, nickel, cobalt and cadmium are on average between 2200 and 5000 times greater in PW3 than at X2. Sulphate concentrations are approximately 400 times greater.

The results indicate that the dominant signature of seepage from the S cluster area reporting to NFRC is, as expected, elevated zinc concentrations and to a lesser extent elevated cadmium, cobalt, manganese and nickel concentrations. The effect on sulphate concentrations in NFRC as a result of seepage from the S-wells area are expected to be marginal. It should be noted that metal loadings will likely be altered during the migration through the subsurface as a result of adsorption, precipitation, oxidation or ion exchange processes.

The water quality at NFRC stations SC-1, SC-2. SC-3, SC-4 and X2 were examined with respect to the parameters identified as potential seepage signatures. Station SC-1 is located upstream from the S-wells area, station SC-2 and SC-3 are located adjacent to the area, and stations SC-4 and X2 are located downstream/down-gradient of the S-wells (Figure 1-1).

Figure 4-17 shows concentrations of dissolved zinc at the NFRC sampling stations. The elevated zinc concentrations at stations SC-4 and X2 between January and April 2010 are a distinct signature of zinc impacted seepage. During the spring freshet, the summer and fall months, the zinc signature is less pronounced, likely as a result of dilution by the increasing surface water flows. The figure shows that the majority of zinc loadings report to NFCR between station SC-3 and SC-4 in the first half of the year.

Zinc concentrations at X2 appear to have increased between SC-1 and SC-2 and then decrease between SC-2 and SC-3 in the open water season. It is not clear whether this observation is a result of analytical or sampling error or if some other explanation can account for this trend.

Figure 4-18 shows trends of nickel concentrations in the NFRC. The nickel signature is evident in the winter and early spring but not in the open water season following freshet. As may be expected based on the results discussed above, the nickel signature in NFRC is less pronounced than the zinc signature.

Manganese concentrations in NFRC for the 2010 season are shown in Figure 4.19. The trend in manganese concentrations generally follow the trends observed for zinc. However, the magnitude of the manganese signature is greater than expected. Also, manganese loadings reporting to the NFRC between SC-3 and SC-4 appear to be approximately equal in magnitude to loadings reporting between SC-4 and X2. This could indicate the influence of the existing plume under the NFRC;

characteristics are similar to water in monitoring well SP8B downstream of SC-4. The observation could be a result of greater advancement of the manganese plume relative to the zinc plume (retardation of zinc in the soil matrix). Similar concentration trends have been observed in the Rose Creek Aquifer near the Intermediate Dam.

Figure 4-20 shows the trends in sulphate concentrations at stations in the NFRC. Upstream of SC-4, the trend in sulphate concentration follows the trends observed for zinc: a distinct signature in the winter months, which disappears in the open water season and summer months. However, the data shows that considerable sulphate loadings report to the creek downstream of SC-4. This is likely related to the same mechanism as for manganese (i.e., contributions from existing plume).

Copper concentrations in NFRC are shown in Figure 4-21. Copper concentration appeared to be constant for all stations along the creek. This observation agrees with the results shown Figure 4-16 (no copper signature from seepage expected).

4.2.5 Sulphate and Metal Loadings Balances

Loadings of zinc and sulphate pumped from wells PW2, PW3 (incremental load with PW2 load subtracted) and present in PW1 in 2010 are shown in Figure 4-22 and 4-23, respectively. PW1 was inactive in 2010. In order to estimate potential loadings from PW1, a flow rate of 1.0 L/s (approximate pumping rate in 2009) was assumed for the loading calculations. The results show that less than 0.5% of total zinc loadings and less than 5% of total sulphate loadings would originate from PW1 if the pump was activated. Due to the limited zinc loading from PW1 – and because zinc concentrations in the NFRC were reduced in 2010 when PW1 was inactive – it is concluded that the benefits of operating PW1, in terms of reducing zinc concentrations in NFRC, are negligible.

Figure 4-24 and 4-25 show comparisons of total zinc and sulphate loadings pumped from PW3 (PW2 and PW3 loadings combined) in 2009 and 2010 as well as loadings present in the NFRC at X2 in 2010. Loading estimates shown for 2008 and 2009 were based on the 2010 flows and were included to provide an order-of-magnitude comparison. Flow data for X2 was not available for the winter months. Therefore, loading estimates are not shown for the winter months when the peak concentrations occur.

Although zinc concentrations (and hence loading) in the S-wells area has continued to increase throughout operation of the S-wells SIS, it can be shown that a significant portion of the zinc load did not reach the NFRC (even prior to operation of the SIS) suggesting that much of the S-cluster seepage does not directly discharge into the NFRC.

Notably:

- The total zinc load in the NFRC in 2008, when the SIS was not operating, was on the order of 1 to 2 tonnes/year.
- In 2009, when the SIS was operational, the annual zinc loading to the NFRC was of the same order as in 2008 (between 1 and 2 tonnes/ year); in that year 22.4 tonnes of zinc was extracted by the SIS.
- In 2010, the zinc loading in NFRC had been reduced to 0.4 tonnes/year, while 25 tonnes/year was pumped from PW3.

The comparison above demonstrates that:

- In 2009 the SIS was effective at capturing significant zinc loads from the shallow and deep aquifer. The interception of the loads resulted in substantial improvements to the water quality in the shallow aquifer downstream (Figure 4-10, SRK08-SP7A). However, effects on NFRC water quality were marginal.

- The modifications made to the SIS in 2009 improved the capture of seepage reporting to the NFRC considerably, while maintaining the water quality improvement in the shallow aquifer.

In the years prior to operation of the SIS, the majority of loadings associated with impacted aquifers did not report to the NFRC. Three phenomena may explain this observation: the flow path of the aquifer may follow a trajectory below the creek; zinc may attenuate along the flow path prior to discharge into the NFRC; or the leading edge of the zinc plume may not have reached its intersection with NFRC. The water quality trend observed in SP7B suggests that the SIS has reversed or mitigated the downstream migration of the zinc plume. Ongoing monitoring will show whether a residual plume will migrate and intersect with the NFRC further downstream.

Total sulphate loadings pumped from PW3 to Faro Pit in 2010 was approximately 360 tonnes. Loadings of sulphate extracted from PW3 in 2010 were comparable to loadings already present in the creek in the open water season (Figure 4-25). Therefore, if all sulphate loadings from PW3 were to report to the NFRC, the sulphate concentration would approximately double. If only a fraction of the seepage in the shallow aquifer reported to the NFRC, sulphate would not be a significant signature of S-wells seepage to the NFRC.

The distribution of sulphate shown in Figure 4-20 shows that a greater load of sulphate report to NFRC between stations SC-4 and X2 than between stations SC-3 and SC-4, which are located immediately downstream of the S-wells SIS. Meanwhile, the greatest contribution of zinc loadings occurs between SC-3 and SC-4 (Figure 4-17).

Exploring the possibility that a plume is present downstream of SC-4 (which is located approximately 40m downstream of SP8), it was noted that concentrations of sulphate and manganese in monitoring well SP8B were orders of magnitude greater than concentrations in the NFRC. SP8B is located approximately 20 m from the NFRC and has a screen depth of 3 to 6 m. It is possible to calculate the rate of seepage from SP8B-quality water that is required to increase sulphate concentrations as observed in the NFRC (downstream of SC-4). In fact, such calculations can be carried out using load balances for any conservative water quality parameter. Figure 4-26 shows calculated seepage rates of SP8B water to NFRC based on sulphate, zinc and manganese load balances. Flow rates in April would have been between 5 and 7 L/s and between 7 and 11 L/s in May 2010. The fact that flow calculations based on the different parameters agree relatively well supports the hypothesis that a plume similar in composition to SP8B contributes loadings to the NFRC downstream of SC-4.

4.3 Pipeline Scaling

In 2009 severe scaling was noticed in the pipes for the SIS pumping system (Figure 4-27). Analysis of the scale showed that 75% of the metal content was iron, with approximately 8% zinc, 7% silicon and trace amounts of other constituents. The scale forms when ferrous iron oxidizes to ferric iron, which precipitates as hydroxides and oxides in the near-neutral pH seepage. The main source of ferric iron was thought to be well PW1. In 2010, PW1 was not operated in an attempt to limit iron scaling in the SIS pipes.

The performance of the pumping system in 2010 was assessed to determine if scale formation could have compromised pumping rates. Figure 4-28 shows flow rates delivered by the PW3 pump along with recorded discharge pressures when the variable frequency drive (VFD) is running at 100%

speed; data collected during freshet when the 4 inch pipe was in use are not shown on the figure. An increase in discharge pressure and a decrease in flow rates – typical indicators of pipe scaling – were noted between December 2009 and February 2010. In July 2010 pressures and flows appear to have stabilized. It is not known if maintenance was carried out on the 2 inch pipeline in the preceding months. Between July 2010 and January 2011 the PW3 discharge pressure increased from approximately 200 to 208 psi, while flow rates decreased from 2.5 to 2.1 L/s. It should be noted that the VFD did not reach 100% capacity between late December 2010 and late April 2011, presumably because PW1 was inactive.

Assuming that the trends shown on Figure 4-28 are not a result of operational or configuration changes (valve set-points, reconfiguration of pipes or fittings, etc.) the data indicate that the 2 inch pipe is gradually scaling. Visual inspection of the pipe (by disassembling the pipe or using a pipe camera) must be completed to verify this indication.

The following actions are recommended based on the observations presented:

- Pipeline pressure appears to be slowly increasing maximum pump speed (VFD = 100%). Further scaling will result in further pipeline pressure increase and, consequently, reduced pumping rate. CAUTION: *the pipeline pressure relief valve should be checked regularly to confirm that it functions properly. As the pipeline pressure increases, the proper operation of that valve becomes more important.*
- Easily accessible pipe fittings should be disassembled and cleaned.
- If required, the 2 inch pipeline should be jetted or 'pigged'.
- If feasible, the 4 inch pipeline should be used whenever possible (during non-freezing conditions) to reduce exposure of the 2 inch line to ferric precipitation. ***THIS SHOULD BE STARTED IMMEDIATELY TO ALLOW ASSESSMENT OF THE 2-INCH LINE.***
- The c-can data logging system should be reprogrammed to include VFD frequency and pressure to allow ongoing assessment of the performance of the PW3 pump.

The addition of antiscalants or ferric stabilizers, such as citric acid or EDTA, to the PW3 well water could be considered as an ongoing mitigation measure. However, a field or laboratory investigation is required to assess the effectiveness of such reagents given the high concentrations of zinc and other metals in the well water.

A field investigation is required to provide additional specific recommendations.

5 Conclusions

The conclusions and observations made for the S-wells review are presented below.

5.1 Hydraulic Performance

- The PW3 sump water level is achieving the performance objective.
- PW2 and PW3 pumping rates appear sufficient to achieve the performance objective.
- Assessment of PW2 pump physical condition is not possible (i.e., whether or not the pump has to work increasingly hard over time to maintain the recorded rates).
- PW3 performance has deteriorated somewhat over time, probably related to pipe scaling.
- It may be possible to operate PW2 at a higher rate, but this may jeopardize the ability of PW3 to maintain the 1083 masl water level during times of the year when the SIS utilizes the 2-inch pipeline, due to pipeline pressure rating limitations.

- Manual water levels at monitoring wells SIS1 to SIS4 suggest that the interceptor trench is typically achieving the performance objective of drawing down the water level below the base of the Shallow Aquifer.
- Manual water levels at monitoring wells SIS5 and SIS6 suggest that the permeable units in which these monitoring wells are completed are not being as effectively intercepted as units monitored by SIS1 to SIS4.
- Continuous monitoring of water levels within the SIS monitoring wells should be modified to provide improved confidence of performance over time.

5.2 Water Quality and WQ Parameter Loadings

- The SIS effectively reduced zinc concentrations in the NFRC in 2010. However, the operation of the SIS appeared to have only a minor or negligible effect on sulphate concentrations.
- Zinc was expected to be the dominant signature of seepage from the S-wells area into the NFRC; the average zinc concentration in PW3 was 22,000 times greater than the average zinc concentration in NFRC.
- In 2010, loadings of zinc and sulphate pumped to Faro Pit from PW3 were approximately 25 tonnes and 360 tonnes, respectively. Approximately 78,000 m^3 of water was pumped from the SIS to Faro Pit in 2010.
- A comparison of the zinc loadings extracted from PW3 in 2009 and 2010 to zinc loadings present in NFRC in 2008, 2009 and 2010 suggests that a large portion of the loadings extracted may not have reported directly to NFRC. Rather, the seepage may have followed a flow path below the creek and/or loadings may have become attenuated in the organic material in the subsurface.
- The water quality data from the NFRC suggests that sulphate and manganese may be present at elevated concentrations downstream of SC-3 and that this source, which could be a continuation of the plume from the S-wells area, may in part be the cause of the increase in sulphate concentrations observed at X2. A load balance on SP8B monitoring well water located near SC-4 indicates that impacted groundwater in this area may contribute to loadings observed at X2.
- The operation of PW1 appears to be of negligible or no benefit in terms of mitigating water quality effects in NFRC; therefore, reactivating of the well is not recommended.

5.3 Pipeline Scaling

- PW3 discharge pressure and flow data (at 100% VFD speed) indicate that the 2 inch pipeline may gradually be accumulating ferric scale.

6 Recommendations

The following recommendations were made based on the findings in the S-wells review.

6.1 System Operation

- The PID controller parameter setting should be evaluated to reduce the response time of the VFD operating the PW3 pump to water level variations (i.e. speed up how quickly it responds).
- If feasible, the 4 inch pipeline should be used whenever possible to (during non-freezing conditions) to reduce exposure of the 2 inch line to ferric precipitation. If feasible, both pipelines should be used during high flow periods.
- Current operational methods appear to work as intended. No additional changes to the existing operation are required.

6.2 Monitoring

- Sampling at the following stations should continue according to the current schedule:
  - PW1, PW2 and PW3;
  - SC-1, SC-2, SC-3, SC-4 and X2;
  - SIS1 to SIS6; and
  - Sampling at other groundwater monitoring wells.
- Flow measurements and sampling of all NFRC surface water stations should continue on the same schedule.
- A staff gauge or other fixed point should be installed in the NFRC down gradient of the SIS, surveyed and measurements taken on a monthly basis, to provide better control on NFRC water level elevation.
- Monitoring points should be installed within the interceptor trench, as per the original design.
- The c-can data logging system should be reprogrammed to include VFD frequency and pressure to allow ongoing assessment of the performance of the PW3 pump.
- Data loggers should be installed in SIS1 to SIS6 and SRK05-SP4b to a depth just above the bottom of each monitoring well. Loggers should be set to record on an hourly basis.
- A data logger should be installed in SRK05-SP5 to allow direct assessment of PW2 hydraulic performance.

6.3 Pipeline Scaling

- The WP3 pump curve should be consulted to determine how further pressure increase will affect the pumping rate and thereby compromise the operation of the SIS. This would help assess whether critical flow rates can be maintained during the fall and winter of 2011/2012 when maintenance of the 2 inch pipeline is difficult.
- Easily accessible pipe fittings should be disassembled and cleaned.
- If required, the 2 inch pipeline should be jetted or ‘pigged’.

A field investigation is required to provide additional specific recommendations.

6.4 Interceptor Trench Modifications

Effectiveness of the interceptor trench in the vicinity of SIS-5 and SIS-6 is uncertain due to limited data. Monitoring at these locations should be continued, if possible, to allow assessment of system performance in this specific area. While interceptor trench modifications in this area are not specifically recommended at this time, additional monitoring may indicate bypass in the area of the eastern interceptor trench extension. The necessity and utility of interceptor trench modifications in this area (i.e., deepening) should be assessed as part of future performance reviews.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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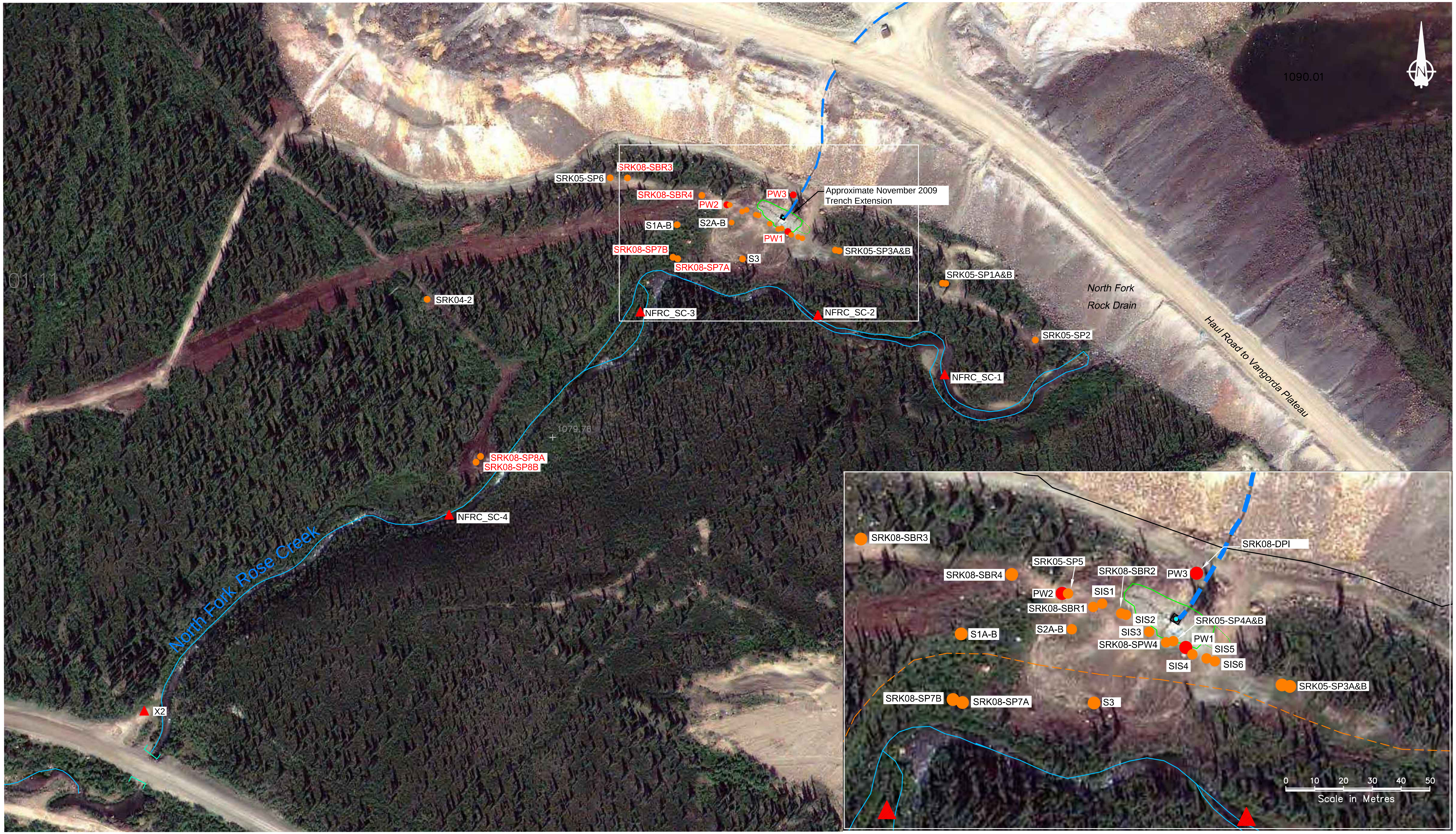
Figures



Legend

- S-Wells Seepage Interception Trench
- S-Wells SIS Pipeline
- Groundwater Pumping Well
- Surface Water Monitoring Station
- Monitoring Well

0 100 200 300 400 500
Scale in Metres

Survey control based on:
UTM NAD27, Zone 8

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Faro Mine Closure
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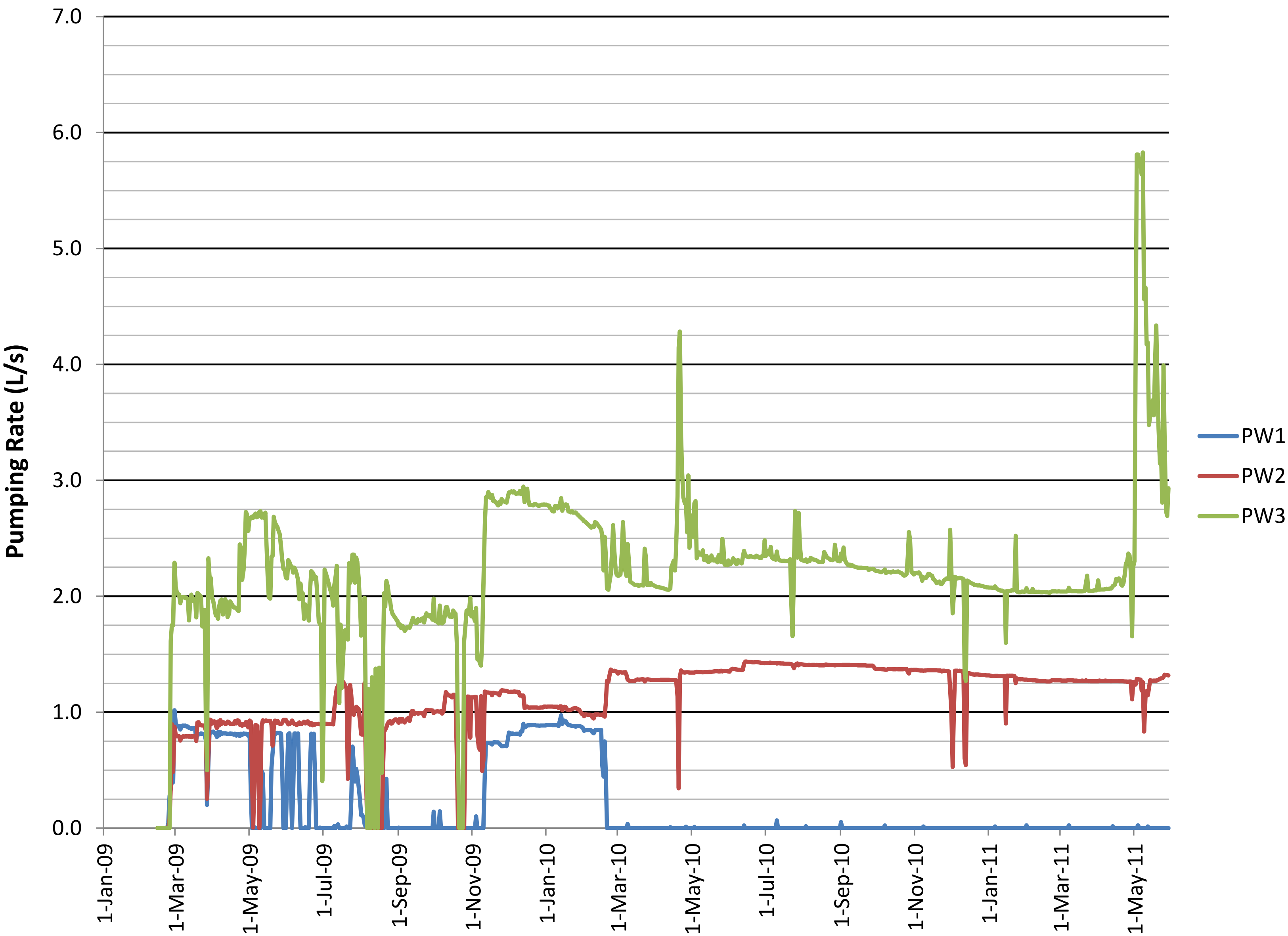
S-Wells Seepage Collection System and Monitoring Stations

SRK JOB NO.: 1CY001.050

FILE NAME: 1CY001_026-4_Rev_B.dwg

Faro Mine Complex

DATE:	APPROVED:	FIGURE:
July 2011	PMH	1-1



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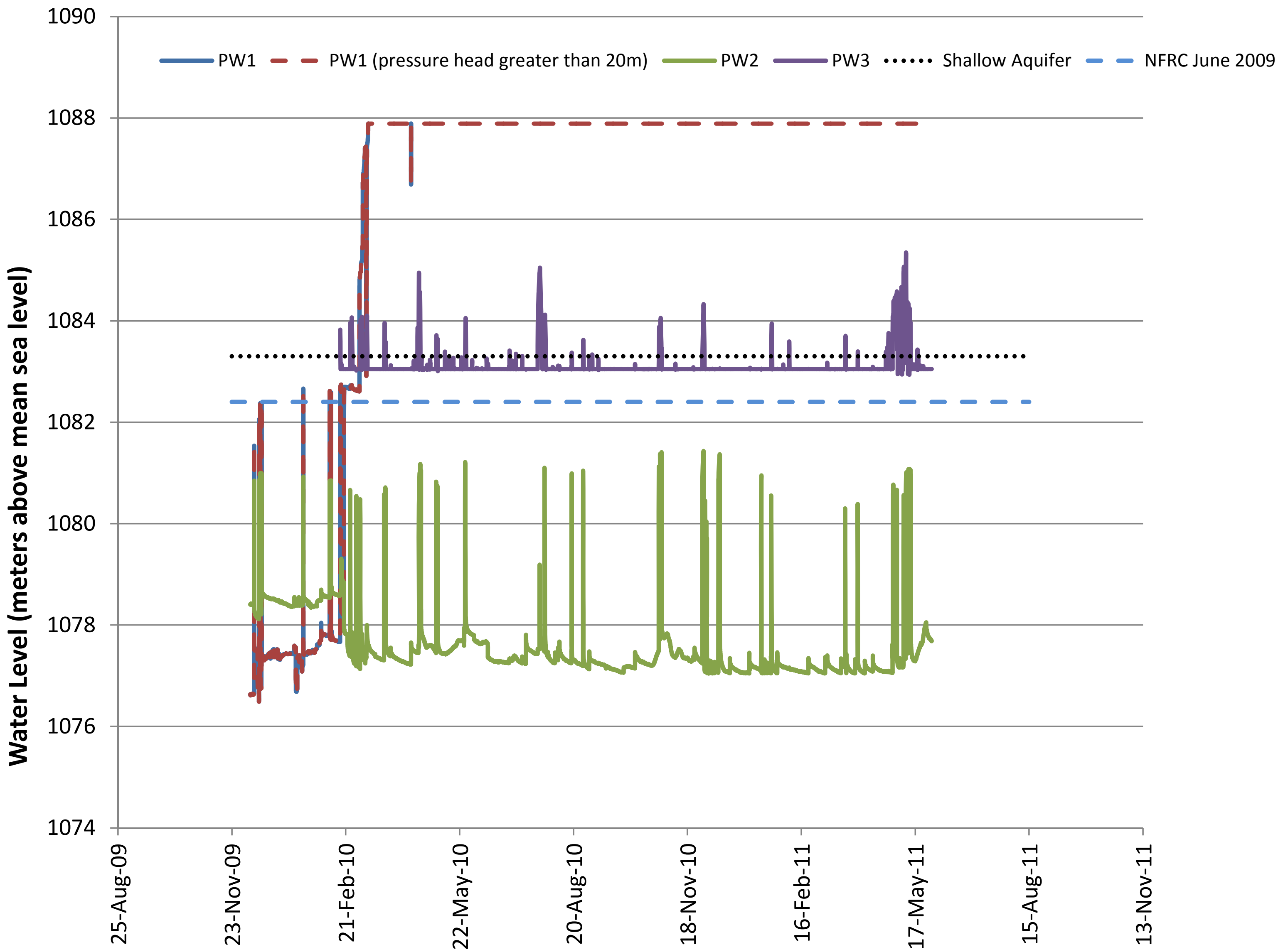
		Daily Average Pumping Rates for PW1, PW2 and PW3
Job No: 1CY001.050 Filename: Figure: 4-1_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: 4.1



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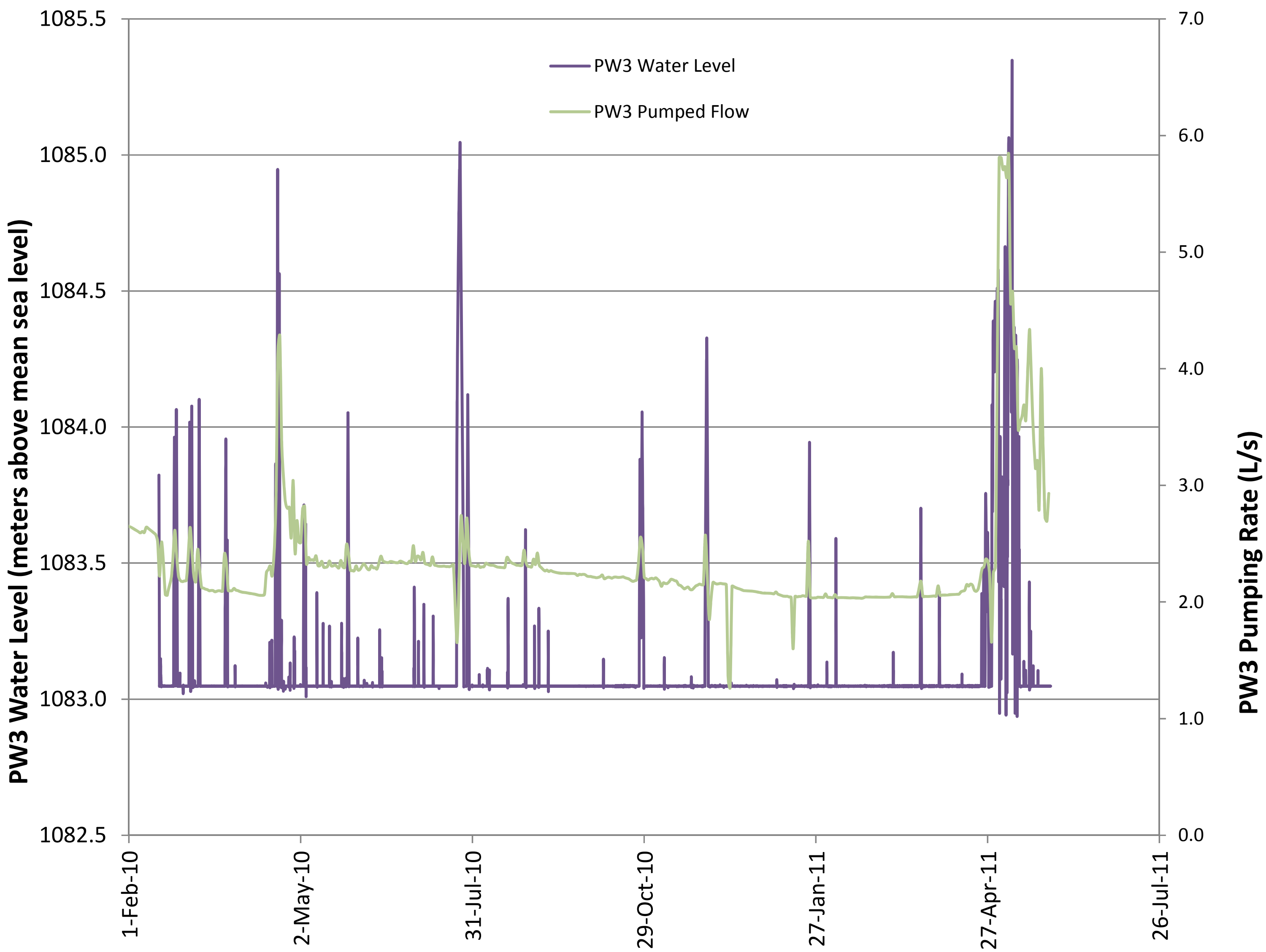
Job No: 1CY001.050 Filename: Figure: 4-2_20110721.pptx	2011 S-wells Performance Review FINAL	2011 S-wells Performance Review FINAL Recorded Water Levels in Wells PW1, PW2 and PW3		
		Date: July 2011	Approved: DM	Figure: 4.2



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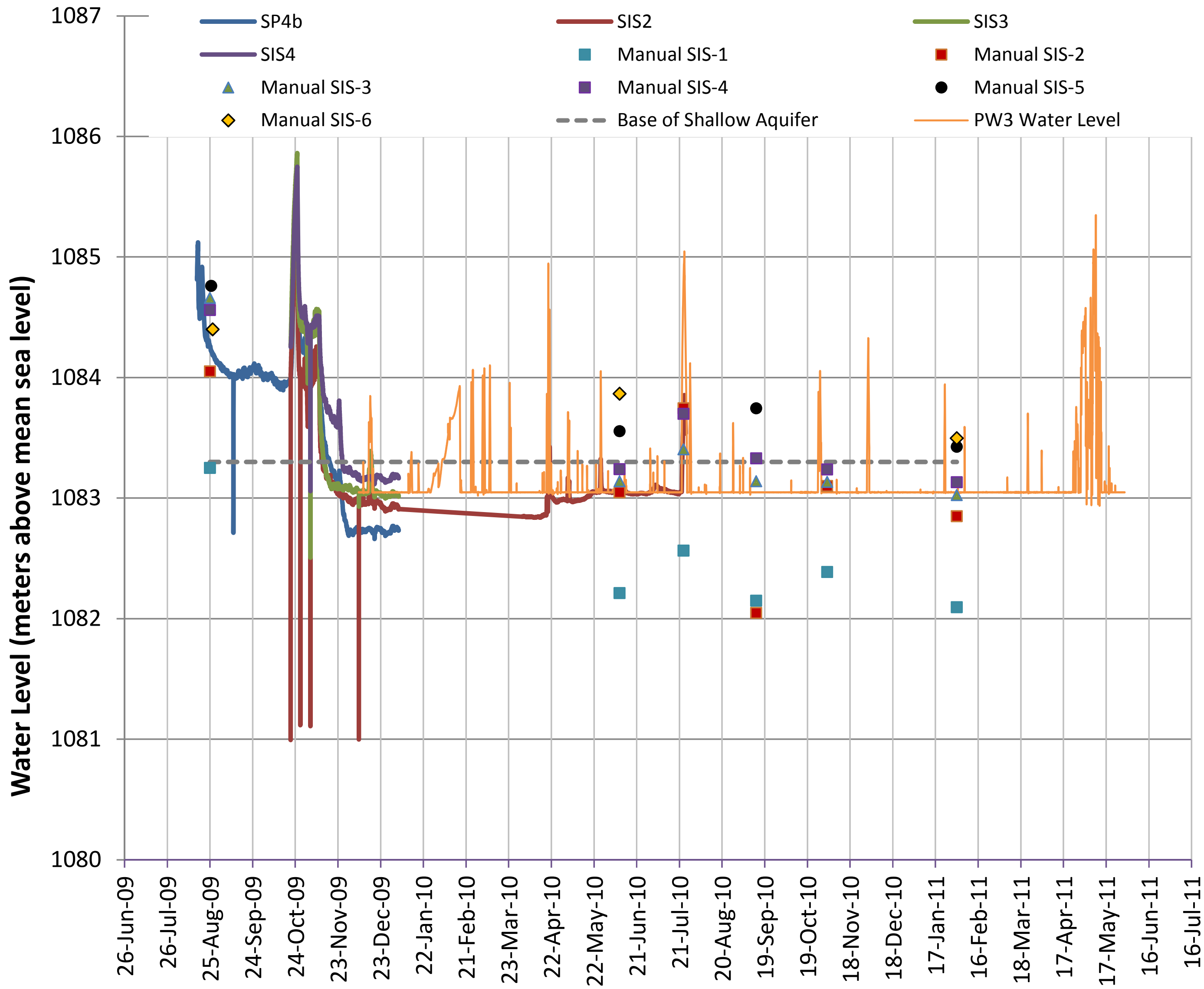

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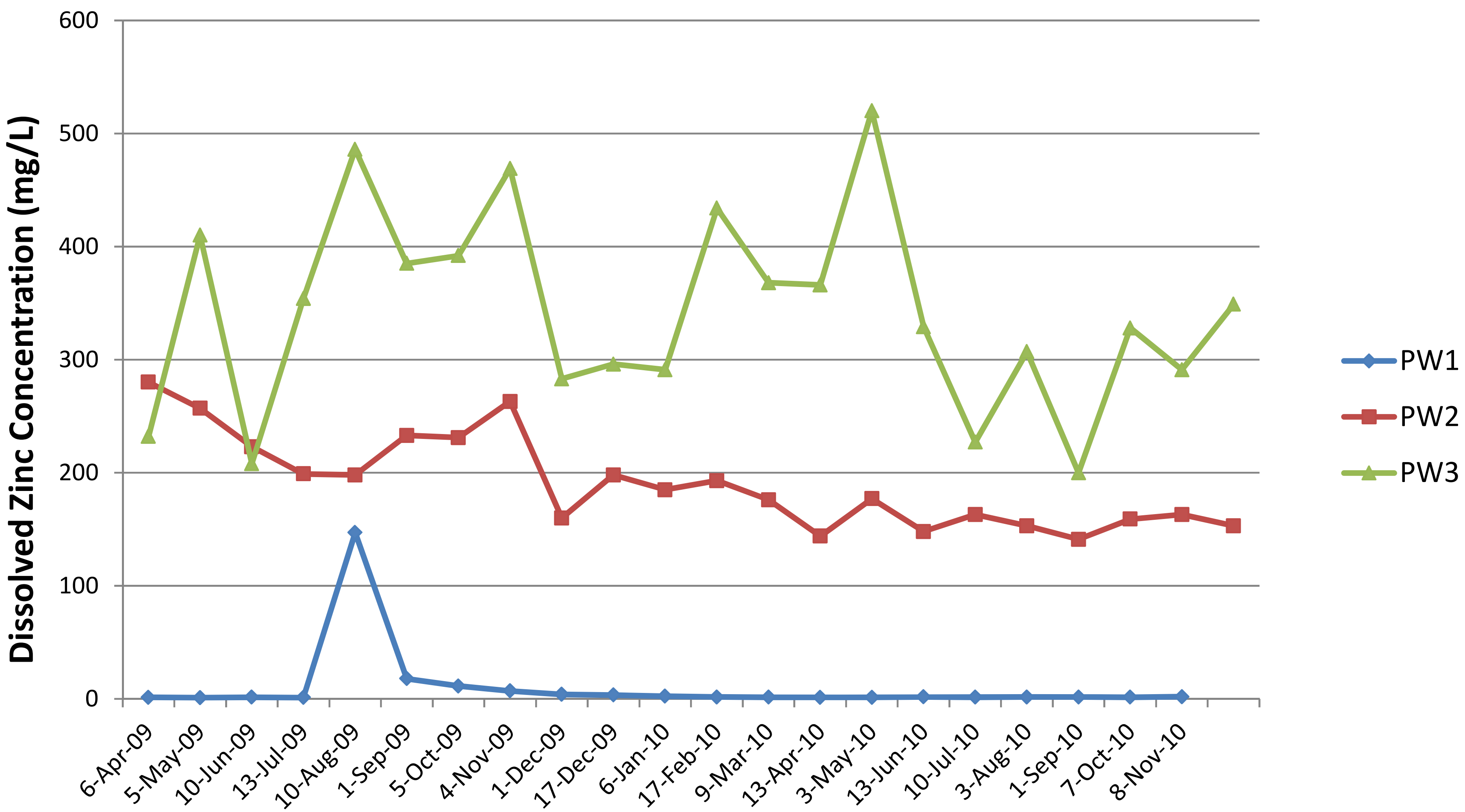

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Zinc Concentrations in S-wells (2009 to 2010)

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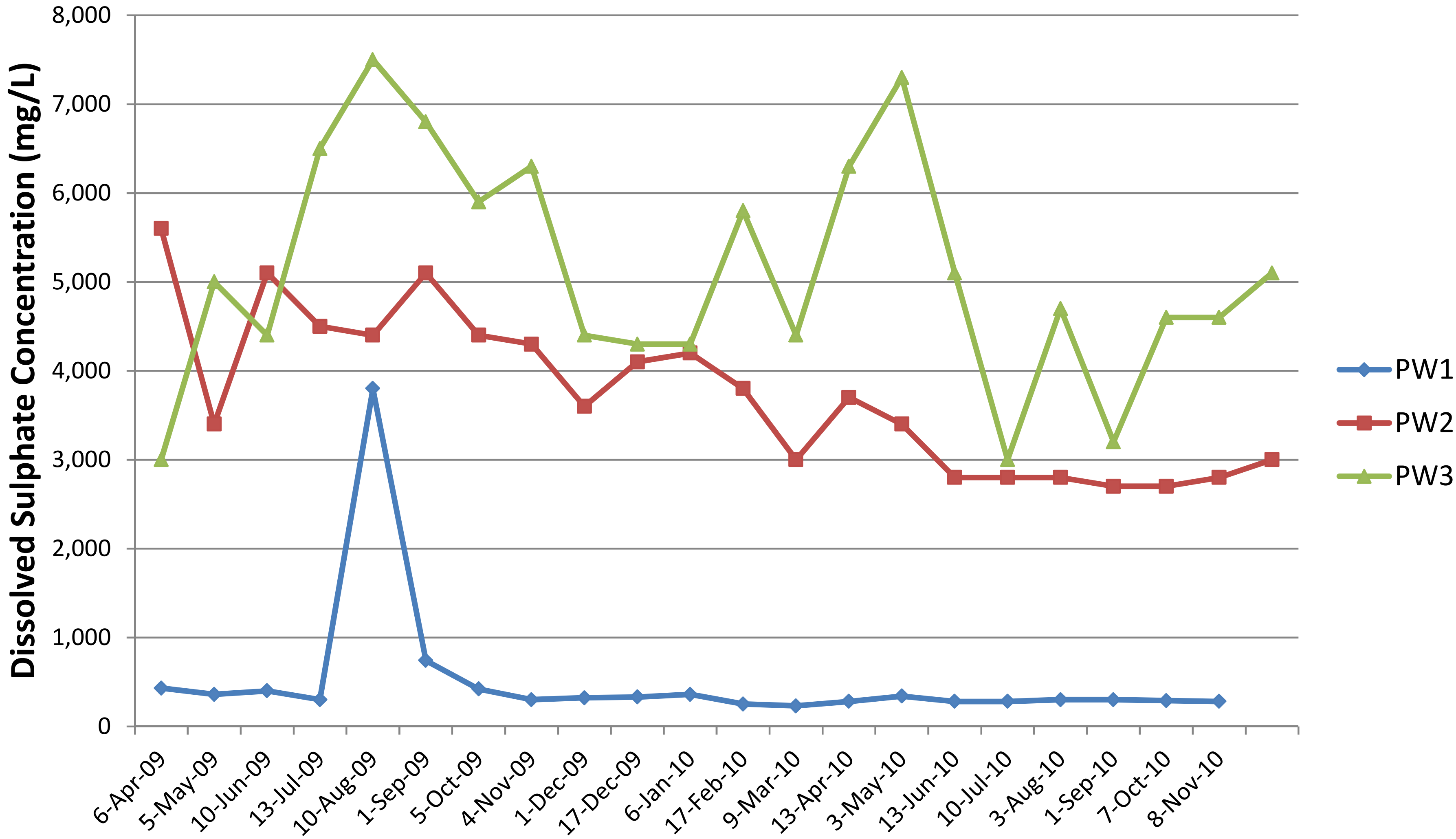

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		Sulphate Concentrations in S-wells (2009 to 2010)
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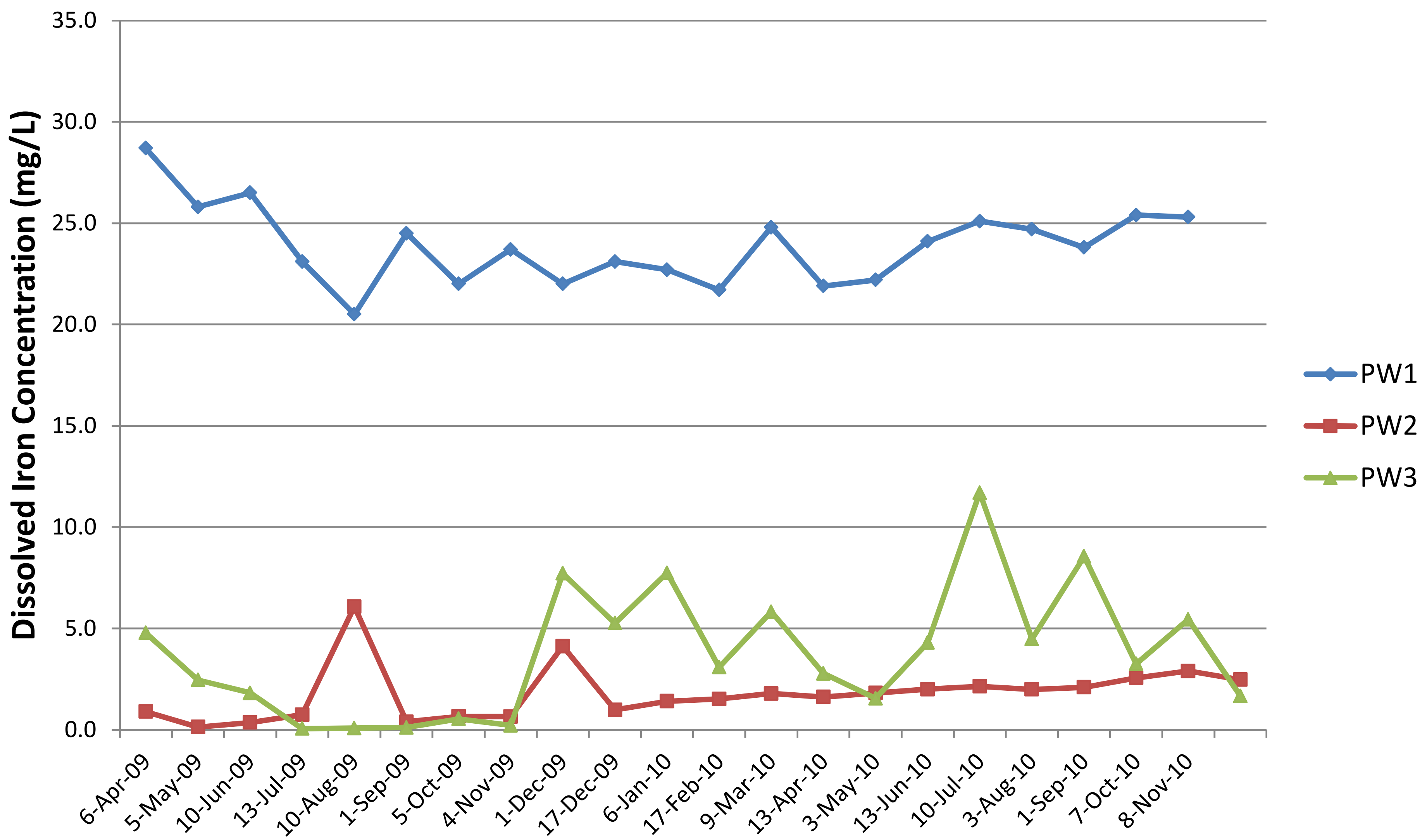

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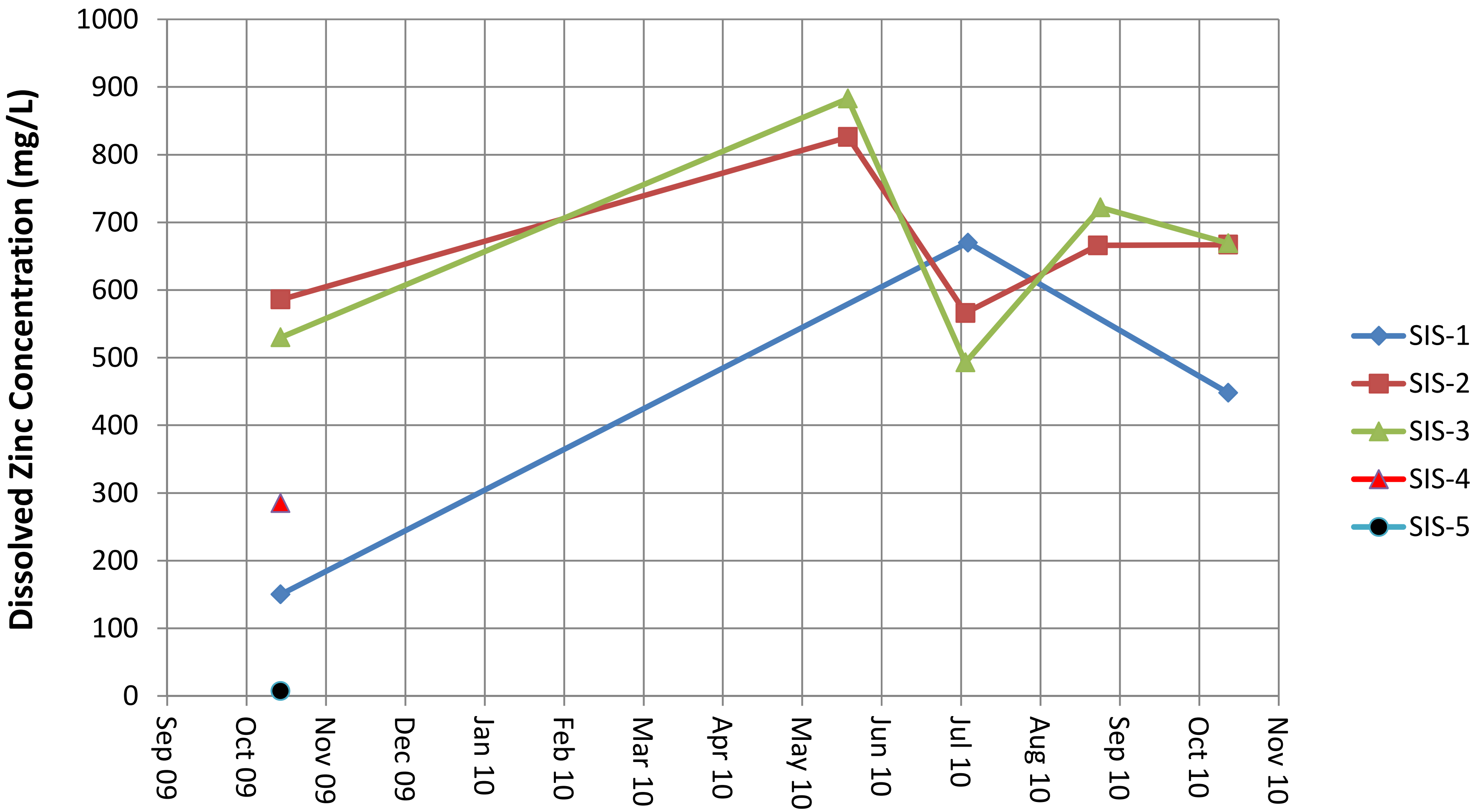

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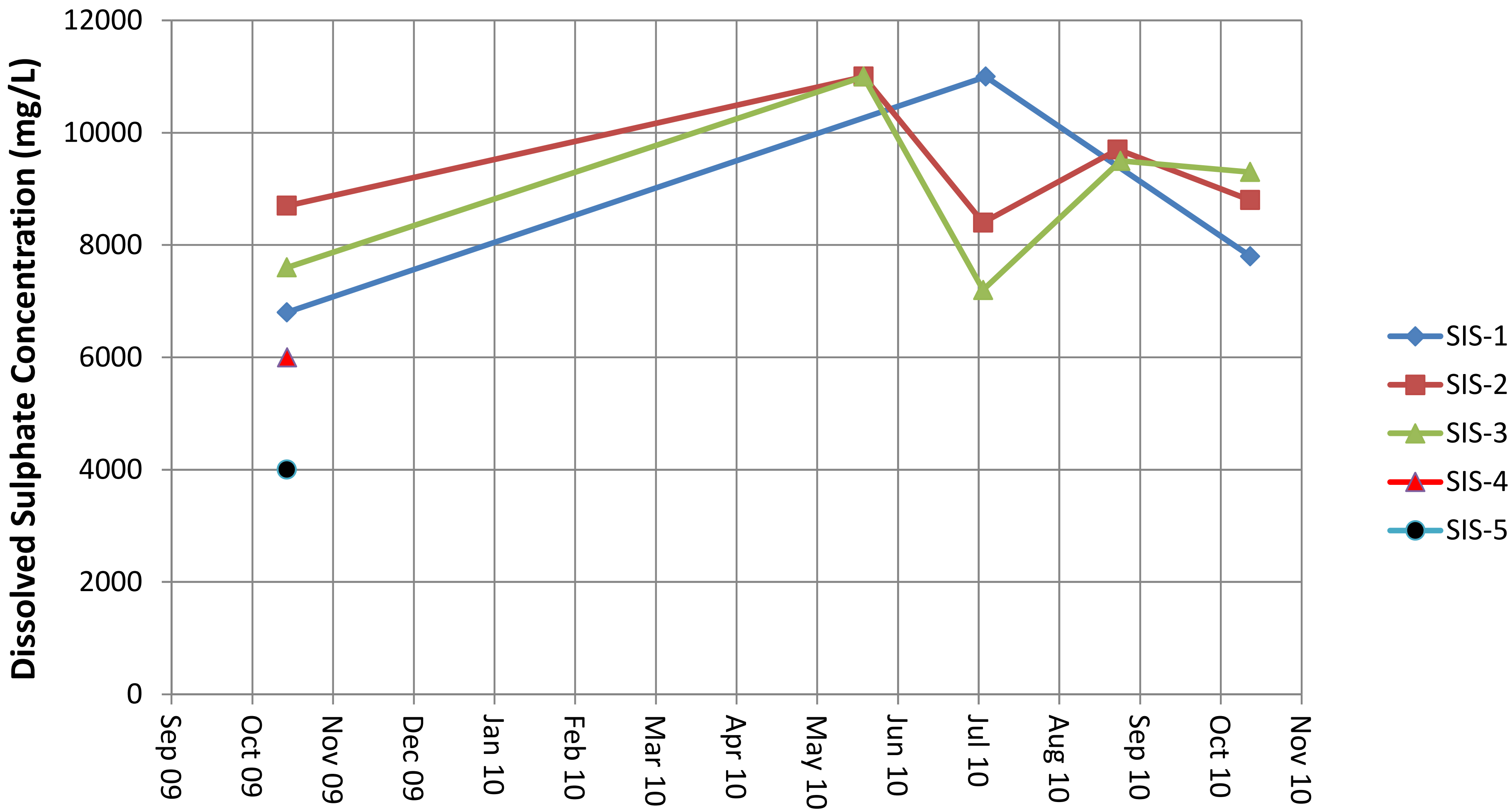

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Sulphate Concentrations in SIS Monitoring Wells (2009 to 2010)

Job No: 1CY001.050

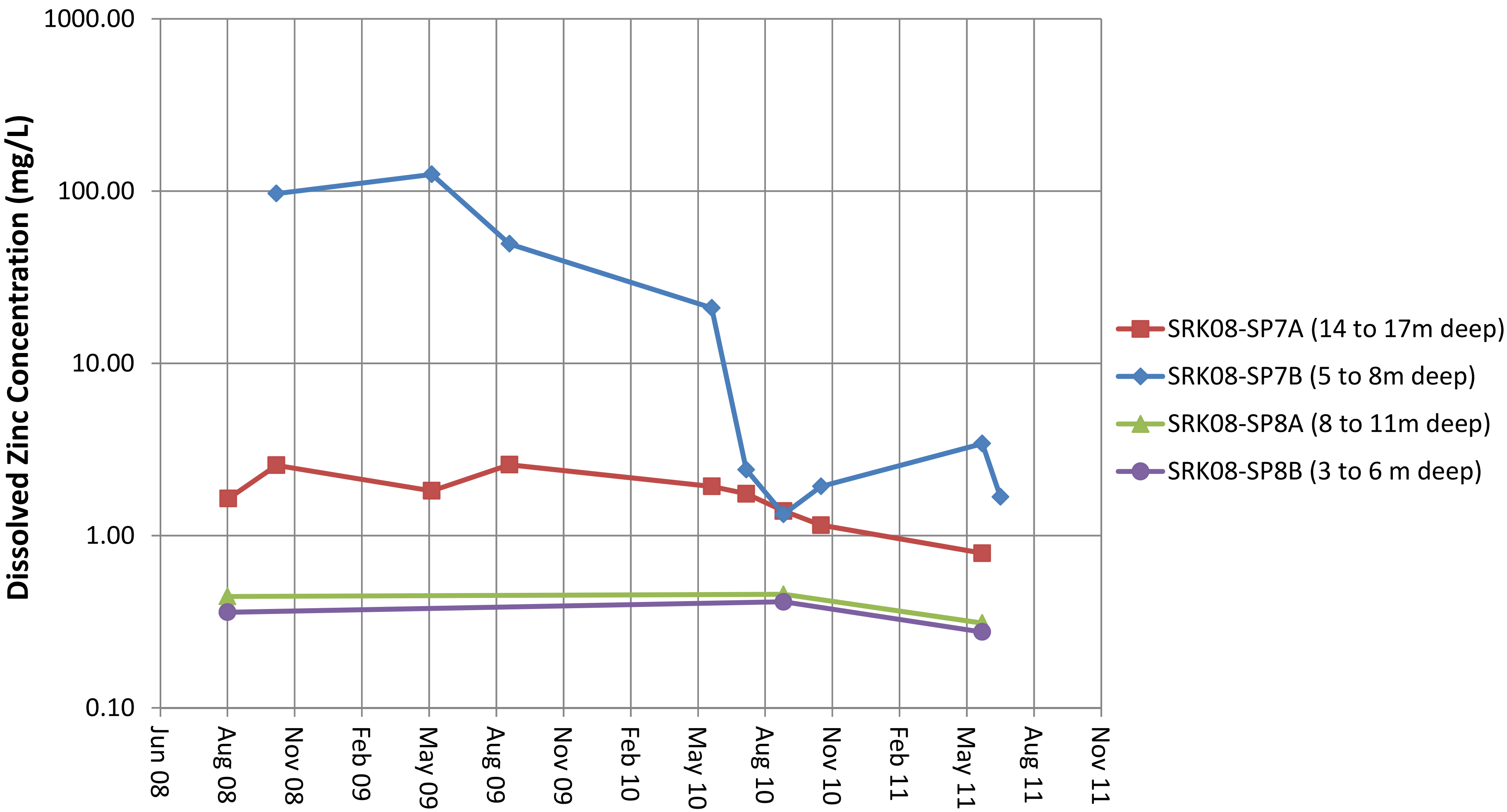
Filename: Figure: 4-9_20110721.pptx

2011 S-wells Performance Review FINAL

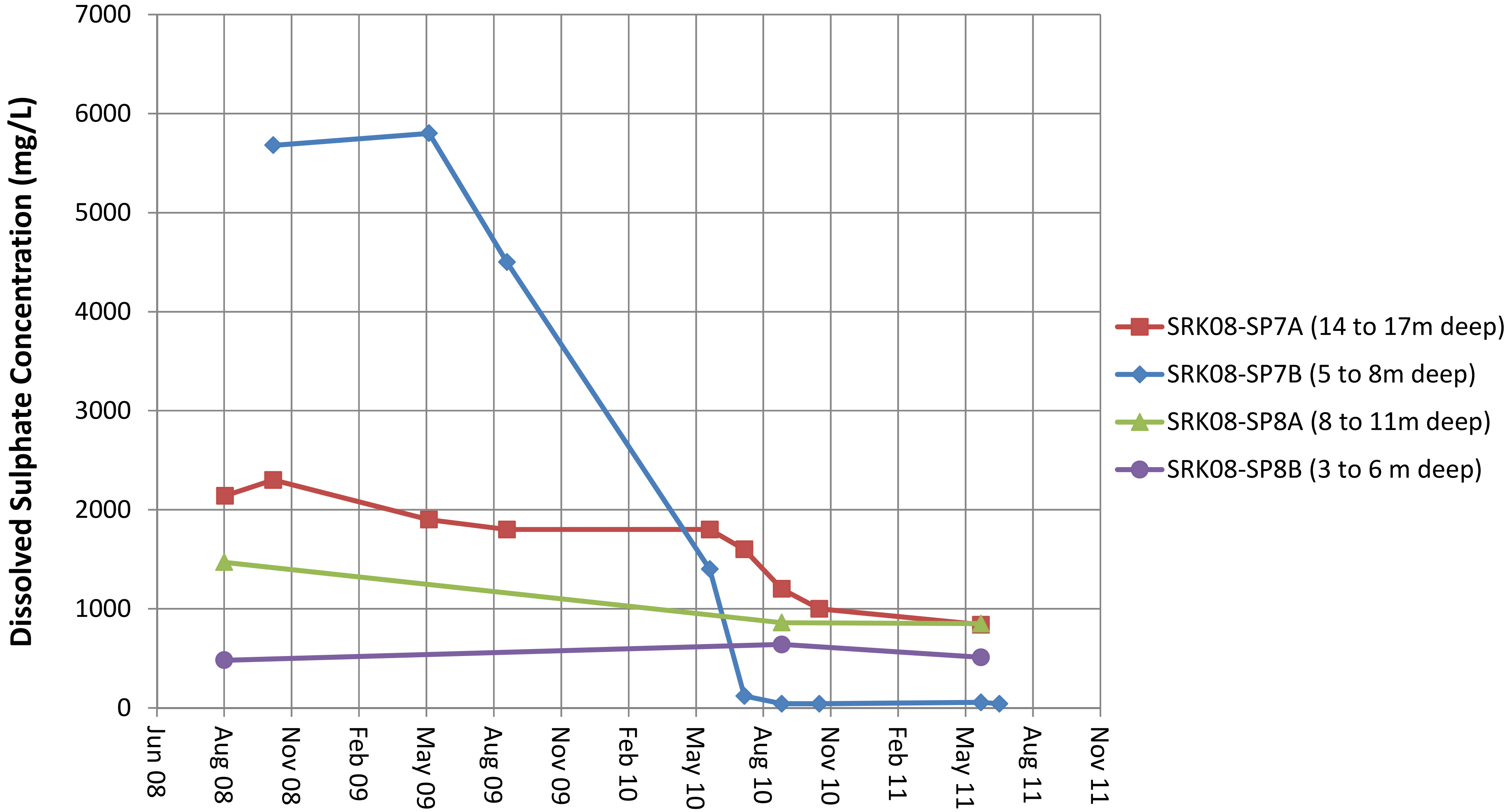
Date: July 2011

Approved: DM

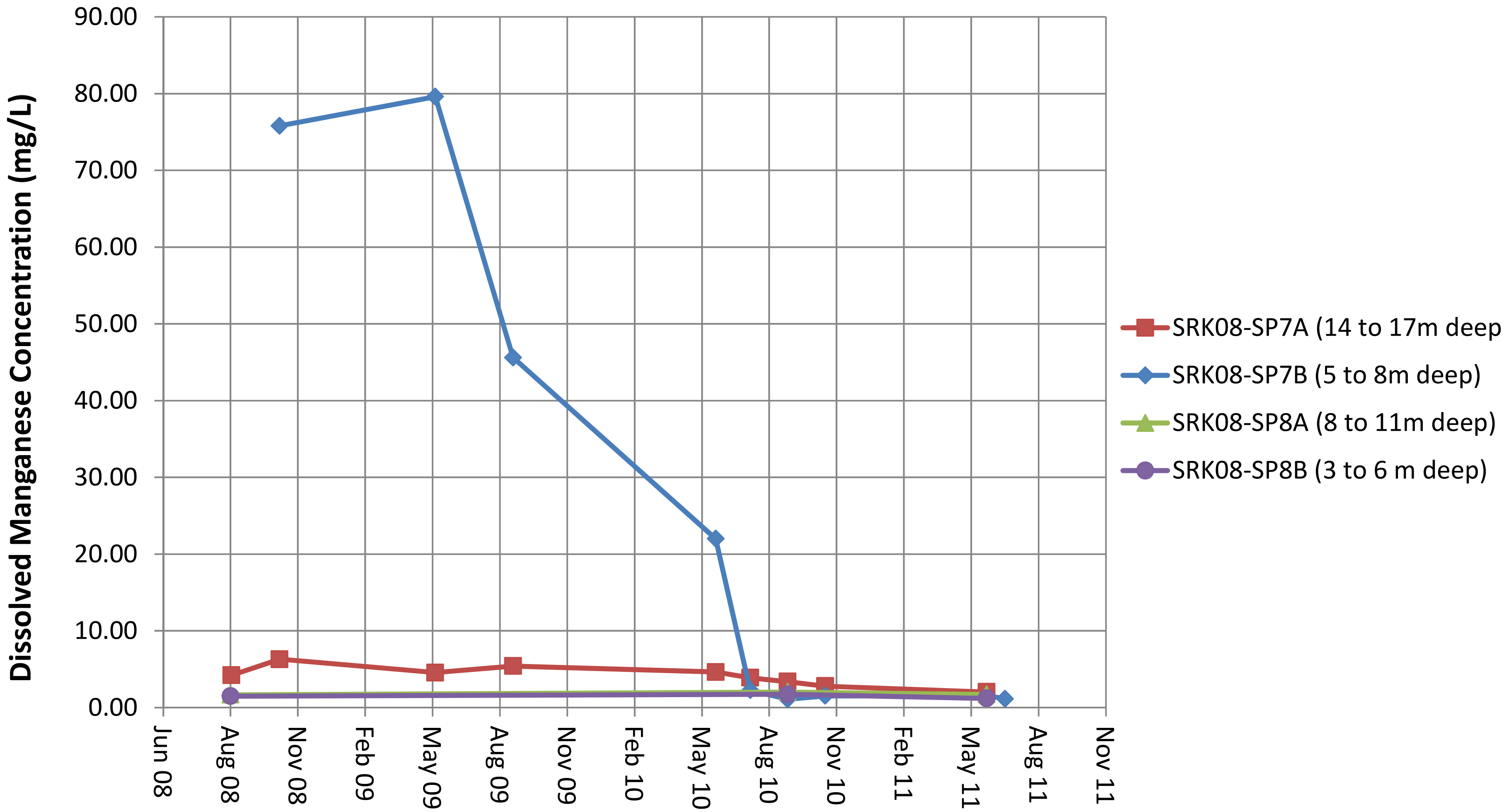
Figure: 4.9



srk consulting	Faro Mine Closure / Fermeture de la mine Faro; Yukon Government	2011 S-wells Performance Review FINAL
		Zinc Concentrations in SP7 and SP8 Monitoring Wells (2008 to 2011)
Job No: 1CY001.050 Filename: Figure: 4-10_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: **4.10**



srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Sulphate Concentrations in SP7 and SP8 Monitoring Wells (2008 to 2011)
Job No: 1CY001.050 Filename: Figure: 4-11_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: **4.11**



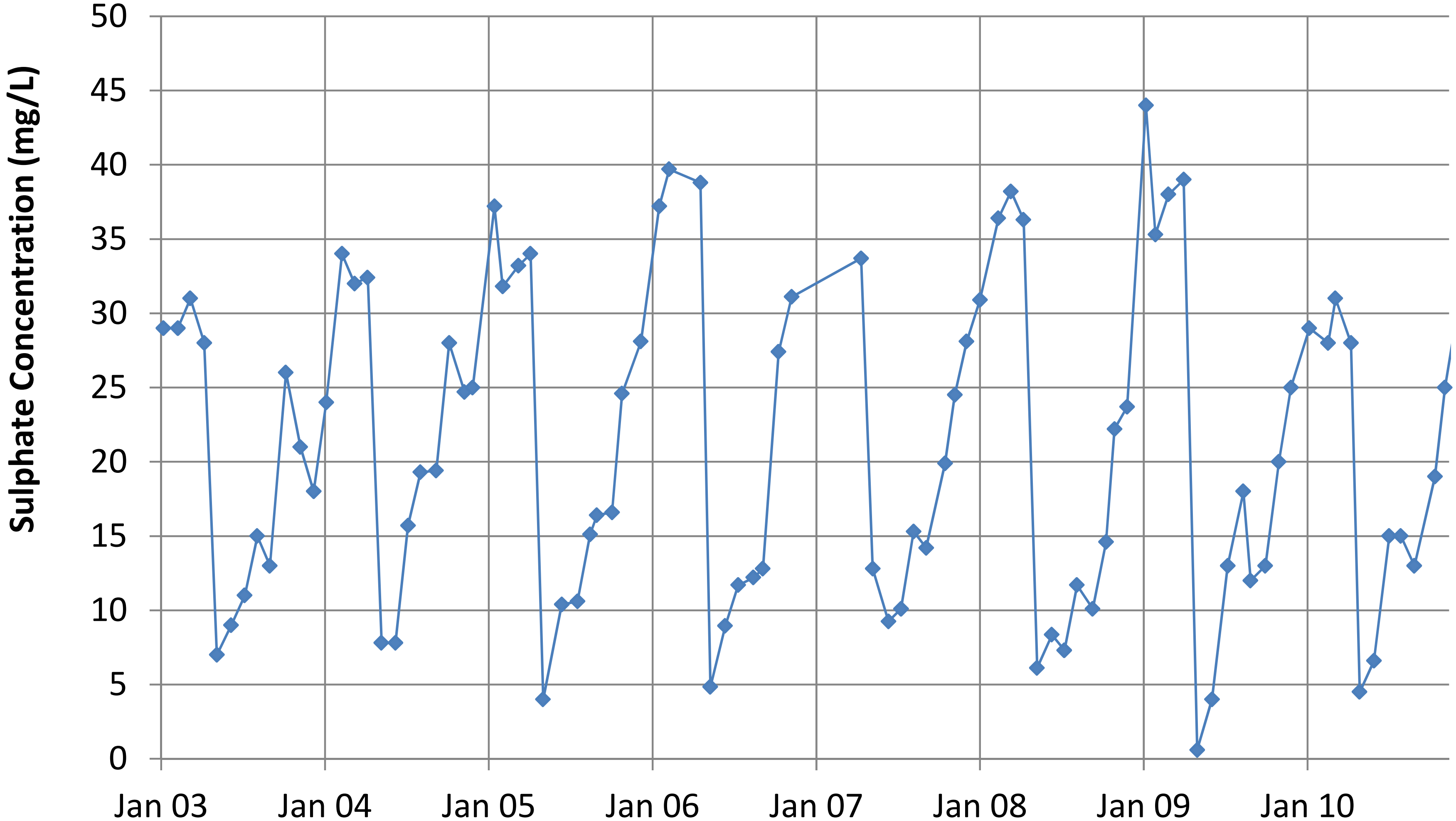
srk consulting | Faro Mine Closure / Fermeture de la mine Faro — Yukon Government | 2011 S-wells Performance Review FINAL

Manganese Concentrations in SP7 and SP8 Monitoring Wells (2008 to 2011)

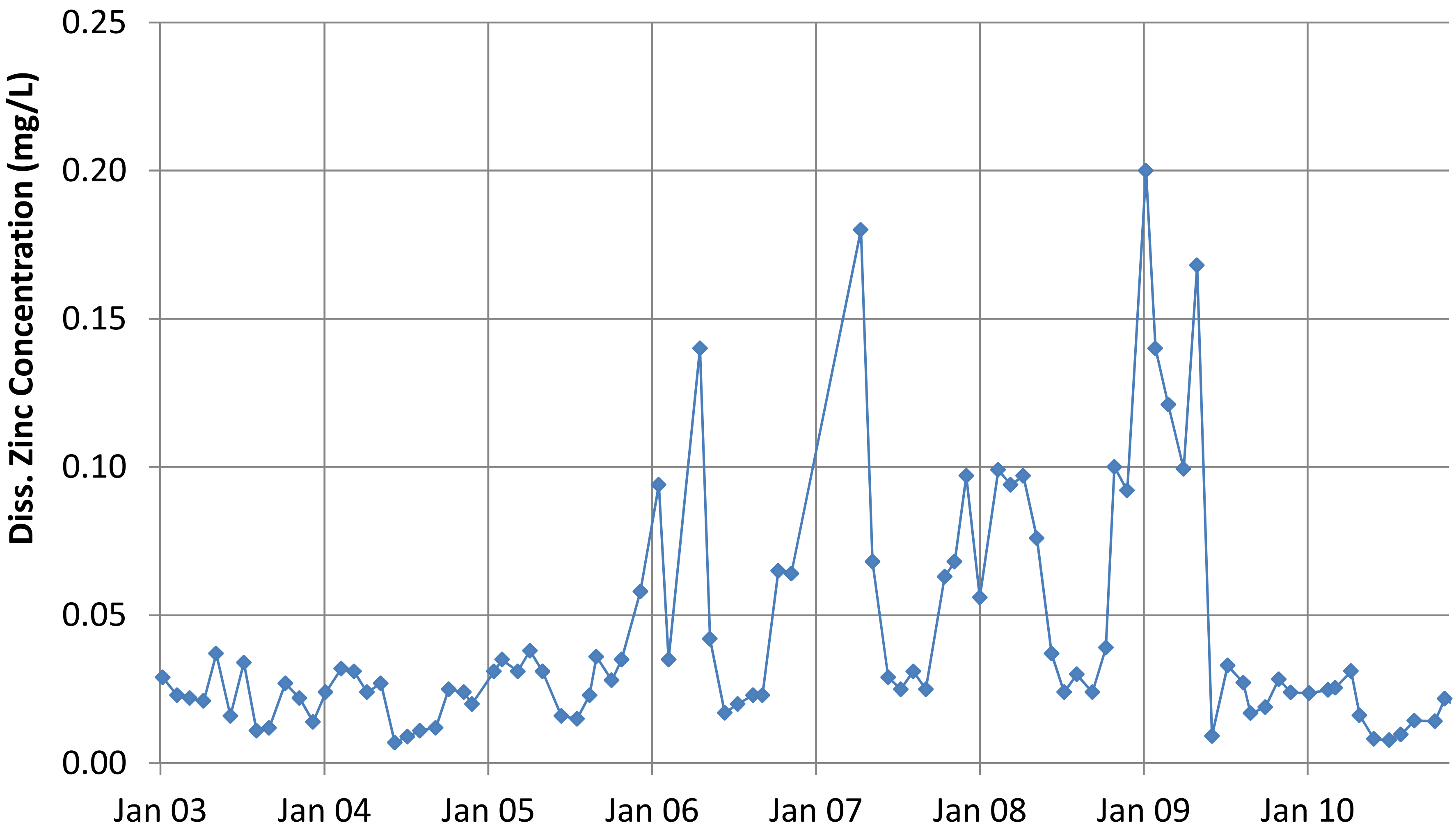
Job No: 1CY001.050
Filename: Figure: 4-12_20110721.pptx

2011 S-wells Performance Review FINAL

Date: July 2011 | Approved: DM | Figure: 4.12



srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Zinc Concentrations at X2, 2003 to 2010
Job No: 1CY001.050 Filename: Figure: 4-13_20110721.pptx	2011 S-wells Performance Review FINAL DRAFT	Date: July 2011 / Approved: DM / Figure: **4.13**



srk consulting	Faro Mine Closure / Fermeture de la mine Faro; Yukon Government	2011 S-wells Performance Review FINAL
		Sulphate Concentrations at X2, 2003 to 2010
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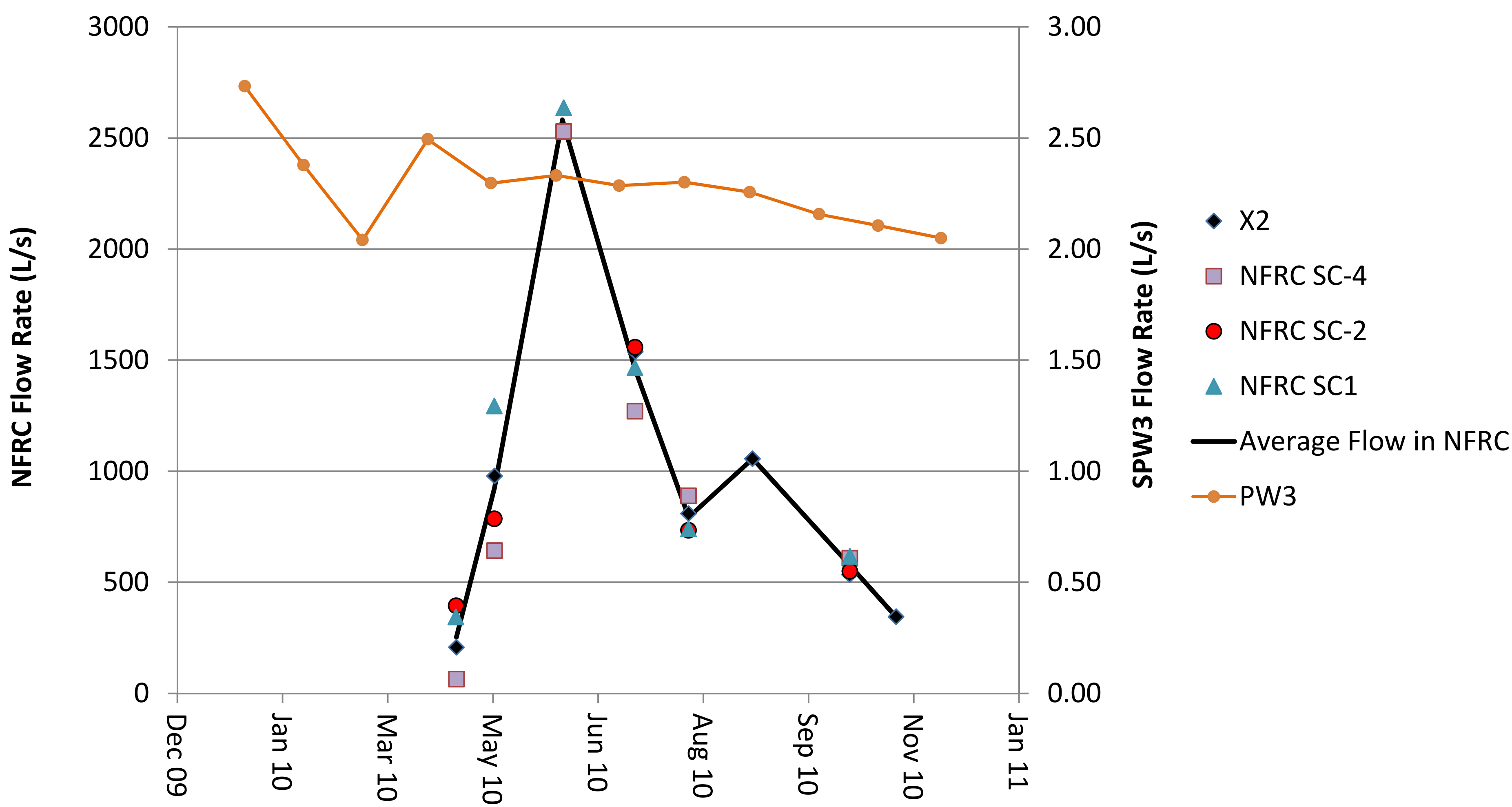
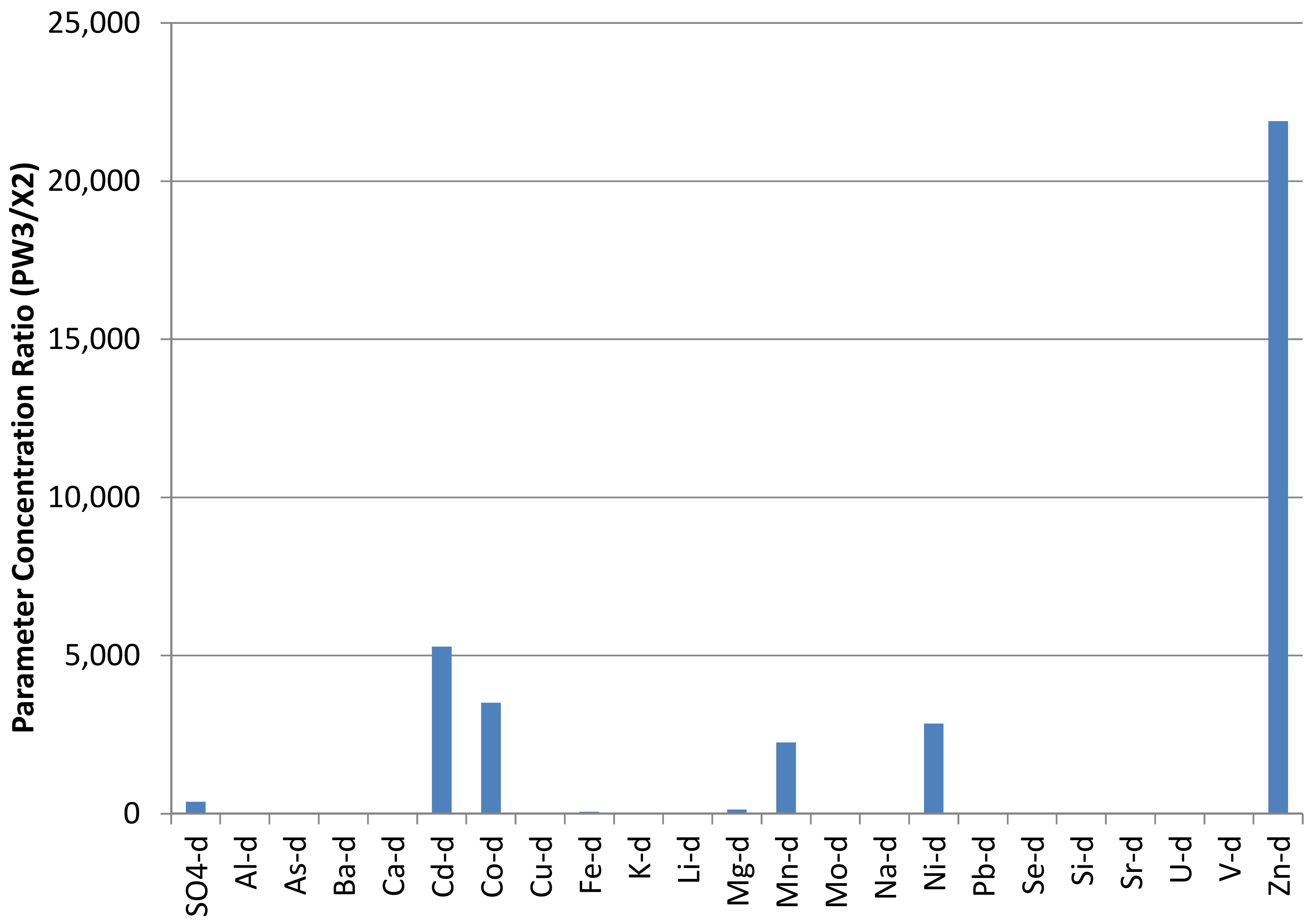
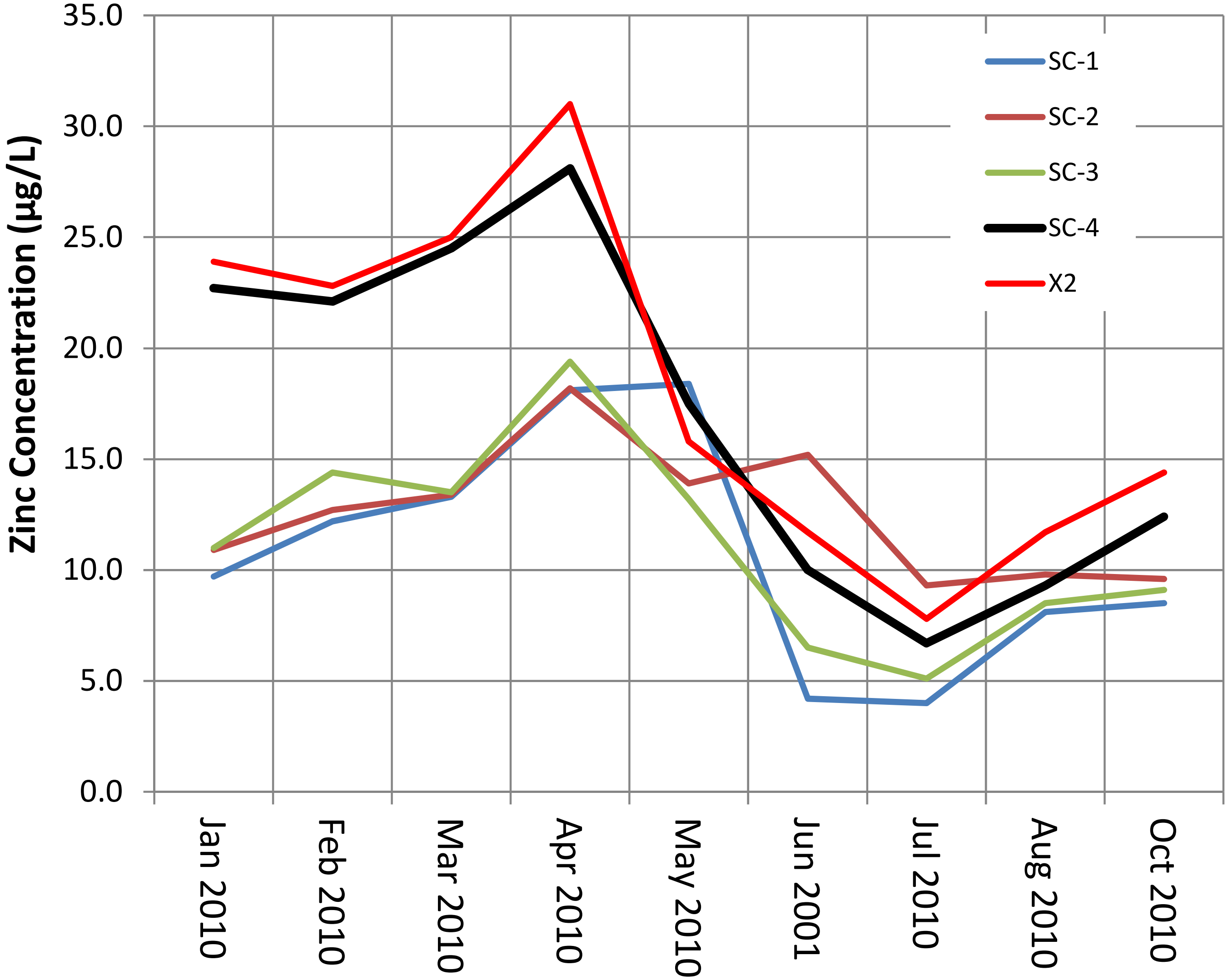


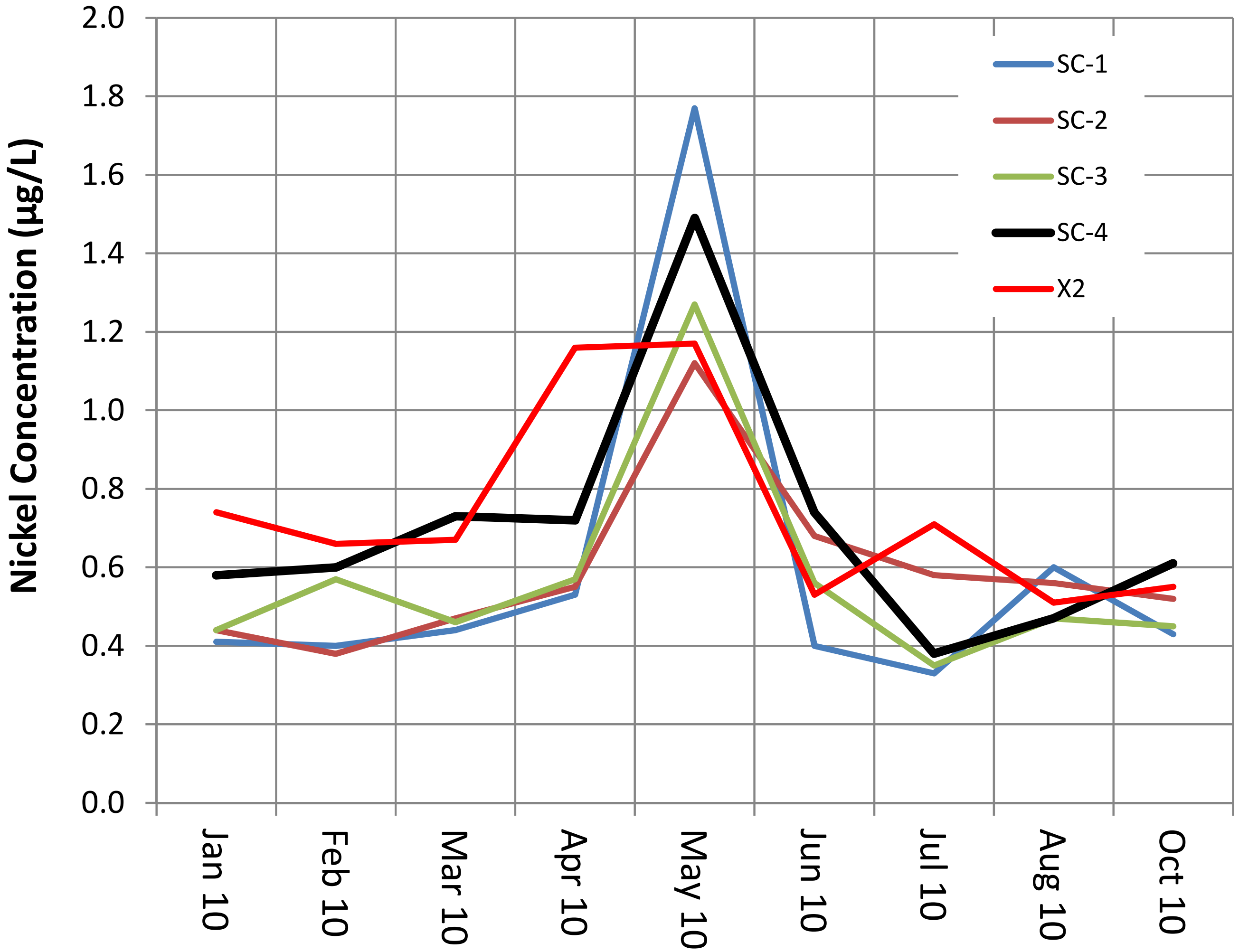
srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		NFRC and PW3 Flow Rates, 2010
Job No: 1CY001.050 Filename: Figure: 4-15_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: 4.15



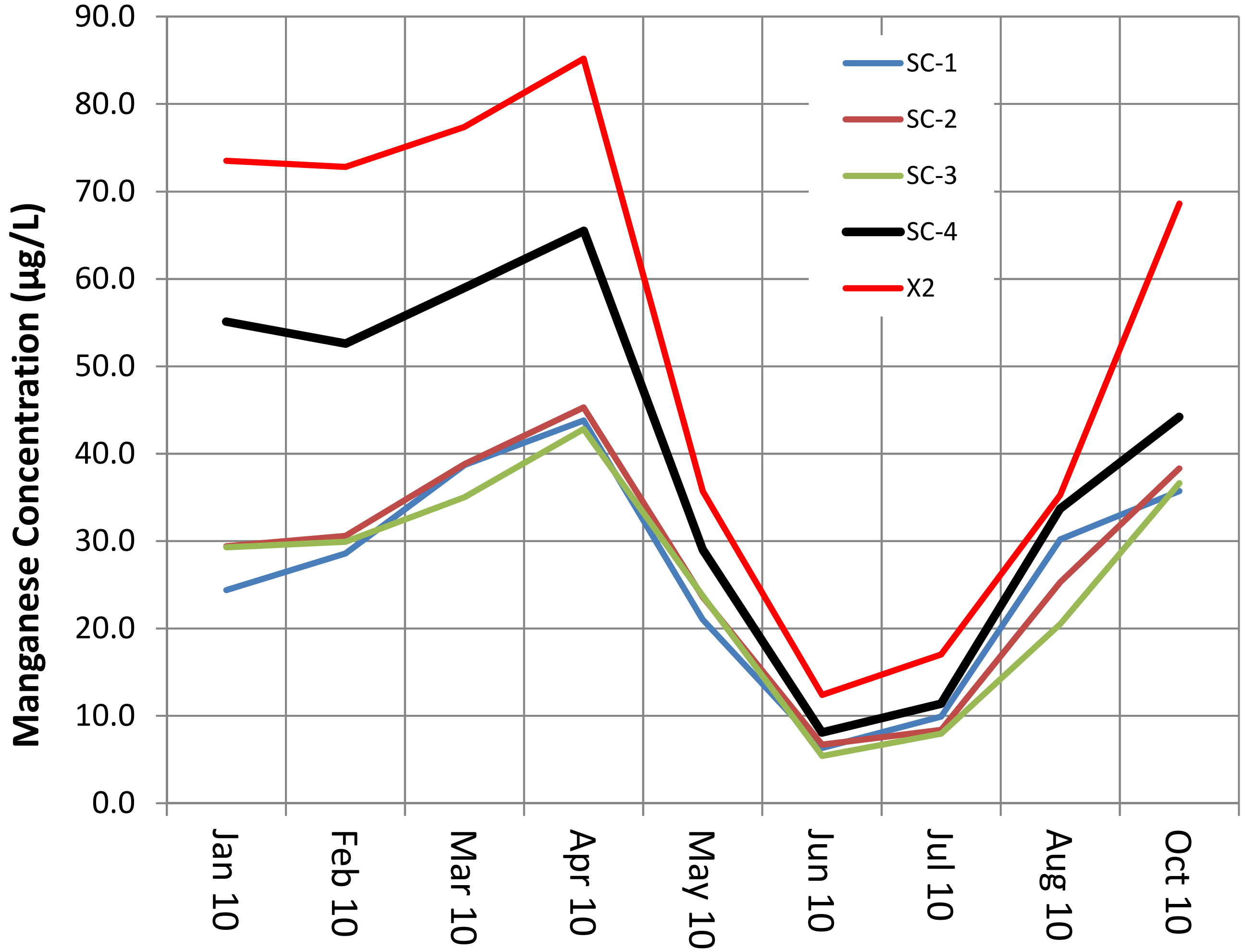
srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Parameter Concentration Ratios PW3/X2
Job No: 1CY001.050 Filename: Figure: 4-16_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 | Approved: DM | Figure: 4.16



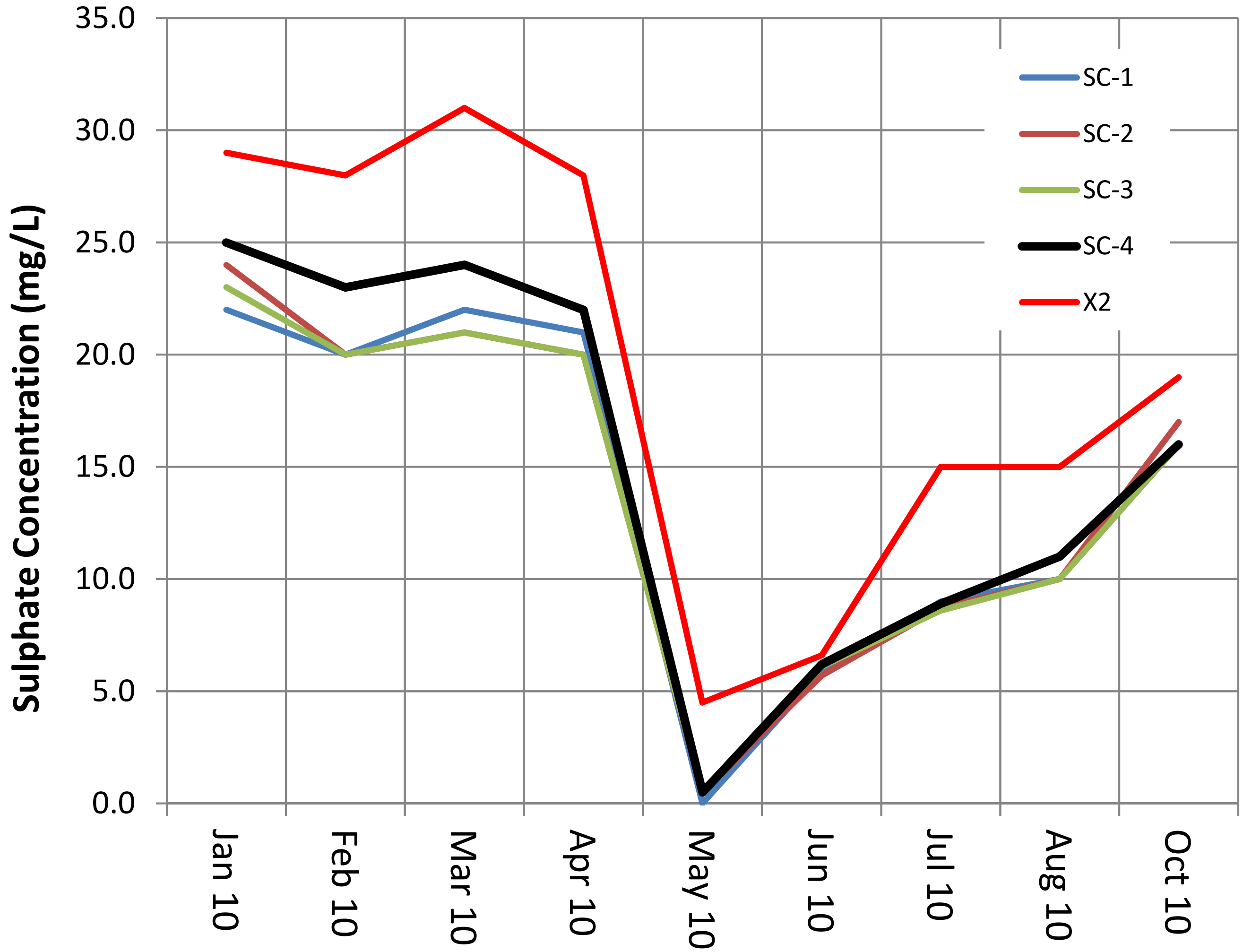
srk consulting	Faro Mine Closure / Fermeture de la mine Faro; Yukon Government	2011 S-wells Performance Review FINAL		
		Zinc Concentrations at Stations on NFRC		
Job No: 1CY001.050 Filename: Figure: 4-17_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011	Approved: DM	Figure: **4.17**



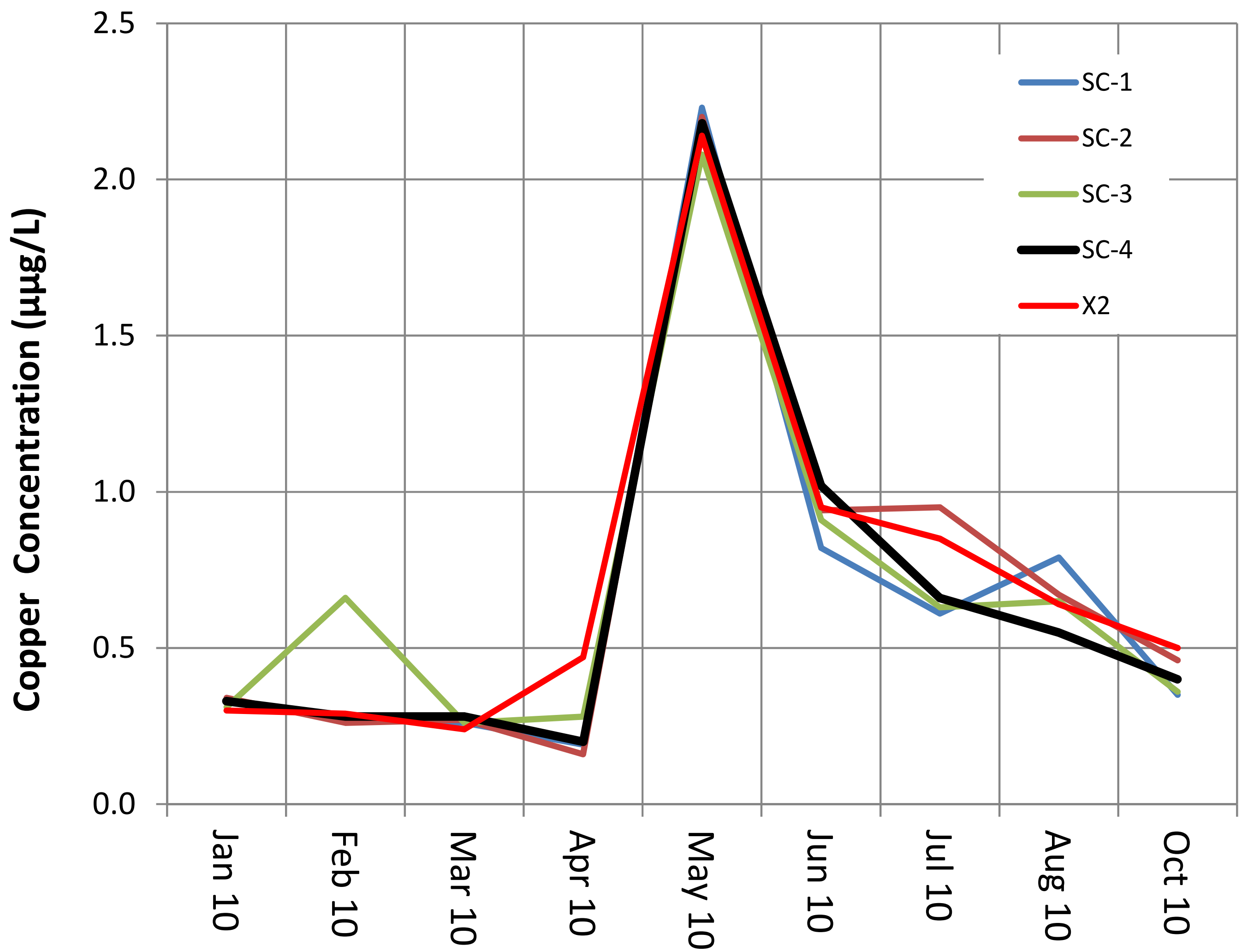
srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Nickel Concentrations at Stations on NFRC
Job No: 1CY001.050 Filename: Figure: 4-18_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 | Approved: DM | Figure: **4.18**



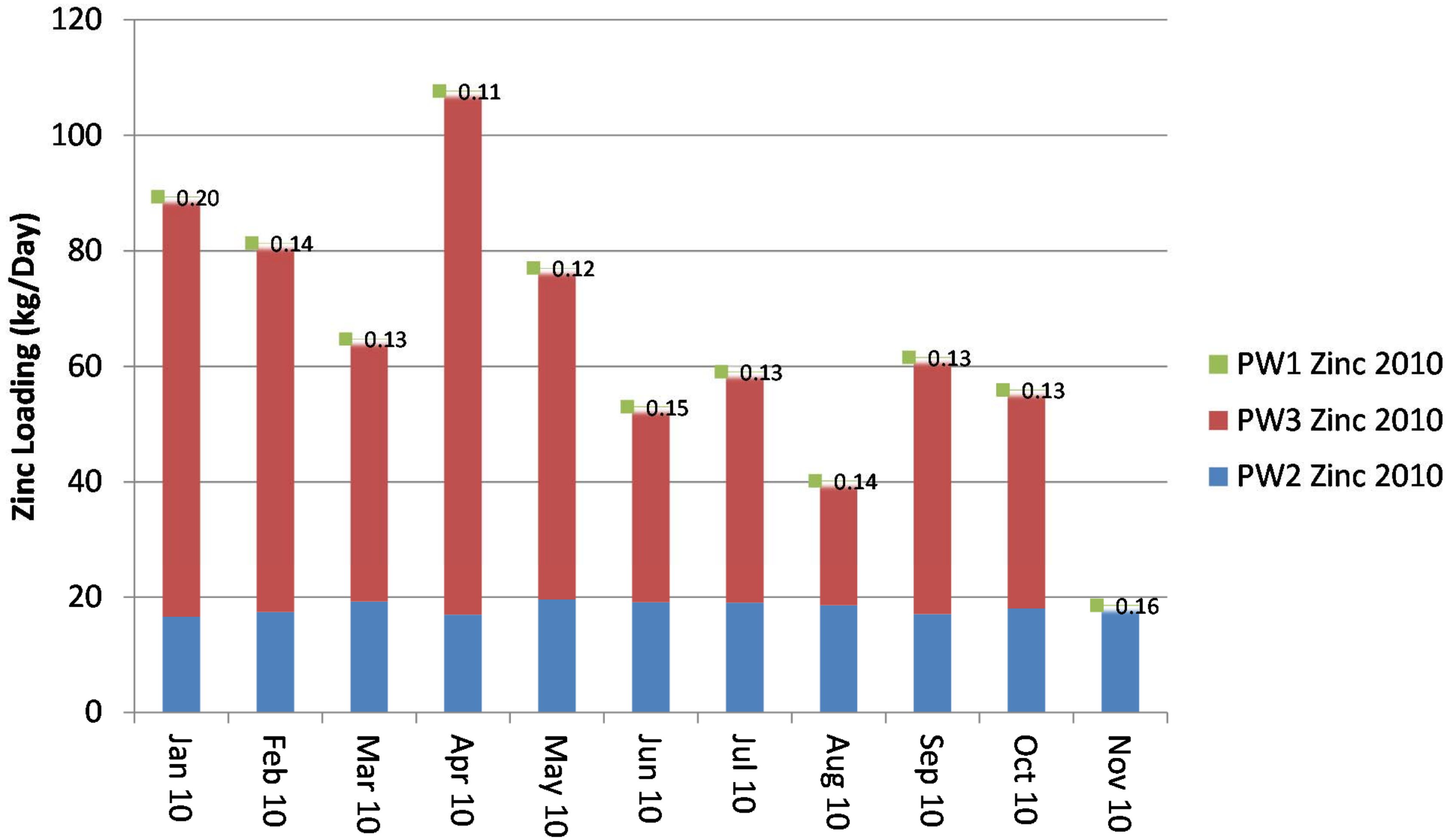
srk consulting	Faro Mine Closure / Fermeture de la mine Faro; Yukon Government	2011 S-wells Performance Review FINAL
		Manganese Concentrations at Stations on NFRC
Job No: 1CY001.050 Filename: Figure: 4-19_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: 4.19



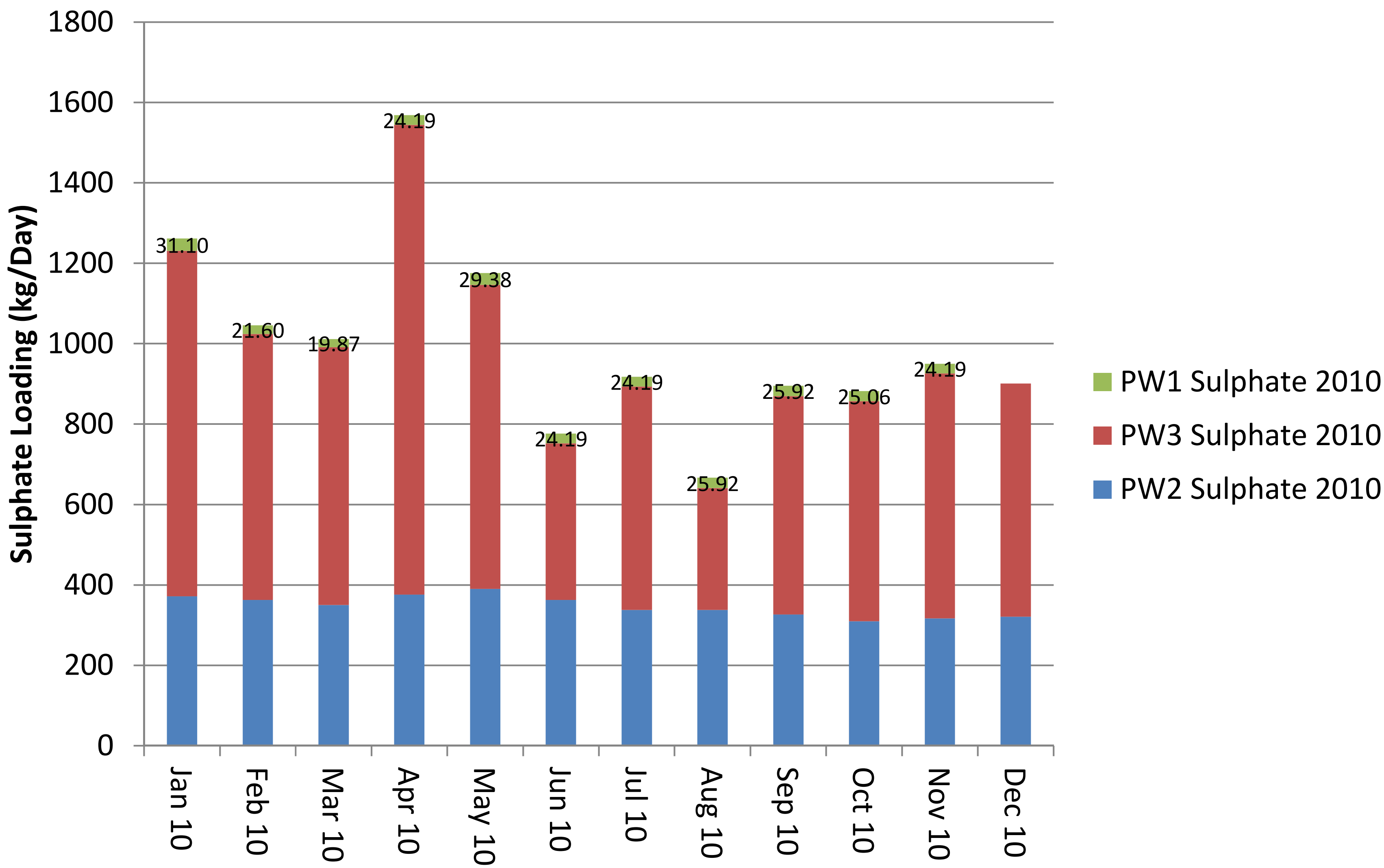
srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Sulphate Concentrations at Stations on NFRC
Job No: 1CY001.050 Filename: Figure: 4-20_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 · Approved: DM · Figure: 4.20



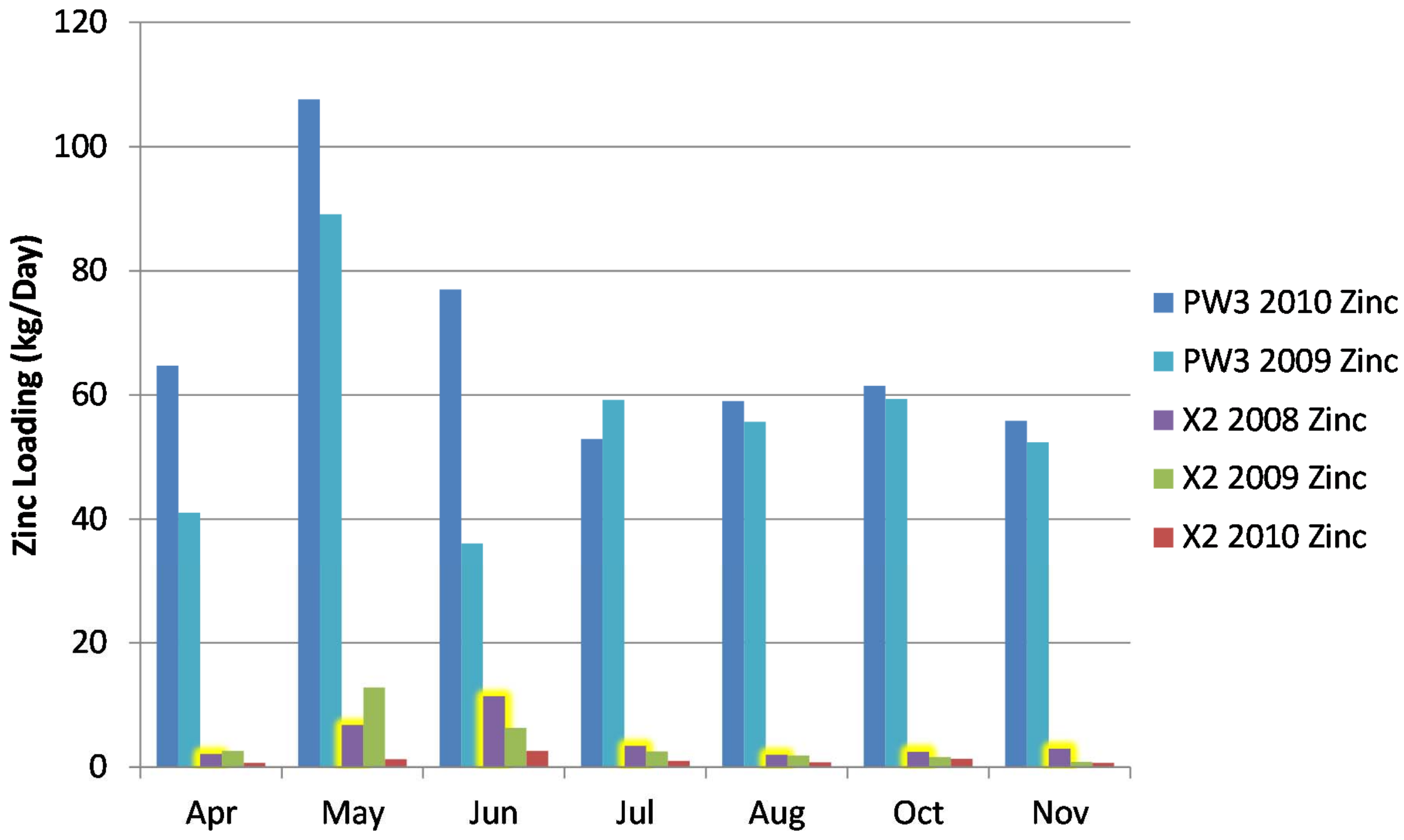
srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Copper Concentrations at Stations on NFRC
Job No: 1CY001.050 Filename: Figure: 4-21_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: **4.21**



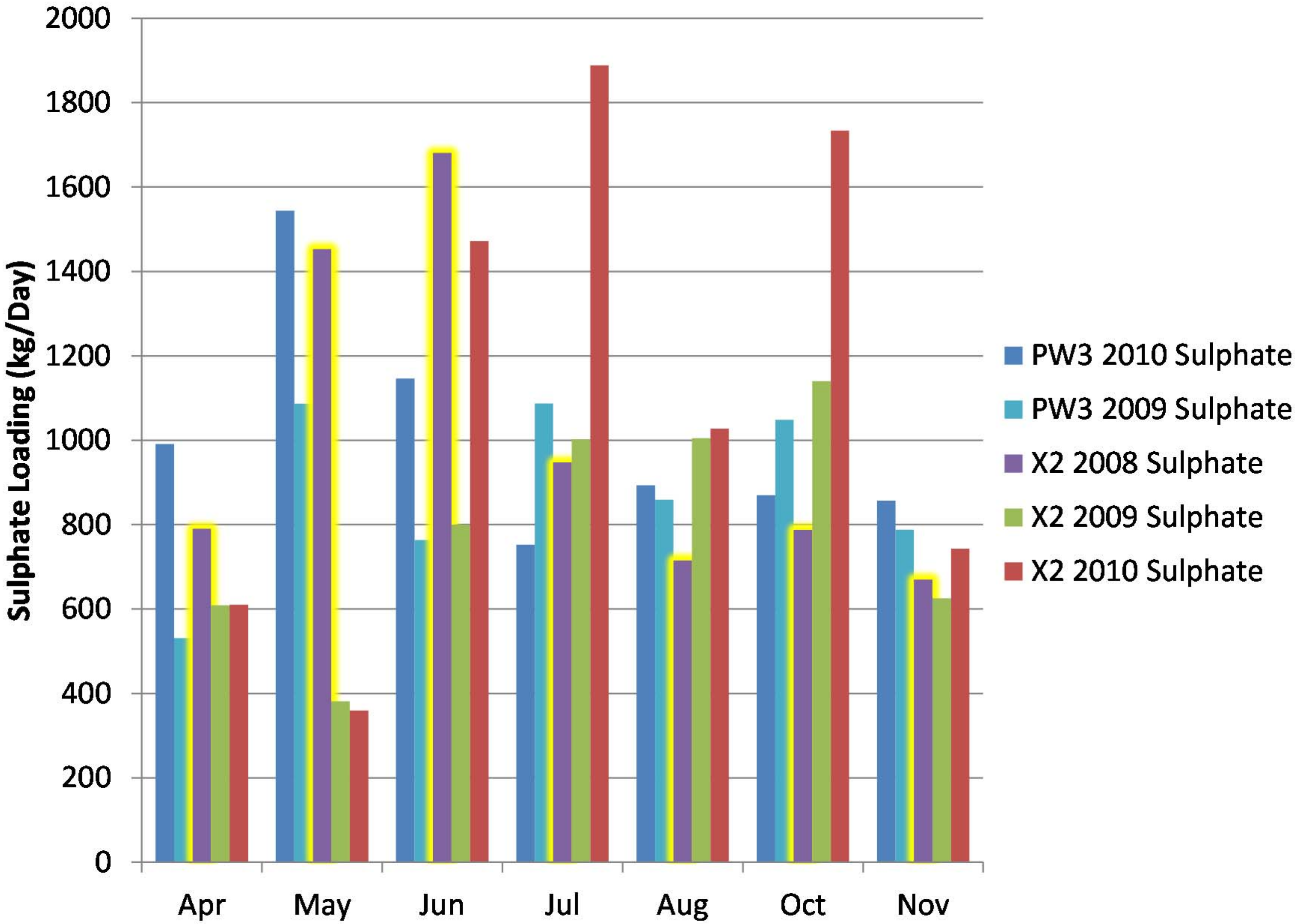
srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Zinc Loadings from PW1, PW2, and PW3 in 2010
Job No: 1CY001.050 Filename: Figure: 4-22_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: 4.22



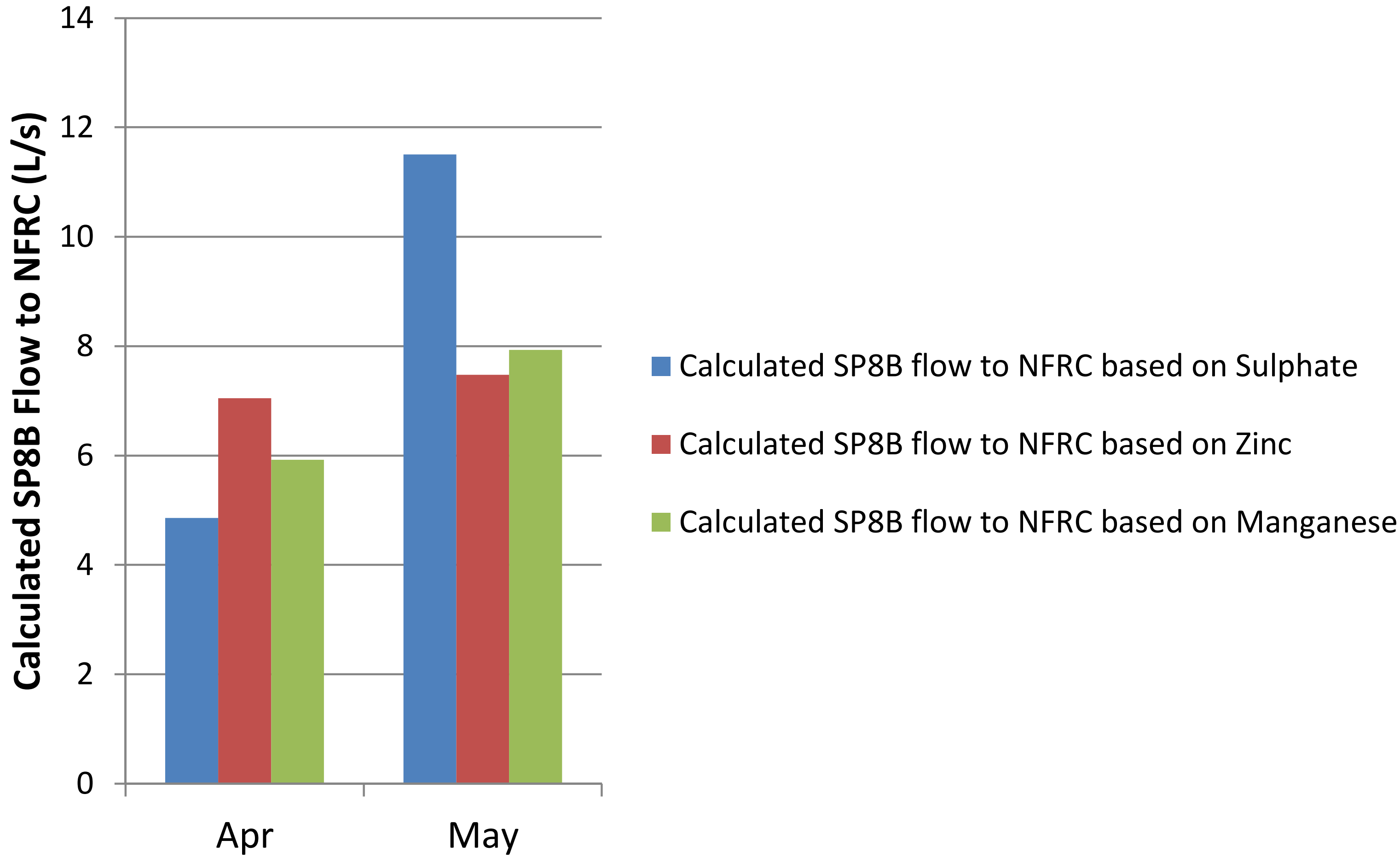
srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL Sulphate Loadings from PW1, PW2, and PW3 in 2010
Job No: 1CY001.050 Filename: Figure: 4-23_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: **4.23**



srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL Zinc Loadings from PW3 and in NFRC, 2010
Job No: 1CY001.050 Filename: Figure: 4-24_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: 4.24

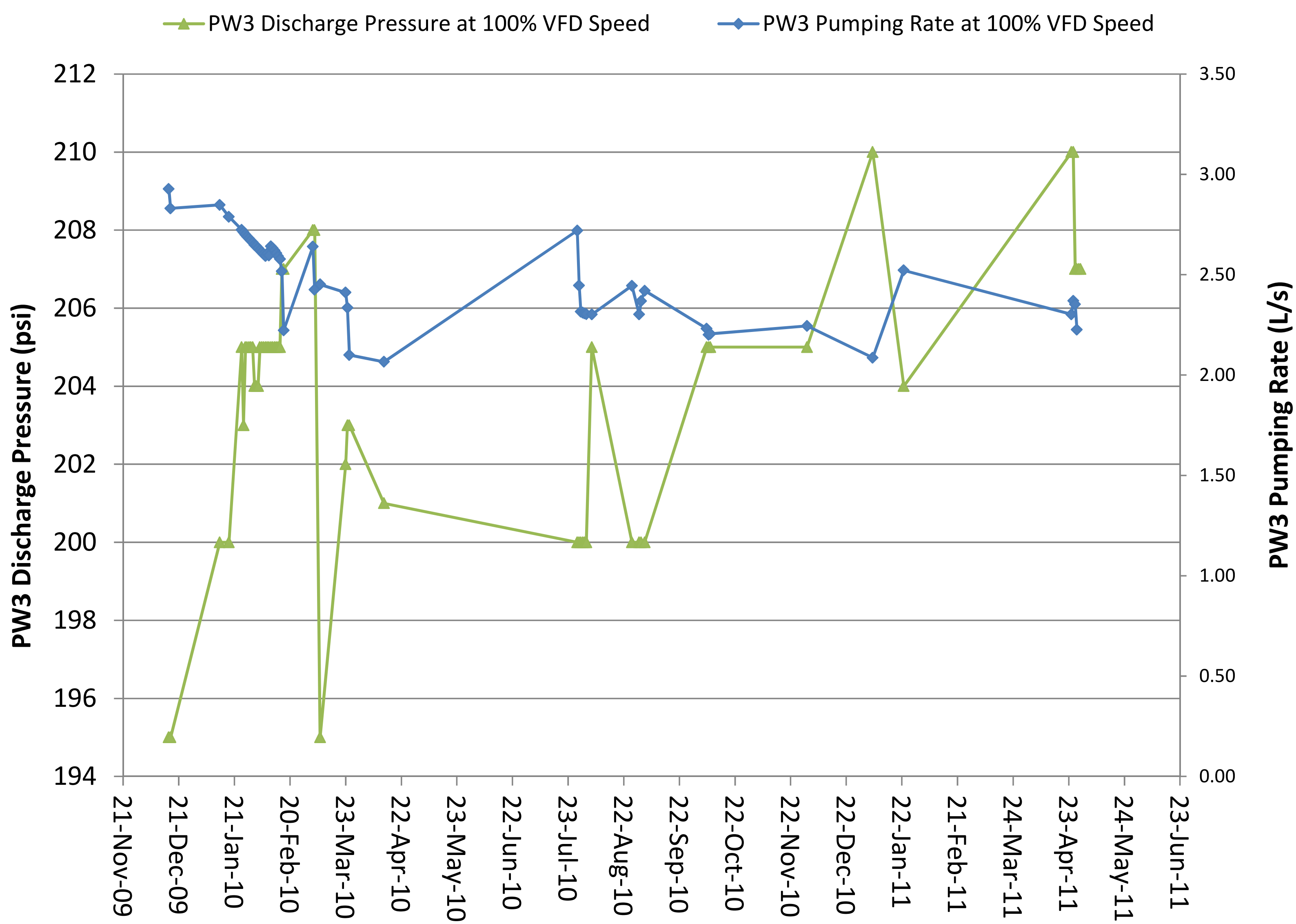


srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Sulphate Loadings from PW3 and in NFRC, 2010
Job No: 1CY001.050 Filename: Figure: 4-25_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 · Approved: DM · Figure: 4.25



srk consulting	Faro Mine Closure / Fermeture de la mine Faro — Yukon Government	2011 S-wells Performance Review FINAL
		Calculated SP8B Seepage flow to NFRC d/s of SC-4
Job No: 1CY001.050 Filename: Figure: 4-26_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 / Approved: DM / Figure: 4.26

srk consulting	Faro Mine Closure / Fermeture de la mine Faro; Yukon Government	2011 S-wells Performance Review FINAL
		Example of Pipe Scaling, SIS Pumping System
Job No: 1CY001.050 Filename: Figure: 4-27_20110721.pptx	2011 S-wells Performance Review FINAL	Date: July 2011 | Approved: DM | Figure: **4.27**



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Example of Pipe Scaling, SIS Pumping System

Job No: 1CY001.050

Filename: Figure: 4-28_20110721.pptx

2011 S-wells Performance Review FINAL

Date: July 2011

Approved: DM

Figure: 4.28

Appendices

Appendix A – Digital Data