TECHNICAL MEMORANDUM

Date: November 18, 2011
Project No.: 073-93081-02.480
To: Hank Nelson
Company: Avista Corporation
From: Brian Mattax / Dana Schmidt
cc:
Email: bmattax@golder.com

RE: 2011 TDG MONITORING AT POST FALLS HED

Avista Corporation (Avista) owns and operates Post Falls Hydroelectric Development (HED) under the Spokane River Project No. 2545 license issued by the Federal Energy Regulatory Commission (FERC). Post Falls HED is the eastern-most of these five HEDs and is located on the Spokane River in northern Idaho (Kootenai and Benewah counties). The Spokane River originates at the outlet of Coeur d'Alene Lake in Idaho and flows westerly approximately 111 miles to the confluence with the Columbia River in eastern Washington (which is now within Lake Roosevelt, the impoundment created by Grand Coulee Dam). Post Falls HED is located 9 miles downstream of Coeur d'Alene Lake at river mile 102.

During relicensing of the project, preferential use of the south channel was identified as a potential means to reduce naturally high total dissolved gas (TDG) production below the Post Falls HED. To facilitate this goal, Avista developed conceptual Interim Spill Gate Operating Protocols to maximize the use of the South Channel to the degree reasonably practical given the requirements for manual operation of these gates. A team of Avista engineers, operators, and license implementation staff refined the Post Falls HED Interim Spill Gate Operating Protocols as described in Figure 1. Under this protocol South Channel gates will be placed into service before the North Channel sector gate for forecasted prolonged high-flow spill events.

The North Channel tainter gates, which offer much more versatile control than either the sector gate or South Channel gates, will be the first spill gates placed into operation. After the North Channel tainter gates reach capacity, South Channel gates will be used, followed by the North Channel sector gate. If the spill event is forecasted to be of moderate flow or short duration, Option B is chosen. This choice utilizes the North Channel sector gate if the tainter gates reach capacity. Specific procedures for operation of these gates are found in Appendix A of the Total Dissolved Gas (TDG) Control and Mitigation Program[1].

[1] Golder Associates Inc. 2010. Post Falls Hydroelectric Development Total Dissolved Gas Control and Mitigation Program, Ordering Paragraph H, Spokane River Hydroelectric Project FERC Project No. 2545. Prepared for Avista Corporation. June 2010.

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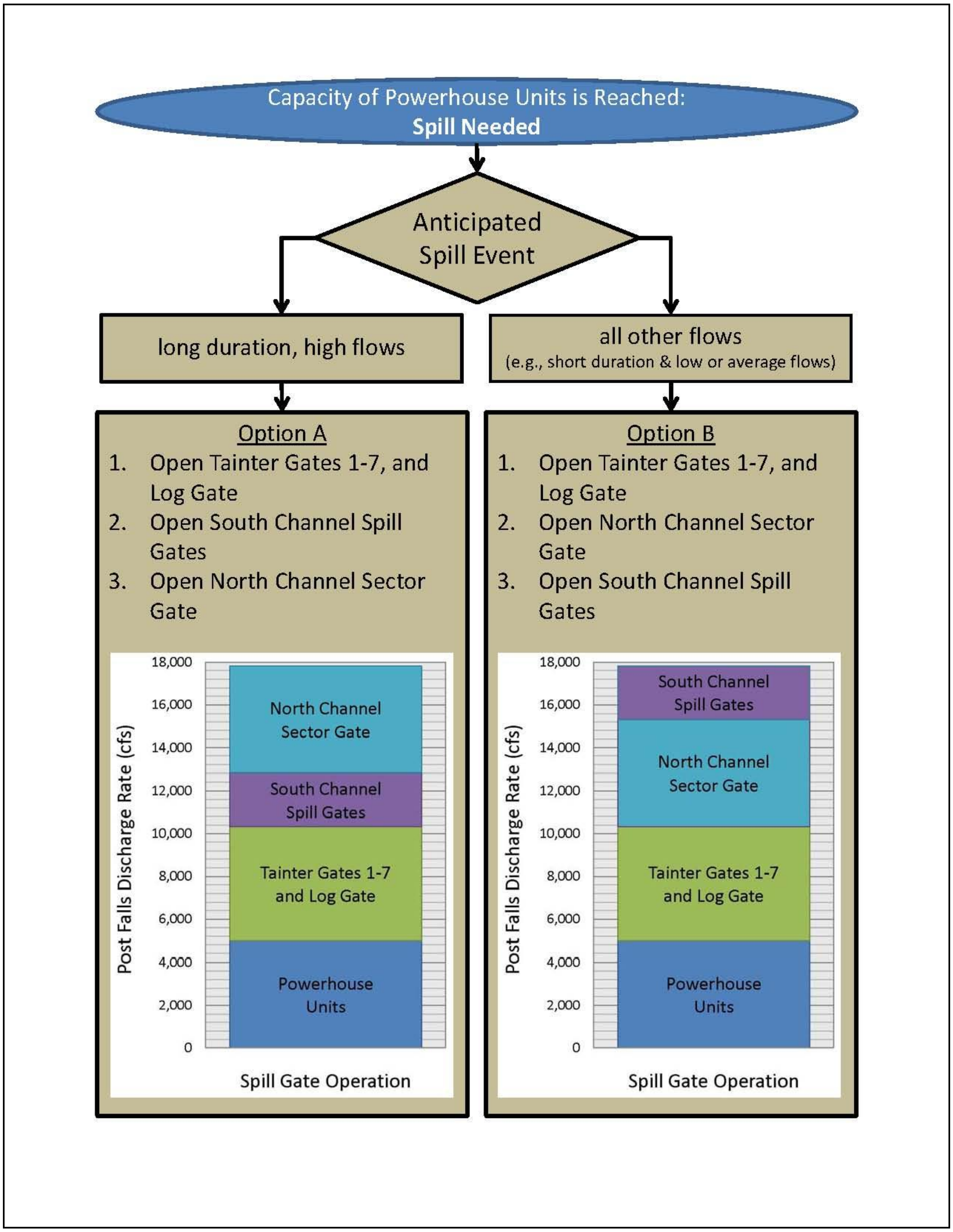

Figure 1: Interim Spill Gate Operating Protocols

The monitoring plan for the Post Falls HED TDG Control and Mitigation Program has an objective to:

- Confirm that the Interim Spill Gate Operating Protocols are effective at reducing TDG levels as compared to typical operations, which preferentially use the North Channel for spills.

During 2011, TDG monitoring targeted total discharges of 11,000 to 17,500 cfs, and prioritized Option A spill gate operations following procedures described in the Post Falls HED TDG Control and Mitigation Program. Spot measurements of TDG were made in the Post Falls HED forebay and at the U.S. Geological Survey (USGS) gage No. 12419000 near Post Falls, Idaho (Table 1). In order to minimize varied discharges of paired TDG spot measurements, monitoring was done first at the upstream (forebay) station then the USGS gage. USGS 15-minute discharge data for the “Near Post Falls” gage were acquired from the USGS for the duration of the TDG monitoring season. Avista provided Post Falls HED operations data for days that spot measurements were conducted.

Table 1: Post Falls HED TDG Monitoring Stations

Station Code	Description	Latitude / Longitude (NAD83)	Monitoring Type
PFFB	Post Falls HED forebay	47°42'33" / 116°57'38"	Spot measurements
PFTR	Spokane River Near Post Falls, Idaho USGS gage station 12419000	47°42'11" / 116°58'40"	Spot measurements

1.0 DATA SUMMARY AND CONCLUSIONS

TDG measurements were conducted on four days during the 2011 Post Falls HED spill season. Option A operations occurred on the first three days and Option B operations occurred on the last day. Table 2 summarizes Post Falls HED discharges from generation and spillways along with discharges measured at the USGS gage near Post Falls (No. 12419000) coinciding with TDG measurements at the corresponding station (i.e., HED operations for PFFB and USGS discharges for PFTR).

Table 2: Post Falls HED Operations During TDG Measurements

		Post Falls HED						USGS 12419000	
Date	**Interim Spill Gate Option**	**PFFB Time (PDT)**	**North Channel Sector Gate (ft)**	**South Channel Spill Gates**	**Total Generation (cfs)**	**Total N-S Channel Spill (cfs)**	**Total Discharge (cfs)**	**PFTR Time (PDT)**	**USGS Discharge (cfs)**
3/21	A	15:00	0.8	W	5,010	6,690	11,700	17:30	11,900
4/18	A	9:30	4.75	W	4,880	11,620	16,500	10:45	16,700
4/26	A	9:00	1	W	5,000	9,000	14,000	10:45	14,000
7/01	B	8:00	2	C	5,050	8,350	13,400	9:15	13,300

Notes:
C = closed; W = wide open
Total Discharge and USGS Discharge are for times of TDG monitoring at each station and therefore are different in most cases.

Measurements of TDG and other water quality are shown in Table 3. Table 3 also presents differences between tailrace and forebay station measurements for the corresponding day. The greatest difference in TDG was 8.5 percent of saturation (64 mm Hg), which occurred with a total discharge of 13,300 cfs under Option B. Under Option A, differences in TDG were 4.5 percent of saturation (36 mm Hg) for total discharge of 11,900 cfs, 3.4 percent of saturation (28 mm Hg) for total discharge of 14,000 cfs, and 7.3 percent of saturation (55 mm Hg) for total discharge of 16,700 cfs. These differences support the hypothesis that Option A operations result in less TDG loading between the HED dams and USGS gage.

Additional TDG monitoring will provide a more comprehensive understanding of any benefits in reduced TDG from preferential use of Option A. Specific targets for additional TDG measurements are Option B operations with total discharge near 11,900, 14,000, and 16,700 cfs; and Option A operations with total discharge near 13,300 cfs.

Table 3: Comparison of TDG and Other Water Quality Measurement Results

Option and cfs	Station	Date Time (PDT)	Water Temp (°C)	Barometric Pressure (mm Hg)	TDG (mm Hg)	DO (mg/L)	TDG (%)	DO (%)
A11900	PFFB	3/21/2011 15:00	2.8	692	678	12.2	97.9	98.8
	PFTR	3/21/2011 17:30	2.8	697	714	12.8	102.4	103.7
	PFTR-PFFB	2:30	0.1	5	36	0.7	4.5	4.9
A16700	PFFB	4/18/2011 9:30	4.1	701	737	11.8	105.2	98.4
	PFTR	4/18/2011 10:45	4.3	704	792	13.0	112.5	107.9
	PFTR-PFFB	1:15	0.1	3	55	1.2	7.3	9.5
A14000	PFFB	4/26/2011 9:00	4.8	703	737	11.9	104.8	100.5
	PFTR	4/26/2011 10:45	4.9	707	765	12.7	108.2	107.0
	PFTR-PFFB	1:45	0.1	4	28	0.8	3.4	6.5
B13300	PFFB	7/1/2011 8:00	13.5	708	735	10.1	103.8	104.1
	PFTR	7/1/2011 9:15	13.6	712	799	11.1	112.2	114.1
	PFTR-PFFB	1:15	0.1	4	64	1.0	8.5	10.0

Notes:
"Option and cfs" is a combination of the Interim Spill Gate Operating Protocol option (first letter) and Post Falls discharge (following five digits represent cfs) for USGS 12419000 when TDG was measured there.
Barometric Pressure was calculated by correcting the Spokane at Felts Field weather station data (http://www.wunderground.com/cgi-bin/findweather/getForecast?query=47.68277740,-117.32250214) for differences in altitude.

The TDG measurements are displayed with Post Falls HED generation and spill discharges and spill gate option in Figure 2. The first three TDG measurements were conducted during Option A operations and the final TDG measurements were conducted during Option B operations.

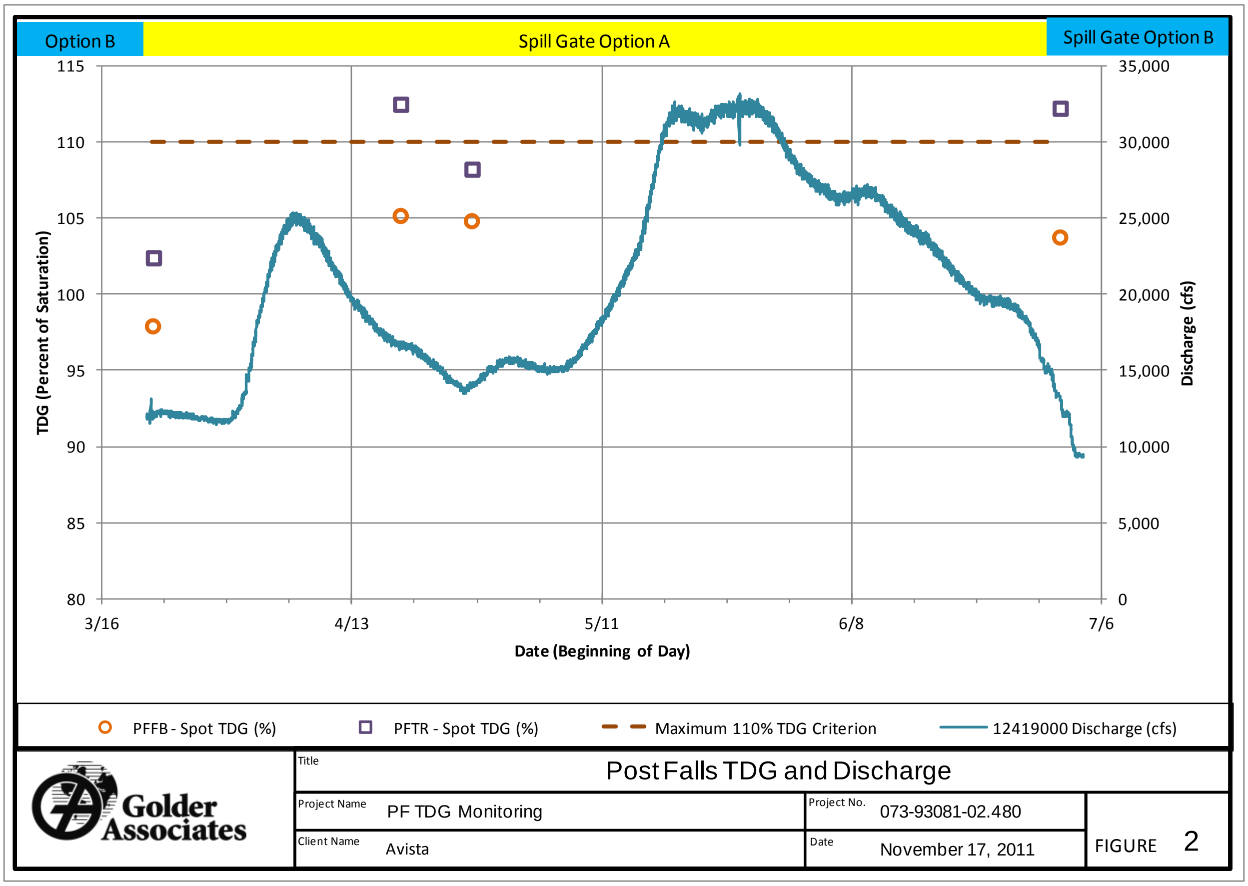

Figure 2: Post Falls TDG and Discharge

2.0 DATA QUALITY SUMMARY

Data quality objectives (DQOs) and Measurement Quality Objectives (MQOs) are the quantitative and qualitative terms used to specify how good the data need to be to meet the project's specific monitoring objectives. DQOs for measurement data, also referred to as data quality indicators, include measurement range, accuracy, precision, representativeness, completeness, and comparability. The range, accuracy, and resolution for each measured parameter are provided in Table 4.

Table 4: Range, Accuracy, and Resolution of Parameters Recorded

Parameter	Range	Accuracy	Resolution
Total Dissolved Gas	400 to 1300 mm Hg	±0.1 % of span	1.0 mm Hg
Dissolved Oxygen	0 to 30 mg/L	± 0.01 mg/L for 0 to 8 mg/L ± 0.02 mg/L for >8mg/L	0.01 mg/L
Temperature	-5 to 50°C	±0.10°C	0.01°C
Depth (0-25 meters)	0 to 25 meters	±0.05 meter	0.01 meter

Notes: Source: Hach's MS5 User Manual[2]

[2] Hach Corporation. 2006. Hydrolab DS5X, DS5, and MS5 Water Quality Multiprobes User Manual. February 2006, Edition 3. Catalog Number 003078HY

MQOs are the performance or acceptance thresholds or goals for the project's data, based primarily on the data quality indicators precision, bias, and sensitivity. Table 5 presents MQOs selected during preparation of the Post Falls HED TDG Control and Mitigation Program along with the same MQO for dissolved oxygen as used for the Long Lake HED tailrace DO monitoring plan.[3]. The station-specific root mean squared error (RMSE) of the calibration corrections applied after each calibration, and an overall RMSE for all stations compared to MQOs are shown in Table 6.

Table 5: Measurement Quality Objectives (MQOs)

Parameter	**MQOs**
Barometric Pressure	2 mm Hg
Temperature	0.5°C
Total Pressure	1% (5 to 8 mm Hg)
TDG%	1%
Dissolved Oxygen	0.5 mg/L

[3] Golder Associates, Inc. 2010. Detailed Dissolved Oxygen Phase II Feasibility and Implementation Plan, Washington 401 Certification, Section 5.6(B), Spokane River Hydroelectric Project FERC Project No, 2545. Prepared for Avista Corporation. June 11, 2010.

Table 6: Difference Between RMSE and MQOs by MS5

Part 1: Barometric Pressure, Total Pressure, and Total Dissolved Gas

	RMSE [1]			MQO			RMSE - MQO		
Meter ID	**BP[2] (mm Hg)**	**Total Pressure[3] (%)**	**TDG[4] (%)**	**BP (mm Hg)**	**Total Pressure (%)**	**TDG (%)**	**BP (mm Hg)**	**Total Pressure (%)**	**TDG (%)**
48762	7.07	1.00	1.02	2.0	1.0	1.0	5.07	0.00	0.02
60376	5.83	0.83	0.84	2.0	1.0	1.0	3.83	-0.17	-0.16
Overall RMSE	6.36	0.90	0.91	2.0	1.0	1.0	4.36	-0.10	-0.09

Notes:
Shaded values indicate exceedance of MQO.
[1] Pooled RMSE calculated at each station service period and removal.
[2] Pooled RMSE calculated from BP record for station during service period as compared to corresponding TDG in air new reading.
[3] Pooled RMSE calculated as the difference in TDG in air new minus the BP, then divided by the TDG and multiplied by 100.
[4] Pooled RMSE calculated at each station during service period and removal. TDG calculated as TDG in air new divided by the BP and multiplied by 100.

Root mean squared error (RMSE) = $\sqrt{\frac{\sum_{i=1}^{n}(x_{1,i} - x_{2,i})^2}{n}}$.

Table 6 (Continued): Difference Between RMSE and MQOs for Meters During the Long Lake HED TDG Monitoring Table

Part 2: Temperature and Dissolved Oxygen

	RMSE[1]		MQO		RMSE - MQO	
Meter ID	**Temperature[2] (°C)**	**DO[3] (mg/L)**	**Temperature (°C)**	**DO (mg/L)**	**Temperature (°C)**	**DO (mg/L)**
48762	0.21	0.10	0.5	0.5	-0.29	-0.40
60376	0.58	0.37	0.5	0.5	0.08	-0.13
Overall RMSE	0.466	0.29	0.5	0.5	-0.03	-0.21

Notes:
Shaded values indicate exceedance of MQO.
[1] Pooled RMSE calculated from temperature record at station during service period and removal.
[2] Temperature verification based on the difference between the meter and calibration thermometer.

[3] Calculated RMSE as difference of point measurement and 100% saturation as determined by DO saturation vs. temperature curves.

Root mean squared error (RMSE) = $\sqrt{\frac{\sum_{i=1}^{n}(x_{1,i}-x_{2,i})^2}{n}}$.

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2.1 Measurement Range

The measurement range, range of reliable readings of an instrument or measuring device, specified by the manufacturer is displayed in Table 4 for each measured parameter. Maintenance of field sampling equipment was conducted in a manner consistent with the corresponding manufacturer's recommendations to provide reliable readings within each instrument's reported measurement range.

2.2 Bias

TDG meters, like other field monitoring instruments, are subject to bias due to systematic errors introduced by calibration, equipment hardware or software functioning, or field methods. Bias was generally minimized by following standard protocols for calibration and maintenance, and by following field protocols for stabilization of meter readings. During this study's first MS5 calibration event, the TDG sensor in air was calibrated using barometric pressure that was incorrectly adjusted for altitude. All associated TDG pressure values were corrected by adding an offset to account for the error in BP. Following this event, a spreadsheet was prepared and used to ensure correct calculation of BP from weather station data.

2.3 Precision

Precision refers to the degree of variability in replicate measurements. Instrument precision was evaluated through the calibration and maintenance activities. The MQO for total pressure was met for both meters used; whereas one of the MS5s slightly exceeded the MQO for TDG%. However, BP, the difference between the local barometric pressure and TDG sensor in air, did not meet the MQO of 2 mm Hg for any of the MS5s, due to using an incorrect barometric pressure for the first calibration event. TDG pressure data were corrected by adding the difference between the local barometric pressure and the corresponding value used to calibrate the TDG sensor, and data quality code assigned to track this situation.

The 0.5-mg/L MQO for dissolved oxygen was met by both MS5s used; whereas, one of the MS5s slightly exceeded the 0.5°C MQO for temperature.

Discharge data were obtained from Avista and USGS, both of which use well-established monitoring programs. Golder reviewed the variability of discharge data to determine whether it was appropriate based on expected values. All discharge data were deemed acceptable.

2.4 Accuracy

Accuracy is a measure of confidence that describes how close a measurement is to its "true" value, or the combination of high precision and low bias. Throughout this seasonal TDG monitoring study, the MS5s underwent verification procedures. All differences between TDG pressure, dissolved oxygen, temperature, depth, and barometric pressure were recorded and these differences were discussed above.

2.5 Representativeness

Representativeness qualitatively reflects the extent to which sample data represent a characteristic of actual environmental conditions. For this project, representativeness was addressed through proper design of the sampling program to ensure that the monitoring locations were properly located and sufficient data were collected to characterize TDG at that location.

2.6 Comparability

Comparability is the degree to which data can be compared directly to previously collected data. Comparability was achieved by consistently monitoring the same monitoring stations that had been monitored in the past.

2.7 Completeness

Completeness is the comparison between the quantity of data planned to be collected and how much usable data was actually collected, expressed as a percentage. Data collection was planned for four sets of spot measurements for each monitoring station, all of which were successful in collection of usable data (Table 7).

Table 7: Project Completeness

	PFFB		PFTR	
Parameter	**Count**	**Completeness**	**Count**	**Completeness**
BP (mm Hg)	4	100.0%	4	100.0%
TDG (mm Hg)	4	100.0%	4	100.0%
TDG (% saturation)	4	100.0%	4	100.0%
Water Temperature (°C)	4	100.0%	4	100.0%
DO (mg/L)	4	100.0%	4	100.0%

3.0 CLOSING

We trust this technical memorandum meets your needs. If you have any questions, please contact Brian Mattax at 425-883-0777.

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BLM/DS/tp