**Hydrographic and Sub-Bottom Profiling Survey – Cross Valley Dam Pond**

NTS: 105K/06, Faro Mining Complex, Yukon Territory, Canada

WORK PERFORMED:
October 20 – 27, 2015

Prepared for:

ch2m

Prepared by:

AURORA GEOSCIENCES

**DRAFT TECHNICAL REPORT**
**Hydrographic and Sub-Bottom Profiling Survey – Cross Valley Dam Pond**

Effective Date: August 22, 2016

Prepared for:
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# 1 INTRODUCTION

Aurora Geosciences Ltd. was retained by CH2M Hill Canada Limited to conduct bathymetric and sub-bottom profiling of the Cross Valley Dam (CVD) and Intermediate Dam (ID) ponds at the Faro Mine, Faro, Yukon Territory. Only the multi-beam bathymetry and sub-bottom surveys on the CVD Pond were completed during the 2015 survey due to the onset of cold weather and subsequent formation of ice, rendering further boat work on the ponds impossible. Work on the Intermediate Dam pond was completed in June 2016 and is described in a separate report. The single-beam bathymetry was completed on the CVD Pond in June 2016 along with some supporting RTK measurements.

Complete coverage of the CVD Pond bathymetry was obtained through a multi-beam sonar investigation, coupled with a supplemental single-beam sonar survey in shallow areas, and RTK-GPS survey (to define the shoreline). The survey revealed greater depths toward the North as well as Western side of the pond, producing a maximum depth of 14.68 metres.

Acoustic sub-bottom profiling was also completed on the pond with a line spacing of 10m.

All geographic locations in this report are relative to North American Datum 1983 (CSRS) and all elevations are orthometric heights relative to the HT2 geoid. Non-geodetic coordinates are expressed in Universal Transverse Mercator Zone 8N metric coordinates. All measurements are expressed in the metric SI system.

# 2 LOCATION & ACCESS

The crew was based in the town of Faro, YT for the duration of the project and accessed the CVD Pond daily by truck and then by 16-foot aluminum boat. The pond is approximately 15 kilometers north-northwest of the town of Faro; Figure 1 is a map of the CVD Pond within the Faro Mine area.


**Figure 1: Location map of the CVD pond within the Faro Mine area. Map is from the CH2M Hill Agreement 10201-7-100723. The distance from the Town of Faro to the CVD Pond is approximately 15 km.**

# 3 WORK PROGRAM

This section describes the October 2015 and June 2016 work programs conducted at the CVD Pond. A bathymetric survey was completed comprising of multi-beam sonar, selected areas of single-beam sonar, selected lead-line measurements and RTK-GPS survey both for shoreline definition and for single-beam line extensions to allow comparison to existing topographic data; this is described in Section 3.1. A sub-bottom survey was completed using a 4-24 kHz chirped acoustic signal; this is described in Section 3.2. Figure 2 shows the line-path of the multi-beam bathymetry (yellow), 2015 single-beam bathymetry (black), sub-bottom profiling (red) and RTK shoreline survey points (blue symbols). A complete project log detailing the work performed by the Aurora Geosciences field crew is in Appendix I.

QA/QC of the surveys is examined in Section 3.3.

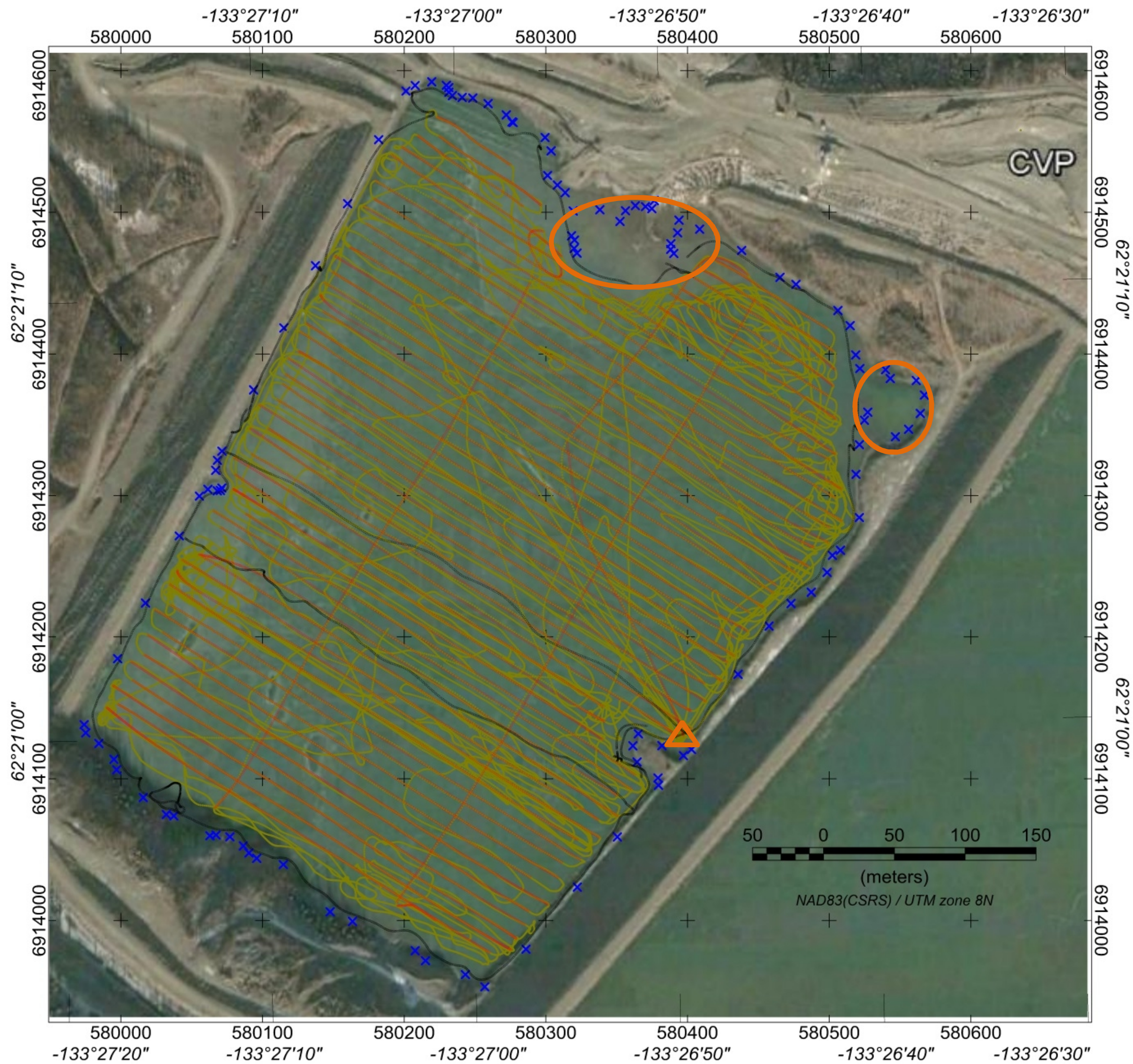


**Figure 2: Surveys on CVD Pond. Yellow shows the path of the multi-beam bathymetry, red of the sub-bottom profiling, black of the 2015 single-beam bathymetry and the blue symbols are the shore GPS measurements. The location of the CVP monument used for a GPS base is shown in the north-east corner. Areas shown in orange are shallow water where no data were collected. Daily check-in location is shown by the orange triangle.**

## 3.1 Bathymetric Survey

The multi-beam bathymetric survey provides an extremely high resolution depth database of the CVD Pond, with a data density of approximately 3.6 cm. Positional data were determined through an RTK GPS streaming data to the multi-beam system, with the GPS base station set up at the nearby CVP control point. The shoreline was also surveyed using RTK GPS, to both define the areal limit of the pond and to measure the water elevation. A single-beam sonar survey supplemented the multi-beam survey in shallow water, though with a much lower data density. There are two areas on the north side of the pond that were not surveyed using either method due to the very shallow water, as well as obstacles in the water (rocks, metallic debris). In addition, two traverses of the pond were done using the single-beam survey, to compare with the multi-beam dataset.

The single-beam survey was a lower priority than the planned multi-beam and sub-bottom surveys of the Intermediate Dam Pond (not completed). However, due to the daily tear down time of the multi-beam equipment, the crew was able to collect some single-beam data on the CVD Pond in 2015 without any impact on production of multi-beam or sub-bottom data collection despite this not conforming to the stated priority.

Multi-beam data collection was completed and single-beam data collection was partially completed at CVD Pond in 2015 and six traverses of the pond were done using the single-beam survey in 2016 to compare with the multi-beam dataset. No bathymetric data were collected at the Intermediate Dam Pond due to the onset of cold weather and ice formation in 2015.

### *3.1.1 Equipment*

The crew was equipped with the following instruments and equipment:

| | | |
|---|---|---|
| Equipment: | 1 | VS101 Hemisphere GPS box s/n: AA1129-14928-00016 |
| | 2 | A21 Hemisphere GPS sensors s/n: 7179, 7169 |
| | 1 | Digibar S water velocity sensor s/n: 4714 |
| | 1 | MB1 multi-beam sonar head s/n: 206 |
| | 1 | RTAII real time appliance s/n: 220083 |
| | 1 | Digibar V water velocity sensor (sonar head) s/n: 5683 |
| | 1 | IMU S-108 Subsea Motion Sensor s/n: 4078 |
| | | Miscellaneous multi-beam cables, brackets and equipment |
| | 1 | Trimble GeoExplorer XT2008 |
| | 1 | Garmin GPSmap 527 |
| | 1 | Airmar SS510 smart transducer |
| | | Miscellaneous single-beam cables, brackets and equipment |
| | 1 | Leica GS15 sensor rover s/n 1502720 |
| | 1 | Leica GS14 sensor base s/n 2806121 |
| | 1 | Leica CS15 controller s/n 2907005 |
| | 1 | Pac Crest ADL Vantage Pro Radio s/n 13086191 |
| | 1 | Pac Crest Radio s/n 1301949 |
| | | Miscellaneous GPS cables, tripods and equipment |
| Communications: | 4 | VHF handheld radios |
| | 1 | DeLorme InReach |
| Vehicles & Vessels: | 1 | Flat deck truck |
| | 1 | Truck Trailer |
| | 1 | Arctic Cat ATV |
| | 1 | 16ft aluminium boat |
| | 1 | Inflatable Zodiac rescue boat |
| | 1 | 6 HP outboard motor |
| | 1 | 2 HP electric motor |
| Safety: | 4 | Government certified personal floatation devices (PFDs) |
| | 2 | ATV helmets |
| | 4 | Hard hats |

| | | |
|---|---|---|
| | 100 | Nitrate gloves |
| | 9 | Tyvek suits |
| | 8 | Safety glasses |
| | 4 | High Visibility Vests |
| | 2 | Fire extinguisher |
| | 2 | Level 2 First aid kit |
| | 4 | Spare paddles |
| | 2 | 15m floating rope |
| | 2 | Bailers |
| Computers & Software: | 1 | Laptop with Edgetech Discover Sub-Bottom 4.0 |
| | 1 | Laptop with HyPack 2015, SonarWiz 6 |
| | 1 | Laptop with Image, SMC IMU Config, Digibar Pro 3.0 |
| Other | 20 | 6 mil plastic garbage bags |
| | 1 | Pressure washer |
| | 1 | Water tank |
| | 1 | Office box |
| | 1 | Geophysical Toolbox |

### *3.1.2 Survey Specifications & Field Procedures*

All manufacturer and model information for equipment referenced in this section can be found in Section 3.1.1.

#### 3.1.2.1 RTK GPS

A GPS base station was established daily with the Leica GS14 antenna over the permanent control marker 2010-P5 at CVP. As this primary control monument was suitable for all areas of the CVD pond, a secondary control network was not established.

For the 2016 points, the published position for 2010-P5 was inadvertently not programmed into the GPS base prior to starting work in the field and an arbitrary position was therefore used the first day. For consistency the arbitrary base position was used throughout the 2016 survey and all RTK data were corrected by a post-survey datum shift to align the base with the published position.

As per the published *Survey Standards for Faro Mine Closure* included with CH2M Hill Agreement 10201-7-100723, the coordinates for the antenna established at 2010-P5 are 6914557.921 N, 580635.174 E (NAD83 CSRS Epoch 2002, UTM Zone 8 coordinates with a CSF of 0.999505) with an orthometric height above the HT2 Geoid Model of 1060.480 m. This base location was broadcast continuously via radio to the Leica GS15 rover so that a phase-corrected RTK solution was being transferred to the multi-beam equipment via NMEA string at all times during multi-beam sonar collection.

Point RTK positions with the Leica GS15 antenna were taken along the shoreline to constrain the gridding of the water depths in the shallows and to provide a measure of the water-surface elevation. Where the shoreline is straight, station spacing is nominally 50 m, with decreasing station spacing as required to capture smaller scale shoreline features; these points are shown as blue crosses in Figure 2.

In 2016, point RTK positions were also recorded as rough extensions of all single-beam lines, extending roughly 15 m back from the shoreline.

Also in 2016, RTK positions were taken during single-beam collection and matched to the single-beam data by time-stamp.

#### 3.1.2.2 Multi-Beam Sonar

An Odom Teledyne MB1 multi-beam echo-sounder was used for the collection of primary bathymetric data from all areas of the CVD Pond, in areas with water depths greater than approximately 1 m. The sonar head was equipped with a sensor that monitored changes in water velocity from fluctuations in water temperature and purity. A motion sensor was also used to monitor the heave, pitch and roll of the boat. The later was calibrated each morning to account for slight variations in crew weight as well as position. A Hemisphere marine GPS unit with two widely spaced antennae, positioned perpendicular to the sonar head (parallel to the axis of the vessel), provided precision bearings at all times. The Leica GS15 rover with a radio link to a base antenna was attached 1.09 metres directly above the sonar head to provide high accuracy positional data. The part of the system above water is shown in Figure 3.

**Figure 3: Universal mounting pole with three GPS antennae and subsea motion sensor visible.**

Each day the MB1 sonar head, RTK sensor and all secondary control instruments were bolted to the same place on a universal mounting pole, ensuring constant registration relative to the boat across multiple days of surveying. Data from all instruments were fed to an Odem Real Time Appliance for time registration and for interfacing with laptop computers.

A pair of onboard computers was used to control and monitor the instruments, while simultaneously recording data. One laptop, equipped with Odom Image, monitored the sonar head and water velocity sensor. The second laptop, equipped with Hypack 2015, recorded all data and plotted results allowing for real time feedback on quality and coverage.

The crew conducted a series of control tests at the beginning and end of each day. A control station was established at 580395, 6914126 (NAD83 UTM Zone 8N coordinates) by the suspension of a survey flag over the pond shown by the orange triangle in Figure 2; GPS and multi-beam sonar data were recorded for a minimum of 30 seconds during check-ins at this control station. Patch test data were recorded during normal data collection each day to correct potential errors arising from mounting variations as well as pitch, roll and yaw motion. Patch test corrections generated by the Hypack software were negligible and were not applied to the final data set. Water velocity data were collected by a second water velocity sensor independent of the sonar head that was lowered to the pond floor, producing a water velocity profile for the full depth of the pond with data points collection every 10 cm. 12 casts were attempted in various locations to assess any spatial variability of the acoustic velocity.

The MB1 sonar head operated at 170-220 kHz and is capable of recording a 120˚ swath which, over flat terrain, is approximately 4 x the water column depth. As a quality control measure to account for variations in the pond floor and potential noise near the edge of the swath, the crew aimed for an initial 33% overlap in data, with occasional insufficient overlap to be cleaned up at the end of the survey. These were identified in preliminary processing and all were successfully in-filled on the final day of surveying resulting in a complete contiguous dataset. Data was collected across the full 120˚ swath with a total of 512 beams and preserved in the raw files. In practice, the useful data swath was approximately 80˚ and the pond was, in general, much shallower than expected, resulting in many extra passes to ensure complete data coverage. As another quality control measure, the Hypack software was configured so as to not log any data if a phase-corrected RTK signal was not present. Occasional drops in RTK signal quality due to temporary loss of radio-link therefore created data gaps obvious to the operator during data collection and were immediately rectified by a repeat pass over the affected area for complete coverage.

Line spacing for the multi-beam survey was variable, although initial passes follow the same bearing (122˚) as the intended sub-bottom lines. Target boat speed was approximately 3 knots, though care was taken in shallower areas to protect the sensitive equipment.

#### 3.1.2.3 Single-Beam Sonar

The single-beam bathymetry survey was conducted to fill in data voids in shallow water where use of the multi-beam transducer was not practical. Fill-ins were done along the entire perimeter of the Cross Valley Dam Pond and attempts were made to fill in shallow areas at the north and north-east edges of the pond. These shallow areas proved to be unnavigable even for the inflatable zodiac, which was used instead of the 14-ft vessel for the 2015 single-beam survey.

In 2015, only two EW reference lines were surveyed to create a secondary control database against which to measure the multi-beam bathymetry data, the other planned reference lines were not completed due to the onset of winter and ice on the pond. For consistency, all six of the planned lines were surveyed in 2016 and the 2015 lines were not used in the analysis. Four of these lines spanned the width of the pond at a bearing of approximately 122˚ and set 100 m apart. The two other lines spanned the length of the pond at a bearing of 30˚ and were spaced 150 m apart.

Data were collected at a 1 second interval with data from the Airmar SS510 transducer. The transducer operates at a frequency of 200 kHz with a beam width of 9˚. Target boat speed was 2 knots in open water but speeds in potentially shallow areas were lower.

In 2015, data from the Trimble Geoexplorer GPS antenna and the Airmar transducer were streamed to the Trimble GeoXT controller for storage. The vertical offset between the GPS antenna and the transducer was 1.1 m. There was no horizontal offset.

In 2016, data from the Airmar transducer were streamed to the Trimble GeoXT controller for storage and were georeferenced using data from the RTK-GPS Leica GS15 rover. A 17 second offset was applied to the single-beam sonar data prior to time-stamp matching to account for the different time convention (GPS versus UTC time) used by each instrument. The vertical offset between the GPS antenna and the transducer was 1.44 m. There was no horizontal offset.

#### 3.1.2.4 Lead-Line Measurements

In 2016, lead-line measurements were taken to create a tertiary database against which to measure the other bathymetric data, however because of an impending shortage of safety personnel at the Faro Mine area, the lead-line survey was cut short and only six points were measured on the CVD Pond.

A best effort was made to make the measurement when the lead-line was plumb but the survey vessel was not anchored during the measurements and there was significant drift from high winds at the time of the lead-line survey so some bias towards longer measurements because of the angled line is expected. Additionally, the operators often observed significant muck on the lead-line after retrieval so the weight may have been penetrating some centimeters beyond the mudline as measured by the sonar data.

### 3.1.3 Data Processing

#### 3.1.3.1 RTK-GPS

For the 2016 portion of the survey, the use of an arbitrary initial reference point required that a datum shift be applied to all raw data to reposition the base station to the published position of 2010-P5. All points were shifted -2.005 m N, 1.733 m E and elevation was shifted -6.501 m.

Data were logged to the Leica receiver, exported to csv files and then edited to correct labelling or entry errors; the raw daily base and rover files, as well as the exported rover files are included with the data package of this report. The 2015 positional quality is shown in Figure 4 and the 2015 height quality in Figure 5 as reported by the Leica Geo Office software package from the raw rover files (with no post-processing); both have a 95% confidence level well below 10 cm. The effective positional and height quality is better than the histograms portray because, as indicated in Section 3.1.2.2, the multi-beam unit was configured so as to not log any data if a phase-corrected RTK signal from the base was not present. On a handful of occasions the RTK radio link was down, but the operator noticed the data gap while surveying and immediately re-surveyed the missing section with RTK corrected positional and height data. These data nevertheless remain in the GPS database shown in Figure 4 and Figure 5.

The position and height data for Oct 21 were mistakenly not independently recorded on the GPS rover and are therefore not included in the histograms. However, as the operator did not see any data gaps during collection, these data are known to be of good quality.

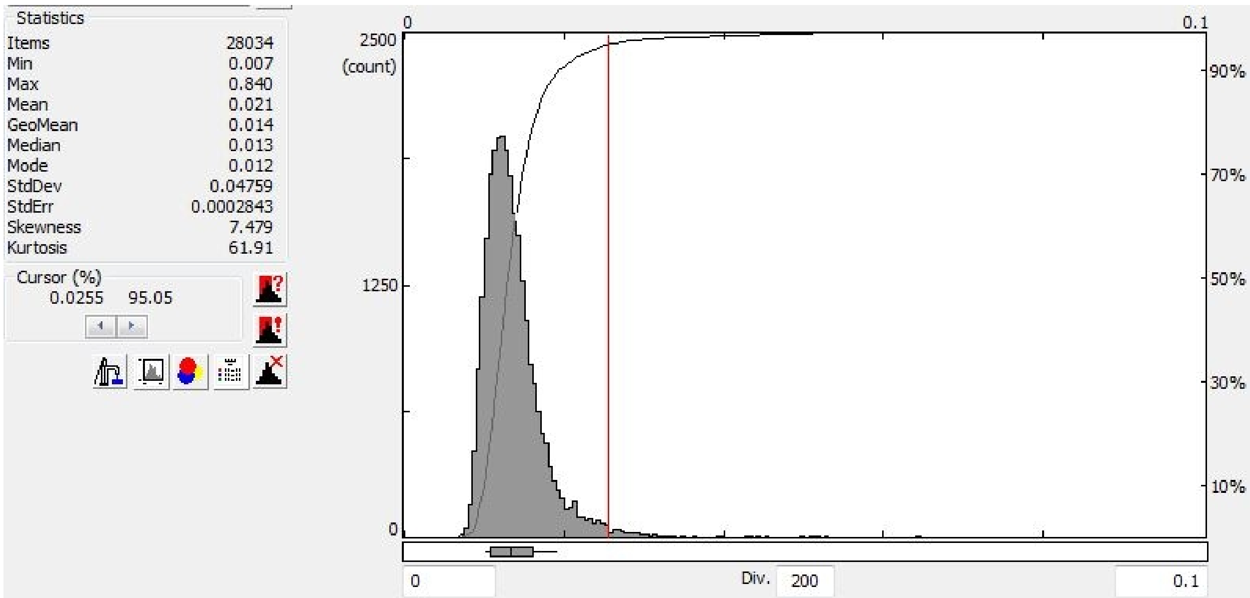


**Figure 4: Position quality of GPS solutions during multi-beam bathymetry acquisition. The red line shows the 95% of the position quality is at 0.026 m.**

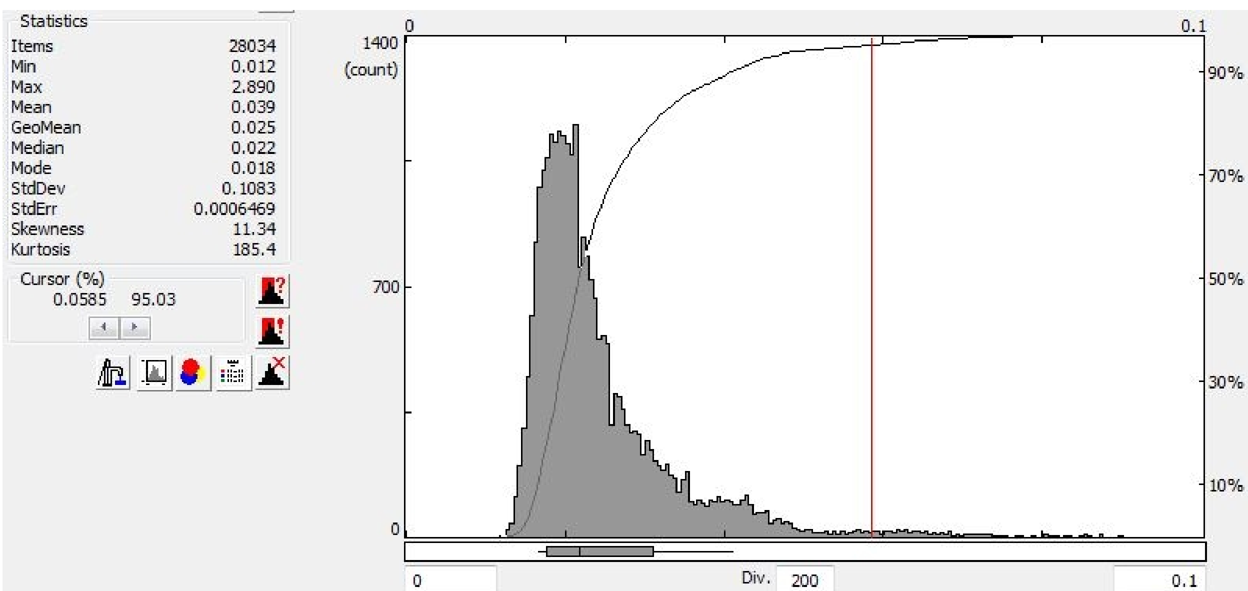


**Figure 5: Height quality of GPS solutions during multi-beam bathymetry acquisition. The red line shows the 95% of the height quality is at 0.059 m.**

#### 3.1.3.2 Single-Beam Sonar

For the 2015 survey, base GPS data were exported to RINEX format and processed with Trimble Pathfinder software to obtain a differentially corrected position. The Trimble Geoexplorer GPS used with the single-beam sonar was not equipped with an RTK radio link to the base; the solutions are therefore not phase corrected and the accuracy is significantly less than those of the multi-beam sonar; an estimate of horizontal accuracy for the 4956 positons as reported by the Pathfinder software in shown in Table 1.

**Table 1: Estimated accuracy of single-beam horizontal position.**

| Estimated accuracy range | Percentage of points |
|---:|---:|
| 0 – 5 cm | 0% |
| 5 – 15 cm | 0% |
| 15 – 30 cm | 66.87% |
| 30 – 50 cm | 33.05% |
| 0.5 – 1 m | 0.06 % |
| 1 – 2 m | 0.02 % |

The base location used for the Pathfinder correction is taken from the average measured position of the GPS base and is reported in the processing log file. A datum shift of 0.432 m (north), 4.171 m (east) and -9.260 (elevation) was applied to correct the base station to the published location of point CVP 2010-P5. Acoustic water velocity was assumed to be 1500 m/s during acquisition and this is corrected to 1426 m/s, a measured average velocity for the pond (Section 3.1.3.3 and Figure 6).

For the 2016 data, RTK GPS data were exported and matched by timestamp to the single-beam data with a time-shift of 17 seconds to account for a GPS to UTC time datum adjustment.

In 2016, pond bottom elevations were calculated by subtracting depths derived from the single-beam from the elevation of the single-beam sonar head as measured by the RTK GPS. In 2015, pond bottom elevations were calculated by subtracting depths derived from the Hypack software from the average elevation of the shoreline as measured by the RTK GPS (1028.6792 m).

#### 3.1.3.3 Multi-beam Sonar

Multi-beam sonar data were processed using Hypack's Hysweep 64-bit Editor. Beam angle limits of 40 degrees were imposed on both port and starboard sides for all data, with lower limits being applied where deemed necessary by visual inspection. An over/under filter and a Savitzky-Goalay filter were applied to highlight and remove potentially erroneous data. All data were then visually inspected in batches of 1000 swaths or less. Single spike anomalies and areas of high noise were removed. In general, the data collected at the widest angle from the sonar head were unreliable and discarded.

Secondary instrumentation data were also inspected and areas where high heave, pitch, roll or speed were recorded, were removed from the dataset. Water velocity data were inspected, showing little variation across time and location. Averaged values from 4 casts were used to create a water velocity profile from 0 m to 14 m, shown in Figure 6. Values from this profile are applied to all data and recorded depths were adjusted accordingly in the Hypack software.

Pond bottom elevations were calculated by subtracting depths derived from the Hypack software from the average elevation of the shoreline as measured by the RTK GPS (1028.6792 m).

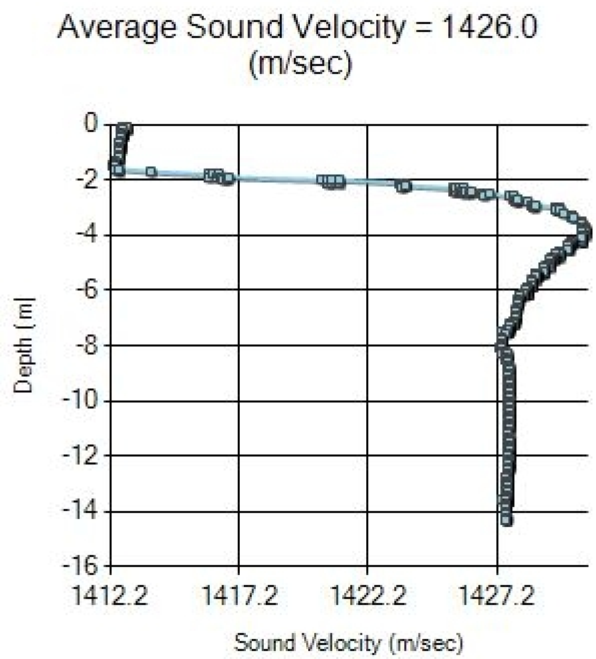


**Figure 6: Average acoustic water velocity profile.**

Multi-beam data collected on October 23rd and 24th were subject to time shift errors by malfunctions in the RTAII real-time appliance. These errors were not detectable from the Hypack software used for data collection and were only evident during post-processing. From discussions of this malfunction with the instrument supplier, the appropriate solution to correct the issue is to individually correct each time entry.

Time stamps assigned by the RTAII appear in the raw logging files as an incrementing value representing the number of seconds since midnight. Whenever the time shift error occurred, this time stamp value would suddenly decrease while other data continued to be logged correctly at regular intervals with correct times. Data from all sources would be logged in chronological order in the same file regardless of any time stamp error, making it possible to identify and calculate the value of any time shift. A script was written to create a new log file for each time shift error and adjust erroneous time stamps to match the nearest correct time stamp (usually every 0.050 - 0.100 seconds.) A total of 19 errors were corrected in data collected October 23rd, and 30 errors in data collected on October 24th.

RTK GPS points taken at 95 shoreline locations adjacent to the surveyed area were assigned a depth of 0 m and used to interpolate a full shoreline. Orthometric heights are recorded for these shoreline locations. This shoreline data was integrated with all multi-beam and single-beam bathymetry data to create all grids and contour files associated with this pond. Gridded bathymetry data were created using a 0.5 m cell size and windowed to exclude points outside of the RTK GPS surveyed perimeter created by the gridding algorithm. No filters were applied to the final bathymetry grids. All 25 cm and 50 cm contours were made after 3 passes of a 3x3 Hanning filter on the bathymetry grid.

### *3.1.4 Products*

| **Folder / File** | **Description** |
|---|---|
| Raw data/Multi-beam/Raw/*.hsx | Raw multi-beam data in Hypack Raw format |
| Raw data/Single-beam /*.obs | Raw single-beam data in GeoXT format, with supporting files for both 2015 and 2016 CVD surveys. |
| Raw data/Multi-beam/Time Edit/*.hsx | Time error-corrected data in Hypack Raw format |
| Raw data/GPS/Base/*.m00 and Rover/*.m00 | Base and rover GPS data from Oct 21-24 are associated with bathymetry and shoreline data in Leica m00 format. Data from June 17 are associated with single-beam bathymetry and on-shore extensions. |
| Processed data/GPS/CVD Pond shoreline/*.csv and *.txt | Corrected shoreline rover GPS data in ASCII formats. |
| Processed data/GPS/Daily Surveying/*.csv and *.txt | Corrected rover GPS data in ASCII formats. Data from Oct 21-24 are associated with multi-beam data. |
| Processed data/GPS/CVD shoreline extensions/*.xyz | Corrected rover GPS data in ASCII formats. |
| Processed data/GPS/Daily check-ins/*.csv and *.txt | Corrected rover GPS data in ASCII formats. Data from Oct 21-24 are associated with multi-beam data. |
| Processed data/GPS/channels.txt | Description of columns for ASCII GPS files. |
| Processed data/Lead-line/CVD lead lines.xyz | Lead-line data for CVD pond, collected in 2016. |
| Processed data/Lead-line/channels.txt | Description of columns for ASCII lead-line file. |
| Processed data/Multi-beam/bathymetry final.xyz | Master ASCII database of all final bathymetry data in depth of water. |
| Processed data/Single-beam/CVD single-beam secondary data.xyz | Master ASCII database of all secondary control single-beam data from common transect lines. |
| Processed data/Single-beam/channels.xyz | Description of cloumns for ASCII single-beam data. |
| Processed data/Multi-beam/feature channels.txt | Description of columns for ASCII final bathymetry and secondary control databases. |

| | |
|---|---|
| Processed data/Multi-beam/water velocity profile.vel | Master ASCII database of averaged water velocity profiles. |
| Processed data/Multi-beam/*checkins.xyz | ASCII database of all bathymetry check-in data. |
| Processed data/Multi-beam/0.5m elevation rasterized/ESRI/CVD_pondBottom_Elevation_0,5_esri.flt* | ESRI raster grid at 0.5 m cell size with supporting files. |
| Processed data/Multi-beam/0.5m elevation rasterized/ESRI/CVD_pondBottom_Elevation_0,5.grd | Geosoft raster grid at 0.5 m cell size with supporting files. |
| Processed data/Multi-beam/500 25cm contours.dxf | 1:500 scale 25cm contours of depth, with a 3 pass 3x3 Hanning filter in AutoCAD version12 DXF format |
| Processed data/Multi-beam/1250 50cm contours.dxf | 1:1250 scale 50cm contours of depth, with a 3 pass 3x3 Hanning filter in AutoCAD version12 DXF format |
| Figures/Bathymetry 500.pdf | 1:500 scale map with gridded bathymetry (depth) data and 25cm contours in PDF format |
| Figures/Bathymetry 1250.pdf | 1:1250 scale map with gridded bathymetry (depth) data and 50cm contours in PDF format |

## 3.2 Sub-Bottom Survey

Acoustic sub-bottom data collection was completed at CVD Pond, but no sub-bottom data were collected at the Intermediate Dam Pond in 2015 due to the cold temperatures and ice formation. This was completed in 2016 and is described in a separate report. The data were collected at lines with 10 m spacing. The coverage is slightly less complete than the bathymetric data set due to survey restrictions in shallow water from the sub bottom instrument as illustrated in Figure 2.

### *3.2.1 Equipment*

The crew was equipped with the following instruments and equipment:

| | | |
|---|---|---|
| Equipment: | 1 | EdgeTech SB-424 towfish s/n: 38803 |
| | 1 | Edgetech 3100P sub-bottom topside unit s/n: 38688 |
| | 1 | Leica GS15 sensor rover s/n 1502720 |
| | 1 | Leica GS14 sensor base s/n 2806121 |
| | 1 | Leica CS15 controller s/n 2907005 |
| | 1 | Pac Crest ADL Vantage Pro Radio s/n 13086191 |
| | 1 | Pac Crest Radio s/n 1301949 |
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| Communications: | 4 | VHF handheld radios |
| | 1 | DeLorme InReach |
| Vehicles: | 1 | Flat deck truck |
| | 1 | Truck Trailer |
| | 1 | Arctic Cat ATV |

| | | |
|---|---|---|
| | 1 | 16ft aluminium boat |
| | 1 | Inflatable Zodiac rescue boat |
| | 1 | 6 HP outboard motor |
| | 1 | 2 HP electric motor |
| Safety: | 4 | Government certified personal floatation devices (PFDs) |
| | 2 | ATV helmets |
| | 4 | Hard hats |
| | 100 | Nitrate gloves |
| | 9 | Tyvek suits |
| | 8 | Safety glasses |
| | 4 | High Visibility Vests |
| | 2 | Fire extinguisher |
| | 2 | Level 2 First aid kit |
| | 4 | Spare paddles |
| | 2 | 15m floating rope |
| | 2 | Bailers |
| Computers & Software: | 1 | Laptop with Edgetech Discover Sub-Bottom 4.0 |
| Other: | 20 | 6 mil plastic garbage bags |
| | 1 | Pressure washer |
| | 1 | Water tank |
| | 1 | Office box |
| | 1 | Geophysical Toolbox |

### *3.2.2 Survey Specifications & Field Procedures*

#### 3.2.2.1 RTK GPS

A GPS base station was established daily over the permanent control marker 2010-P5 at CVD. As this primary control monument was suitable for all areas of the CVD pond, a secondary control network was not established.

As per the published *Survey Standards for Faro Mine Closure* included with CH2M Hill Agreement 10201-7-100723, the coordinates for the antenna established at 2010-P5 are 6914557.921 N, 580635.174 E (NAD83 CSRS Epoch 2002, UTM Zone 8 coordinates with a CSF of 0.999505) with an orthometric height above the HT2 Geoid Model of 1060.480 m. This base location was broadcast continuously via radio to the rover so that a phase-corrected RTK solution was being transferred to the sub-bottom equipment via NMEA string at all times during data collection.

#### 3.2.2.2 Sub-bottom Profiling

Sub-bottom profiling was performed along 54 lines running 122˚ west to east across the pond, and along 3 perpendicular tie-lines for cross reference. Survey line spacing was 10 m with tie-lines being profiled at uneven spacing, in an attempt to profile different features that appeared during the initial passes.

Target boat speed was approximately 3 knots and attempts were made to maintain constant speeds in an effort to avoid distorting produced images.

The Edgetech SB-424 towfish, 3100P topside unit and Discover software were used to collect all sub-bottom data. The SB-424 is capable of outputting a variety of FM chirps, each of which was tested before surveying began. Of the chirps tested, it was decided that the highest range of frequencies available (4-24kHz) provided the best resolution; whereas limiting the signal to lower frequencies seemed to offer no significant advantage with regard to depth of penetration.

### *3.2.3 Data Processing*

#### 3.2.3.1 RTK

Data were logged to the Leica receiver and exported to csv files; both raw daily base and rover files, in addition to the exported rover files, are included with the data package of this report. The positional quality is shown in Figure 7 and the height quality in Figure 8 as reported by the Leica Geo Office software package from the raw rover files (with no post-processing); both have a 95% confidence level well below 10 cm.

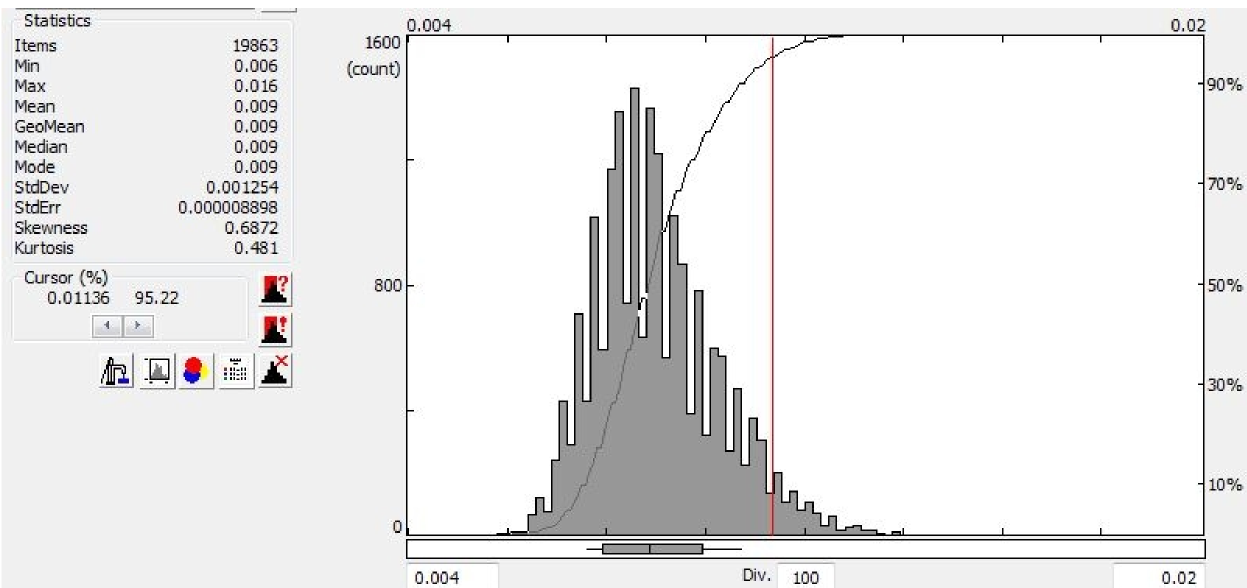



**Figure 7: Position quality of GPS solutions during sub-bottom profiling acquisition. The red line shows the 95% of the position quality is at 0.011 m.**

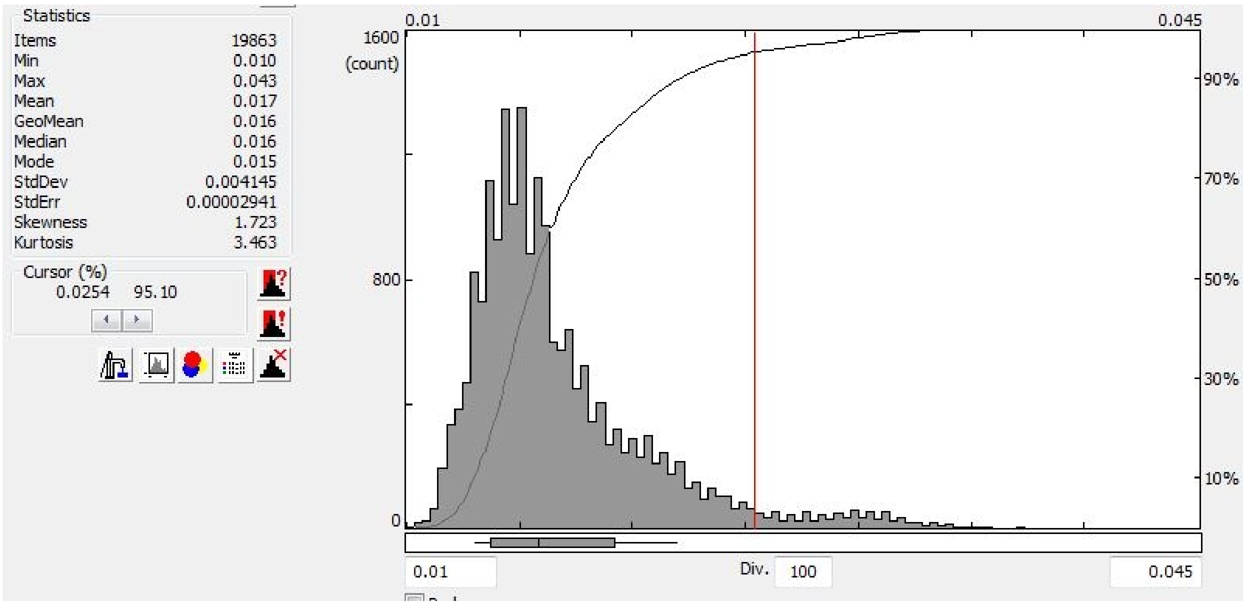



**Figure 8: Height quality of GPS solutions during sub-bottom profiling acquisition. The red line shows the 95% of the height quality is at 0.025 m.**

#### 3.2.3.2 Sub-Bottom

Initial processing of sub-bottom profiles was performed with SonarWiz 6. User gain controls were adjusted to increase the visibility of responses at depth and have a minimal impact on near surface responses. Once set, this gain was applied universally across all lines allowing for objective comparisons between them. Auto-detection of the pond bottom was used but was insufficiently accurate. All features, including the pond bottom, were drawn in after visual inspection. Features were first drawn on the 3 perpendicular tie-lines. The depths of these features were then plotted to all sonargrams and used only as visual cues to calibrate the drawing of all subsequent features. Tie-line feature depths were not included in the final dataset. .

#### Definitions of Features

Feature A – this is the mudline, first signal to return indicating the bottom of the water column.

Feature B – There are two main divisions for Feature B. The first is a package of layered sediment, with each individual layer typically 25 cm thick. On the north side of the pond, the thickest package of layered sediment outlines a well-defined pit. The layers are not always well defined – sometimes because the layer is too thin and only a single non-reflective layer is being imaged, but also sometimes because the response grades from well-defined layers to a more homogeneous mass sitting on top of Feature C (see below). It’s possible that a single thin layer of high reflectance material similar to Feature C is not detectable, and therefore is included in the thickness of Feature C.

Line 44 shows many of these features from the north end of the pond, while Line 4 shows similar features from the south end of the pond. There is another pit-like feature imaged in Line 4, but it is not visible on the two adjacent lines.

The second division included in Feature B is more irregular layers sitting on top of Feature C. These are more common in the middle of the pond and are typified by the response on Line 35.

There are only a few cases where multiple instances of Feature B are stacked. An example of this on the west end of Line 3.

Feature C – This is a high reflectance layer that underlays large areas of the pond. There is a rough correlation between high thickness of Feature C and shallower water. The difference between Feature C and Feature D is subtle.

Feature D – This is very similar to Feature C, but has a mottled texture with very small irregular areas of lower reflectance. Lineaments of high thickness of Feature D tend to follow bathymetric relief; on steeper slopes, Feature C tends to be absent resulting in a greater thickness of Feature D. This supports the interpretation that Feature C represents fines which slough off on the steeper slopes. Examples of this are the scarps in the southeast corner of the pond, in the middle of the pond (Lines 21-28) and all along the western edge of the pond.

There are also greater thicknesses of Feature D in between the two spits protruding into the ponds on lines 18, 19 and 20.

Feature E – This feature outlines all areas where the high reflectance of features C and D is no longer present but enough reflectance to outline some texture remains.

Feature F – This feature represents areas where no textured reflectance is discernable but some traces of the signal are still being reflected. When present above other features, it clearly outlines a lack of a returning signal. When present below all other features, it is an arbitrarily chosen limit specific to the gain settings used during data processing, where the plotted response still appears more gray than blank. Because the gain settings were kept constant on all sonograms, the relative thickness of this layer at depth could be representative of the rate of signal attenuation.

Feature G – This feature represents all areas that show weaker responses than feature F. With the gain settings used during data processing, this feature appeared more white or blank than gray. The lower limit of this feature is always the first multiple from the mudline (Feature A) which is generally quite strong and masks any deeper responses.

### Export and Processing of Features

The features described above were identified on a line-by-line basis and images of each EW line with the interpreted features are included with this report. Features were validated through cross-referencing with the NS lines but no feature lines were drawn on the NS lines. The data on the EW lines were exported to an ASCII master database and AutoCAD v12 DXFs with all the interpreted features that were produced for each line. As no core or velocity data were available at the time of processing, the velocities of all layers are assumed to be 1500 m/s upon export and all data downstream of the export are in metres. The data should be transformed back to the time domain and all depths and thicknesses re-calculated once further data become available.

To calculate the thickness of each feature the distance to the feature defined above it is extracted from the master database. Feature A is the first arrival of the pulse and represents the mudline; this feature is present in all sub-bottom data. Several of the features are interleaved and to obtain a total thickness, the sub-features (e.g. B1 and B2) are summed. The summed feature thicknesses are exported to ASCII and are gridded with a minimum curvature algorithm and a cell size of 2.0 m, which is an appropriate cell-size for 10 m line-spacing. Grids are provided in both Geosoft and ESRI formats. Contours for each feature are made at 10 cm intervals and are exported in AutoCAD v12 DXF format.

### Cross-Sections

Cross-sections were produced at 50 m intervals for the pond in both the east-west and north-south directions. A database was developed for each cross-section with 1m resolution and the final bathymetric database is sampled to obtain the pond bottom along the cross-section.

The down-line sub-bottom data interval is 0.25 – 0.30 m and the line spacing is approximately 10m. Many of the features are sparsely distributed over the pond and therefore a Triangular Irregular Network (TIN) method is used with linear interpolation between TIN points to sample each sub-feature along the cross-sections. This ensures no gridding artifacts from sparse data, typical of other gridding algorithms, are sampled into the cross-sections. Nevertheless, line-to-line features that run obliquely to the line direction and that are small relative to the lines spacing of 10 m, have artifacts in between the lines. This is particularly apparent on the cross-section at 6914100 N.

The bathymetric dataset is superior to that defined by Feature A in the sub-bottom data and the depth of each sub-feature relative to Feature A is more robust than the absolute depth. Therefore the depth of each sub-feature is calculated below Feature A and then this depth is subtracted from the bottom, determined by the bathymetric survey (so as to use the higher quality dataset). This method does transfer some small scale roughness imaged in the bathymetry survey to the lower resolution sub-bottom layers. An example is shown in Figure 9, where the circles area illustrates the roughness introduced into the cross-section. Although the left-hand panel (L27.jpg) is oblique to the right-hand panel (6414350.pdf), the excerpts circled in blue are approximately coincident.

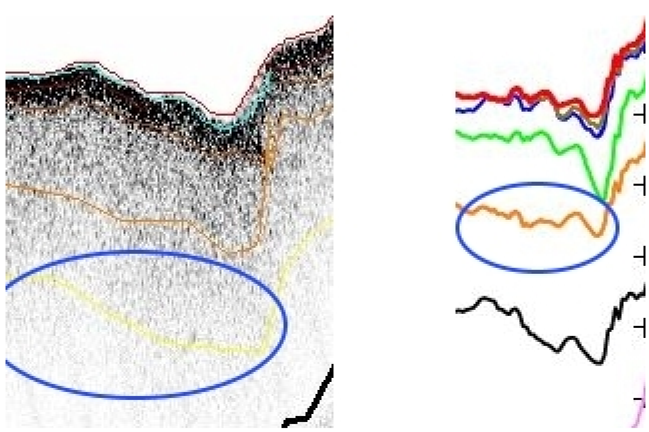


**Figure 9: Example of introduced roughness to the sub-bottom dataset. The left-hand panel is an interpreted section (L27.jpg), the right-hand panel is a cross-section (6914350.pdf) with introduced small scale roughness.**

### 3.2.4 Sub-bottom Products

The following files and figures are appended to this report:

| Folder / File | Description |
|---|---|
| Raw data/Sub-Bottom/*.jsf | Sub-bottom data by line in EdgeTech jsf format (see Appendix III. |
| Raw data/Sub-Bottom/on-water control CVP/*.jsf | Sub-bottom raw data at the on-water control point. |
| Raw data/Sub-Bottom/faro freq tests/*.jsf | Sub-bottom on-site tests with different waveforms. |
| Raw data/GPS/Base/*.m00 and Rover/*.m00 | Base and rover GPS data from Oct 25 are associated with sub-bottom data in Leica m00 format. |
| Processed data/GPS/Daily Surveying/*.csv and *.txt | Corrected rover GPS data in ASCII formats. Data from Oct 25 are associated with sub-bottom data. |
| Processed data/GPS/Daily check-ins/*.csv and *.txt | Corrected rover GPS data in ASCII formats. Data from Oct 25 are associated with sub-bottom data. |
| Processed data/GPS/channels.txt | Description of columns for ASCII GPS files. |
| Processed data/Sub-bottom/Interpreted sub-bottom - depth.xyz | Master ASCII database of all interpreted sub-bottom features in depth from mudline. |
| Processed data/Sub-bottom/Interpreted sub-bottom - elevation.xyz | Master ASCII database of all interpreted sub-bottom features in elevations. |
| Processed data/Sub-bottom/ channels.txt | Description of columns for ASCII master sub-bottom database. |
| Processed data/Sub-bottom/Feature thickness/ASCII XYZ/Feature_*.xyz | Calculated thickness of each sub-bottom feature. |
| Processed data/Sub-bottom/Feature thickness/ASCII XYZ/channels.txt | Description of columns for ASCII feature thickness. |
| Processed data/Sub-bottom/Feature thickness/DXF contours/Feature*.dxf | Contour of feature thickness (interval of 0.1 m) in AutoCAD version12 DXF format. |
| Processed data/Sub-bottom/Feature thickness/ESRI grids | Raster grid at 2 m cell size of feature thickness. |
| Processed data/Sub-bottom/Feature thickness/Geosoft grids | Raster grid at 2 m cell size of feature thickness. |
| Processed data/Sub-bottom/Images | Images of processed data for every line with interpreted layers in jpg format. |
| Processed data/Sub-bottom/Line-by-line DXFs | Interpreted layers in AutoCAD version12 DXF format. |
| Figures/Cross-sections/DXFs | EW and NS cross-sections with bathymetry and interpreted sub-bottom layers in AutoCAD version12 DXF format. |
| Figures/Cross-sections/PDFs | EW and NS cross-sections with bathymetry and interpreted sub-bottom layers in PDF format. |

## 3.3 Quality Control Checks

### *3.3.1 Common Transects*

Six transects were completed across the pond in 2016 with the single-beam transducer to create a dataset suitable for comparison with the multi-beam data. These six lines represent 1504 single-beam readings which, on average, are 0.2 m shallower than the multi-beam data for the same location and have a maximum difference of 2.24 m (Figure 10). The transect paths are shown in Figure 11 while the transect data are shown in Figure 12 and Figure 13.

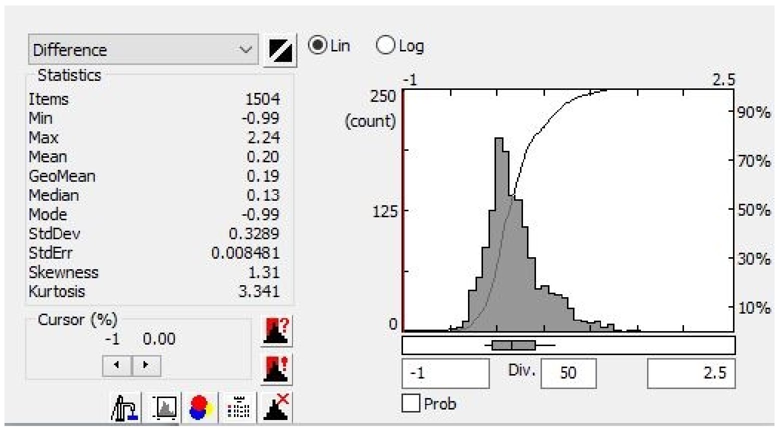



**Figure 10: Histogram of difference between single-beam and multi-beam surveys.**

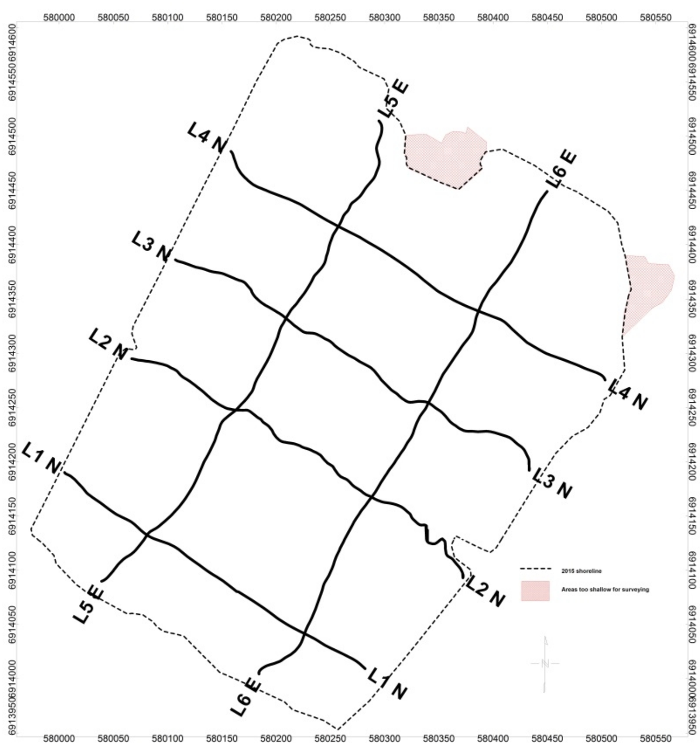



**Figure 11: Single-beam common transects surveyed in 2016 and shoreline from 2015.**

The purpose of the single-beam data collection is to provide an independent check (in addition to the lead-line dataset) on the multi-beam data. The distribution of the differences shows a bias towards deeper measurements for the multi-beam but also has positive skewness, indicating a larger range on the positive end (Figure 10). Examination of transects shown in Figure 12 show that many of these positive outliers, circled in blue, are not random; they often occur where the pond bottom has a steep gradient.

One possible explanation for this systematic difference is that in an area of steep bottom topography, the footprint of the sonar will cover a wide range of depths. The multi-beam system is calibrated with a pair of GPS antenna for heading determination and pitch, roll and heave detectors. Although the beam width is larger than the single beam (120˚ versus 9˚), the multi-beam operates with 512 beams over the 120˚ instead of a single beam over 9˚. The wider footprint per beam and the lack of heading and motion detectors on the single-beam instrumentation means there is greater ambiguity in imaging a dipping subsurface. The observed discrepancy between the datasets would be consistent with the single-beam taking the earliest reflection as bottom.

The area at the junction of transects 4 and 6 shows higher variability in the single-beam data than the multi-beam data. The fact that this high variability is observed in two perpendicular transects argues against an instrument malfunction cause; the reason for the effect is unknown.

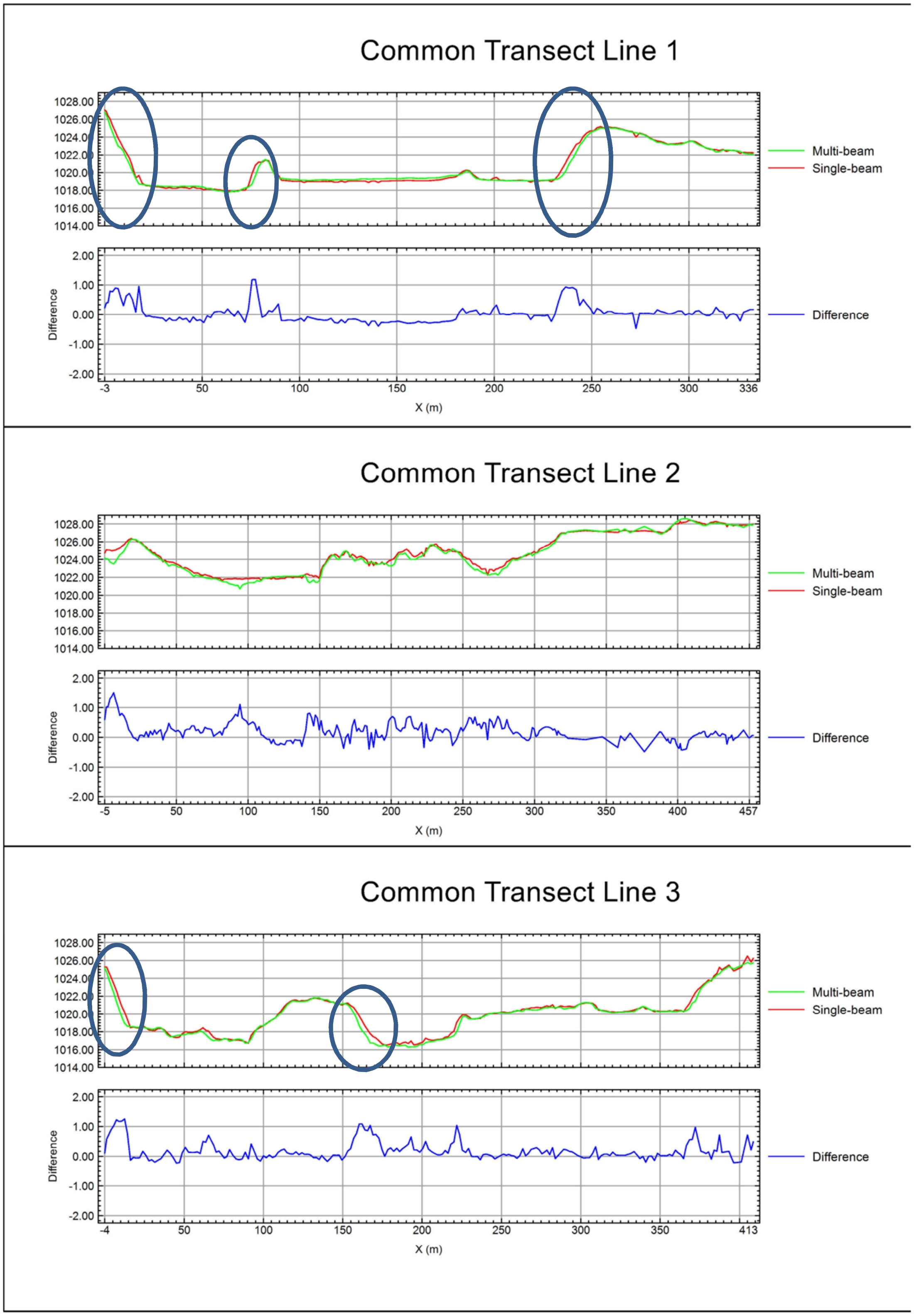



**Figure 12: Common single-beam and multi-beam transects 1, 2 and 3, showing pond bottom elevation (top panel) and single-beam / multi-beam difference (bottom panel). Blue ellipses show areas of steep bottom gradient and where a systematic difference between single-beam and multi-beam depth is observed.**

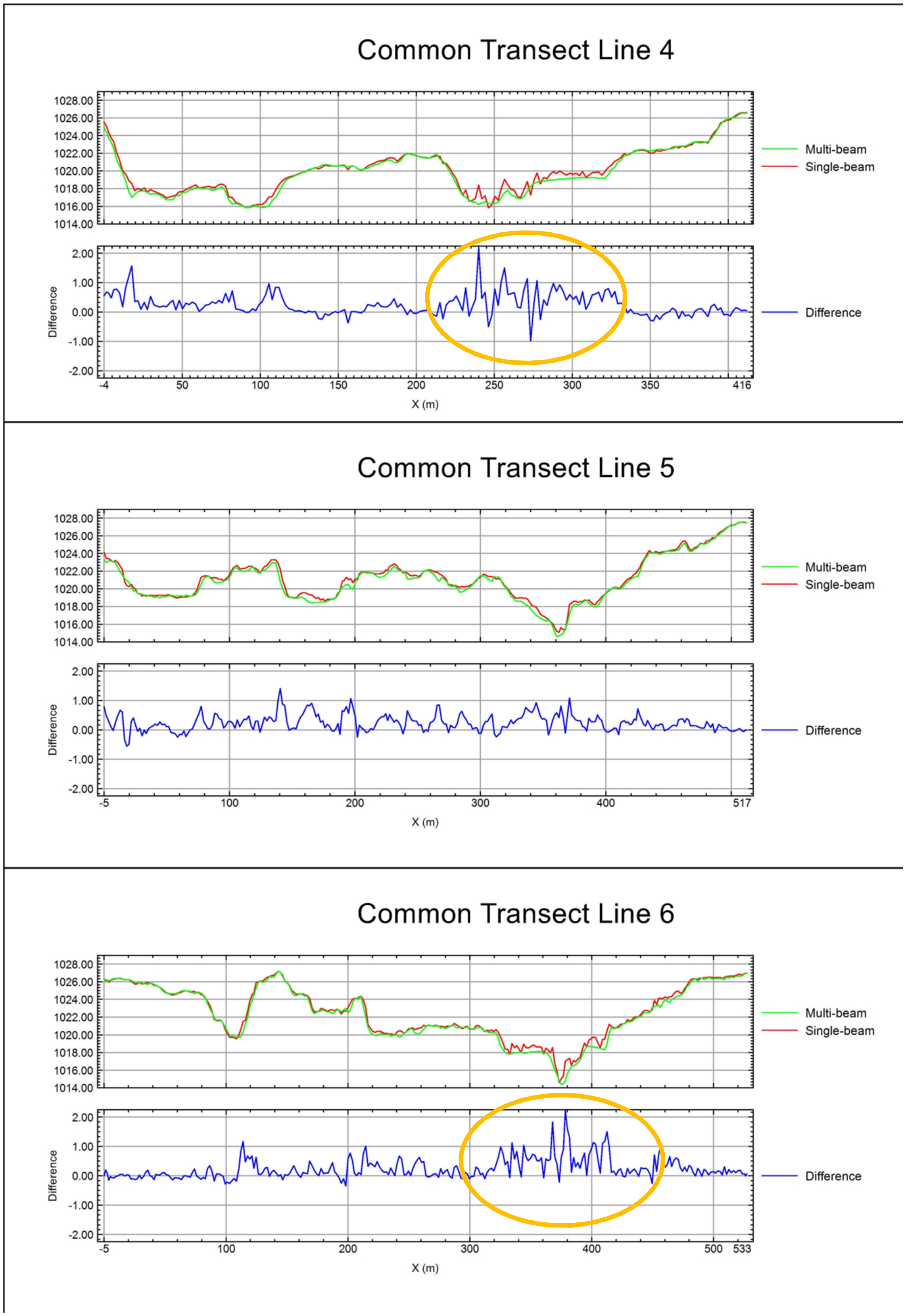



**Figure 13: Common single-beam and multi-beam transects 4, 5 and 6, showing pond bottom elevation (top panel) and single-beam / multi-beam difference (bottom panel). The orange ellipses show an area of single-beam roughness, near the junction of transects 4 and 6.**

### *3.3.2 Lead-line comparisons*

Six lead-line measurements were made at CVD pond in 2016 and are detailed in Table 2 – the full planned lead-line dataset was not collected because the site safety officer could no longer remain on site and a premature demobilization of the Aurora crew was required. The lead-line points were not sufficiently close to the single-beam lines to allow a direct comparison.

**Table 2: Lead-line measurements at CVD Pond. UTM coordinates are in NAD83 (CSRS) datum and elevations are metres above the HT2 geoid.**

| Point | UTM Easting (m) | UTM Northing (m) | Water Depth (m) | Lead-line derived bottom elevation (m) | Sonar derived bottom elevation (m) | Difference (m) |
|---|---|---|---|---|---|---|
| CVD 1 | 580316.7 | 6914146 | 7.4 | 1022.6632 | 1022.7132 | -0.05 |
| CVD 2 | 580346.1 | 6914133 | 2.7 | 1027.3632 | 1028.1116 | -0.75 |
| CVD 3 | 580128.9 | 6914267 | 8.2 | 1021.8632 | 1022.1312 | -0.27 |
| CVD 4 | 580167 | 6914246 | 8.4 | 1021.6632 | 1021.907 | -0.24 |
| CVD 5 | 580245.5 | 6914213 | 7.4 | 1022.6632 | 1022.8937 | -0.23 |
| CVD 6 | 580279.8 | 6914180 | 6 | 1024.0632 | 1023.9936 | 0.07 |

It should be noted that the greatest discrepancy at CVD 2 is in shallow water. Because the water elevation when the lead-line measurements were collected in 2016 is much higher than when the sonar data were collected in 2015, the water would have been too shallow for the multi-beam equipment and the sonar derived depth at CVD 2 is either an interpolation between shore line and single-beam point or single-beam point and multi-beam point and is therefore subject to much greater error than the other points.

Ignoring CVD 2, the mean difference is nevertheless biased negative (-0.14 m) which indicates the lead-line measurements are in general deeper than the multi-beam measurements. This bias is in part due to the methodology as the boat was not anchored while taking the measurements and was drifting significantly in the wind. Efforts to take the best data possible were made, but the lead-lines were to not vertical at the time of measurement which would explain the deep bias. Also adding to the deep bias of the lead-line measurements, based on the observations of ubiquitous and thick mud on the weighted part of the line, it was clear that the bottom of ID pond is very soft in places and the weight would have had significant penetration.

### *3.3.3 Daily check-ins*

GPS, multi-beam and sub-bottom data were collected during QA/QC check-ins at the beginning and end of each day. A control station was established at 580395, 6914126 (NAD83 UTM Zone 8N coordinates) by the suspension of a survey flag over the pond shown by the orange triangle in Figure 2; GPS and multi-beam sonar data were recorded for a minimum of 30 seconds during check-ins at this control station. Although not exemplary as a control station, this was deemed the best option that would be accessible by the survey vessel. The topography and geometry of the shoreline did not offer many suitable options to set up the control flag and consequently the water depth of chosen check-in site was shallower than ideal.

To allow meaningful comparison from day to day, the full range of the sonar swath was windowed to a small section (approximately 1 X 0.1 m) that was common to several days. Although small, this area does compare on the order of 125 individual multi-beam measurements which is sufficient for statistical analysis. The depths were gridded and then differenced to an arbitrary reference (the first day). The statistics of the differenced grids are instructive to the repeatability of the survey and are shown in Figure 14 for the days with sufficient overlap for good statistical analysis.

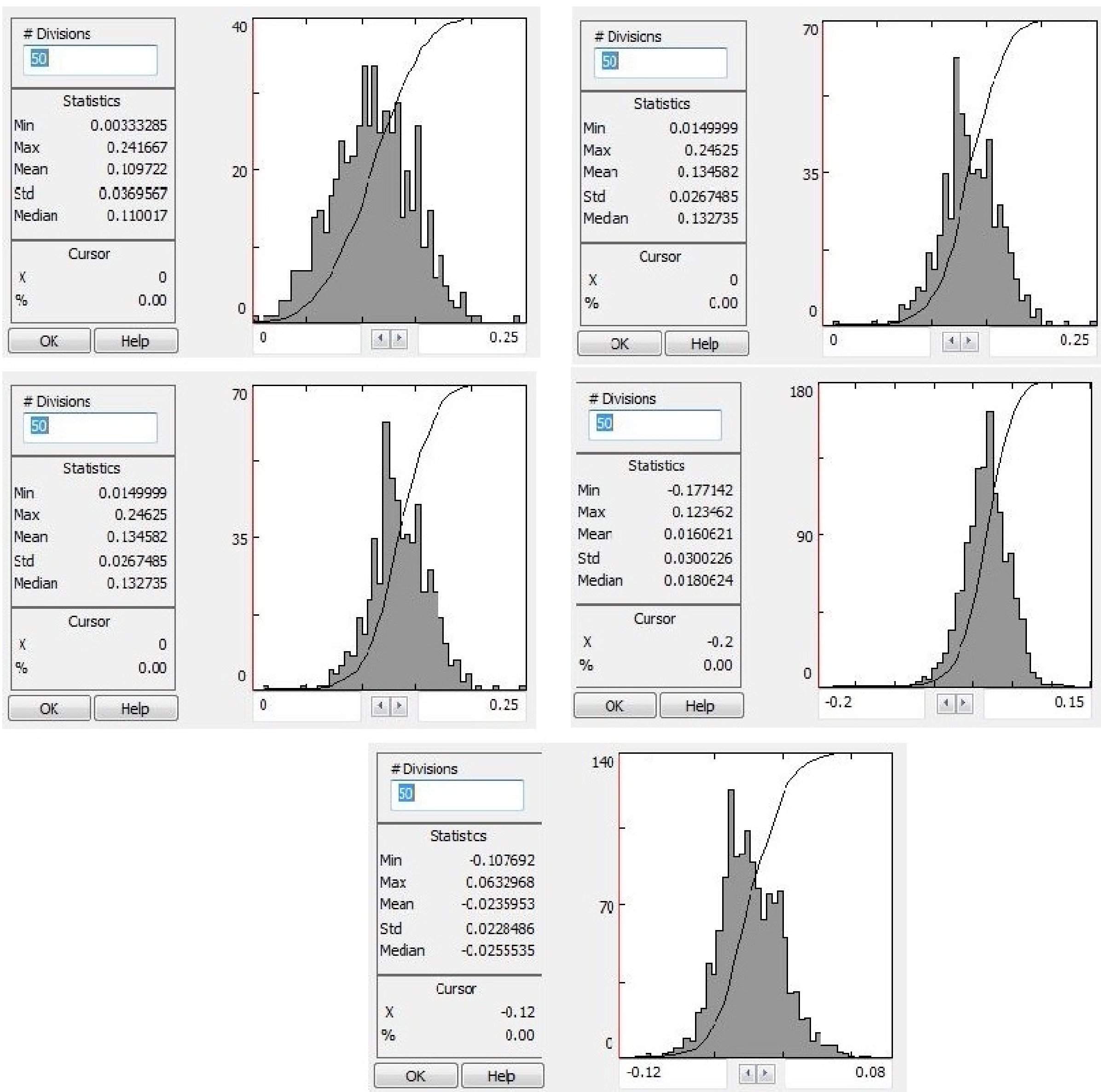



**Figure 14: Histograms of the differenced grids from multi-beam control points.**

The mean difference between the reference control point and individual repeats at that control point vary from a few centimeters to 13.4 centimeters. The standard deviation of the differenced grids is more consistent at 2 – 4 cm. This indicates that the 95% confidence level, which is approximately 2 standard deviations, is on the order of 6 cm. The larger datum shifts between the individual control readings are interpreted to be variations in the water elevation and not a representative measure of survey error. Variation of the water elevation was not measured systematically throughout the survey however there was approximately a 10 cm water elevation change in between Oct 21 and Oct 23 when two suites of shoreline measurements were taken, consistent with the above interpretation.

The sub-bottom control point data, taken at the same location and same methodology as the multi-beam data, from the single day of surveying are shown in Figure 15 (morning) and Figure 16 (afternoon). Qualitatively, the responses are equivalent, demonstrating proper equipment function.

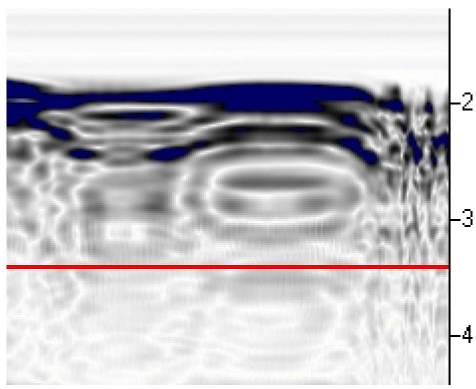



**Figure 15: Morning sub-bottom data at the flagged control point at 580395, 6914126 (NAD83 UTM Zone 8N coordinates) .**

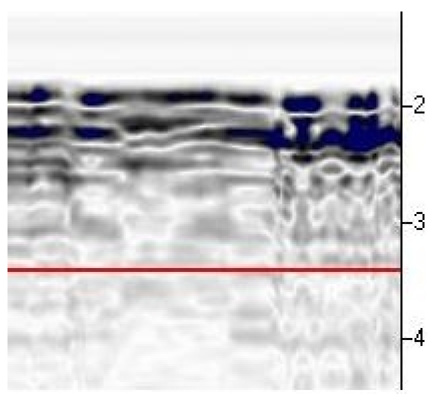



**Figure 16: Afternoon sub-bottom data at the flagged control point at 580395, 6914126 (NAD83 UTM Zone 8N coordinates).**

# 4 DISCUSSION AND INTERPRETATION

## 4.1 Bathymetry

The mean elevation of the shoreline during the 2015 survey is 1028.679 m (orthometric height above the HT2 geoid) with a standard deviation of 4.6 cm (n=111).

The total volume of water in the CVD Pond during the 2015 survey, given a shoreline at 1028.679 m, is 1,413,045.8 cubic metres. There is no allowance in this calculation for the water in the shallow areas where no data were collected, but a rough estimate indicated that this extra amount of water would be a small amount, on the order of 0.25% of the total pond volume.

The multi-beam sonar survey provides a very high resolution dataset of the water depth shown in Figure 17. The maximum depth of the pond is 14.68m in the northern part of the pond. There are several lineaments of sharp relief, interpreted to reflect dikes or pits that were part of the design of CVD pond, prior to its flooding.

Agreement was generally good between the lead-line depths, single-beam transects and the multi-beam data, providing confidence in the data veracity of all three products. The notable exceptions are depth mismatches between the single-beam and multi-beam in areas of high pond bottom slope and one area of the pond where high variability is noted in the single-beam dataset. The multi-beam system is designed to account for slope in the calculation of depths while the single-beam is a simpler system that likely takes the first (i.e. most shallow) reflector and this would explain the discrepancy. Because of the more advanced instrumentation and strategy to account for such topography, the multi-beam is the preferred dataset.

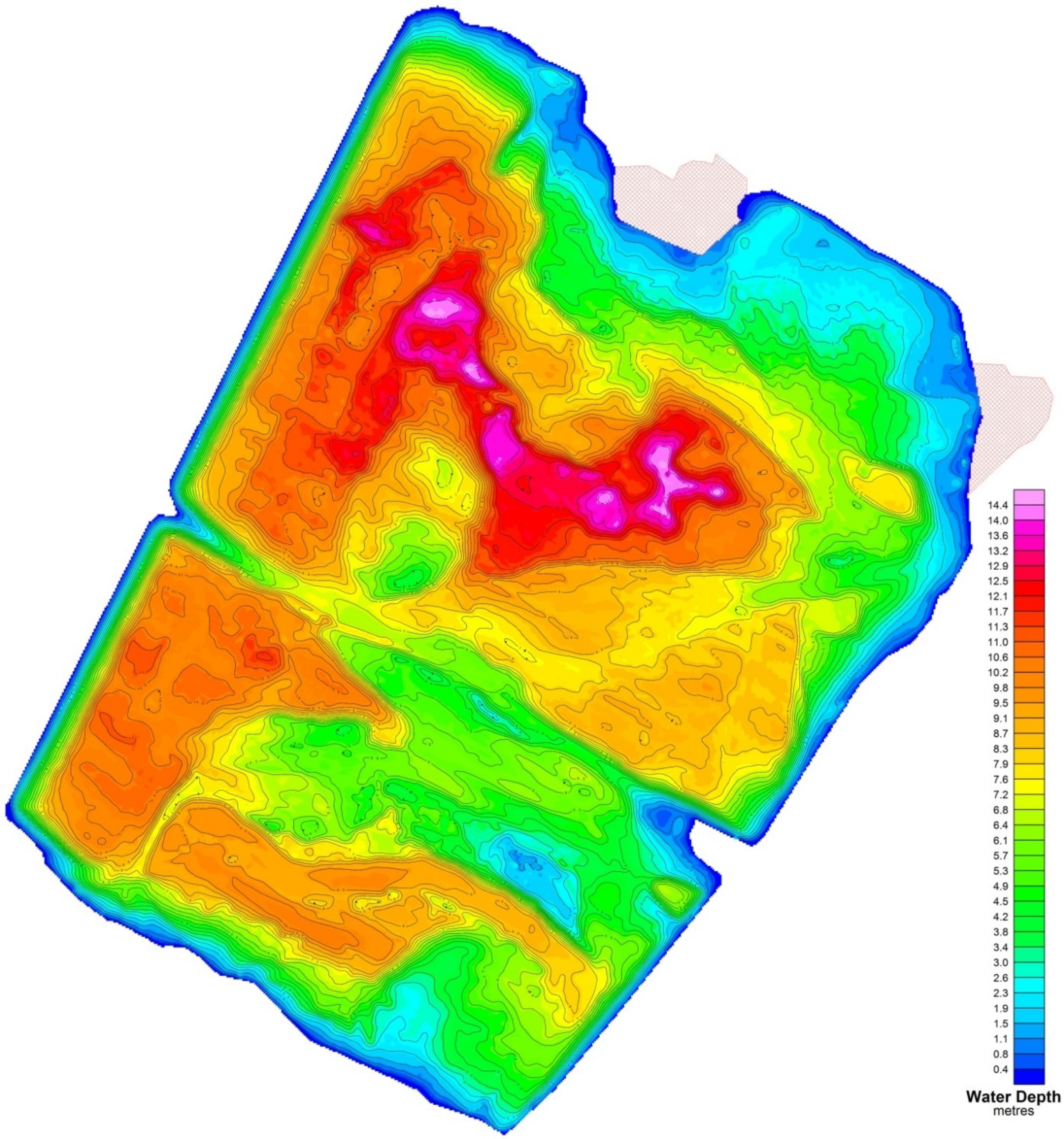



**Figure 17: Bathymetry of CVD Pond.**

## 4.2 Sub-bottom

The sub-bottom data of the CVD pond is markedly different from that of the ID pond where thick packages of the equivalent of Feature B are ubiquitously imaged. Additionally a distinct reflector is often seen below the Feature B equivalent at the ID pond while this was not observed at CVD pond. Both datasets support an interpretation of Feature B representing tailings but the nature of Features C through G are not clear and, with the hindsight of the data from the ID pond, calls into question whether they represent real manifestations of sub-bottom variation at all. The two subsurface logs obtained in the winter of 2015-2016 do not lend themselves to drawing conclusion on these features

Despite the ambiguity of the interpretation of the sub-bottom data at CVD a few comments can be made from the sections as well as from examination of the bathymetric data with the sub-bottom data.

The layered material which defines Feature B is well correlated with bounding escarpments, particularly in the south of the pond as seen in Figure 19 and . These features appear to represent a constructed pit where layers of sediment (fines from the polishing mill) were settled.

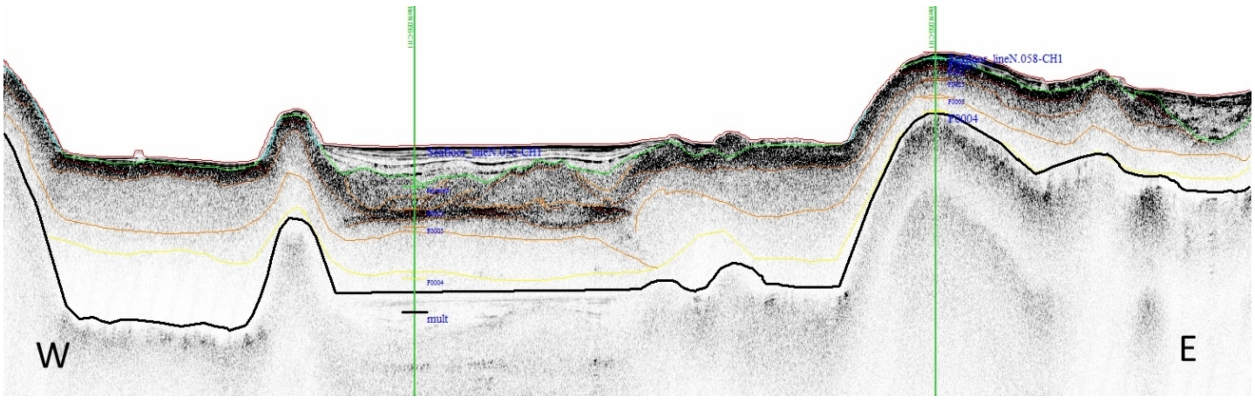



**Figure 18: L4 sub-bottom profile. The trace of this profile is shown as a red line in Figure 19.**

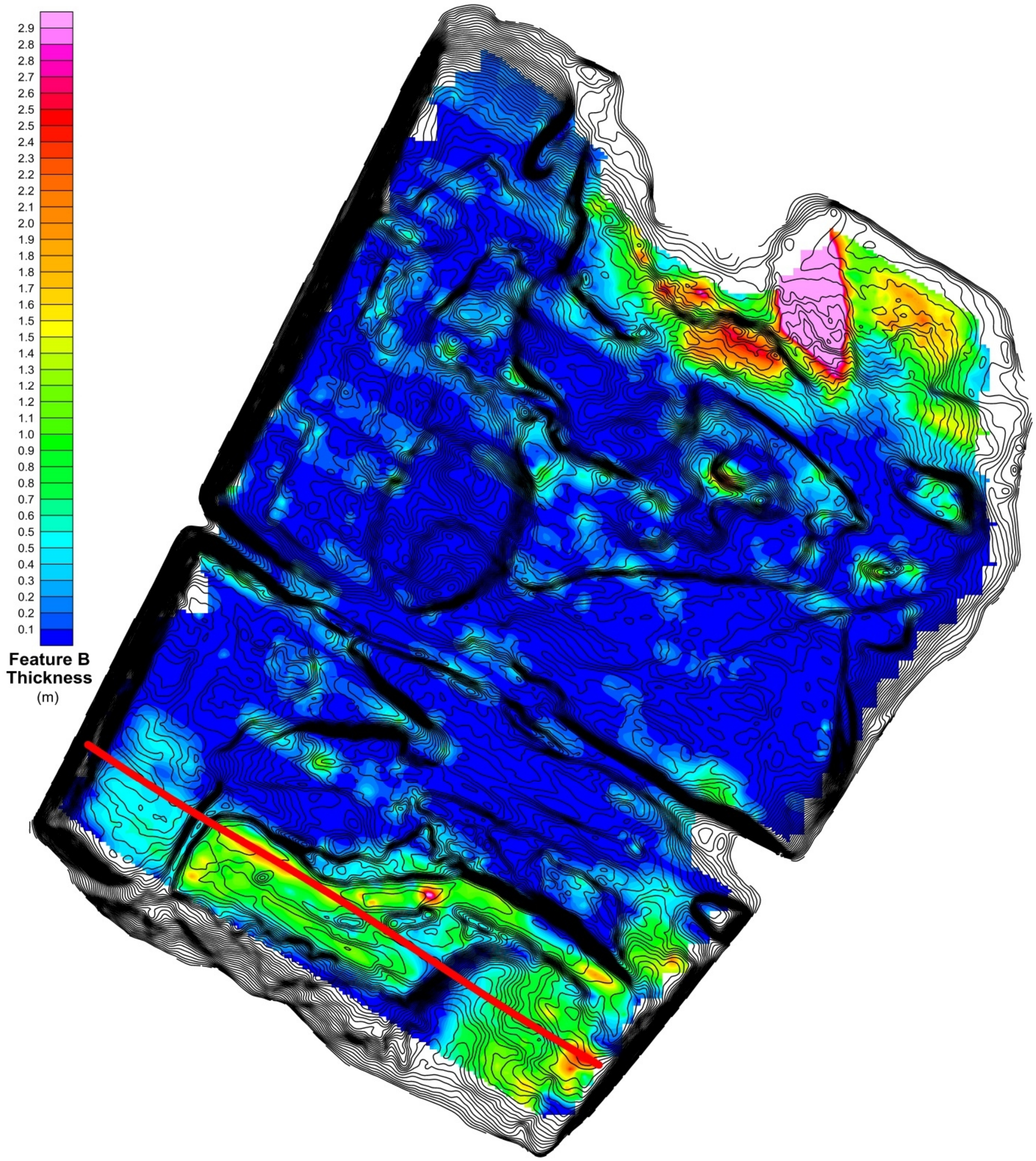



**Figure 19: Feature B thickness with bathymetry contours. The red line shows the trace of L4, the profile of which is Figure 18.**

Feature D thickness, the color contour in Figure 21, is well correlated with steep slopes. Figure 20 shows the profile for L26 which is drawn as a red line in Figure 21. On the slopes, the character of the response changes and does not have the layer of very high amplitude reflectance, prevalent in most of the section. Because of the lack of this high reflectance layer, represented by Feature C, Feature D thickens here. The interpretation is that Feature C represents finer material which has sloughed off the steeper slopes, leaving only the coarser material represented by Feature D. This interpretation should be verified with ground data.

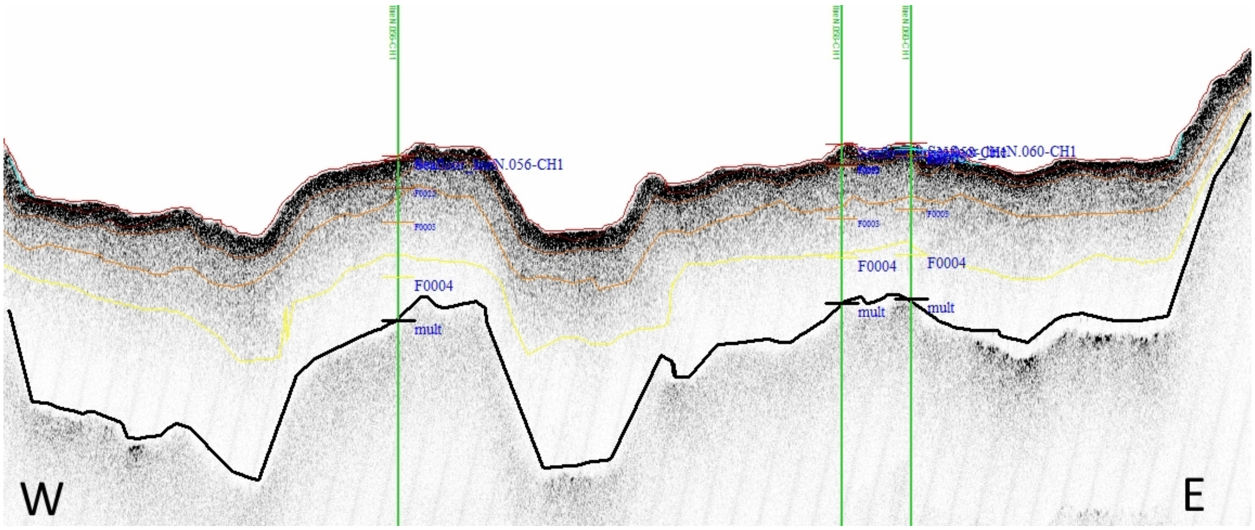



**Figure 20: L26 sub-bottom profile. The trace of this profile is shown as a red line in Figure 21.**

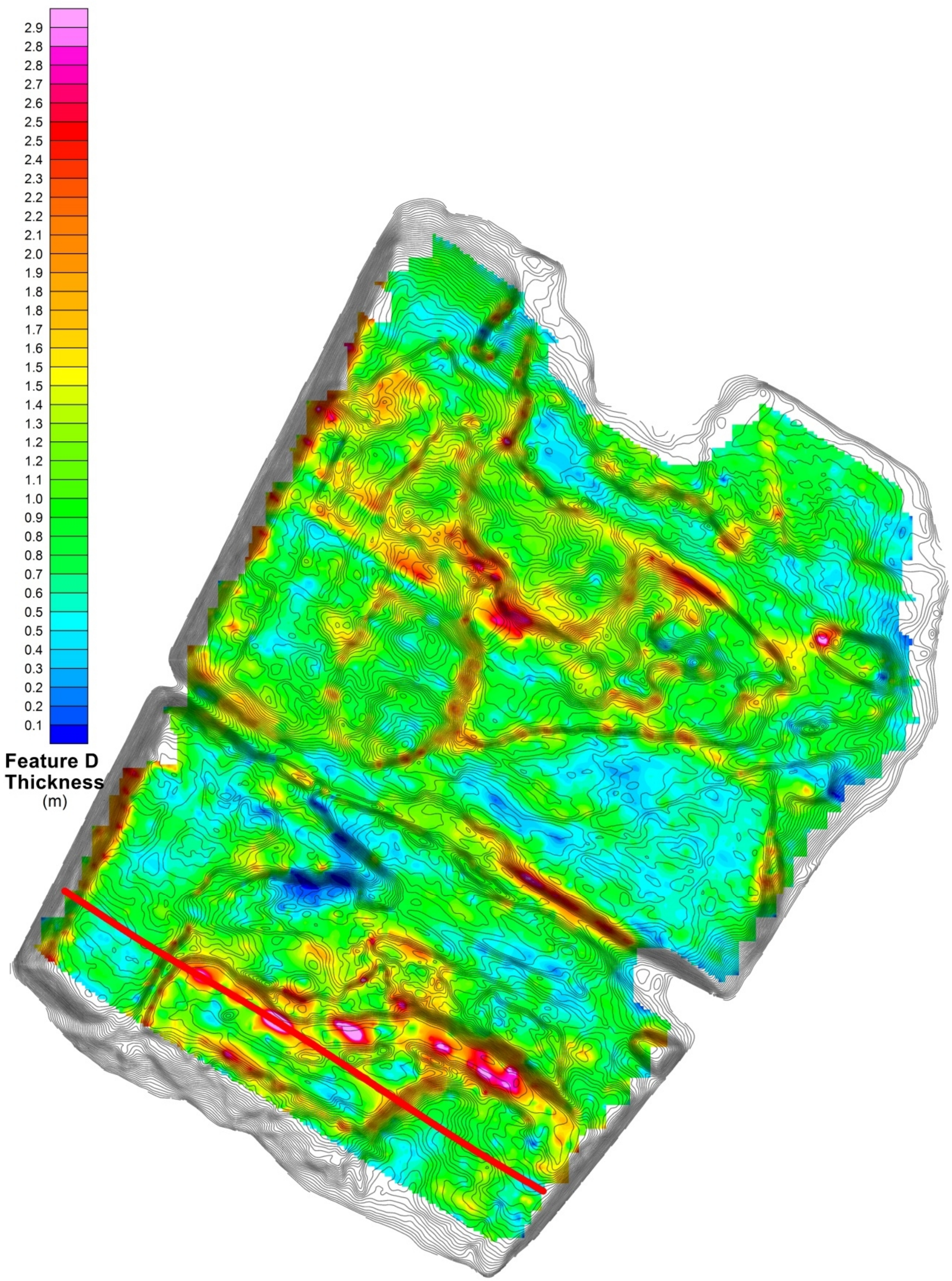
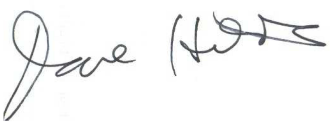



**Figure 21: Bathymetry contours with Feature D thickness colour contour underlay. The red line shows the trace of L26, the profile of which is Figure 20.**

Ground Penetrating Radar (GPR) is a complementary technique to acoustic sub-bottom profiling; GPR relies on a contrast in dielectric constant to image different sub-bottom material while the acoustic profiler depends on velocity and density contrasts. The depth of penetration of GPR may be limited, particularly in conductive environments.

The acoustic profiling data acquisition is slow and sometimes impossible to collect in shallow water. While this was not a serious problem at CVD, the Intermediate Dam Pond has a significant portion of the pond that is very shallow. A GPR survey on the ice may be an economical alternative / complement to shallow acoustic sub-bottom profiling, particularly when the ice is frozen directly to the pond bed; GPR coupling to the bed is maximized in the absence of a strong ice-water reflective interface.



2016.08.22 14:41:52 -07'00'

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Dave Hildes, P.Geo., Ph. D.
Geophysicist

__________________________

Shawn Scott,
Geophysical Technician

## Appendix I

**Project Log**

AURORA GEOSCIENCES

# CHM-15537-YT

| | Shawn Scott | Darrell Epps | Hannah Warrington | Dave Hildes |
|---|---|---|---|---|
| **Total** | 1 | 1 | 1 | 1 |
| **Tue 20-Oct-2015** | Mobe | Mobe | Mobe | Mobe |
| **Wed 21-Oct-2015** | Multi-beam | Shore Support | Shore Support | Multi-beam/Demobe |
| **Thu 22-Oct-2015** | Multi-beam | Multi-beam | Shore Support | N/A |
| **Fri 23-Oct-2015** | Multi-beam/Single Beam | Multi-beam/ RTK GPS | Shore Support | N/A |
| **Sat 24-Oct-2015** | Multi-beam | Multi-beam | Shore Support | N/A |
| **Sun 25-Oct-2015** | Sub-bottom | Sub-bottom | Shore Support | N/A |
| **Mon 26-Oct-2015** | Weather day | Weather day | Weather day | N/A |
| **Tue 27-Oct-2015** | Demobe | Demobe | Demobe | N/A |
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# Production Summary

| | | | | | | |
|---|---|---|---|---|---|---|
| | CVP Multi-beam | CVP Single-beam | CVP Sub-bottom | Intermediate Multi-beam | Intermediate Single-beam | Intermediate Sub-bottom |
| Estimate percentage completed | 100 | 30 | 100 | 0 | 0 | 0 |
| Tue 20-Oct-2015 | mobe and orientation | | | | | |
| Wed 21-Oct-2015 | 25 | | | | | |
| Thu 22-Oct-2015 | 35 | | | | | |
| Fri 23-Oct-2015 | 30 | 30 | | | | |
| Sat 24-Oct-2015 | 10 | | | | | |
| Sun 25-Oct-2015 | | | 100 | | | |
| Mon 26-Oct-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tue 27-Oct-2015 | shoreline RTK GPS points and demobe | | | | | |

AURORA GEOSCIENCES

# Faro Bathymetry and Sub-Bottom

**DATE:** October-20-15

**PREPARED BY:**

**Shawn Scott**

***LOGISTICS***

| *Type* | *Contractor/Renter* | *Hrs or units* |
|---|---|---|
| Truck | AGL | 1 |
| Trailer | AGL | 1 |
| Boat | AGL | 1 |
| Sub-bottom 424 | Rental | 0 |
| Multibeam MB1 & controller | Rental | 1 |
| Single Beam | AGL | 0 |
| ATV & trub trailer | AGL | 0 |

***Crew***

| *Position* | *Contractor* | *Hrs or units* |
|---|---|---|
| Geophysicist | Dave Hildes | 10 |
| Geophysicist | Darrell Epps | 10 |
| Technician | Shawn Scott | 10 |
| Field Hand | Hannah Warrington | 10 |

***Comments***

Weather

Clear turning to slightly overcast. +5 in Whitehorse

*Notes (production comments, incidents, other)*

Mobilized to Faro from Whitehorse via truck around 7:30am and completed hazard assessment. Arrived in Faro around noon, grabbed a bite to eat and then completed the TES orientation and safety orientation with Robin. Completed a site visit with Robin later in the afternoon and logistics planning.

AURORA GEOSCIENCES

# Faro Bathymetry and Sub-Bottom

| | |
|---|---|
| **DATE:** | October-21-15 |

**PREPARED BY:**

**Shawn Scott**

***LOGISTICS***

| *Type* | *Contractor/Renter* | *Hrs or units* |
|---|---|---|
| Truck | AGL | 1 |
| Trailer | AGL | 1 |
| Boat | AGL | 1 |
| Sub-bottom 424 | Rental | 0 |
| Multibeam MB1 & controller | Rental | 1 |
| Single Beam | AGL | 0 |
| ATV & trub trailer | AGL | 1 |

***Crew***

| *Position* | *Contractor* | *Hrs or units* |
|---|---|---|
| Geophysicist | Dave Hildes | 10 |
| Geophysicist | Darrell Epps | 10 |
| Technician | Shawn Scott | 10 |
| Field Hand | Hannah Warrington | 10 |

***Comments***

Weather

Snow in the morning. Clear in the afternoon

*Notes (production comments, incidents, other)*

Safety Meeting at CH2MHill office at 8am
Set up through the morning. Initial set up and unloading took longer than what is anticipated for daily set up.
Calibration of instruments and intial tests in the early afternoon.
Multibeam surveying started at approximately 14:45 and ended at 16:40.
No issues with data aquisition and early progress is encouraging.
Approximately 25% of CVP is completed.
All equipment and apparell cleaned with safe water and equipment packed at end of day by 18:00. Must prepare to leave earlier in future days to avoid a late checkout at CH2MH office.
Dave Hildes demobed at the end of the day and is no longer on site.

AURORA GEOSCIENCES

# Faro Bathymetry and Sub-Bottom

| DATE: | October-22-15 |
|---|---|

| PREPARED BY: |
|---|
| Shawn Scott |

***LOGISTICS***

| *Type* | *Contractor/Renter* | *Hrs or units* |
|---|---|---|
| Truck | AGL | 1 |
| Trailer | AGL | 1 |
| Boat | AGL | 1 |
| Sub-bottom 424 | Rental | 0 |
| Multibeam MB1 & controller | Rental | 1 |
| Single Beam | AGL | 0 |
| ATV & trub trailer | AGL | 1 |

***Crew***

| *Position* | *Contractor* | *Hrs or units* |
|---|---|---|
| Geophysicist | Darrell Epps | 10 |
| Technician | Shawn Scott | 10 |
| Field Hand | Hannah Warrington | 10 |
| | | |

***Comments***

Weather

Snow in the morning again, rain in the afternoon. One sliver of sun in the late afternoon.

*Notes (production comments, incidents, other)*

Safety Meeting at CH2MHill office at 800am
Reviewed boating AHA and FLRA with Robin.
Day was spent continuing multi-beam surveying on the CVP.
Networking issues with instruments caused an hour's delay when we first set out.
Most of the data acquisition was in shallow water, requiring many, many passes to get good coverage.
RTK coverage failed momentarily at the end of the day, the issue was resolved in time for a last qc checkpoint reading.
Checked out at 540pm.

AURORA GEOSCIENCES

# Faro Bathymetry and Sub-Bottom

| DATE: | October-23-15 |
|---|---|

**PREPARED BY:**

**Shawn Scott**

***LOGISTICS***

| *Type* | *Contractor/Renter* | *Hrs or units* |
|---|---|---|
| Truck | AGL | 1 |
| Trailer | AGL | 1 |
| Boat | AGL | 1 |
| Sub-bottom 424 | Rental | 0 |
| Multibeam MB1 & controller | Rental | 1 |
| Single Beam | AGL | 1 |
| ATV & trub trailer | AGL | 1 |

***Crew***

| *Position* | *Contractor* | *Hrs or units* |
|---|---|---|
| Geophysicist | Darrell Epps | 10 |
| Technician | Shawn Scott | 10 |
| Field Hand | Hannah Warrington | 10 |
| | | |

***Comments***

Weather

Snow in the morning yet again, sunny by noon.

*Notes (production comments, incidents, other)*

Safety Meeting at CH2MHill office at 800am
On the water by 1030am. Started the day by continuing the multibeam bathymetry but RTA had wasn't able to connect until an hour later. Did a sound velocity cast and check-in with RTK while waiting. Finished most of the multibeam with a bit of cleanup to be done tomorrow. In order to maximize our efficiency without risking a late checkout at the CH2MHill office, we completed the labour intensive tear down work early. With the time left before we needed to be off site, we collected RTA GPS data along the shore of the CVP and also collected some single beam data with the zodiac along the perimeter where it is too shallow for the large boat.
Checked out of CH2MHIll at 550pm.

# Faro Bathymetry and Sub-Bottom

AURORA GEOSCIENCES

| DATE: | October-24-15 |
| --- | --- |

**PREPARED BY:**

**Shawn Scott**

***Comments***

Weather

Cloudy to start the day and then sunny through the afternoon.

***LOGISTICS***

| *Type* | *Contractor/Renter* | *Hrs or units* |
| --- | --- | --- |
| Truck | AGL | 1 |
| Trailer | AGL | 1 |
| Boat | AGL | 1 |
| Sub-bottom 424 | Rental | 0 |
| Multibeam MB1 & controller | Rental | 1 |
| Single Beam | AGL | 1 |
| ATV & trub trailer | AGL | 1 |

***Crew***

| *Position* | *Contractor* | *Hrs or units* |
| --- | --- | --- |
| Geophysicist | Darrell Epps | 10 |
| Technician | Shawn Scott | 10 |
| Field Hand | Hannah Warrington | 10 |
| | | |

*Notes (production comments, incidents, other)*

Safety Meeting at CH2MHill office at 800am
On the water by 945am. Continued problems waiting for the RTA to warm up. Spent most of the day doing detail work to ensure full coverage for the multibeam survey. Spent some time at the end of the day trying to prepapre for sub-bottom survey for tomorrow.
Continued problems connecting to the Digibar -S sound velocity probe, managed two complete casts but spent much more time attempting to read data from it. Tried again to access shallow areas to the north of the pond but again struck a large rock. Had the same problem there the day before in the zodiac and have found no safe solution to surveying there.
Checked out of CH2MHIll at 550pm.

# Faro Bathymetry and Sub-Bottom

AURORA GEOSCIENCES

| DATE: | October-25-15 |
|---|---|

**PREPARED BY:**

**Shawn Scott**

***LOGISTICS***

| *Type* | *Contractor/Renter* | *Hrs or units* |
|---|---|---|
| Truck | AGL | 1 |
| Trailer | AGL | 1 |
| Boat | AGL | 1 |
| Sub-bottom 424 | Rental | 1 |
| Multibeam MB1 & controller | Rental | 1 |
| Single Beam | AGL | 1 |
| ATV & trub trailer | AGL | 1 |

***Crew***

| *Position* | *Contractor* | *Hrs or units* |
|---|---|---|
| Geophysicist | Darrell Epps | 10 |
| Technician | Shawn Scott | 10 |
| Field Hand | Hannah Warrington | 10 |
| | | |

***Comments***

Weather

Sunny and clear. Cold though, ice on edges of the water.

*Notes (production comments, incidents, other)*

Safety Meeting at CH2MHill office at 800am
On the water by 930am.
Set up the sub-bottom and tested several lines repeatedly with different frequency chirps. Ran survey all day with few problems.
Finished the day with little time to spare but completed the sub-bottom survey on the Cross Valley Dam.
Checked out of CH2MHIll at 555pm.

AURORA GEOSCIENCES

# Faro Bathymetry and Sub-Bottom

| DATE: | October-26-15 |
|---|---|

**PREPARED BY:**

**Shawn Scott**

***LOGISTICS***

| *Type* | *Contractor/Renter* | *Hrs or units* |
|---|---|---|
| Truck | AGL | 1 |
| Trailer | AGL | 1 |
| Boat | AGL | 1 |
| Sub-bottom 424 | Rental | 1 |
| Multibeam MB1 & controller | Rental | 1 |
| Single Beam | AGL | 1 |
| ATV & trub trailer | AGL | 1 |

***Crew***

| *Position* | *Contractor* | *Hrs or units* |
|---|---|---|
| Geophysicist | Darrell Epps | 10 |
| Technician | Shawn Scott | 10 |
| Field Hand | Hannah Warrington | 10 |
| | | |

***Comments***

Weather

Sunny all day but significantly colder. Ice fully covering both ponds all day.

*Notes (production comments, incidents, other)*

Safety Meeting at CH2MHill office at 800am
Arrived at ponds to discover they were both completely covered in ice. Contacted CH2MHill and notified them of the problem, saying we would carry on preparing to work in hopes of the ice melting. We continued to monitor the ice thickness and maintained close contact with Robin and Robert of CH2MHill, who felt it was unsafe to attempt to launch a boat on either pond. The ice did not melt and we were advised to consider today a weather day and return ready to work in the morning, should conditions allow.

AURORA GEOSCIENCES

# Faro Bathymetry and Sub-Bottom

| DATE: | October-27-15 |
| --- | --- |

**PREPARED BY:**

**Shawn Scott**

***LOGISTICS***

| *Type* | *Contractor/Renter* | *Hrs or units* |
| --- | --- | --- |
| Truck | AGL | 1 |
| Trailer | AGL | 1 |
| Boat | AGL | 1 |
| Sub-bottom 424 | Rental | 1 |
| Multibeam MB1 & controller | Rental | 1 |
| Single Beam | AGL | 1 |
| ATV & trub trailer | AGL | 1 |

***Crew***

| *Position* | *Contractor* | *Hrs or units* |
| --- | --- | --- |
| Geophysicist | Darrell Epps | 10 |
| Technician | Shawn Scott | 10 |
| Field Hand | Hannah Warrington | 10 |
| | | |

***Comments***

Weather

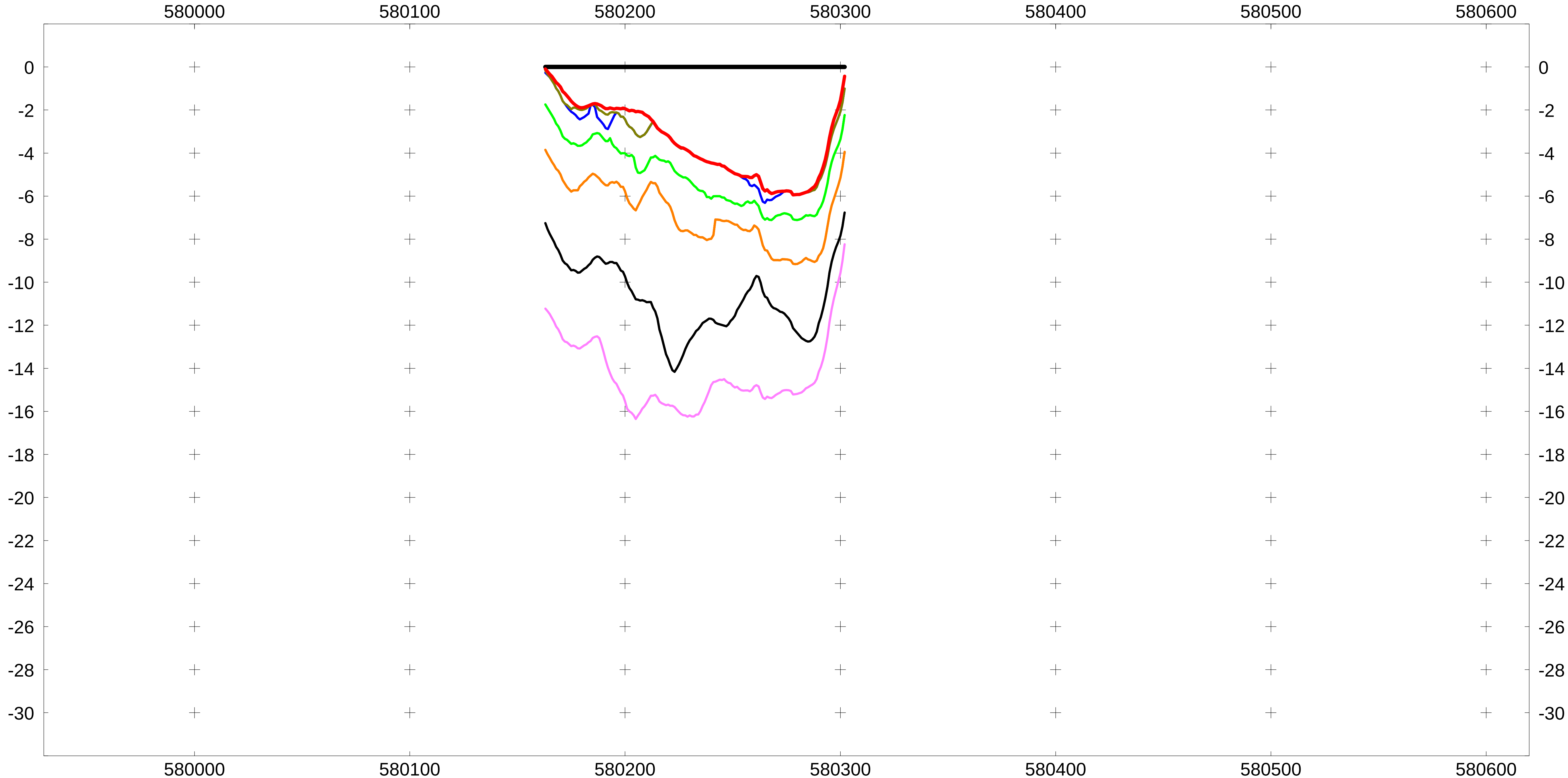
overcast and temperature hovering around -5

*Notes (production comments, incidents, other)*

The weather stayed below zero overnight and the short term forecast calls for more of the same. Discussions between CH2M Hill and Aurora Geosciences determined that the survey could not proceed any longer due to the ice on the ponds and that the data collection/field work would be ended. Collected some shoreline RTK-GPS points in the morning and then left site around 11am. Loaded up equipment and instruments after lunch and demobilized via truck back to Whitehorse around 3pm.

## Appendix II

**Cross-sections**




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

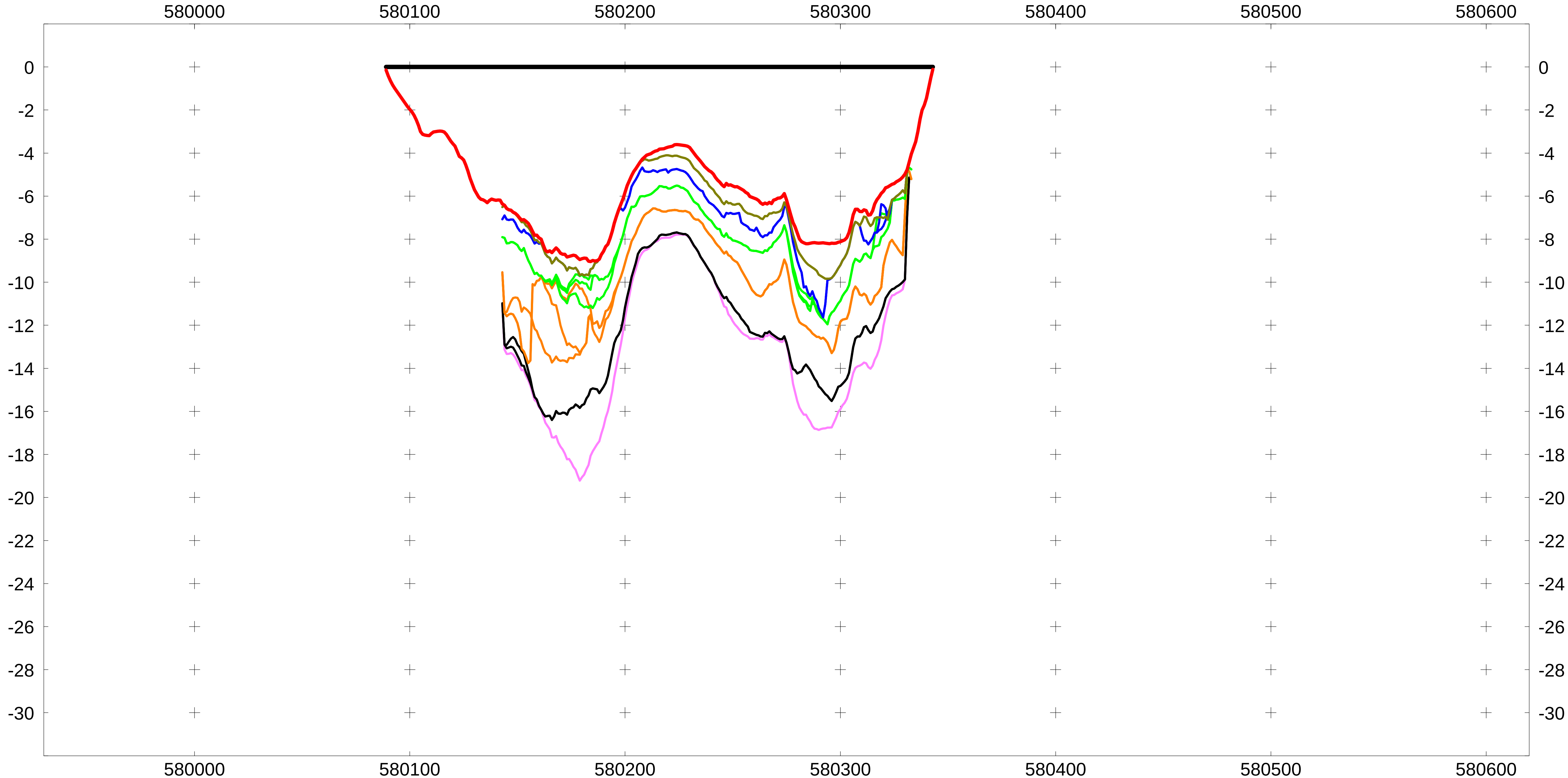
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**
**Bathymetric and Sub-Bottom Survey**
**Cross section at UTMN 6914000**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




## LEGEND

- Water :
- Bottom :
- Feature B :
- Feature C :
- Feature D :
- Feature E :
- Feature F :
- Feature G :

**Scale (horizontal)**

25 0 25 50

(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5

(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

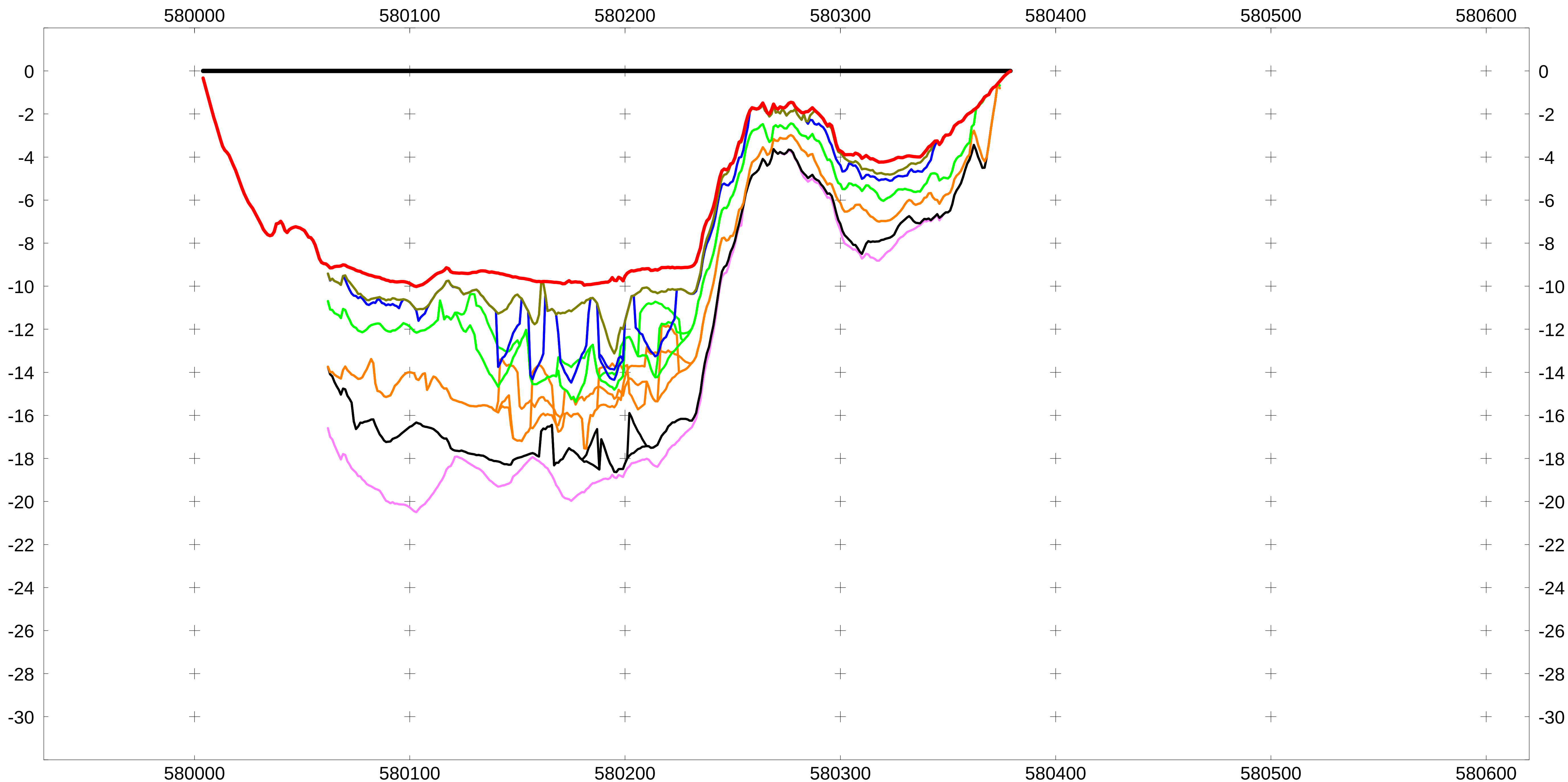
### Bathymetric and Sub-Bottom Survey

### Cross section at UTMN 6914050

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

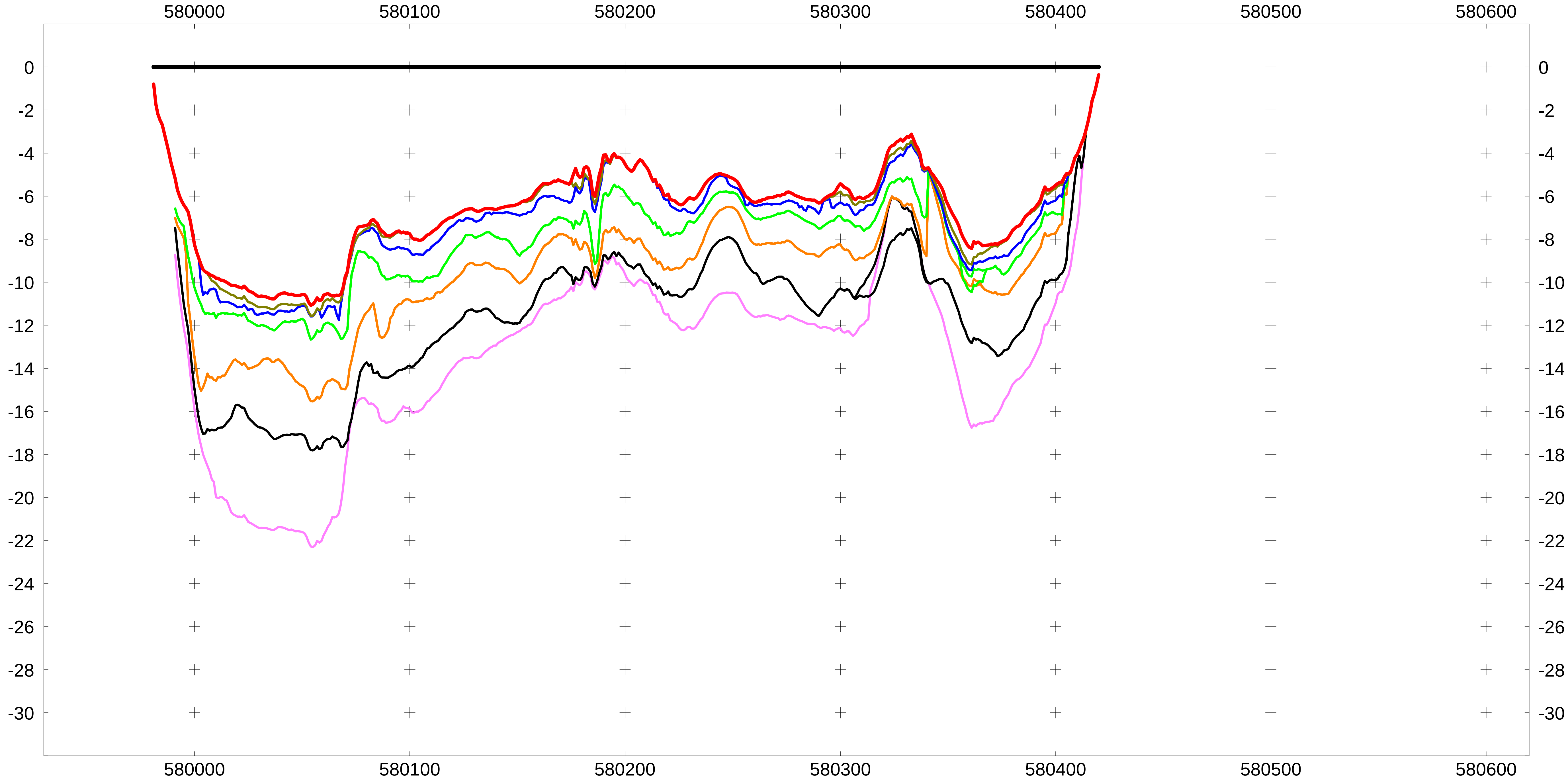
## CH2M HILL LTD.

## CROSS VALLEY DAM POND
### Bathymetric and Sub-Bottom Survey
### Cross section at UTMN 6914100

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

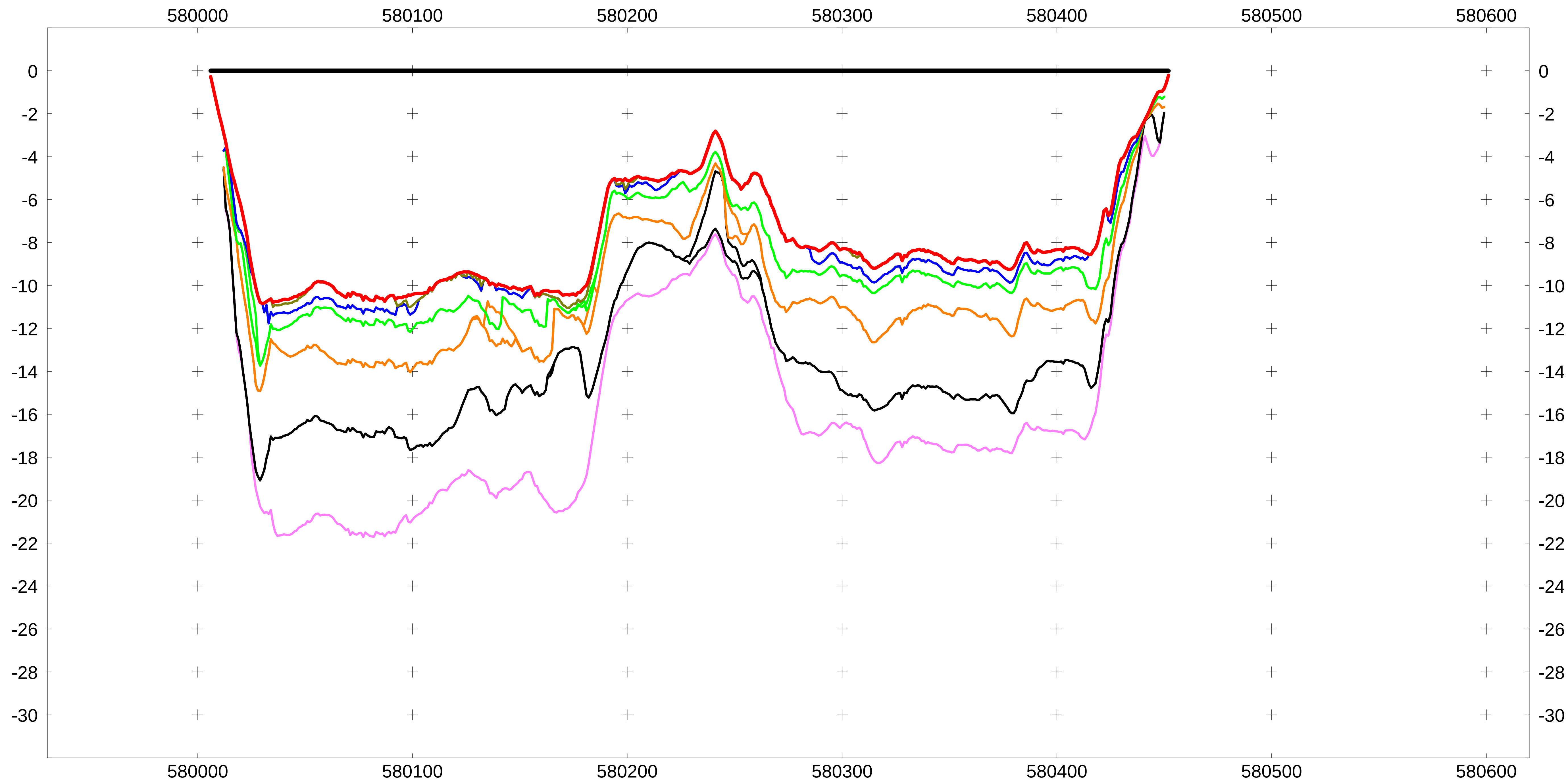
## CH2M HILL LTD.

## CROSS VALLEY DAM POND
**Bathymetric and Sub-Bottom Survey**
**Cross section at UTMN 6914150**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

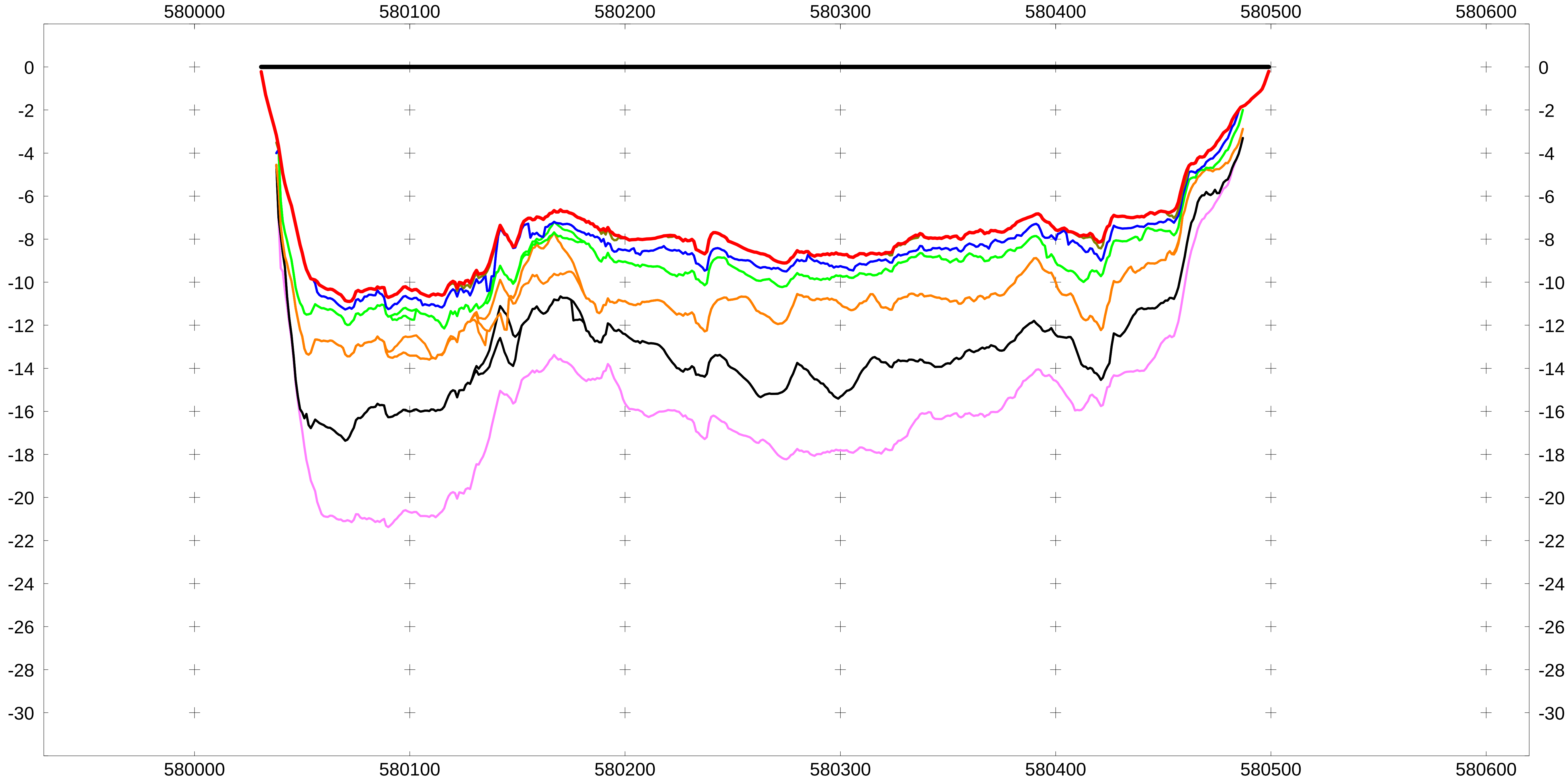
## CH2M HILL LTD.

## CROSS VALLEY DAM POND
**Bathymetric and Sub-Bottom Survey**
**Cross section at UTMN 6914200**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

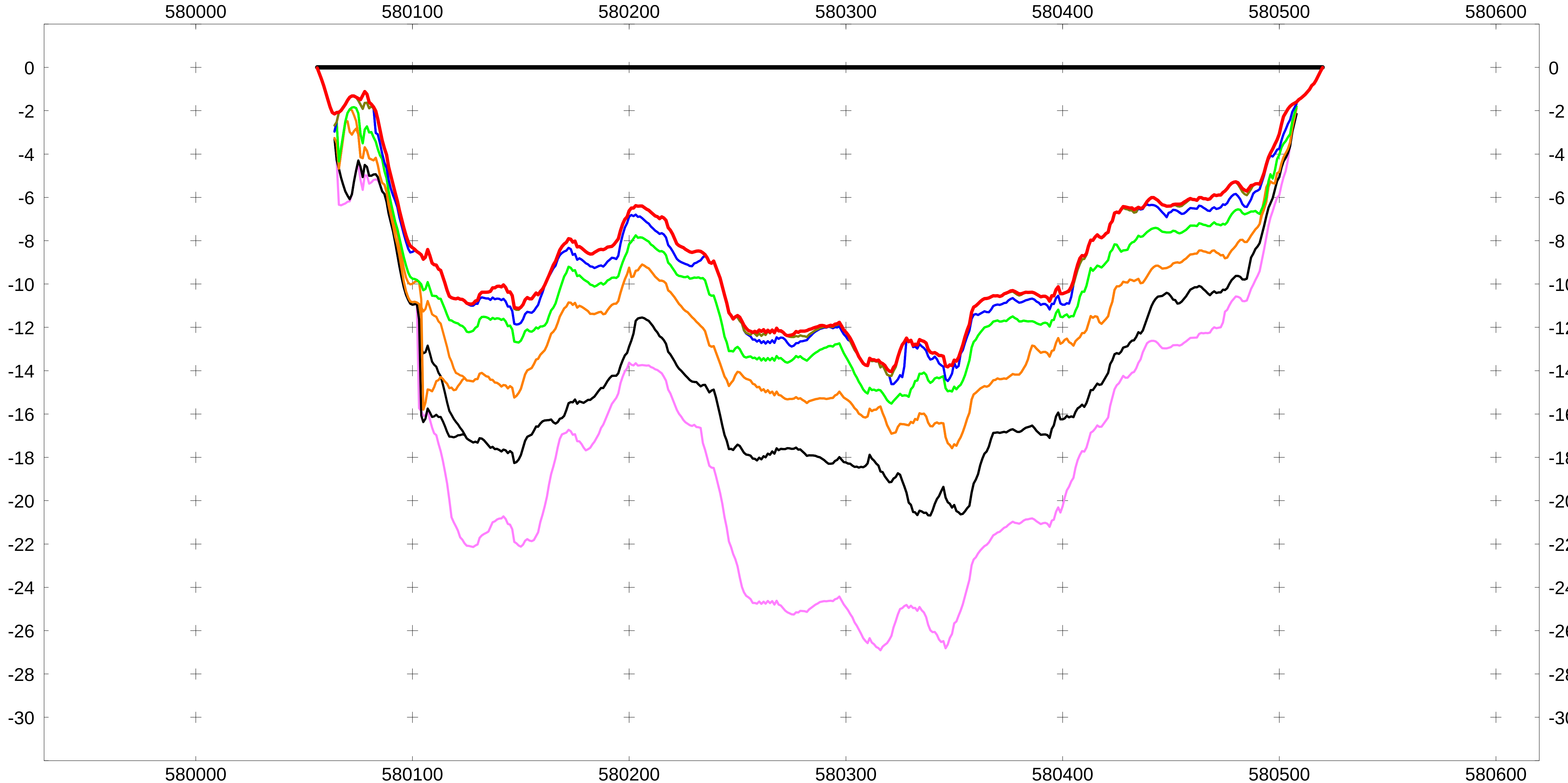
## CROSS VALLEY DAM POND

**Bathymetric and Sub-Bottom Survey**
**Cross section at UTMN 6914250**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

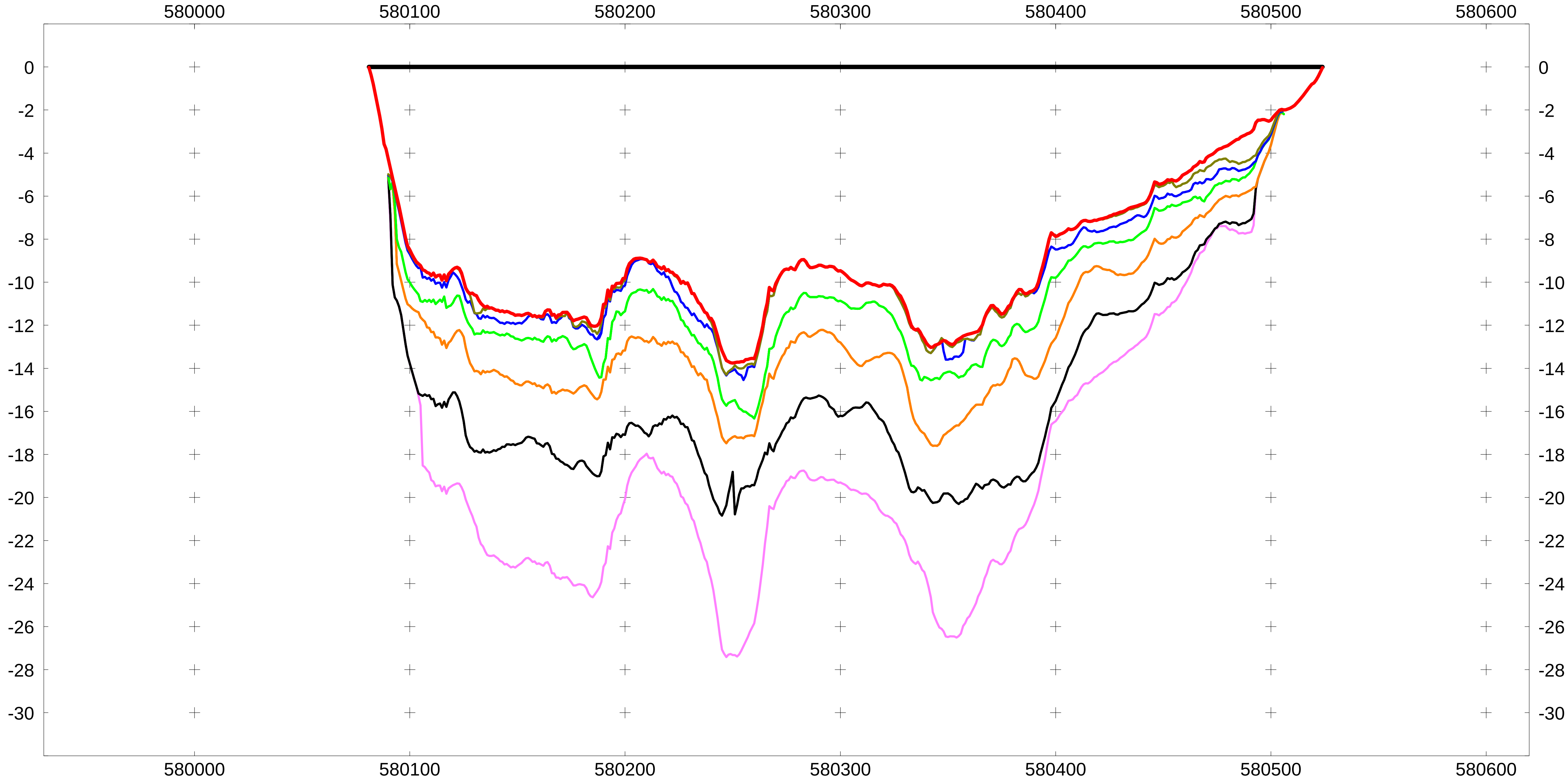
### Bathymetric and Sub-Bottom Survey

### Cross section at UTMN 6914300

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS)**
**UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

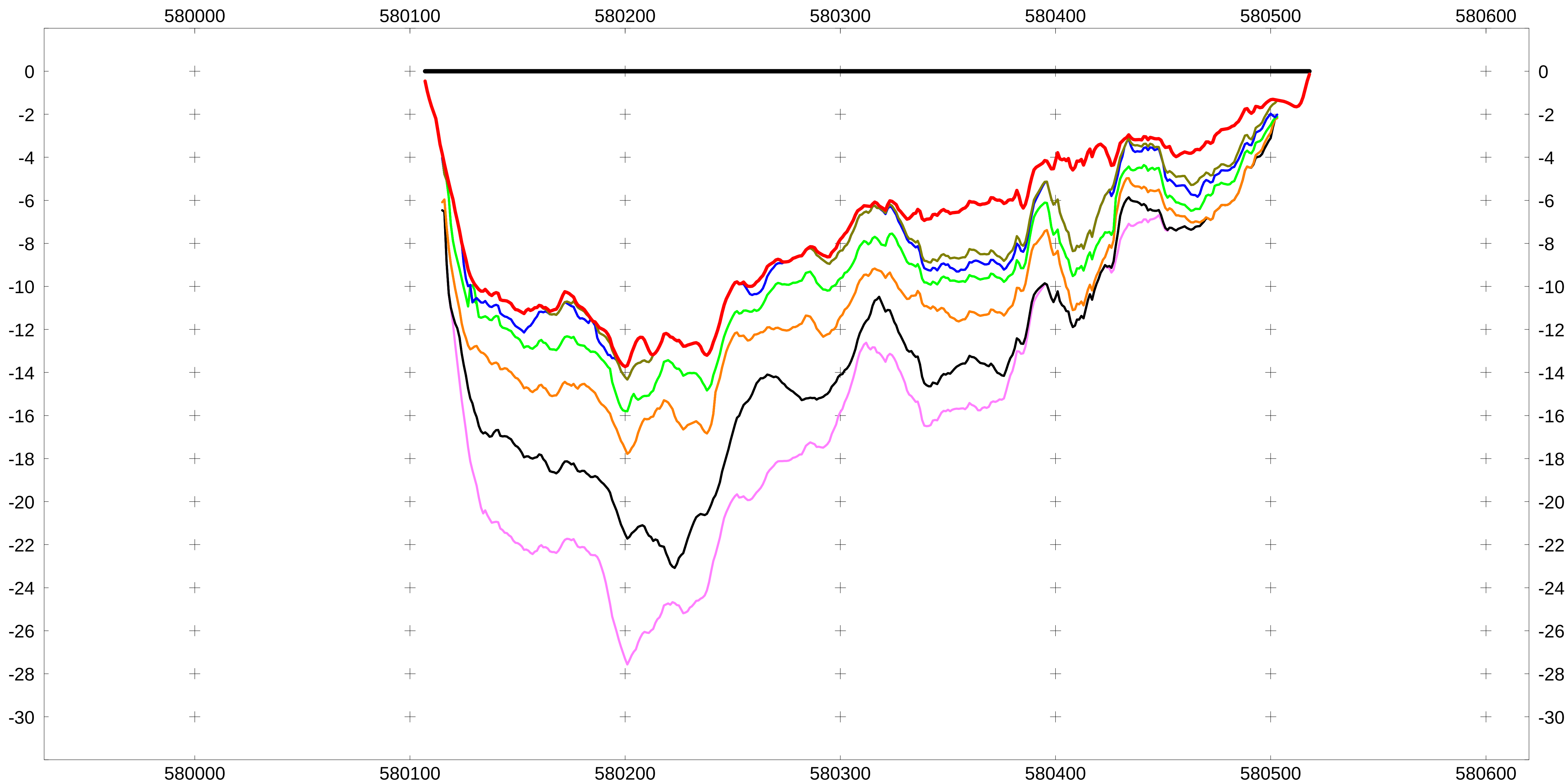
## CROSS VALLEY DAM POND

**Bathymetric and Sub-Bottom Survey**
**Cross section at UTMN 6914350**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

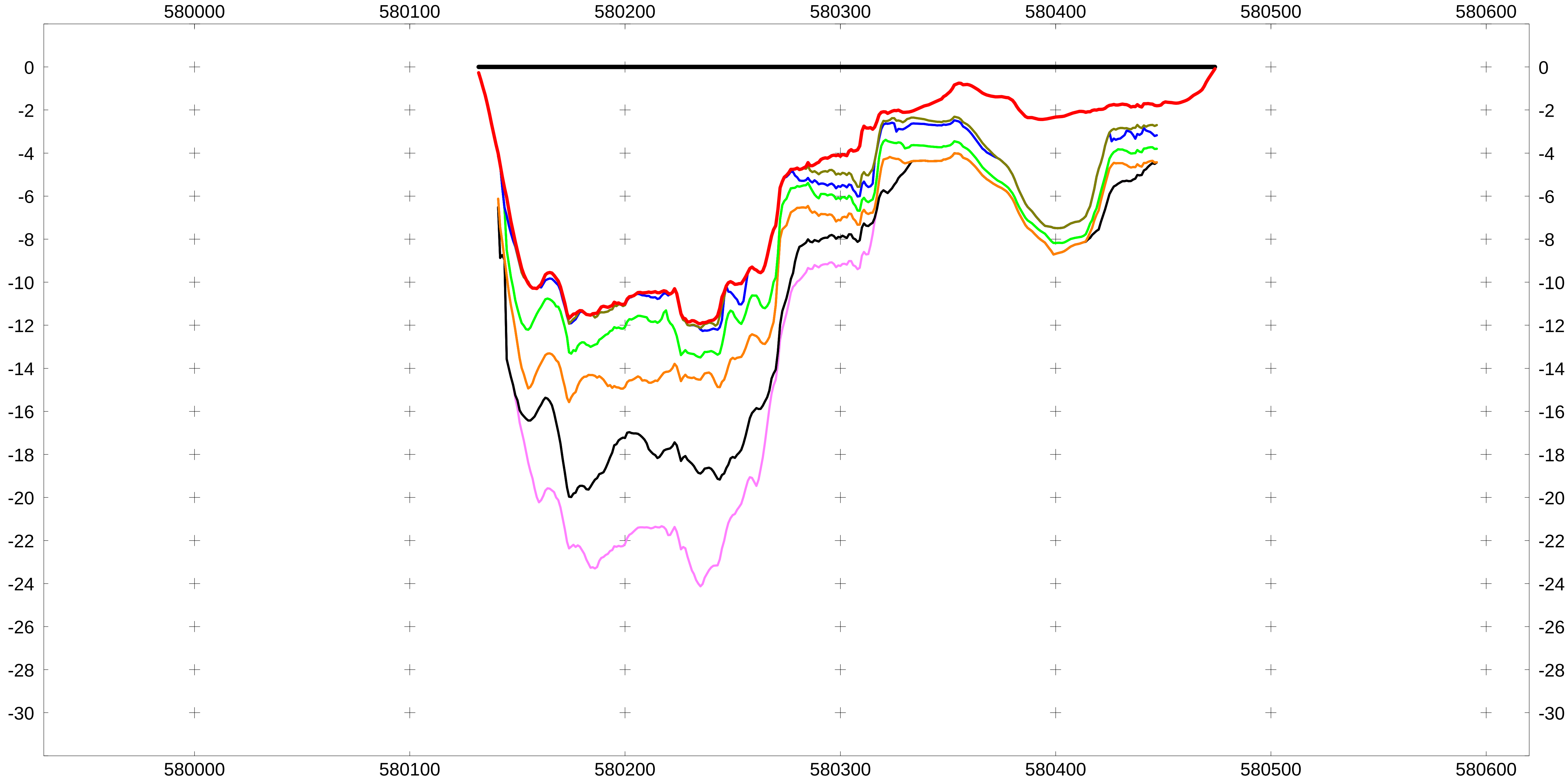
### Bathymetric and Sub-Bottom Survey

### Cross section at UTMN 6914400

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

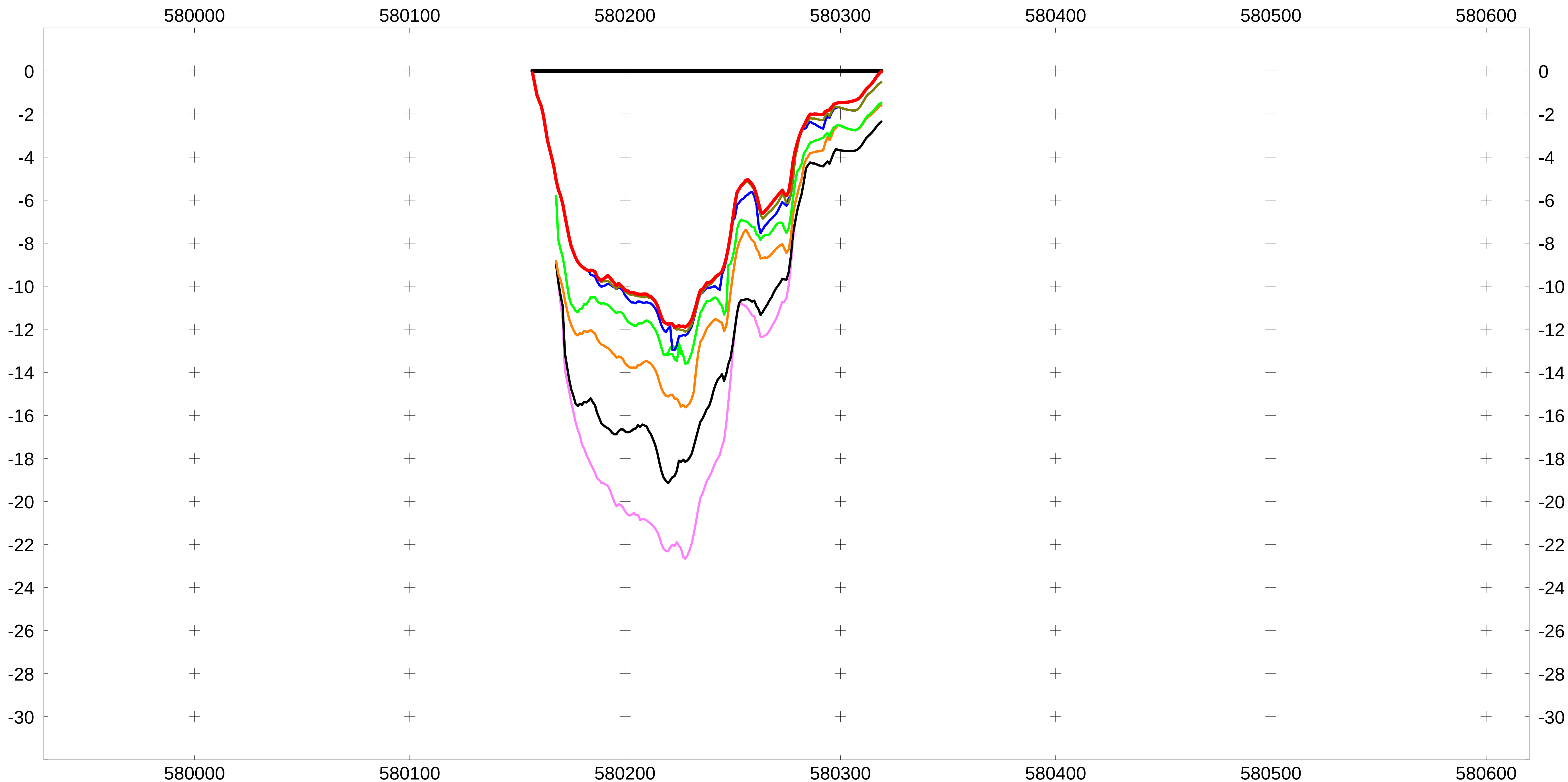
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**
**Bathymetric and Sub-Bottom Survey**
**Cross section at UTMN 6914450**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

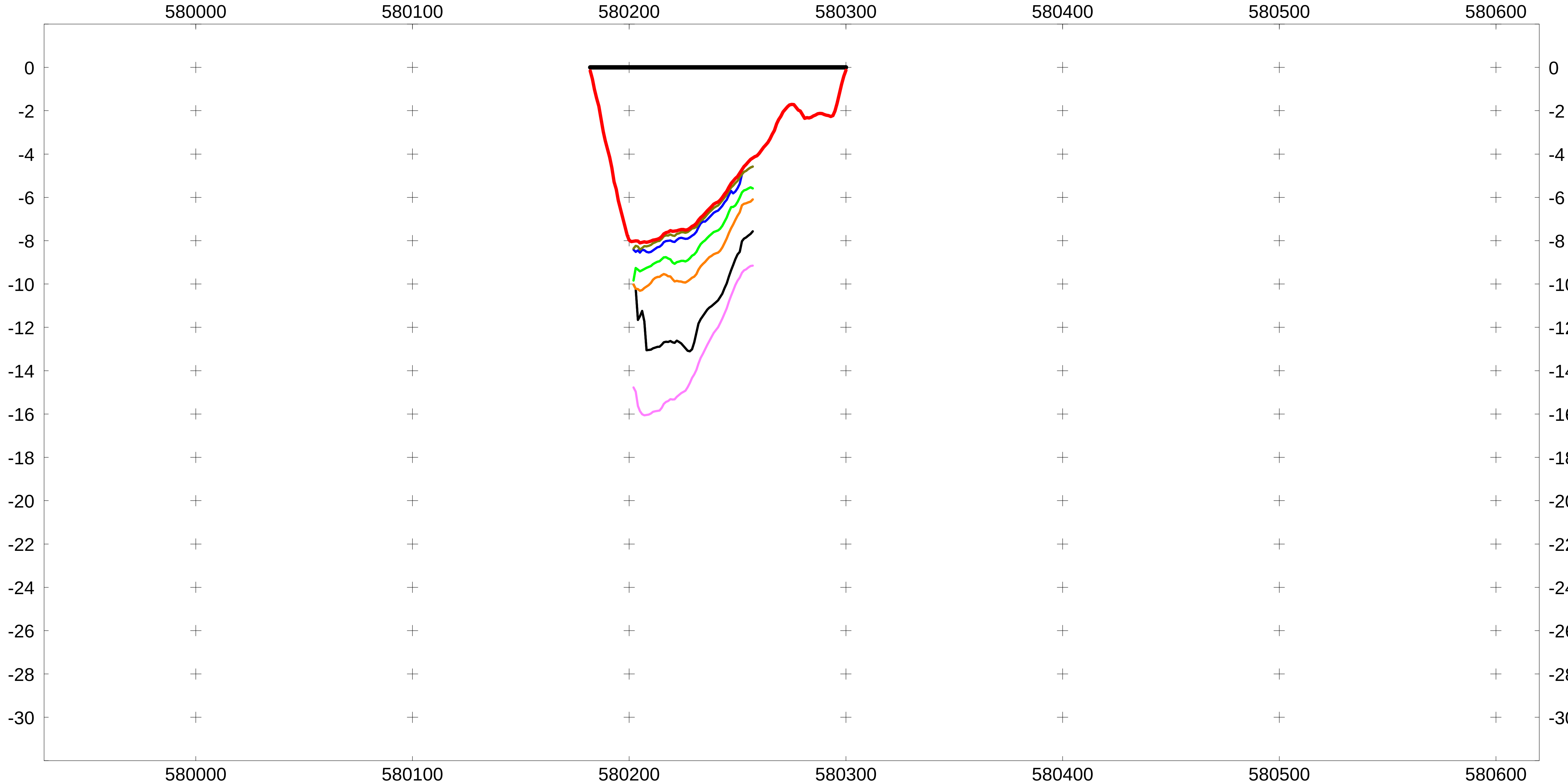
### Bathymetric and Sub-Bottom Survey

### Cross section at UTMN 6914500

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




**LEGEND**

| | |
|---|---|
| Water : | black thick line |
| Bottom : | red line |
| Feature B : | olive line |
| Feature C : | blue line |
| Feature D : | green line |
| Feature E : | orange line |
| Feature F : | black line |
| Feature G : | pink line |

**Scale (horizontal)**

25 0 25 50

(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5

(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Easting**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

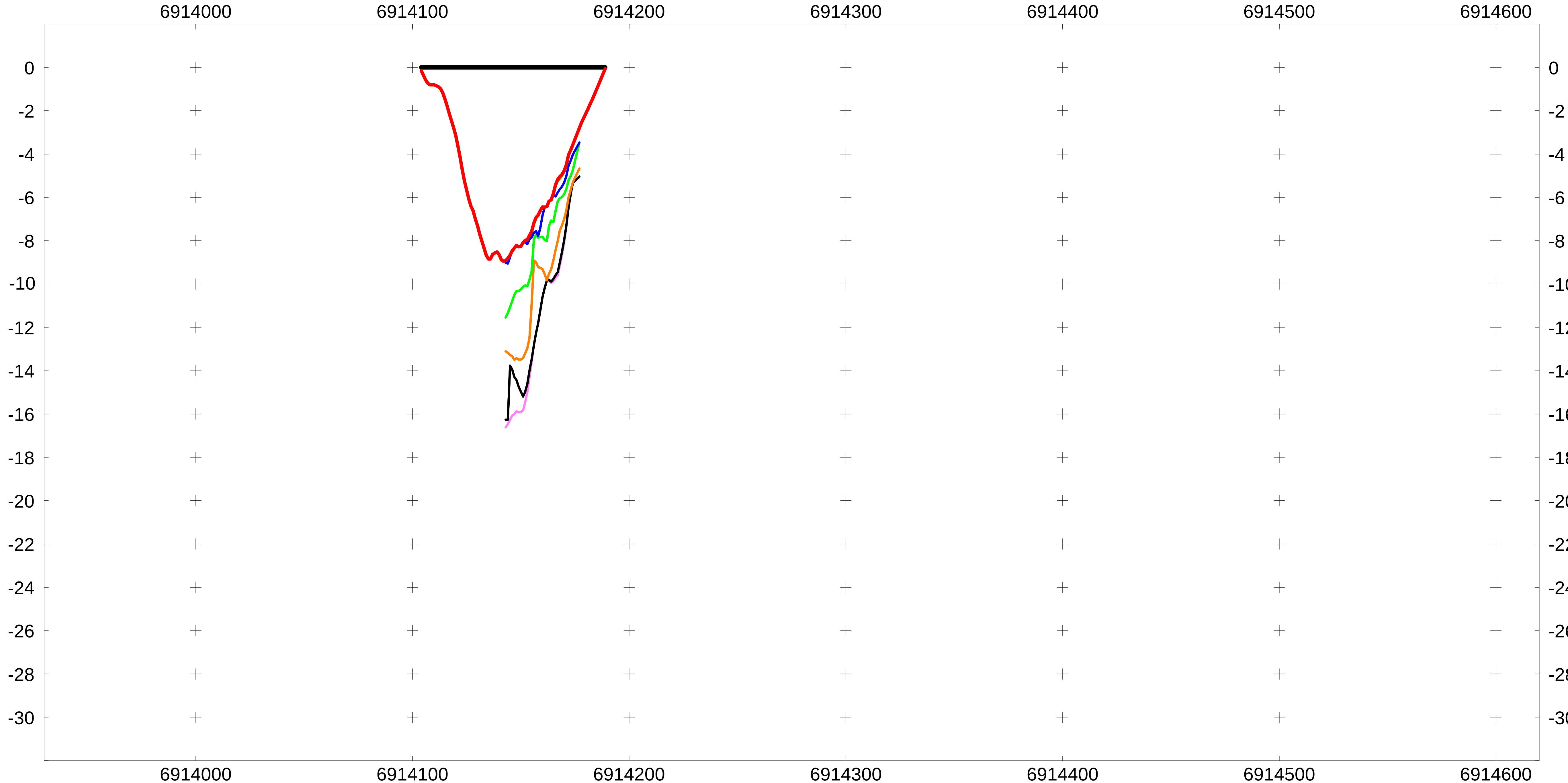
**Bathymetric and Sub-Bottom Survey**

**Cross section at UTMN 6914550**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

Scale (horizontal)

25 0 25 50
(meters)

Scale (vertical) exaggeration X10

2.5 0 2.5 5
(meters)

X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing

Y-AXIS - Depth relative to Water Surface

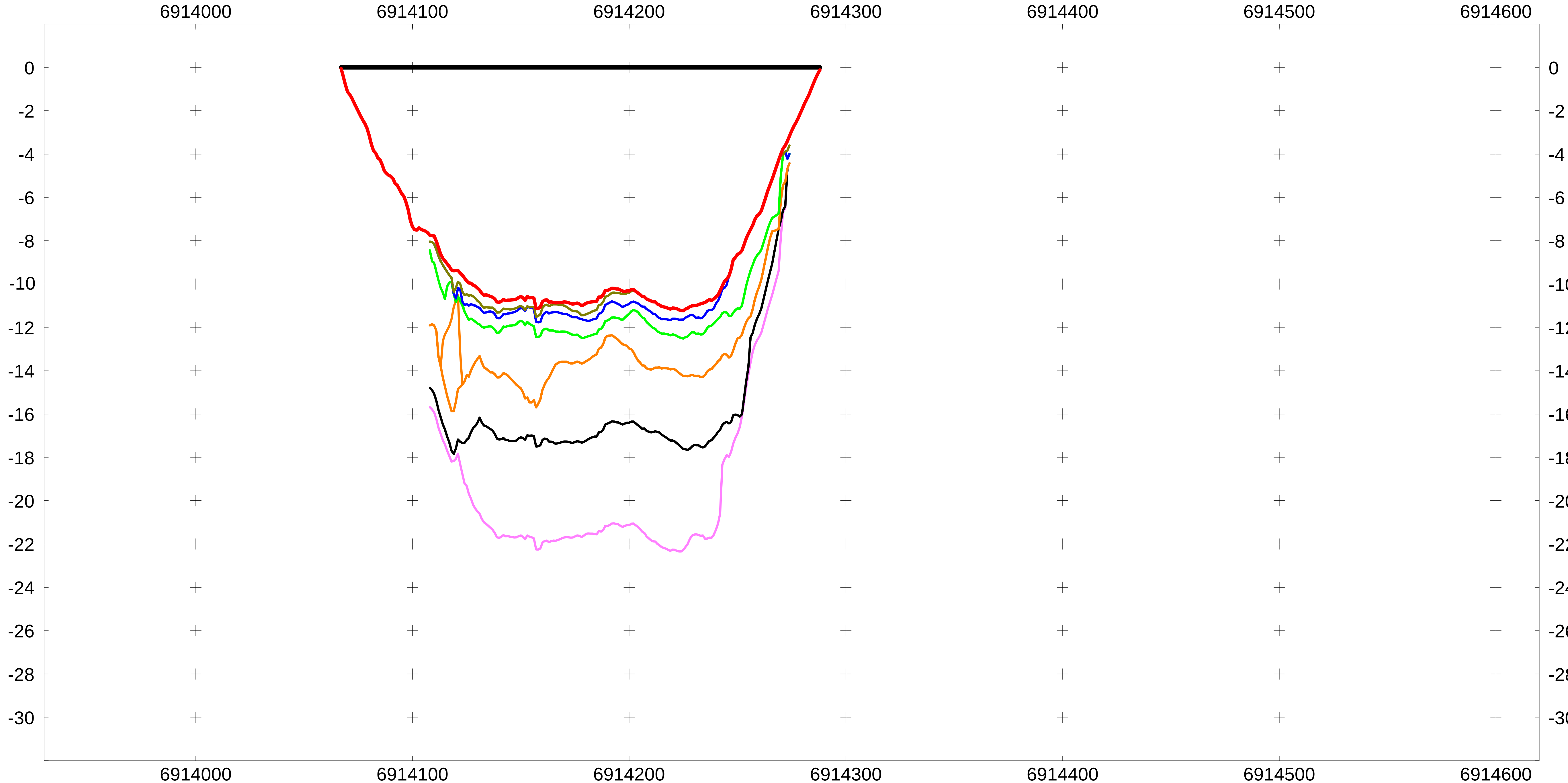
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**
**Bathymetric and Sub-Bottom Survey**
**Cross section at UTME 580000**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

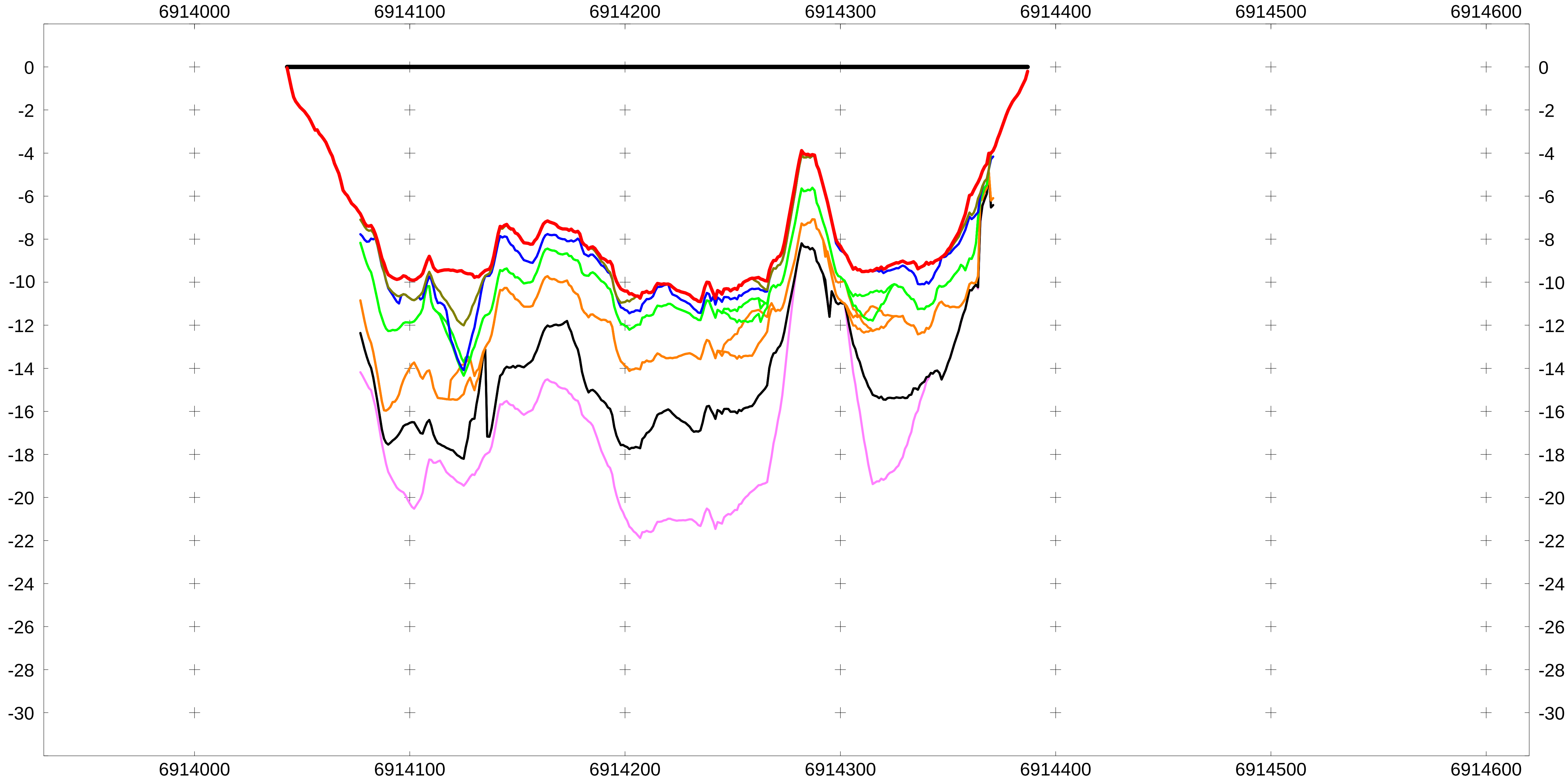
**Bathymetric and Sub-Bottom Survey**

**Cross section at UTME 580050**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

- Water :
- Bottom :
- Feature B :
- Feature C :
- Feature D :
- Feature E :
- Feature F :
- Feature G :

**Scale (horizontal)**

25 0 25 50

(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5

(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

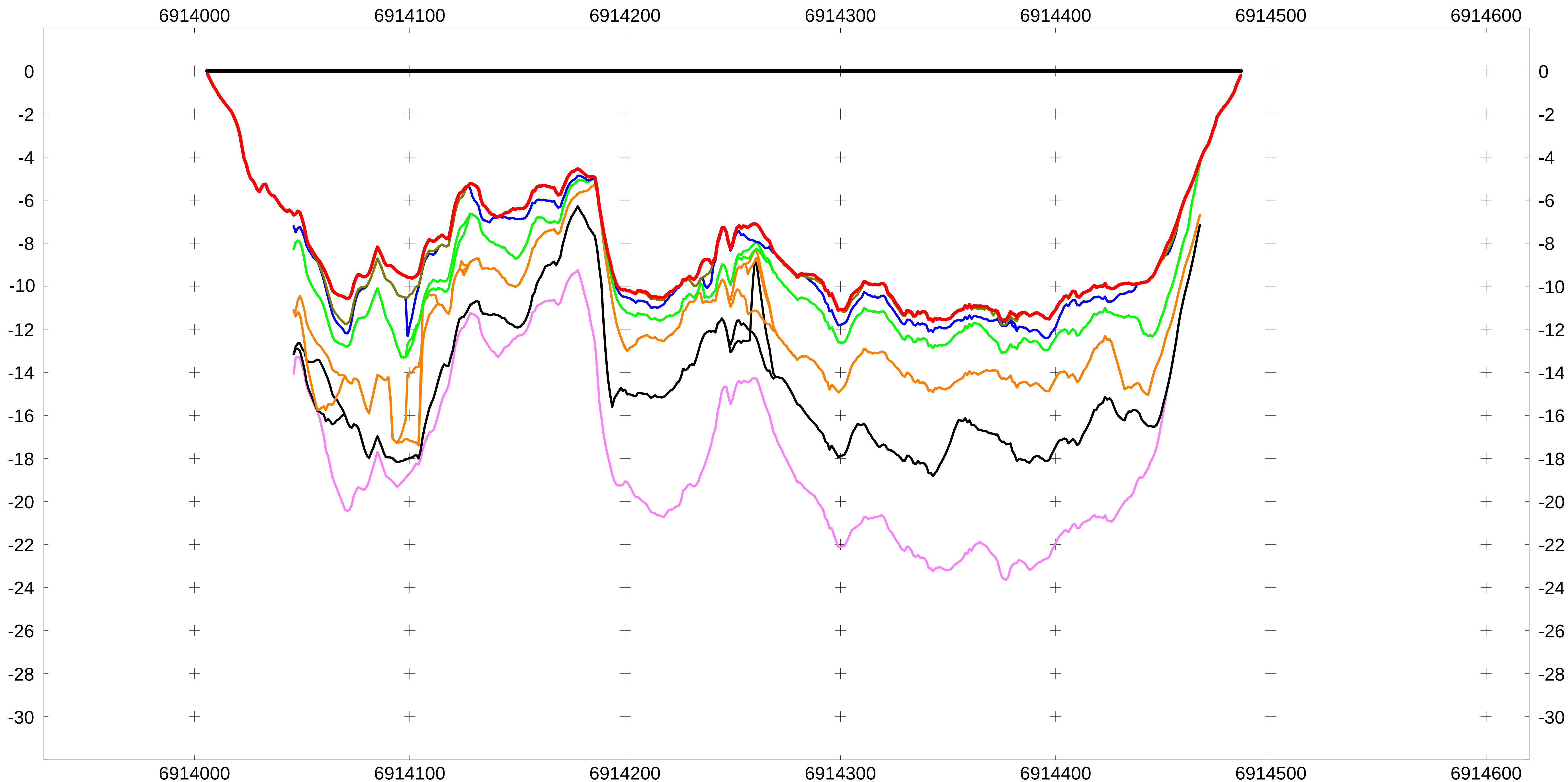
### Bathymetric and Sub-Bottom Survey

**Cross section at UTME 580100**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

- **Water :**
- **Bottom :**
- **Feature B :**
- **Feature C :**
- **Feature D :**
- **Feature E :**
- **Feature F :**
- **Feature G :**

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical)**
**exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS)**
**UTM Zone 8N Northing**

**Y-AXIS - Depth relative**
**to Water Surface**

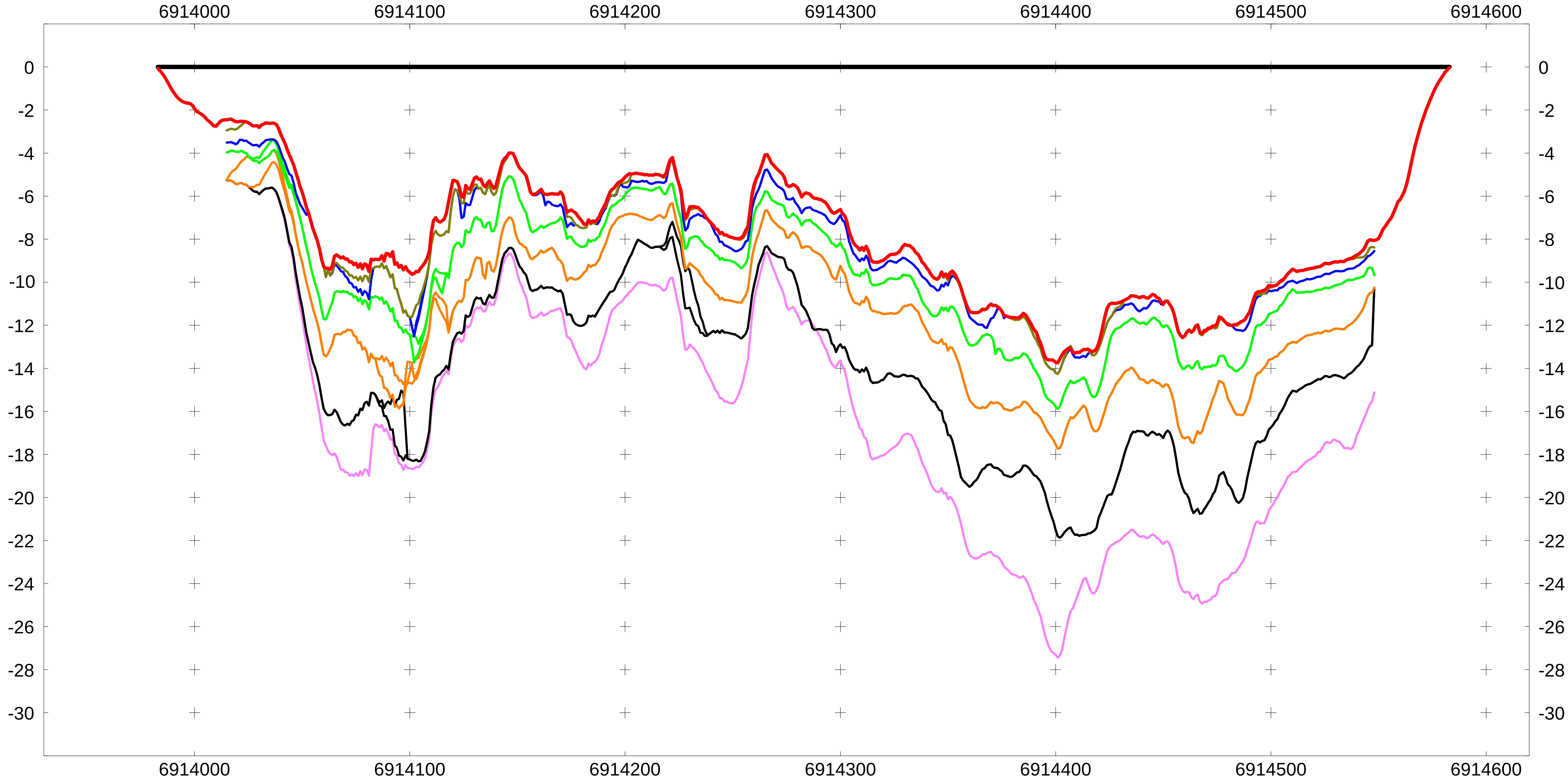
## CH2M HILL LTD.

## CROSS VALLEY DAM POND
### Bathymetric and Sub-Bottom Survey
### Cross section at UTME 580150

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing**

**Y-AXIS - Depth relative to Water Surface**

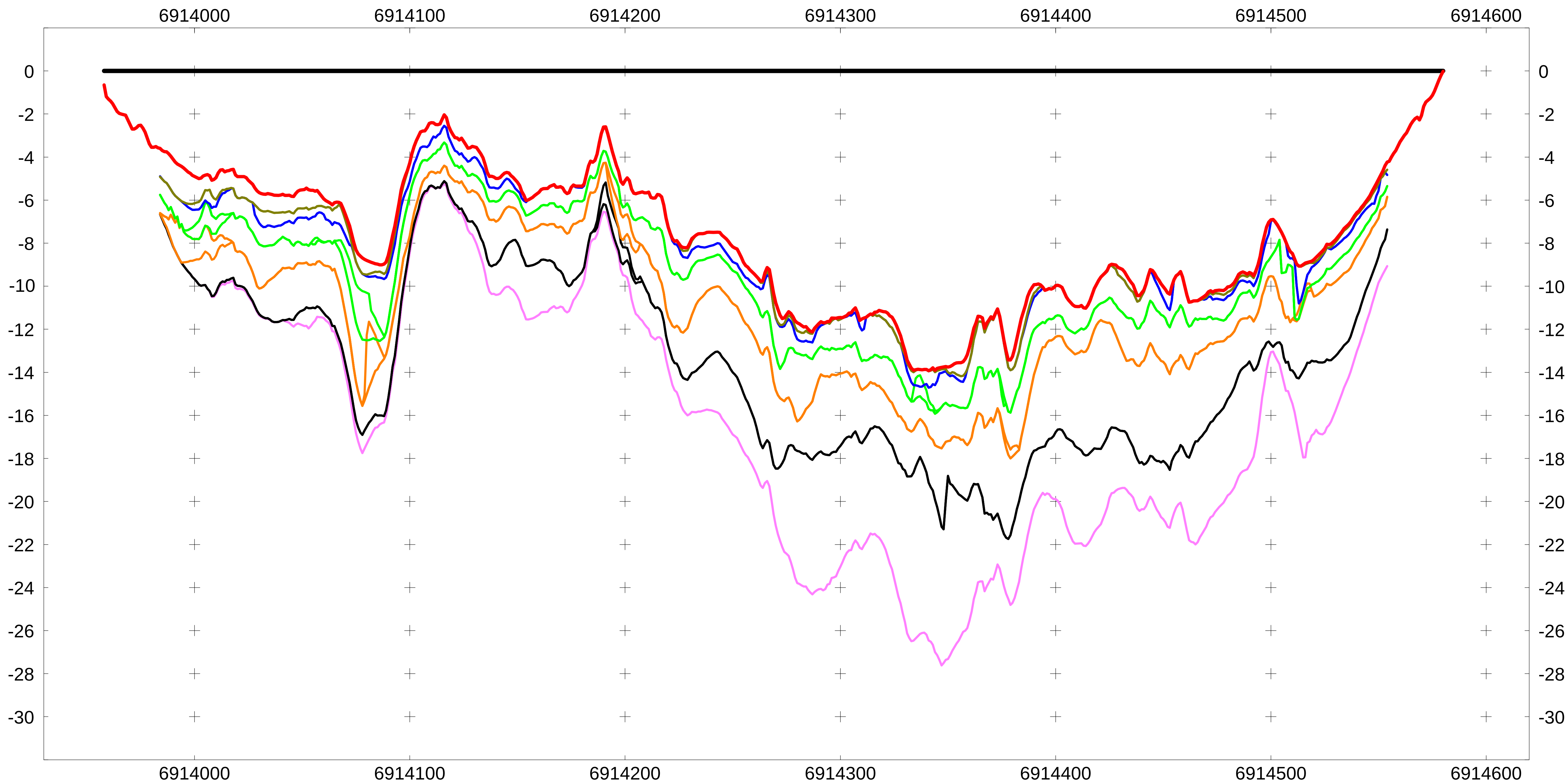
## CH2M HILL LTD.

## CROSS VALLEY DAM POND
**Bathymetric and Sub-Bottom Survey**
**Cross section at UTME 580200**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

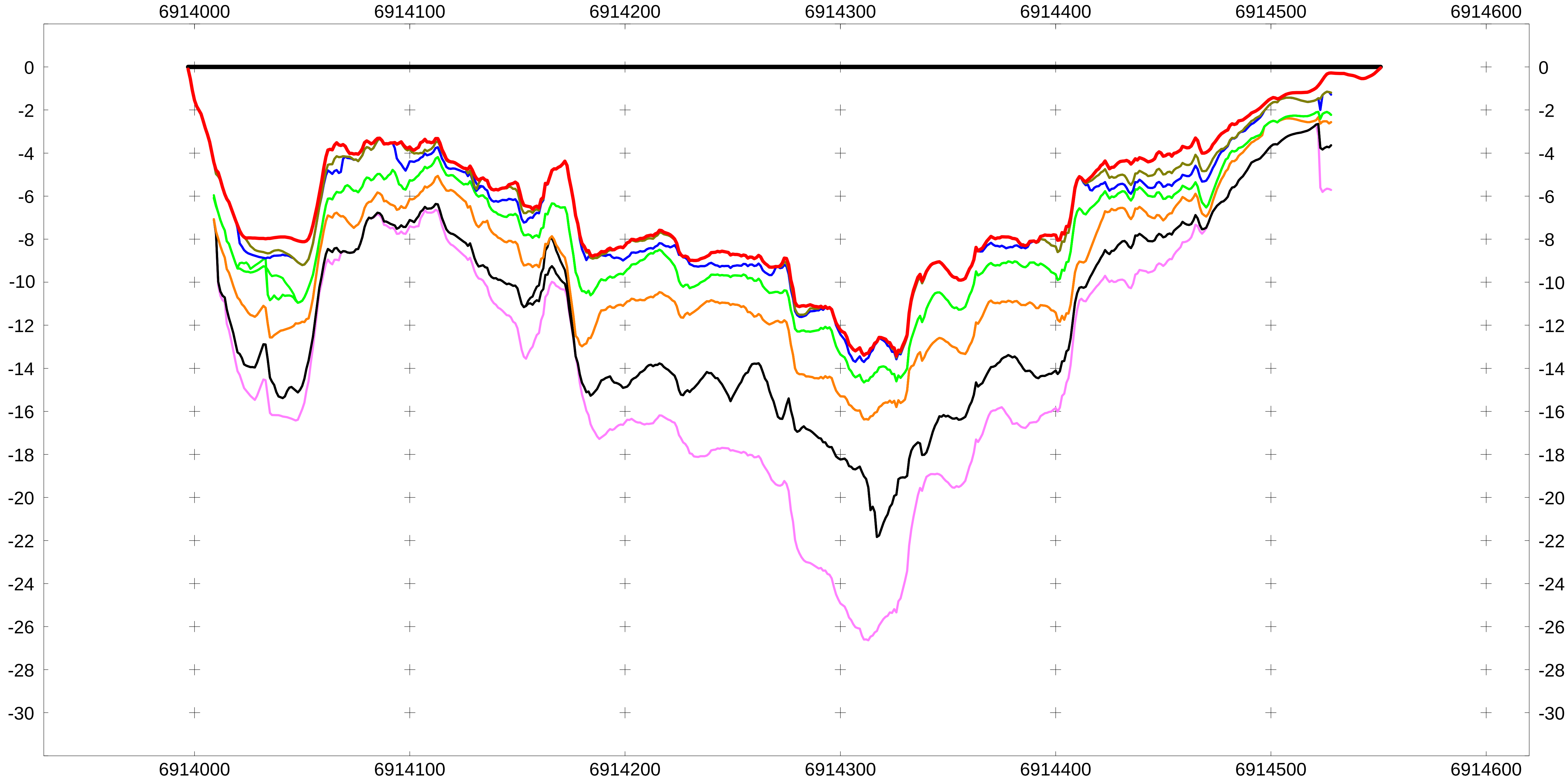
**Bathymetric and Sub-Bottom Survey**

**Cross section at UTME 580250**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




**LEGEND**

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**
25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**
2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing**

**Y-AXIS - Depth relative to Water Surface**

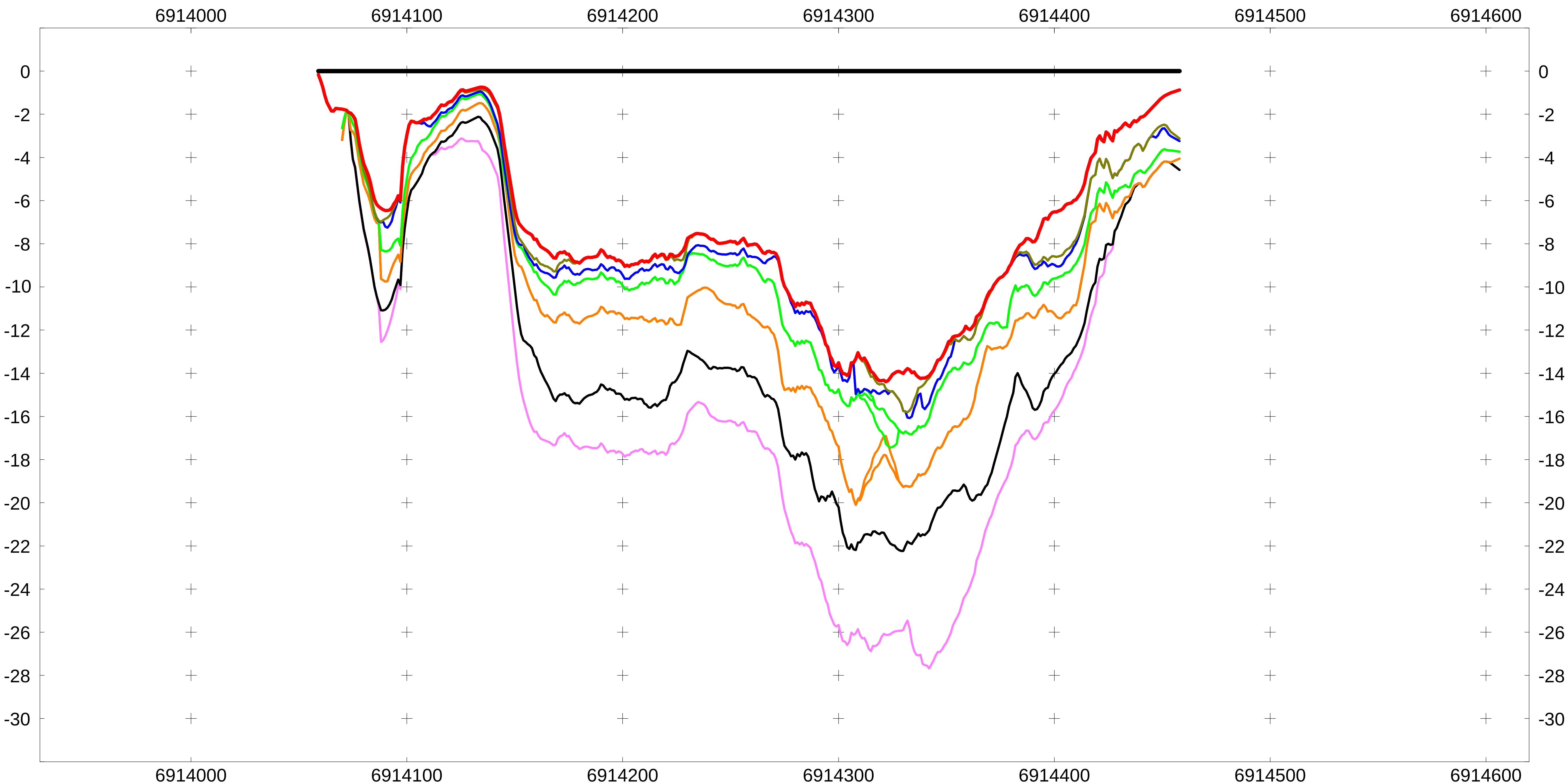
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**
**Bathymetric and Sub-Bottom Survey**
**Cross section at UTME 580300**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing**

**Y-AXIS - Depth relative to Water Surface**

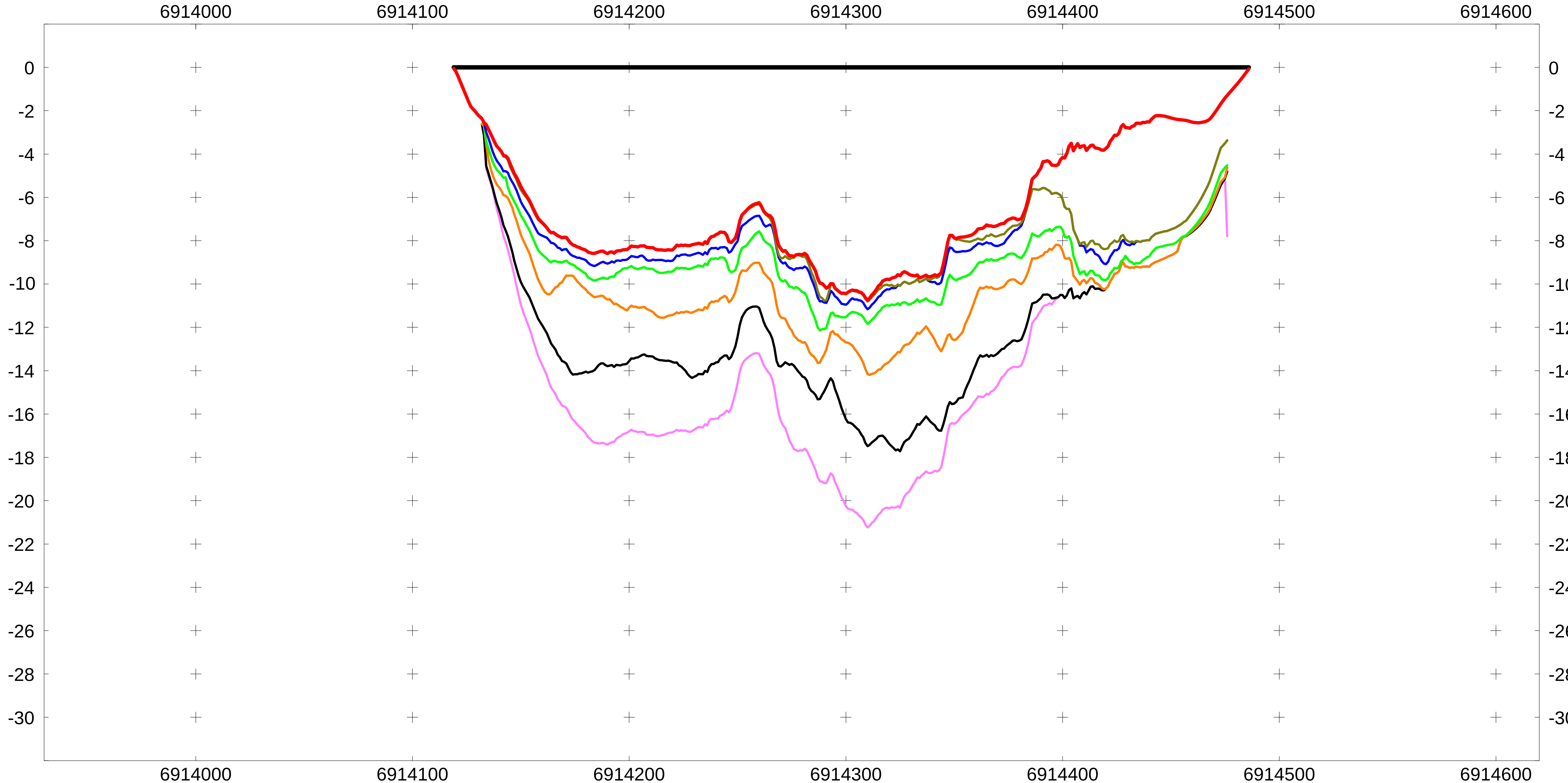
## CH2M HILL LTD.

## CROSS VALLEY DAM POND
### Bathymetric and Sub-Bottom Survey
**Cross section at UTME 580350**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS)
UTM Zone 8N Northing**

**Y-AXIS - Depth relative
to Water Surface**

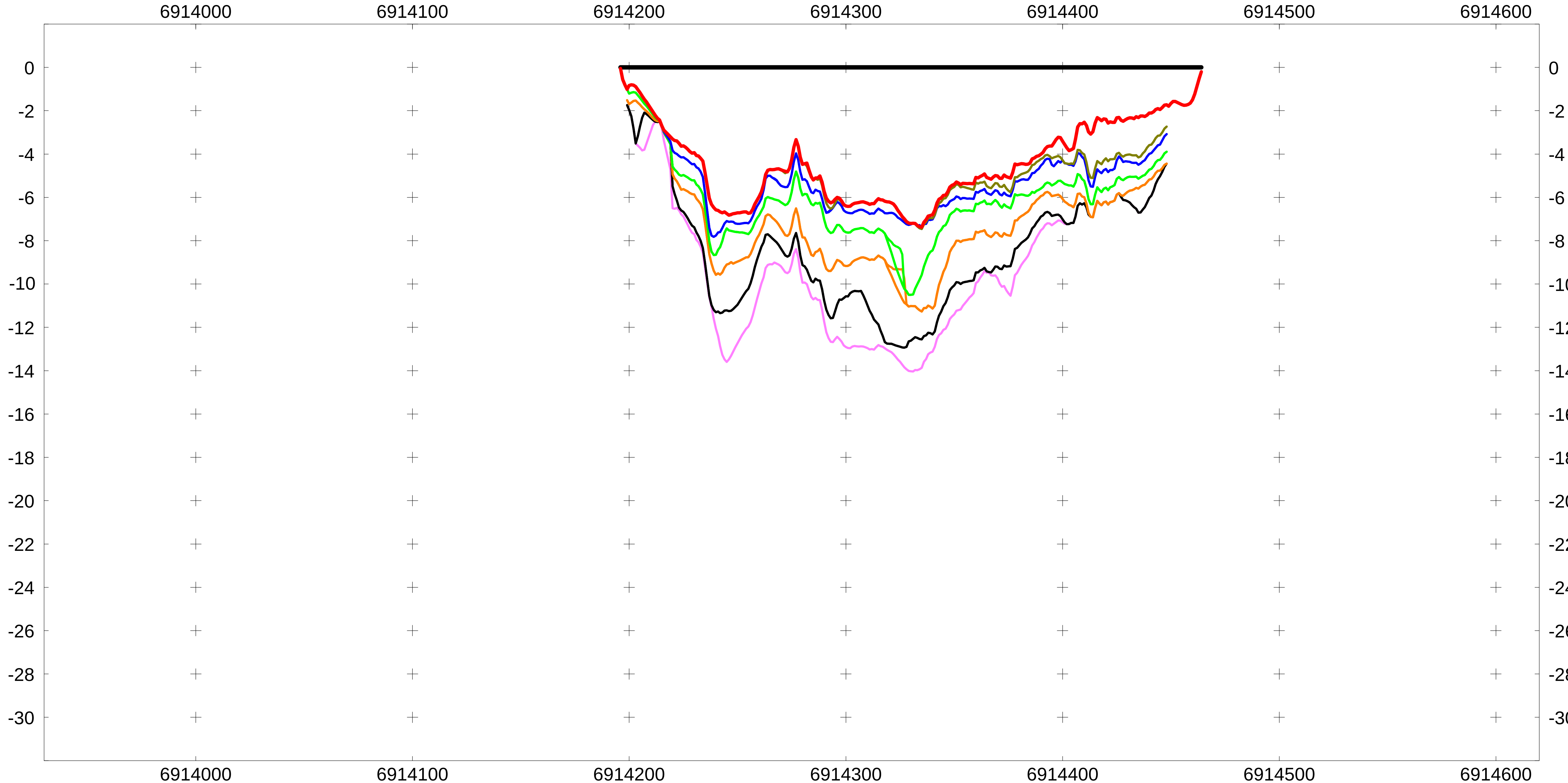
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**
**Bathymetric and Sub-Bottom Survey**
**Cross section at UTME 580400**

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

Water :
Bottom :
Feature B :
Feature C :
Feature D :
Feature E :
Feature F :
Feature G :

**Scale (horizontal)**

25 0 25 50
(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5
(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing**

**Y-AXIS - Depth relative to Water Surface**

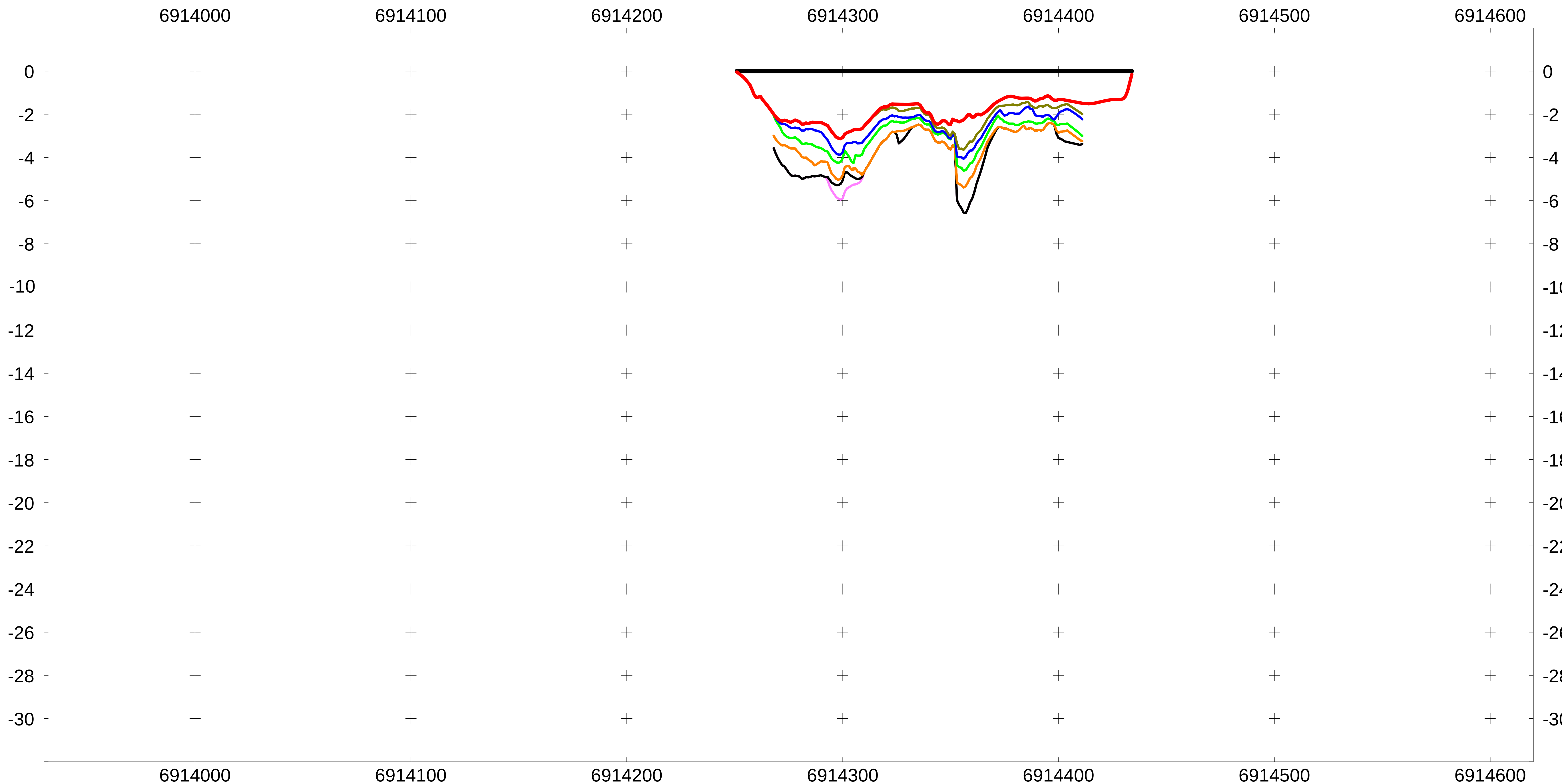
## CH2M HILL LTD.

## CROSS VALLEY DAM POND
### Bathymetric and Sub-Bottom Survey
### Cross section at UTME 580450

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.




# LEGEND

- Water :
- Bottom :
- Feature B :
- Feature C :
- Feature D :
- Feature E :
- Feature F :
- Feature G :

**Scale (horizontal)**

25 0 25 50

(meters)

**Scale (vertical) exaggeration X10**

2.5 0 2.5 5

(meters)

**X-AXIS - NAD83 (CSRS) UTM Zone 8N Northing**

**Y-AXIS - Depth relative to Water Surface**

## CH2M HILL LTD.

## CROSS VALLEY DAM POND

### Bathymetric and Sub-Bottom Survey

### Cross section at UTME 580500

Surveyed Oct 20-26, 2015
Faro Mining Complex
NTS: 105k/06

Surveyed by: SS & DE
Map drawn: Dec 10, 2015
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.

## Appendix III

**EdgeTech jsf format**

# EDGETECH SONAR DATA FILE FORMAT

# DESCRIPTION OF THE EDGETECH (.jsf) FILE FORMAT

## Document No. 990-0000048-1000

*Revision: 1.8 / October 2009*

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Web: http://www.edgetech.com

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Fax: (508) 291-2491

141 Holland Drive, Suite 1
Boca Raton, FL 33487
Tel: (561) 995-7767
Fax: (561) 995-7761

# TABLE OF CONTENTS

# INTRODUCTION

EdgeTech topsides by default record in JSF file format, which consists of a set of messages. Each message begins with a 16-byte header which indicates the type of data to follow and its size. Different types of data will have different message numbers (Message Type field). Sonar data is recorded on a per-channel basis. Therefore, for a single frequency side-scan system there will be two messages per ping – one for port (channel 0) and one for starboard (channel 1). Other types of sensors (such as pitch roll) will have their own message numbers as well, and will similarly have a single message per reading set. A typical file might have the following:

Header1: Sonar Data for Subsystem SSL and channel 0 (Port Side)
- Sonar Data Header for Message 1 (Ping number 1, Port, Time Stamp)
- Sonar Data for Message 1 (16-bit integers – one per sample)

Header2: Sonar Data for Subsystem SSL and channel 1 (Starboard Side)
- Sonar Data Header for Message 2 (Ping number 1, Starboard, Time Stamp)
- Sonar Data for Message 2 (16-bit integers – one per sample)

Header3: Pitch Roll reading
- Serial Device Standard Header (Time Stamp)
- Pitch Roll Data Structure

Header4: Sonar Data for Subsystem SB
- Sonar Data Header for Message 4 (Ping number 1, Time Stamp)
- Sonar Data for Message 4 (16-bit integer pairs – one pair per sample)

Since data is stored in a binary format, the byte ordering of 16-bit and 32-bit values is important. JSF uses little endian (Intel) format for binary data where the least significant bytes are stored first. This is the native format for Intel x86 computers such as the IBM PC and compatibles. If data is read on a big endian machine (such as most Sun Workstations), you will need to byte reverse the data so that the 2 bytes of a 16-bit value are flipped, and the 4 bytes of a 32-bit value are flipped (Bytes 0, 1, 2, 3 become Bytes 3, 2, 1, 0).

EdgeTech topsides often have an option to limit the size of created files, and will generate a sequence of files for a long data run. In this case, the concatenation of these files will yield a valid JSF file for a longer run time if desired.

This document describes the messages of common interest to those processing JSF files. It is not intended to be a complete description of all valid messages.

## C/C++ Code Example for Reading a JSF File

Here is a C code example for reading an entire JSF file.

```
void readFile(char *fileName)
{
  FILE *fid;
  int i;
  SonarMessageHeaderType hdr; /* Basic 16-byte message header */

  fid = fopen(fileName, “rb”);
  if (fid == NULL) return;

  while(!feof(fid))
  {
    if (fread(&hdr, sizeof(hdr), 1, fid) != 1)
      break;
    if (hdr.startOfMessage != SONAR_MESSAGE_HEADER_START)
    {
      printf(“Invalid file format\n”);
      break;
    }
    for(i = 0; i < hdr.byteCount; i++)
    {
      if (getc(fid) == EOF)
      {
        printf(“Invalid file format\n”);
        break;
      }
    }
    printf(“Message Type %d\n”, hdr.sonarMessage);
  }
  fclose(fid);
}
```

Details of data structure of the types of messages in a JSF file are described below.

## 16-Byte Message Header

A JSF file is a collection of messages, and every message in a JSF file begins with a sixteen byte long header. It identifies the type and size of the message, as well as the originating subsystem and channel.

| Byte Offsets | Description | Size |
|---|---|---|
| 0 – 1 | Marker for the Start of Header (always 0x1601) | UINT16 |
| 2 | Version number of protocol used (e.g.10) | UINT8 |
| 3 | Session Identifier | UINT8 |
| 4 – 5 | Message Type (e.g. 80 = Sonar Trace Data) | UINT16 |
| 6 | Command Type<br>2 = Normal data source | UINT8 |
| 7 | Subsystem Number<br>0 = Sub-bottom<br>20 = Single or Lower Frequency Side Scan<br>21 = Higher Frequency Side Scan | UINT8 |
| 8 | Channel for a Multi-Channel Subsystem<br>For Side Scan Subsystems, 0 = Port, 1 = Starboard<br>For Serial Ports: Port # | UINT8 |
| 9 | Sequence Number | UINT8 |
| 10 – 11 | Reserved | UINT16 |
| 12 – 15 | Size of following Message in Bytes | UINT32 |

Every message header begins (bytes 0 - 1) with a 0x1601 start of a message header marker. This serves as a sanity check during file processing.

The Protocol level (byte 2) indicates which revision of this specification was used to write that message. Messages of differing protocol levels may be interspersed in the same file. Maintaining backward compatibility in the public interface is a priority. Protocol level changes involve additional messages or changes to the non-public portion of the interface.

The session identifier (byte 3) is used for internal routing and can be ignored.

The Message Type field (bytes 4 - 5) defines the type of data to follow. Some data formats of interest are detailed in the following sections. If the Message Type field contains an unwanted or unknown (i.e. not defined below) type, use the Size of the message (bytes 12 – 15) to skip over the data to the next Message Header.

The message protocol is used for command and control as well as data. The command type field (byte 6) while of interest during real time operation can normally be ignored when reading JSF files.

The subsystem number (byte 7) is used to determine the source of the data. Common subsystem assignments are as follows:

Sub-bottom data - 0

Single frequency sidescan data - 20

| | |
|---|---|
| Lower frequency data of a dual frequency sidescan | - 20 |
| Higher frequency data of a dual frequency sidescan | - 21 |
| Raw serial data | - 100 |
| Parsed serial data | - 101 |

The channel (byte 8) is zero for single channel (most sub-bottom) systems. For most sidescan systems, it is zero for port and one for starboard. For serial port data the channel number is the logical port number, which often differs from the physical COM port in use.

The sequence number (byte 9) and reserved fields (bytes 10 - 11) can normally be ignored when reading JSF files.

The byte count (bytes 12 – 15) is the number of bytes until the next start of message header. This is the amount of additional data to read if processing the current message, or the amount of data to skip over if the current message is not of interest.

## Message Type 80: Sonar Data Message (jsfdefs.h)

The Sonar Data Message consists of a single ping (receiver sounding period) of data for a single channel (such as Port Side Low Frequency Side-Scan). Standard sidescan sub-systems have two channels of data, port and starboard. Standard sub-bottom sub-systems have a single channel of data. Data files with higher channel counts exist. Which fields have data present depends on the system used and data acquisition procedures. This message may contain data from multiple non-acoustic sensors. Non-acoustic data contained in this message will often not be time interpolated. EdgeTech strongly recommends that if high positional or situational accuracy is required that the individual sensor messages be processed. Otherwise, this may be the only message that will need to be interpreted in a JSF file. Validity flags indicate which auxiliary fields are populated. By convention, if a value is not present the field is set to 0.

A Sonar Data Message consists of a 240-byte header, which is very similar to a traditional SEGY header, and the actual acoustic sample data follows the header. This 240-byte header described below:

| Byte Offsets | Description | Size |
|---|---|---|
| 0 – 3 | Ping Time in seconds [since the start of time based on time() function] (1/1/1970) (added in protocol version 8)[1] | INT32 |
| 4 – 7 | Starting Depth (window offset) in samples<br>- usually zero | UINT32 |
| 8 – 11 | Ping Number (increments with each ping) | UINT32 |
| 12 – 15 | Reserved – Do not use | INT16 x 2 |
| 16 – 17 | MSBs – Most Significant Bits – High order bits to extend 16 bit unsigned short values to 20 bits. The 4 MSB bits become the most significant portion of the new 20 bit value.<br>Bits 0 - 3 – start frequency<br>Bits 4 - 7 – end frequency<br>Bits 8 – 11 – samples in this packet<br>Bits 12 – 15 – reserved<br>(added in protocol version 10)(see description below) | UINT16 |
| 18 – 27 | Reserved – Do not use | INT16 x 5 |
| 28 – 29 | ID Code (always 1)<br>1 = Seismic Data | INT16 |
| 30 – 31 | Validity Flag (See mapping below) | UINT16 |
| 32 – 33 | Reserved – Do not use | UINT16 |
| 34 – 35 | Data Format<br>0 = 1 short per sample - Envelope Data<br>1 = 2 shorts per sample - Analytic Signal Data, (Real, Imaginary) | INT16 |
| 36 – 37 | Distance from Antenna to Tow point in Centimeters, Aft + (Fish Aft = +) | INT16 |
| 38 – 39 | Distance from Antenna to Tow Point in Centimeters, Starboard + (Fish to Starboard = +) | INT16 |
| 40 – 43 | Reserved – Do not use | INT16 x 2 |

The Most Significant Bits fields are used to extend sixteen bit integers to twenty bits. These are added as needed when the range of possible values exceeds what can be stored in a sixteen bit integer. The simplest way to use these additional bits is to treat the value as a 32 bit integer, the existing value becomes the least significant 16 bits, the MSB field becomes the next most significant 4 bits with the most significant 12 bits set to zeros.

[1] NOTE: For protocol revisions 7 and before this field was always zero.

Validity flags bitmap:
Bit 0: Lat Lon or XY valid
Bit 1: Course valid
Bit 2: Speed valid
Bit 3: Heading valid
Bit 4: Pressure valid
Bit 5: Pitch roll valid
Bit 6: Altitude valid
Bit 7: Reserved
Bit 8: Water temperature valid
Bit 9: Depth valid
Bit 10: Annotation valid
Bit 11: Cable counter valid
Bit 12: KP valid
Bit 13: Position interpolated

## Navigation Data

This is most often the position at the last navigation fix. See the time NMEA Navigation Data fields for the time of the fix. On most systems, position is not time interpolated and should not be used for mosaicing or other processing requiring high accuracy positioning. Validity flags indicate whether these fields are valid and interpolated. The representation of the navigation data depends on the coordinate-units field. For Latitude / Longitude representations, a positive value designates east of the Greenwich Meridian or north of the equator.

| Byte Offsets | Description | Size |
|---|---|---|
| 44 – 47 | Kilometer of pipe (see bytes 30-31) | FLOAT32 |
| 48 – 79 | Reserved – Do not use | INT16 x 16 |
| 80 – 83 | X in millimeters or decimeters or<br>Longitude in Minutes of Arc / 10000<br>(see bytes 30-31 and 88-89) | INT32 |
| 84 – 87 | Y in millimeters or decimeters or<br>Latitude in 0.0001 Minutes of Arc<br>(see bytes 30-31 and 88-89) | INT32 |
| 88 – 89 | Coordinate Units<br>1 = X, Y in millimeters<br>2 = Longitude, Latitude in minutes of arc times $10^{-4}$<br>3 = X, Y in decimeters | INT16 |

# Pulse Information

This data describes the transmitted pulse characteristics, as well as sampling parameters.

| Byte Offsets | Description | Size |
|---|---|---|
| 90 – 113 | Annotation String (ASCII Data) | UINT8 x 24 |
| 114 – 115 | Number of data samples in this packet<br>See bytes 16 – 17 for MSB information<br>Note: Very large sample sizes require multiple packets. | UINT16 |
| 116 – 119 | Sampling Interval in Nanoseconds | UINT32 |
| 120 – 121 | Gain Factor of ADC | UINT16 |
| 122 – 123 | User Transmit Level Setting (0 – 100) percent | INT16 |
| 124 – 125 | Reserved – Do not use | INT16 |
| 126 – 127 | Transmit pulse starting frequency in decahertz (daHz) (units of 10Hz)<br>See bytes 17 – 18 for MSB information | UINT16 |
| 128 – 129 | Transmit pulse ending frequency in decahertz (daHz)(units of 10Hz)<br>See bytes 16 – 17 for MSB information | UINT16 |
| 130 – 131 | Sweep Length in milliseconds | UINT16 |
| 132 – 135 | Pressure in milliPSI (1 unit = 1/1000 PSI)<br>(see bytes 30-31) | INT32 |
| 136 - 139 | Depth in millimeters (if not = 0) (see bytes 30-31) | INT32 |
| 140 – 141 | Sample Freq of the data in hertz, modulo 65536 NOTE * | UINT16 |
| 142 – 143 | Outgoing pulse identifier | UINT16 |
| 144 – 147 | Altitude in millimeters (If bottom tracking valid)<br>0 implies not filled (see bytes 30-31) | INT32 |
| 148 - 155 | Reserved – Do not use | INT32 x 2 |

NOTE* : For all data types EXCEPT RAW (Data Format = 2) this is the Sampling Frequency of the data. For RAW data, this is one-half the Sample Frequency of the data (Fs/2). All values are modulo 65536. Use this in conjunction with the Sample interval (Bytes 114-115) to calculate correct sample rate.

# CPU Time

The time that the Acoustic data was recorded. The time of the start of the ping of data represented by the following trace data is the Ping Time.

The Ping Time in seconds since 1/1/1970, (in the same time base as the device messages that follow), is contained in bytes 0-3. The millisecondsToday field (bytes 200-203), MODULO 1000, will yield the milliseconds in current second, compatible with the time stamp of the device messages. This time stamp is only valid for data recorded in Protocol Revision 8 and above.

The Ping Time can also be determined from the Year, Day, Hour, Minute and Seconds as per bytes 156 to 165. Thus provides 1 second level accuracy and resolution. For higher resolution (milliseconds) use the Year, and Day values of bytes 156 to 159, and then use the milliSecondsToday value of bytes 200-203 to complete the timestamp. System time is set to UTC, regardless of time zone. This time format is backwards compatible with all older Protocol Revisions.
These 2 time stamps are equivalent and identical.

| Byte Offsets | Description | Size |
|---|---|---|
| 156 – 157 | Year (e.g. 2009) (see Bytes 0-3) (Should not be used) | INT16 |
| 158 – 159 | Day (1 – 366) (Should not be used) | INT16 |
| 160 – 161 | Hour (see Bytes 200-203) (Should not be used) | INT16 |
| 162 – 163 | Minute (Should not be used) | INT16 |
| 164 – 165 | Second (should not be used) | INT16 |
| 166 – 167 | Time Basis (always 3) | INT16 |

# Weighting Factor

The trace data is transmitted as sixteen bit integers in block floating point format per message. This saves bandwidth and storage space while preserving dynamic range. The weighting factor MUST BE applied to each of the sixteen bit integer values to restore the original floating point value.

| Byte Offsets | Description | Size |
|---|---|---|
| 168 – 169 | Weighting Factor N (Signed Value!) Defined as $2^{-N}$ | INT16 |
| 170 – 171 | Number of pulses in the water | INT16 |

# Orientation Sensor Data

These fields contain useful information about the attitude of the sonar sensor. The Compass heading will be magnetic heading of the towfish. If a Gyro sensor is properly interfaced to the Discover Topside acquisition unit, with a valid NMEA HDT message, this field will contain the Gyro heading, relative to true north

| Byte Offsets | Description | Size |
|---|---|---|
| 172 – 173 | Compass Heading (0 to 360 ) in units of 1/100 degree (see bytes 30-31) | UINT16 |
| 174 – 175 | Pitch: Scale by 180 / 32768 to get degrees, + = bow up (see bytes 30-31) | INT16 |
| 176 – 177 | Roll: Scale by 180 / 32768 to get degrees, + = port up (see bytes 30-31) | INT16 |
| 178 – 179 | Tow fish electronics Temperature, in unit of 1/10$^{th}$ degree C | INT16 |

## Miscellaneous Data

| Byte Offsets | Description | Size |
|---|---|---|
| 180 – 181 | Reserved – Do not use | INT16 |
| 182 – 183 | Trigger Source<br>0 = Internal<br>1 = External<br>2 = Coupled | INT16 |
| 184 – 185 | Mark Number<br>0 = No Mark | UINT16 |

## NMEA Navigation Data

These fields contain the time of the last position fix. If the position data is interpolated this will be the same as the CPU and ping time.

| Byte Offsets | Description | Size |
|---|---|---|
| 186 – 187 | Hour (0 – 23) | INT16 |
| 188 – 189 | Minutes (0 – 59) | INT16 |
| 190 – 191 | Seconds (0 – 59) | INT16 |
| 192 – 193 | Course | INT16 |
| 194 – 195 | Speed | INT16 |
| 196 – 197 | Day (1 – 366) | INT16 |
| 198 – 199 | Year | INT16 |

## Other Miscellaneous Data

| Byte Offsets | Description | Size |
|---|---|---|
| 200 – 203 | Milliseconds today (since midnight) (use in conjunction with Year / Day to get time of Ping) | UINT32 |
| 204 – 205 | Maximum Absolute Value of ADC samples in this packet | UINT16 |
| 206 – 207 | Reserved – Do not use | INT16 |
| 208 – 209 | Reserved – Do not use | INT16 |
| 210 – 215 | Sonar Software Version Number - ASCII | INT8 x 6 |
| 216 – 219 | Initial Spherical Correction Factor<br>(Useful for multi-ping / deep application) * 100 | INT32 |
| 220 – 221 | Packet Number<br>Each ping starts with packet 1 | UINT16 |
| 222 – 223 | 100 times the A/D Decimation Factor. Data is normally sampled at a high Rate. Digital filters are applied to precisely limit the signal bandwidth. | INT16 |
| 224 – 225 | Decimation Factor after the FFT | INT16 |
| 226 – 227 | Water Temperature in units of 1/10 degree C<br>(see bytes 30-31) | INT16 |
| 228 – 231 | Layback in meters | FLOAT32 |
| 232 – 235 | Reserved – Do not use | INT32 |
| 236 – 237 | Cable Out in decimeters (see bytes 30-31) | UINT16 |
| 238 – 239 | Reserved – Do not use | UINT16 |

## Sonar Trace Data

Sonar trace data follows the 240-byte header and consists of sixteen bit integer values. The number of integers to be read can be found by multiplying the number of samples in the trace (bytes 114-115) by the number of integers per sample for the data type used (1 or 2). Further doubling will yield the byte size of the data section. This should exactly match the preceding Message Header byte count, (bytes 12 –15) less the header size of 240.

Each of the data sample values then needs to be scaled by the weighting factor thus:

ScaledDatasample = datasample * 2^(-N). (NOTE Sign !)

Future expansions of this data format will use floating point values to represent samples, and will result in other valid values for Data Format (bytes 34-35). Data readers will be more robust if this data section is skipped over if the Data Type does not match the 4 values presented here.

# Message Type 82: Side Scan Data Message (sidescandefs.h)

Side-Scan Data Messages are no longer used and only described here for historical reasons. While configuring a sonar to generate these messages is still possible, new systems are not configured in that manner. If your sonar is storing Side-Scan Data Messages the configuration should be changed to store Sonar Data Messages instead. Side-Scan Data Messages are never stored by Discover, and are only encountered in data stored by sonar. This data is almost always compressed rendering it unusable without further processing. A Side-Scan Data Message is similar to a Sonar Data Message. It contains the exactly the same acoustic data. While the Side Scan Data Message was intended for Side Scan data, it can also be used for Sub-bottom data. The system configuration determines which type of data is actually stored. Each Side Scan Data Message has an 80 byte header, the content of which is defined below. As with Sonar Data Messages, unused fields should be set to 0.

| Byte Offsets | Description | Size |
|---|---|---|
| 0 – 1 | Subsystem (0 .. n) | UINT16 |
| 2 – 3 | Channel Number (0 .. n) | UINT16 |
| 4 – 7 | Ping number (increments with each ping period) | UINT32 |
| 8 – 9 | Packet number (1..n) Each ping starts with packet 1 | UINT16 |
| 10 – 11 | TriggerSource (0 = internal, 1 = external) | UINT16 |
| 12 – 15 | Samples in this packet | UINT32 |
| 16 – 19 | Sample interval in ns of stored data | UINT32 |
| 20 – 23 | Starting Depth (window offset) in samples | UINT32 |
| 24 – 25 | Weighting Factor : Defined as $2^{-N}$ volts | INT16 |
| 26 – 27 | Gain factor of ADC | UINT16 |
| 28 – 29 | Maximum absolute value for ADC samples for this packet | UINT16 |
| 30 – 31 | Range Setting (in decameters) (meters times 10) | UINT16 |
| 32 – 33 | Unique pulse identifier | UINT16 |
| 34 – 35 | Mark Number (0 = no mark) | UINT16 |
| 36 – 37 | Data format<br>0 = 1 short per sample - envelope data the total number of bytes of data to follow is 2 * samples<br>1 = 2 shorts per sample - stored as real(1), imag(1), the total number of bytes of data to follow is 4 * samples | UINT16 |
| 38 | Number of simultaneous pulses in the water | UINT8 |
| 39 | Reserved – Do not use | UINT8 |

## Computer date / time data acquired

| Byte Offsets | Description | Size |
|---|---|---|
| 40 – 43 | Milliseconds today | UINT32 |
| 44 – 45 | Year | INT16 |
| 46 – 47 | Day of year (1 – 366) | UINT16 |
| 48 – 49 | Hour of day (0 – 23) | UINT16 |
| 50 – 51 | Minute (0 – 59) | UINT16 |
| 52 – 53 | Second (0 – 59) | UINT16 |

## Auxiliary sensor information

| Byte Offsets | Description | Size |
|---|---|---|
| 54 – 55 | Compass heading in minutes (0 – 360) x 60 | UINT16 |
| 56 – 57 | Pitch Scale by 180 / 32768 to get degrees, + = bow up | INT16 |
| 58 – 59 | Roll Scale by 180 / 32768 to get degrees, + = port up | INT16 |
| 60 – 61 | Heave (centimeters) | INT16 |
| 62 – 63 | Yaw (minutes) | INT16 |
| 64 – 67 | Pressure in units of 1/1000 PSI | UINT32 |
| 68 – 69 | Temperature in units of 1/10 of a degree Celsius | INT16 |
| 70 – 71 | Water Temperature in units of 1/10 of a degree Celsius | INT16 |
| 72 – 75 | Altitude in millimeters (or -1 if no valid reading) | INT32 |
| 76 – 79 | Reserved – Do not use | UINT8 x 4 |

## Sonar Trace Data

Sonar trace data follows the 80-byte header and consists of sixteen bit integer values. The number of integers to be read can be found by multiplying the number of samples in the trace (bytes 12-15) by the number of integers per sample for the data type used (1 or 2). Further doubling will yield the byte size of the data section. This should exactly match the preceding 16 byte Message Header byte count, (bytes 12 –15) less the header size of 80. Each of the data sample values then needs to be scaled by the weighting factor thus:

ScaledDatasample = datasample * 2^( - N).

# Message Type 2020: Pitch Roll Data

A pitch roll message consists of a single reading from a pitch roll sensor such as a Seatex MRU, TSS or Octans device. Not all devices provide all data for the defined structure. Use the validity flags to determine which fields are populated.

| Byte Offsets | Description | Size |
|---|---|---|
| 0 – 3 | Time in seconds (since the start of time based on time() function) (1/1/1970) | INT32 |
| 4 – 7 | Milliseconds in the current second | INT32 |
| 8 – 11 | Reserved – Do not use | UINT8 x 4 |
| 12 – 13 | Acceleration in x: Multiply by (20 * 1.5) / (32768) to get Gs | INT16 |
| 14 – 15 | Acceleration in y: Multiply by (20 * 1.5) / (32768) to get Gs | INT16 |
| 16 – 17 | Acceleration in z: Multiply by (20 * 1.5) / (32768) to get Gs | INT16 |
| 18 – 19 | Rate Gyro in x: Multiply by (500 * 1.5) / (32768) to get Degrees/Sec | INT16 |
| 20 – 21 | Rate Gyro in y: Multiply by (500 * 1.5) / (32768) to get Degrees/Sec | INT16 |
| 22 – 23 | Rate Gyro in y: Multiply by (500 * 1.5) / (32768) to get Degrees/Sec | INT16 |
| 24 – 25 | Pitch Multiply by (180.0 / 32768.0) to get Degrees<br>Bow up is positive | INT16 |
| 26 – 27 | Roll: Multiply by (180.0 / 32768.0) to get Degrees<br>Port up is positive | INT16 |
| 28 – 29 | Temperature in units of 1/10 of a degree Celsius | INT16 |
| 30 – 31 | Device specific info. This is device specific info provided for Diagnostic purposes | UINT16 |
| 32 – 33 | Estimated Heave in millimeters | INT16 |
| 34 – 35 | Heading in units of 0.01 Degrees (0…360) | UINT16 |
| 36 – 39 | Data valid flags<br>Bit 0: ax<br>Bit 1: ay<br>Bit 2: az<br>Bit 3: rx<br>Bit 4: ry<br>Bit 5: rz<br>Bit 6: pitch<br>Bit 7: roll<br>Bit 8: heave<br>Bit 9: heading<br>Bit 10: temperature<br>Bit 11: devInfo | INT32 |
| 40 – 43 | Reserved – Do not use | INT32 |

# Message Type 2002: NMEA String

A NMEA String consists of a time stamp followed by a NMEA string as read from a GPS, Gyro or other device. Each message is a single NMEA string excluding the <CR>/<LF>.

| Byte Offsets | Description | Size |
|---|---|---|
| 0 – 3 | Time in seconds since 1970 | INT32 |
| 4 – 7 | Milliseconds in the current second | INT32 |
| 8 | Source, 1 = Sonar, 2 = Discover, 3 = ETSI | INT8 |
| 9 – 11 | Reserved – Do not use | UINT8 x 3 |
| 12 – To Message Length | NMEA string data | INT8 x remaining length |

# Message Type 2060: Pressure Sensor Reading

If a pressure sensor is present in the system these messages will be in the data stream. A single pressure sensor reading is provided, along with a time-stamp. While pressure sensors can be configured in different units, the default is PSI absolute.

| Byte Offsets | Description | Size |
|---|---|---|
| 0 – 3 | Time in seconds (since the start of time based on time() function). | INT32 |
| 4 – 7 | Milliseconds in the current second. | INT32 |
| 8 – 11 | Reserved – Do not use | UNIT8 x 4 |
| 12 – 15 | Pressure in units of 1/1000th of a PSI | INT32 |
| 16 – 19 | Temperature in units of 1/1000th of degree Celsius. | INT32 |
| 20 – 23 | Salinity in Parts Per Million | INT32 |
| 24 – 27 | Data valid flags:<br>Bit 0: pressure<br>Bit 1: temp<br>Bit 2: salt PPM<br>Bit 3: conductivity<br>Bit 4: sound velocity | INT32 |
| 28 – 31 | Conductivity in micro-Siemens per cm | INT32 |
| 32 – 35 | Velocity of Sound in mm per second | INT32 |
| 36 – 75 | Reserved – Do not use | INT 32 x 10 |

# Message Type 2080: Doppler Velocity Log Data (DVL)

This is data from a DVL (if fitted) and often includes velocity and altitude readings.

| Byte Offsets | Description | Size |
|---|---|---|
| 0 – 3 | Time in seconds (since the start of time based on time() function). | INT32 |
| 4 – 7 | Milliseconds in the current second. | INT32 |
| 8 – 11 | Reserved – Do not use | UINT8 x 4 |
| 12 – 15 | Flags. Indicates which values are present.<br>Bit 0: X, Y Velocity present<br>Bit 1: 1 => Velocity in ship coordinates<br>0 => Earth coordinates<br>Bit 2: Z (Vertical Velocity) present<br>Bit 3: X, Y Water Velocity present<br>Bit 4: Z (Vertical Water Velocity) present<br>Bit 5: Distance to bottom present<br>Bit 6: Heading present<br>Bit 7: Pitch present<br>Bit 8: Roll present<br>Bit 9: Temperature present<br>Bit 10: Depth present<br>Bit 11: Salinity present<br>Bit 12: Sound velocity present<br>-------<br>Bit 31: Error detected | UINT32 |
| 16 – 31 | 4 Integers: Distance to bottom in cm for up to 4 beams. | INT32 x 4 |
| | A 0 value indicates an invalid or non-existing reading. | |
| 32 – 33 | X Velocity with respect to the bottom in mm / second<br>Positive => Starboard or East.<br>-32768 indicates an invalid reading. | INT16 |
| 34 – 35 | Y Velocity: Positive => Forward or North (mm/second) | INT16 |
| 36 – 37 | Z Vertical Velocity: Positive => Upward (mm/second) | INT16 |
| 38 – 39 | X Velocity with respect to a water layer in mm / second<br>Positive => Starboard or East | INT16 x 3 |
| 40 - 41 | Y Velocity: Positive => Forward or North | |
| 42 - 43 | Z Vertical Velocity: Positive => Upward | |
| 44 - 45 | Depth from depth sensor in decimeters | UINT16 |
| 46 - 47 | Pitch -180 to +180 degree (units = 0.01 of a degree) + Bow up | INT16 |
| 48 - 49 | Roll -180 to +180 degrees (units = 0.01 of a degree) + Port up | INT16 |
| 50 - 51 | Heading: 0 to 360 degrees (in units of 0.01 of a degree) | UINT16 |
| 52 - 53 | Salinity in 1 part per thousand | UINT16 |
| 54 - 55 | Temperature in units of 1/100 of a degree Celsius | INT16 |
| 56 - 57 | Sound velocity in meters per second | INT16 |
| 58 - 71 | Reserved – Do not use | INT16 x 7 |

## Message Type 2090: Situation Message

A situation message is a composite of several motion / position sensors. This message is not commonly used. The detailed data structure is shown below:

| Byte Offsets | Description | Size |
|---|---|---|
| 0 - 3 | Time in seconds (since the start of time based on time() function). | INT32 |
| 4 - 7 | Milliseconds in the current second. | INT32 |
| 8 - 11 | Reserved – Do not use | INT8 x 4 |
| 12 - 15 | Validity Flags<br>Validity Flags indicate which of the following fields are valid. If the corresponding bit is set the field is valid.<br><br>Bit 0 : microsecondTimestamp<br>Bit 1 : latitude<br>Bit 2 : longitude<br>Bit 3 : depth<br>Bit 4 : heading<br>Bit 5 : pitch<br>Bit 6 : roll<br>Bit 7 : XRelativePosition<br>Bit 8 : YRelativePosition<br>Bit 9 : ZRelativePosition<br>Bit 10 : XVelocity<br>Bit 11 : YVelocity<br>Bit 12 : ZVelocity<br>Bit 13 : NorthVelocity<br>Bit 14 : EastVelocity<br>Bit 15 : downVelocity<br>Bit 16 : XAngularRate<br>Bit 17 : YAngularRate<br>Bit 18 : ZAngularRate<br>Bit 19 : XAcceleration<br>Bit 20 : YAcceleration<br>Bit 21 : ZAcceleration<br>Bit 22 : latitudeStandardDeviation<br>Bit 23 : longitudeStandardDeviation<br>Bit 24 : depthStandardDeviation<br>Bit 25 : headingStandardDeviation<br>Bit 26 : pitchStandardDeviation<br>Bit 27 : rollStandardDeviation | UINT32 |
| 16 - 19 | Reserved – Do not use | UINT x 4 |
| 20 - 27 | Microsecond timestamp, us since 12:00:00 am GMT, January 1, 1970 | UINT64 |
| 28 - 35 | Double float: Latitude in degrees, north is positive | FLOAT64 |
| 36 - 43 | Double float: Longitude in degrees, east is positive | FLOAT64 |
| 44 - 51 | Double float: Depth in meters | FLOAT64 |
| 52 - 59 | Double float: Heading in degrees | FLOAT64 |
| 60 - 67 | Double float: Pitch in degrees, bow up is positive | FLOAT64 |
| 68 – 75 | Double float: Roll in degrees, port up is positive | FLOAT64 |
| 76 - 83 | Double float: X, forward, relative position in meters, surge | FLOAT64 |
| 84 - 91 | Double float: Y, starboard, relative position in meters, sway | FLOAT64 |

| | | |
|---|---|---|
| 92 - 99 | Double float: Z, downward, relative position in meters, heave | FLOAT64 |
| 100 - 107 | Double float: X, forward, velocity in meters per second | FLOAT64 |
| 108 - 115 | Double float: Y, starboard, velocity in meters per second | FLOAT64 |
| 116 - 123 | Double float: Z, downward, velocity in meters per second | FLOAT64 |
| 124 - 131 | Double float: North velocity in meters per second | FLOAT64 |
| 132 - 139 | Double float: East velocity in meters per second | FLOAT64 |
| 140 - 147 | Double float: Down velocity in meters per second | FLOAT64 |
| 148 - 155 | Double float: X angular rate in degrees per second, port up is positive | FLOAT64 |
| 156 - 163 | Double float: Y angular rate in degrees per second, bow up is positive | FLOAT64 |
| 164 - 171 | Double float: Z angular rate in degrees per second, starboard is positive | FLOAT64 |
| 172 - 179 | Double float: X, forward, acceleration in meters per second per second | FLOAT64 |
| 180 - 187 | Double float: Y, starboard, acceleration in meters per second per second | FLOAT64 |
| 188 - 195 | Double float: Z, downward, acceleration in meters per second per second | FLOAT64 |
| 196 - 203 | Double float: Latitude standard deviation in meters | FLOAT64 |
| 204 - 211 | Double float: Longitude standard deviation in meters | FLOAT64 |
| 212 - 219 | Double float: Depth standard deviation in meters | FLOAT64 |
| 220 - 227 | Double float: Heading standard deviation in degrees | FLOAT64 |
| 228 - 235 | Double float: Pitch standard deviation in degrees | FLOAT64 |
| 236 - 243 | Double float: Roll standard deviation in degrees | FLOAT64 |
| 244 - 275 | Reserved – Do not use | UINT16 x 16 |

## Message Type 182: System Information Message

The system information message contains details of the system used to acquire data. This message is normally present at the beginning of a JSF file, and may be repeated if configuration parameters change.

| Byte Offsets | Description | Size |
|---|---|---|
| 0 - 3 | System Type | INT32 |
| 4 – 7 | Reserved – Do not use | |
| 8 – 11 | Version Number of Sonar Software used to generate data | INT32 |
| 12 – 19 | Reserved – Do not use | |
| 20 – 23 | Serial Number of Tow Vehicle used to collect data | INT32 |
| 24 – End | Reserved – Do not use | |

The size of the System Information Message is subject to change as more detailed information is may be added in future versions of the software. The byte count in the message header should be used to determine the total size of the structure and get to the next message in the file.

The System Type is the major type of system used to collect data. To date, the following system types are defined:

| System Type Number | Description |
|---|---|
| 1 | 2xxx Series, Combined Sub-Bottom / Side Scan with SIB Electronics |
| 2 | 2xxx Series, Combined Sub-Bottom / Side Scan with FSIC Electronics |
| 4 | 4300-MPX (Multi-Ping) |
| 5 | 3200-XS, Sub-Bottom Profiler with AIC Electronics |
| 6 | 4400-SAS, 12-Channel Side Scan |
| 7 | 3200-XS, Sub Bottom Profiler with SIB Electronics |
| 11 | 4200 Limited Multipulse Dual Frequency Side Scan |
| 14 | 3100-P, Sub Bottom Profiler |
| 16 | 2xxx Series, Dual Side Scan with SIB Electronics |
| 17 | 4200 Multipulse Dual Frequency Side Scan |
| 18 | 4700 Dynamic Focus |
| 19 | 4200 Dual Frequency Side Scan |
| 20 | 4200 Dual Frequency non Simultaneous Side Scan |
| 21 | 2200-MP Combined Sub-Bottom / Dual Frequency Multipulse Side Scan |
| 23 | 4600 Bathymetric System |
| 128 | 4100, 272 /560A Side Scan |