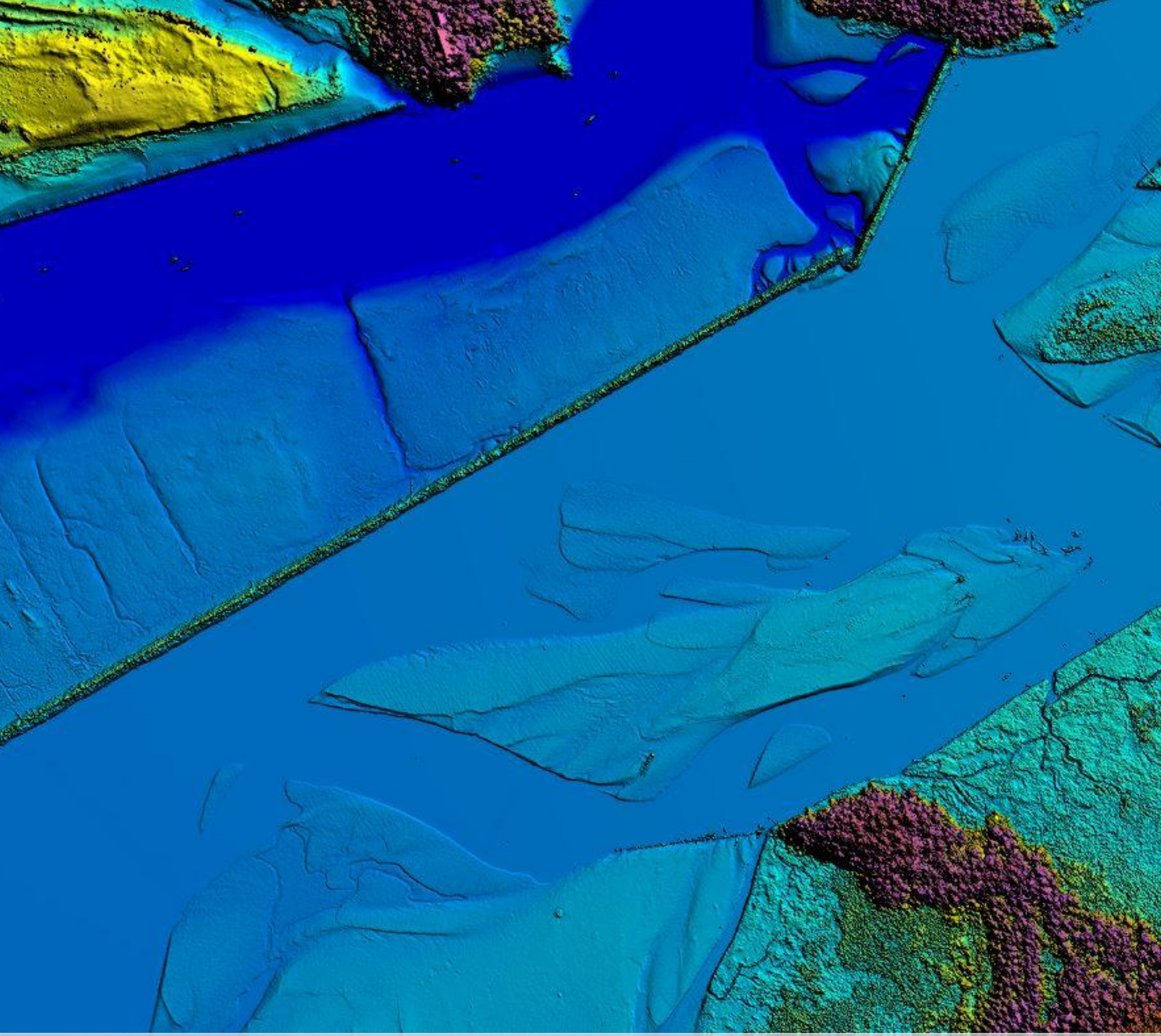

# Miller Creek Aerial Mapping

Aerial LiDAR Survey Swinomish Channel Jetty, LaConner, WA

September 29, 2014

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## Summary

In September 2014, Miller Creek Aerial Mapping (MCA) in conjunction with Terra Remote Sensing Inc. (TRSI) and APS Surveying & Mapping (APS), performed a LiDAR study of a site near La Conner, Washington. The purpose of the project was to gather LiDAR during low-tide conditions (<0ft MLLW) to aid the assessment of jetty and dike conditions in and around the Swinomish Channel.

## Project Details

**LiDAR**

| | |
|---|---|
| Total Acreage | 5428 |
| Coordinate System | Washington State Plane FIPS 4601 |
| Horizontal Datum | NAD 83/91 |
| Vertical Datum | Mean Lower Low Water (MLLW) (NAVD88 + 1.51') |
| Horizontal Point Density (Meters) | 3.84 PPSM |
| RMSEz (Feet)* | 0.094 |

**Table 1 - LiDAR Details**

*Error statistics were computed using survey check shots described below.

## Project Planning

Prior to Notice to proceed, MCA worked closely with APS Surveying & Mapping, Inc. (APS) to determine the dates and times for acquisition that would meet the requirements for the project. APS provided ground survey check points for accuracy assessment of the LiDAR acquisition. MCA also worked closely with TRSI to coordinate the flight date and time and establish a schedule that would meet or exceed the schedule defined in the RFP.

## Acquisition

The LiDAR acquisition was performed by TRSI on August 10, 2014 in a Bell 206 B3 Jet Ranger Helicopter. TRSI using a Riegl Model VQ-480 LiDAR system. This is a compact efficient LiDAR sensor that uses rotating prism technology that transmits a uniform density of pulses over the entire scan angle. The system has a variable Pulse Repetition Rate up to 300 KHz. As specified, the acquisition was performed with the tide conditions of <0ft MLLW.

## Survey Report

APS collected 22 survey check points in areas of relatively easy access (principally at the northern end of the project). The initial values were observed and collected using RTK GPS methods (±0.16 feet horizontal & vertical accuracy), with frequent checks shots into the 3.5 inch USACE Aluminum Monument "MARTHA 2008" [WSPC North Zone in US Survey Feet =N(y) 506387.14 E(x) 1230203.53 and NAVD88 elevation = 10.67 feet]. By comparing the record elevation of "TIDAL 3 (PID TR0236)" a USC&GS First Order Class II monument [23.55 feet NAVD88] with the published tidal data from 9448558, La Conner, Swinomish Slough, WA [7.638 meters MLLW = 25.06 feet MLLW] the difference between NAVD88 and MLLW in the Swinomish Slough is 1.51 feet.

Upon receipt of the edited lidar data and final breaklines from TRSI, MCA observed a consistent bias in the elevations between the lidar/breaklines data and the survey check shots. After statistical analysis, it was determined that there should be a .49 foot shift in the lidar/breakline data to bring it into agreement with the survey check points from APS. The resulting accuracy statistics are found below.

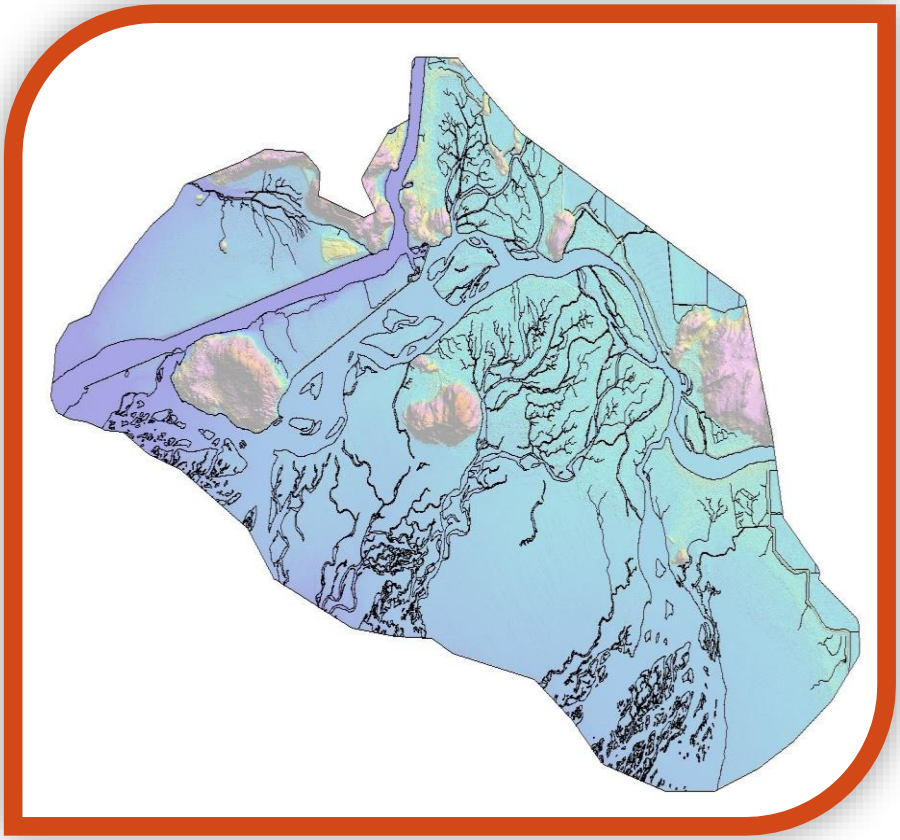
## Data Processing

After acquisition, the raw data was calibrated, the automatic classification was performed and breaklines were collected.

### Point Cloud

The initial point cloud calibration and geo-referencing was performed using TerraSolid's TerraMatch Software package. The TerraSolid software suite was then used to perform the automated point cloud classifications. This process uses complex algorithms to perform in-depth analysis of the point cloud and metadata, and classify the ground points. Shaded relief models are used as a QC tool to ensure the ground is accurately defined.

## Breakline Generation



Breaklines for water features are defined in 2D for wider waters and natively in 3D for narrow creek/stream features.

In the case of hydrology with no apparent gradient (lakes, ponds and oceans) each vertex is projected to the lowest LiDAR hit within or near the hydrological feature.

In the case of hydrology with a downhill gradient (double-edged rivers and streams) hydrological edges are derived in a planimetric view. An alignment is then derived from the approximate centerline of edge features, which is downhill-enforced and projected to a lowest local minimum along the alignment. The 2D planimetric edge elements are projected to 3D by a linear interpolation from the orthogonal intersection of an edge vertex with the alignment. Vertices can optionally be introduced at this 3D intersection to enforce orthogonal elevations spanning the hydrological feature.

## Quality Control

Upon receipt of the processed and edited LiDAR data from TRSI, MCA performed a comprehensive quality control assessment of the data. All datasets were checked against each other for consistency, accuracy and completeness. Specific quality control checks include the following:

1. Point cloud data is checked against survey checkpoints collected independently by APS
2. Inspection of all deliverables for completeness and accuracy
    a. Naming convention check
    b. Map projection check
    c. Data completeness check
    d. Consistency of data between deliverables

## Accuracy Report

**Accuracy Report (Feet)**

| | |
|---|---|
| Average dz* | -0.021 |
| Minimum dz* | -0.290 |
| Maximum dz* | 0.130 |
| Average Magnitude* | 0.068 |
| RMSEz* | 0.094 |
| Standard Deviation* | 0.094 |

**Table 2 - Accuracy Report**

*Error statistics were computed using survey check shots described below.

## Check Point Accuracy

| Number | Easting | Northing | Known Z | Laser Z | Dz |
|---|---|---|---|---|---|
| 1001 | 1240934.45 | 505163.13 | 8.76 | 8.78 | 0.02 |
| 1002 | 1240843.11 | 505108.18 | 8.90 | 8.94 | 0.04 |
| 1003 | 1240737.03 | 505093.19 | 8.93 | 8.94 | 0.01 |
| 1004 | 1240631.86 | 505096.72 | 8.50 | 8.50 | 0.00 |
| 1005 | 1240531.36 | 505098.34 | 8.31 | 8.29 | -0.02 |
| 1006 | 1240432.64 | 505082.52 | 8.25 | 8.27 | 0.02 |
| 1007 | 1240340.76 | 505034.35 | 8.15 | 8.13 | -0.02 |
| 1008 | 1240254.78 | 504978.24 | 9.84 | 9.87 | 0.03 |
| 1009 | 1240174.72 | 504919.16 | 16.57 | 16.58 | 0.01 |
| 1017 | 1234032.92 | 509040.63 | 13.59 | 13.49 | -0.10 |
| 1018 | 1234008.40 | 508925.98 | 13.60 | 13.58 | -0.02 |
| 1019 | 1233989.32 | 508807.82 | 13.41 | 13.31 | -0.10 |
| 1021 | 1230260.12 | 506080.94 | 8.20 | 7.91 | -0.29 |
| 1022 | 1230224.97 | 506180.22 | 7.49 | 7.57 | 0.08 |
| 1023 | 1230182.30 | 506281.39 | 8.51 | 8.63 | 0.12 |
| 1024 | 1230132.67 | 506379.22 | 9.18 | 9.31 | 0.13 |
| 1025 | 1230065.41 | 506464.32 | 9.53 | 9.47 | -0.06 |
| 1026 | 1229989.55 | 506540.34 | 9.04 | 8.96 | -0.08 |
| 1027 | 1229886.89 | 506563.59 | 7.57 | 7.44 | -0.13 |
| 1028 | 1229789.03 | 506581.17 | 8.18 | 8.15 | -0.03 |
| 1029 | 1229673.97 | 506598.82 | 8.25 | 8.12 | -0.13 |
| 1030 | 1229558.32 | 506573.70 | 5.62 | 5.68 | 0.06 |

**Table 3 – Check Point Accuracy**