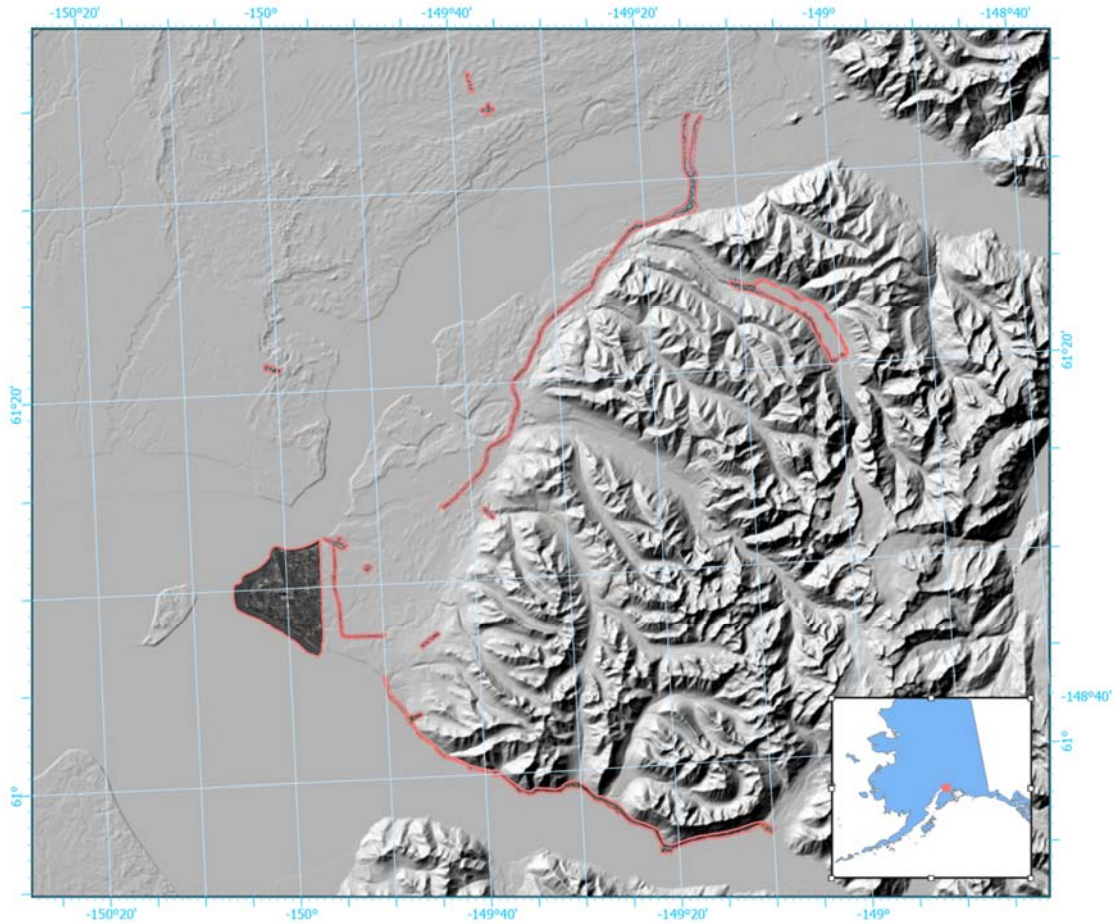


NOVEMBER 30, 2018, Mw 7.1 ANCHORAGE EARTHQUAKE PHOTOGRAMMETRY

J. Barrett Salisbury, Andrew M. Herbst, and Katreen Wikstrom Jones

Raw Data File 2019-10



This report has not been reviewed for technical content or for conformity to the editorial standards of DGGS.

2020
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS



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ABSTRACT

The State of Alaska Division of Geological & Geophysical Surveys (DGGS) produced digital surface models (DSMs) and orthorectified aerial imagery (orthoimagery) over selected locations in the greater Anchorage area following the Mw 7.1 November 30, 2018, Anchorage earthquake. We selected areas of interest (AOIs) based on initial damage reports from the Alaska Department of Transportation & Public Facilities (DOT&PF) and the United States Geological Survey (USGS) in order to document earthquake effects. Aerial photographs collected December 5–6, 2018, were processed using Structure-from-Motion (SfM) photogrammetric techniques to create sub-meter DSMs and orthoimagery.

INTRODUCTION

Data include orthoimagery and digital surface models covering 14 distinct areas of interest across the municipality of Anchorage, Alaska. These data document ground conditions immediately following the 2018 Mw 7.1 Anchorage earthquake.

LIST OF DELIVERABLES

- 3-band RGB orthophotos
- Digital surface models (DSM)
- Metadata

MISSION PLAN

Aircraft and Instrument

Alaska DGGS and the U.S. Bureau of Land Management (BLM) collected digital aerial photographs on December 5–6, 2018, from a fixed-wing (Cessna 180) airborne platform. Photographic survey plans included 60 percent side-lap and 80 percent end-lap coverage at variable above ground-level (AGL) heights, dependent upon the size/shapes of the AOIs and atmospheric conditions. We collected 7,238 photographs, covering 130 square kilometers with ground sample distances (GSDs) ranging from 3.6–22.8 cm. We used a Nikon D850 with an AF-Nikkor 24 mm lens to collect 45.4 Megapixel (8,256 x 5,504 pixels per image), 14-bit NEF.RAW (processed in Adobe Lightroom to 48-bit uncompressed TIFF photographs) and fine JPEGs. The aerial survey was controlled with an automatic flight control system and Aviatrix software, linking the camera shutter release with Global Navigation Satellite System (GNSS), Trimble R7 receiver, and a dual-band Novatel antenna mounted 0.96 m above the camera sensor.

Aerial Survey Report

An equipment malfunction during collection compromised sensor location data for each image. Because the camera shutter maintained synchronicity with GNSS input, surveyed data remained suitable for further processing with additional steps required.

PROCESSING REPORT

SfM Dataset Processing

We processed and calibrated data from each of the 14 AOIs separately in Agisoft Metashape (Version 1.5.2 build 7838), beginning with photograph alignment and calibration of camera positions. We integrated ground control points (GCPs) in these initial procedures to achieve accurate georeferencing for all subsequent data products.

Structure-from-Motion (SfM) processing continued with the construction of point clouds and surface models. Photographs were orthorectified using relative camera positions in conjunction with GCP-controlled surface models. The results were analyzed for quality control using additional checkpoints (see appendices).

Because vertical elevation control is based on a 2015 lidar survey (see Survey Report below), these data are not suitable for calculating regional-scale vertical ground surface deformation.

DSM

Digital surface models (DSMs) represent all observable elevations within the project extent, capturing vegetation heights, building roofs, and other opaque objects. The 14 raster DSM products in this collection are delivered in 32-bit float format and possess heterogeneous spatial properties.

Orthophoto

Orthoimages are aerial photographs that have been geometrically corrected (orthorectified) for spatial accuracy, coordinating surface elevation with the sensor's location throughout the survey to create a geospatial product of uniform map scale. Collected imagery is assembled into composite mosaics for delivery. This collection comprises 14 total mosaics, each with varying spatial properties.

SURVEY REPORT

Ground Control

Due to the size and scale of the study area, conventional ground control methods were unobtainable within the timeframe of the survey. Instead, we extracted photo-identifiable horizontal ground control from Earth Systems Research Institute's (ESRI) orthoimagery map service (ESRI, 2019). This image service provided accuracies of 0.45 m–1 m.

We used a 2015 lidar survey for the Municipality of Anchorage, Alaska for vertical control on those same points. The 2015 Anchorage lidar data provide a vertical accuracy of 7.2 cm and are available through the DGGs Elevation Portal, <https://elevation.alaska.gov/#61.17636:-149.62555:9>, (DGGs Staff, 2013).

Coordinate system and Datum

AOIs were are projected in either NAD83 UTM 5 or UTM 6

QA/QC REPORT

We evaluated data quality based on vertical and horizontal accuracy compared to control data mentioned in the previous paragraph. We provide root mean square error (RMSE) for each AOI in Appendix 1.

ACKNOWLEDGMENTS

This project was funded by State of Alaska general funds. It coincides with and augments a United States Geological Survey QL2 lidar project flown by Kodiak Mapping and available through the DGGs Elevation Portal, <https://elevation.alaska.gov/#61.17636:-149.62555:9> (DGGs Staff, 2013). We thank Seth K. Kiester for assistance with equipment and logistics.

REFERENCES

- DGGs Staff, 2013, Elevation Datasets of Alaska: Alaska Division of Geological & Geophysical Surveys Digital Data Series 4, <http://maps.dggs.alaska.gov/elevationdata/>.
<http://doi.org/10.14509/25239>
- ESRI, 2019, World Imagery (Clarity).
<https://www.arcgis.com/home/item.html?id=ab399b847323487dba26809bf11ea91a>

APPENDIX 2. CONTROL POINTS**Ted Stevens Anchorage International Airport**

| #Label | X/Longitude | Y/Latitude | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-------------|------------|------------|-----------|-----------|-----------|-----------|-------------|-----------|-----------|
| point 1 | -150.053157 | 61.155301 | 59.061 | 2.139047 | 0.512388 | -0.878768 | -1.881687 | -150.053147 | 61.155293 | 57.179313 |
| point 2 | -150.033202 | 61.174293 | 25.843 | 1.890207 | 0.295701 | -0.192909 | 1.85694 | -150.033197 | 61.174291 | 27.69994 |
| point 3 | -150.002352 | 61.200226 | 47.975 | 2.098544 | -0.521487 | 0.254596 | -2.01671 | -150.002362 | 61.200228 | 45.95829 |
| point 4 | -149.982412 | 61.165537 | 36.956 | 6.528629 | 4.686988 | 0.401229 | -4.527047 | -149.982325 | 61.165541 | 32.428951 |
| point 5 | -149.938161 | 61.126681 | 17.263 | 6.741054 | -5.901442 | -1.516279 | 2.883693 | -149.938271 | 61.126667 | 20.14669 |
| point 6 | -149.953723 | 61.201289 | 10.389 | 1.111844 | -1.04869 | 0.305228 | 0.208044 | -149.953743 | 61.201292 | 10.597044 |
| point 7 | -149.989053 | 61.138194 | 51.462 | 2.99301 | 1.354149 | -0.926515 | -2.50319 | -149.989028 | 61.138186 | 48.95881 |
| point 8 | -149.996898 | 61.188278 | 31.3 | 2.246937 | -0.31539 | -0.131555 | 2.220799 | -149.996904 | 61.188277 | 33.520799 |
| point 9 | -150.003536 | 61.159377 | 38.137 | 2.737066 | 0.613717 | -0.189593 | 2.660627 | -150.003525 | 61.159375 | 40.797627 |
| point 10 | -149.954833 | 61.152254 | 37.531 | 2.084071 | 0.746235 | 0.462472 | -1.890133 | -149.954819 | 61.152258 | 35.640867 |
| point 11 | -150.055469 | 61.167822 | 10.928 | 1.189066 | -0.170577 | -0.993752 | 0.630268 | -150.055472 | 61.167813 | 11.558268 |
| point 12 | -149.967551 | 61.185687 | 23.261 | 4.457268 | -0.088689 | 3.67362 | -2.522674 | -149.967553 | 61.18572 | 20.738325 |
| point 13 | -149.995617 | 61.181562 | 29.104 | 4.555099 | 0.312028 | -0.632167 | 4.500215 | -149.995611 | 61.181556 | 33.604214 |
| point 14 | -150.02297 | 61.196564 | 17.978 | 0.951199 | -0.220807 | -0.611349 | -0.694461 | -150.022974 | 61.196559 | 17.283539 |
| point 15 | -149.954945 | 61.174421 | 25.659 | 1.485896 | -0.25851 | 0.980284 | 1.086325 | -149.95495 | 61.17443 | 26.745325 |

Glenn Highway

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|------------|
| point 1 | 354139 | 6791415 | 83.107 | 1.011816 | 0.660346 | -0.29455 | -0.707782 | 354139.6602 | 6791414.705 | 82.399218 |
| point 2 | 355607 | 6792534 | 98.224 | 0.667367 | 0.079165 | 0.654785 | -0.101823 | 355607.0792 | 6792534.655 | 98.122177 |
| point 3 | 356611 | 6793474 | 116.709 | 1.466962 | 0.149757 | 1.258947 | 0.737973 | 356611.1497 | 6793475.259 | 117.446973 |
| point 4 | 358565 | 6795827 | 124.761 | 1.708057 | 0.793937 | 1.32406 | 0.730745 | 358565.7938 | 6795828.324 | 125.491745 |
| point 5 | 361100 | 6798325 | 146.601 | 3.052732 | -0.931701 | -2.90633 | 0.065931 | 361099.0685 | 6798322.094 | 146.666931 |
| point 6 | 360022 | 6797369 | 145.978 | 1.921147 | -0.003769 | -1.89573 | 0.311145 | 360021.9962 | 6797367.105 | 146.28945 |
| point 7 | 362031 | 6800000 | 68.073 | 2.597362 | 0.760774 | -1.193575 | -2.177818 | 362031.7606 | 6799998.807 | 65.895182 |
| point 8 | 361992 | 6801705 | 83.213 | 0.965694 | -0.4392 | 0.175144 | -0.842017 | 361991.5609 | 6801705.175 | 82.370983 |
| point 9 | 361933 | 6803030 | 82.191 | 2.068413 | -1.901695 | 0.643711 | 0.49752 | 361931.0986 | 6803030.644 | 82.68852 |
| point 10 | 362759 | 6803432 | 80.705 | 1.476906 | -0.608308 | 0.894841 | 1.005222 | 362758.3918 | 6803432.895 | 81.710222 |
| point 11 | 364766 | 6807142 | 78.197 | 1.222249 | -0.982051 | -0.727316 | 0.021896 | 364765.0181 | 6807141.273 | 78.218896 |
| point 12 | 365193 | 6807844 | 78.06 | 0.755649 | -0.014814 | 0.198351 | -0.729001 | 365192.9852 | 6807844.198 | 77.330999 |
| point 13 | 364632 | 6806648 | 86.39 | 2.417257 | 2.349689 | 0.482053 | -0.299535 | 364634.3492 | 6806648.482 | 86.090465 |
| point 14 | 363410 | 6804021 | 90.811 | 1.974521 | -0.439665 | 1.409192 | 1.311337 | 363409.5604 | 6804022.409 | 92.122337 |
| point 15 | 368232 | 6809929 | 103.565 | 1.204099 | -0.33283 | -0.44733 | 1.067228 | 368231.6672 | 6809928.553 | 104.632228 |
| point 16 | 369179 | 6810704 | 107.95 | 1.275095 | 0.528679 | 0.253106 | -1.132388 | 369179.5286 | 6810704.253 | 106.817612 |
| point 17 | 370456 | 6812240 | 113.975 | 2.595953 | 1.721049 | 1.921927 | 0.288368 | 370457.7207 | 6812241.922 | 114.263367 |
| point 18 | 372149 | 6813766 | 97.174 | 4.5626 | -2.668247 | -3.700158 | -0.081287 | 372146.3323 | 6813762.301 | 97.092711 |
| point 19 | 373431 | 6815452 | 28.353 | 1.851369 | 1.17175 | 0.848817 | 1.155024 | 373432.1715 | 6815452.849 | 29.508023 |
| point 20 | 374145 | 6816173 | 18.554 | 1.147954 | 0.062103 | 0.866895 | -0.749956 | 374145.0621 | 6816173.867 | 17.804044 |
| point 21 | 374707 | 6816439 | 13.609 | 0.307941 | -0.149071 | 0.058414 | -0.263046 | 374706.851 | 6816439.058 | 13.345954 |
| point 22 | 373878 | 6815866 | 22.802 | 1.129947 | 0.962856 | 0.591341 | 0.002126 | 373878.9627 | 6815866.591 | 22.804126 |

| | | | | | | | | | | |
|-----------|--------|---------|--------|----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 23 | 375563 | 6816445 | 7.391 | 0.935739 | -0.405093 | 0.832574 | 0.135382 | 375562.595 | 6816445.832 | 7.526382 |
| point 24 | 378145 | 6817215 | 7.757 | 0.696596 | 0.213655 | 0.553287 | -0.365337 | 378145.2136 | 6817215.553 | 7.391663 |
| point 25 | 379397 | 6817593 | 9.496 | 0.370407 | 0.290662 | -0.214481 | 0.081941 | 379397.2906 | 6817592.786 | 9.577941 |
| point 26 | 379605 | 6817860 | 8.091 | 0.405407 | -0.110343 | 0.298372 | 0.251303 | 379604.8897 | 6817860.298 | 8.342303 |
| point 40c | 380496 | 6818571 | 12.299 | 0.582004 | 0.379749 | 0.400558 | -0.184587 | 380496.3797 | 6818571.4 | 12.114413 |
| point 41c | 380136 | 6818711 | 14.912 | 1.035161 | -0.258706 | -0.465673 | -0.887569 | 380135.7414 | 6818710.534 | 14.024431 |
| point 42c | 380240 | 6819086 | 8.733 | 0.921084 | 0.095222 | -0.426867 | 0.810625 | 380240.0952 | 6819085.573 | 9.543625 |
| point 43c | 380700 | 6819578 | 8.645 | 1.158308 | -0.110886 | -0.071386 | -1.150776 | 380699.8891 | 6819577.929 | 7.494224 |
| point 44c | 380783 | 6819944 | 7.714 | 3.27393 | 0.105496 | 0.159891 | 3.268322 | 380783.1055 | 6819944.16 | 10.982322 |
| point 45c | 380582 | 6820446 | 7.25 | 1.833589 | 1.111736 | -1.166929 | -0.874281 | 380583.1115 | 6820444.833 | 6.375719 |
| point 46c | 380828 | 6821280 | 7.98 | 1.355117 | -0.349568 | 0.203978 | 1.293266 | 380827.6505 | 6821280.204 | 9.273266 |
| point 47c | 380317 | 6821831 | 6.57 | 2.338561 | 1.387526 | -1.87661 | 0.148231 | 380318.3872 | 6821829.124 | 6.718231 |
| point 48c | 380039 | 6821488 | 9.15 | 2.188509 | -1.136721 | 0.018755 | -1.870049 | 380037.8635 | 6821488.019 | 7.279951 |
| point 49c | 380032 | 6822284 | 6.67 | 1.041443 | -0.762382 | 0.479647 | -0.522796 | 380031.2378 | 6822284.48 | 6.147204 |
| point 50c | 380964 | 6823444 | 7.72 | 0.849187 | -0.728867 | 0.140763 | 0.41238 | 380963.2713 | 6823444.141 | 8.13238 |
| point 51c | 380072 | 6823163 | 7.22 | 1.299625 | -0.407688 | -0.669671 | -1.036511 | 380071.5924 | 6823162.33 | 6.183489 |
| point 52c | 380705 | 6822889 | 7.01 | 0.859444 | -0.300212 | -0.631335 | -0.499933 | 380704.6999 | 6822888.369 | 6.510067 |
| point 53c | 380243 | 6824468 | 8.21 | 1.16549 | -0.711594 | 0.578666 | 0.719129 | 380242.2886 | 6824468.579 | 8.929129 |
| point 54c | 381231 | 6824695 | 10.16 | 1.940469 | 0.222432 | 0.251531 | -1.911198 | 381231.2224 | 6824695.251 | 8.248802 |
| point 55c | 380281 | 6825503 | 7.25 | 0.731287 | -0.153472 | 0.439767 | 0.563766 | 380280.8466 | 6825503.44 | 7.813766 |
| point 56c | 381411 | 6825412 | 8.98 | 1.772226 | 0.345472 | 0.821759 | 1.531713 | 381411.3454 | 6825412.822 | 10.511713 |
| point 57c | 380892 | 6826769 | 22.91 | 0.556761 | 0.479812 | 0.062038 | -0.275525 | 380892.4797 | 6826769.062 | 22.634475 |
| point 58c | 381805 | 6826164 | 33.71 | 0.288527 | 0.035035 | -0.135064 | 0.252543 | 381805.035 | 6826163.865 | 33.962543 |

Seward Highway 1

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 1 | 347081 | 6775762 | 43.32 | 0.580693 | 0.18242 | -0.541573 | -0.10308 | 347081.1824 | 6775761.458 | 43.21692 |
| point 2 | 351108 | 6769096 | 10.824 | 0.18523 | -0.154042 | -0.084519 | 0.058633 | 351107.846 | 6769095.915 | 10.882633 |
| point 3 | 354366 | 6766490 | 10.579 | 0.2682 | -0.18776 | -0.175175 | -0.077403 | 354365.8123 | 6766489.825 | 10.501597 |
| point 4 | 347374 | 6774560 | 6.481 | 0.607258 | -0.17182 | 0.450424 | 0.369268 | 347373.8282 | 6774560.45 | 6.850268 |
| point 5 | 347892 | 6773442 | 7.843 | 0.628392 | -0.462716 | 0.043126 | -0.422978 | 347891.5373 | 6773442.043 | 7.420022 |
| point 6 | 348747 | 6772340 | 9.591 | 1.126004 | 0.604535 | 0.844216 | -0.435571 | 348747.6045 | 6772340.844 | 9.155429 |
| point 7 | 349408 | 6770993 | 12.581 | 0.916846 | -0.306244 | -0.217306 | -0.83642 | 349407.6938 | 6770992.783 | 11.74458 |
| point 8 | 350060 | 6769969 | 70.14027 | 0.200511 | 0.034203 | 0.144854 | 0.134358 | 350060.0342 | 6769969.145 | 70.274628 |
| point 9 | 352047 | 6768166 | 90.18 | 0.49347 | 0.401057 | 0.033706 | -0.285535 | 352047.401 | 6768166.034 | 89.894465 |
| point 10 | 353190 | 6767443 | 75.548 | 0.582384 | 0.225801 | 0.454452 | 0.28576 | 353190.2258 | 6767443.454 | 75.83376 |
| point 11 | 352131 | 6767698 | 9.016 | 0.387971 | -0.277123 | -0.270159 | -0.027177 | 352130.7229 | 6767697.73 | 8.988823 |
| point 12 | 349095 | 6771619 | 5.451 | 1.507972 | 0.111684 | -0.681815 | 1.340386 | 349095.1117 | 6771618.318 | 6.791386 |

Seward Highway 2

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 1 | 356956 | 6765869 | 67.886 | 0.424382 | -0.125485 | 0.388724 | -0.115098 | 356955.8745 | 6765869.389 | 67.770902 |
| point 2 | 355998 | 6765966 | 2.155 | 0.316276 | 0.156186 | 0.20654 | -0.181598 | 355998.1562 | 6765966.207 | 1.973402 |
| point 3 | 364399 | 6763785 | 10.297 | 0.852788 | 0.328221 | -0.645267 | -0.450721 | 364399.3282 | 6763784.355 | 9.846279 |
| point 4 | 363886 | 6763971 | 16.005 | 1.516636 | -1.397359 | 0.129238 | -0.575214 | 363884.6029 | 6763971.129 | 15.429785 |
| point 5 | 365132 | 6763715 | 21.407 | 0.640661 | 0.421431 | 0.223737 | 0.427532 | 365132.4214 | 6763715.224 | 21.834532 |
| point 6 | 362593 | 6763708 | 62.193 | 1.393128 | 0.943326 | 0.503227 | 0.893143 | 362593.9432 | 6763708.503 | 63.086143 |
| point 7 | 360971 | 6763762 | 7.507 | 0.583607 | -0.55252 | -0.169514 | 0.081142 | 360970.4476 | 6763761.831 | 7.588142 |
| point 8 | 359748 | 6763638 | 44.884 | 0.946827 | 0.029323 | -0.374471 | -0.869133 | 359748.0293 | 6763637.626 | 44.014866 |
| point 9 | 358822 | 6764147 | 94.949 | 1.237452 | 0.902176 | 0.332813 | 0.778847 | 358822.902 | 6764147.333 | 95.727847 |
| point 10 | 358417 | 6764532 | 28.482 | 0.803958 | -0.623831 | 0.094063 | -0.498333 | 358416.3763 | 6764532.094 | 27.983667 |
| point 11 | 357354 | 6765436 | 10.078 | 0.790503 | -0.19364 | -0.598219 | 0.479096 | 357353.8064 | 6765435.402 | 10.557096 |
| point 12 | 354636 | 6766460 | 16.457 | 0.1475 | 0.112086 | -0.090881 | 0.030556 | 354636.1121 | 6766459.909 | 16.487556 |

Seward Highway 3

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|------------|
| point 1 | 371991 | 6757937 | 15.342 | 1.477189 | -1.099935 | -0.976333 | 0.137856 | 371989.9003 | 6757936.024 | 15.479856 |
| point 2 | 371451 | 6758919 | 11.46 | 1.425273 | -1.211165 | -0.193615 | -0.725944 | 371449.7891 | 6758918.806 | 10.734056 |
| point 3 | 370363 | 6759536 | 11.206 | 0.343976 | 0.051135 | -0.218808 | 0.260438 | 370363.0511 | 6759535.781 | 11.466438 |
| point 4 | 369134 | 6760379 | 118.865 | 3.470015 | 2.903539 | 1.676577 | 0.894176 | 369136.9029 | 6760380.676 | 119.759175 |
| point 5 | 367807 | 6762014 | 40.616 | 0.604104 | 0.083751 | 0.192372 | 0.566498 | 367807.0837 | 6762014.192 | 41.182498 |
| point 6 | 367747 | 6761378 | 8.08 | 1.138354 | -0.624403 | -0.424407 | -0.851968 | 367746.3757 | 6761377.576 | 7.228032 |
| point 7 | 366491 | 6762283 | 7.935 | 0.548739 | 0.349665 | -0.383693 | -0.177844 | 366491.3496 | 6762282.616 | 7.757156 |
| point 8 | 364358 | 6764413 | 44.869 | 0.753498 | -0.452415 | 0.126908 | 0.589046 | 364357.5477 | 6764413.127 | 45.458046 |
| point 9 | 362743 | 6763515 | 6.668 | 0.802636 | 0.415364 | 0.125189 | 0.675296 | 362743.4153 | 6763515.125 | 7.343296 |
| point 10 | 361079 | 6763765 | 9.193 | 0.970121 | 0.071199 | -0.290369 | -0.922904 | 361079.0712 | 6763764.71 | 8.270096 |
| point 11 | 359856 | 6763646 | 82.338 | 1.220417 | 0.999805 | 0.697196 | 0.061042 | 359856.9996 | 6763646.697 | 82.399041 |
| point 12 | 358560 | 6764286 | 7.918 | 1.771231 | -1.198696 | -1.285813 | 0.216958 | 358558.8015 | 6764284.714 | 8.134958 |

| | | | | | | | | | | |
|----------|--------|---------|--------|----------|-----------|---------|-----------|-------------|-------------|-----------|
| point 13 | 364980 | 6763704 | 18.442 | 1.231113 | -0.288504 | 0.95515 | -0.721174 | 364979.7115 | 6763704.955 | 17.720826 |
|----------|--------|---------|--------|----------|-----------|---------|-----------|-------------|-------------|-----------|

Seward Highway 4

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 1 | 371942 | 6757790 | 9.482 | 0.524283 | 0.208409 | -0.394086 | -0.275924 | 371942.2084 | 6757789.606 | 9.206076 |
| point 2 | 372298 | 6757073 | 9.576 | 1.109145 | -0.02959 | -1.083198 | -0.236665 | 372297.9704 | 6757071.917 | 9.339335 |
| point 3 | 382314 | 6758154 | 9.398 | 1.098934 | -0.257717 | -0.650198 | 0.847633 | 382313.7423 | 6758153.35 | 10.245633 |
| point 4 | 381091 | 6758753 | 9.728 | 1.445771 | 0.52612 | -0.088331 | 1.343744 | 381091.526 | 6758752.912 | 11.071744 |
| point 5 | 379778 | 6758252 | 8.399 | 1.104737 | -0.23688 | 0.428856 | -0.990159 | 379777.7632 | 6758252.429 | 7.408841 |
| point 6 | 377866 | 6757949 | 7.298 | 0.521399 | -0.036789 | 0.5114 | 0.094731 | 377865.9632 | 6757949.511 | 7.392731 |
| point 7 | 376625 | 6757946 | 8.962 | 0.756833 | -0.056142 | 0.751439 | 0.0706 | 376624.9439 | 6757946.751 | 9.0326 |
| point 8 | 375920 | 6757968 | 84.263 | 0.392657 | -0.084186 | 0.062376 | 0.37842 | 375919.9158 | 6757968.062 | 84.64142 |
| point 9 | 379238 | 6758156 | 9.248 | 0.71134 | 0.589363 | 0.357607 | -0.175422 | 379238.5892 | 6758156.358 | 9.072578 |
| point 10 | 374553 | 6757854 | 84.109 | 0.525321 | 0.039238 | -0.068844 | -0.51931 | 374553.0392 | 6757853.931 | 83.58969 |
| point 11 | 373507 | 6757565 | 51.914 | 1.155532 | -0.283143 | 0.707963 | 0.868258 | 373506.7169 | 6757565.708 | 52.782258 |
| point 12 | 382170 | 6758561 | 9.652 | 1.551159 | -0.378653 | -0.534946 | -1.405898 | 382169.6214 | 6758560.465 | 8.246102 |

Eklutna Lake

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|------------|
| point 1 | 383947 | 6810329 | 246.238 | 2.843086 | 1.085538 | 0.70389 | -2.531656 | 383948.0852 | 6810329.704 | 243.706344 |
| point 2 | 385186 | 6809709 | 261.167 | 6.147806 | -0.807808 | 0.086675 | 6.093887 | 385185.1924 | 6809709.087 | 267.260887 |
| point 3 | 385541 | 6810123 | 280.258 | 1.144085 | -0.464397 | 0.029711 | -1.045172 | 385540.5357 | 6810123.03 | 279.212828 |
| point 4 | 384454 | 6810160 | 250.618 | 0.962505 | 0.127439 | 0.268025 | -0.915608 | 384454.1274 | 6810160.268 | 249.702392 |
| point 5 | 384535 | 6810144 | 249.752 | 0.984873 | 0.644418 | -0.181273 | -0.722385 | 384535.6442 | 6810143.819 | 249.029615 |
| point 6 | 393166 | 6802297 | 268.901 | 1.472635 | 1.356295 | 0.439705 | -0.368482 | 393167.3559 | 6802297.44 | 268.532518 |
| point 7 | 389873 | 6808032 | 269.829 | 0.634875 | -0.452975 | -0.410517 | -0.171338 | 389872.5472 | 6808031.59 | 269.657662 |
| point 8 | 390838 | 6806116 | 264.359 | 3.213361 | -2.374636 | -1.829224 | -1.157902 | 390835.6261 | 6806114.171 | 263.201097 |
| point 9 | 391944 | 6806314 | 273.832 | 1.051227 | 0.807182 | 0.606589 | 0.29255 | 391944.8069 | 6806314.606 | 274.12455 |
| point 10 | 393517 | 6803103 | 265.699 | 0.603943 | 0.078818 | 0.286785 | 0.525632 | 393517.0788 | 6803103.287 | 266.224632 |

Minnesota Drive

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 1 | 343398 | 6788480 | 30.491 | 0.57139 | -0.376907 | -0.246592 | -0.351595 | 343397.6231 | 6788479.753 | 30.139405 |
| point 2 | 343403 | 6788255 | 30.578 | 0.652874 | -0.458843 | -0.458352 | 0.074974 | 343402.5412 | 6788254.542 | 30.652974 |
| point 3 | 343424 | 6787227 | 29.344 | 0.385033 | -0.040923 | -0.306452 | 0.229484 | 343423.9591 | 6787226.694 | 29.573484 |
| point 4 | 343391 | 6786629 | 27.597 | 1.402066 | 1.204487 | 0.200546 | -0.689045 | 343392.2044 | 6786629.201 | 26.907955 |
| point 5 | 343285 | 6783863 | 27.824 | 0.685696 | 0.486427 | 0.342327 | 0.341145 | 343285.4864 | 6783863.342 | 28.165145 |
| point 6 | 343017 | 6785294 | 27.969 | 0.805139 | -0.688382 | -0.416167 | 0.034413 | 343016.3117 | 6785293.584 | 28.003413 |
| point 7 | 343360 | 6782739 | 24.015 | 0.789418 | -0.249634 | 0.684503 | -0.303842 | 343359.7504 | 6782739.684 | 23.711158 |
| point 8 | 343313 | 6780396 | 23.108 | 0.584364 | 0.475675 | -0.126433 | 0.315006 | 343313.4756 | 6780395.874 | 23.423006 |
| point 9 | 344518 | 6779960 | 28.118 | 0.955362 | -0.840235 | -0.435974 | -0.129028 | 344517.1599 | 6779959.564 | 27.988972 |
| point 10 | 346084 | 6779857 | 51.72 | 0.600694 | -0.436709 | -0.390749 | -0.132041 | 346083.5633 | 6779856.609 | 51.587959 |
| point 11 | 347376 | 6779833 | 92.575 | 0.620885 | 0.432088 | 0.440873 | 0.066552 | 347376.432 | 6779833.441 | 92.641552 |
| point 12 | 343931 | 6788306 | 31.994 | 0.412411 | -0.112999 | -0.284421 | 0.276439 | 343930.887 | 6788305.716 | 32.270439 |
| point 13 | 343851 | 6789551 | 20.432 | 0.596862 | 0.195908 | 0.448831 | -0.341197 | 343851.1959 | 6789551.449 | 20.090803 |
| point 14 | 343914 | 6789080 | 8.277 | 0.739753 | 0.081874 | 0.430247 | 0.596169 | 343914.0819 | 6789080.43 | 8.873169 |
| point 15 | 343364 | 6781324 | 24.887 | 0.348927 | 0.328188 | 0.117838 | 0.012507 | 343364.3282 | 6781324.118 | 24.899507 |

Westchester Lagoon

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 1 | 343131 | 6789434 | 7.689 | 1.083733 | -0.513607 | -0.222685 | -0.927952 | 343130.4864 | 6789433.777 | 6.761048 |
| point 2 | 344501 | 6788882 | 10.602 | 1.076636 | -0.021849 | 0.12344 | 1.069313 | 344500.9782 | 6788882.123 | 11.671313 |
| point 3 | 344108 | 6788622 | 29.947 | 1.172909 | -0.866084 | -0.272611 | -0.742495 | 344107.134 | 6788621.727 | 29.204505 |
| point 4 | 343570 | 6789280 | 8.731 | 0.528272 | -0.465633 | -0.24194 | 0.061017 | 343569.5344 | 6789279.758 | 8.792017 |
| point 5 | 342956 | 6789499 | 7.435 | 0.97728 | -0.243517 | -0.183138 | 0.928566 | 342955.7565 | 6789498.817 | 8.363566 |
| point 6 | 343353 | 6789425 | 8.802 | 1.608306 | 1.200054 | 0.744413 | -0.769654 | 343354.1999 | 6789425.744 | 8.032346 |
| point 7 | 343545 | 6789035 | 7.056 | 1.20591 | -0.959143 | -0.60833 | 0.405214 | 343544.041 | 6789034.392 | 7.461214 |
| point 8 | 343744 | 6788734 | 31.066 | 2.670892 | 2.377274 | 1.16843 | -0.342058 | 343746.377 | 6788735.168 | 30.723941 |
| point 9 | 343909 | 6789089 | 8.25 | 0.995104 | -0.572422 | 0.172371 | -0.795521 | 343908.4276 | 6789089.172 | 7.454479 |
| point 10 | 342888 | 6789303 | 6.4 | 0.736617 | 0.054552 | 0.113583 | 0.72576 | 342888.0545 | 6789303.114 | 7.12576 |
| point 11 | 344270 | 6788630 | 16.142 | 0.883283 | 0.010367 | -0.793502 | 0.387862 | 344270.0104 | 6788629.207 | 16.529862 |

Campbell Lake Dam

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|---------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 1 | 340841 | 6780684 | 19.231 | 0.125181 | -0.045631 | -0.107759 | -0.044453 | 340840.9544 | 6780683.892 | 19.186547 |
| point 2 | 341346 | 6781622 | 25.765 | 1.363322 | -0.152393 | -0.406125 | 1.292473 | 341345.8476 | 6781621.594 | 27.057473 |
| point 3 | 340434 | 6780758 | 8.837 | 0.829131 | 0.251056 | 0.015203 | 0.790061 | 340434.251 | 6780758.015 | 9.627061 |
| point 4 | 340884 | 6781454 | 16.137 | 1.395358 | -0.339945 | 0.750991 | -1.125821 | 340883.6601 | 6781454.751 | 15.011179 |
| point 5 | 341156 | 6781131 | 8.796 | 0.991377 | 0.285794 | -0.249494 | -0.915917 | 341156.2858 | 6781130.751 | 7.880083 |

Lake O the Hills neighborhood

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|---------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|------------|
| point 1 | 352297 | 6779397 | 258.107 | 0.446816 | -0.196695 | 0.364685 | -0.167215 | 352296.8033 | 6779397.365 | 257.939785 |
| point 2 | 352720 | 6779554 | 294.4794 | 0.796012 | 0.190873 | -0.073031 | 0.76933 | 352720.1908 | 6779553.927 | 295.24873 |
| point 3 | 352104 | 6779025 | 259.39 | 1.518383 | -0.367435 | 0.200572 | -1.459537 | 352103.6326 | 6779025.201 | 257.930463 |
| point 4 | 351506 | 6779128 | 234.438 | 2.185988 | 0.973457 | -1.348067 | 1.419027 | 351506.9733 | 6779126.652 | 235.857027 |
| point 5 | 351544 | 6778733 | 241.264 | 0.827871 | -0.568077 | 0.588091 | -0.129646 | 351543.432 | 6778733.588 | 241.134354 |
| point 6 | 351108 | 6778736 | 235.87515 | 2.025686 | -0.036048 | 1.088423 | -1.708052 | 351107.964 | 6778737.088 | 234.167098 |
| point 7 | 351028 | 6778230 | 242.85 | 1.517183 | 0.003907 | -0.820667 | 1.276062 | 351028.0039 | 6778229.179 | 244.126062 |

Mackenzie Road

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|---------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 1 | 660139 | 6806131 | 50.81 | 0.665245 | -0.64884 | -0.146793 | 0.003058 | 660138.3512 | 6806130.853 | 50.813058 |
| point 2 | 659407 | 6806033 | 54.35 | 1.211806 | -0.951805 | 0.465332 | 0.588225 | 659406.0483 | 6806033.465 | 54.938225 |
| point 3 | 659854 | 6806326 | 53.53 | 1.184765 | -0.79704 | -0.345686 | 0.805541 | 659853.203 | 6806325.654 | 54.335541 |
| point 4 | 660259 | 6805569 | 45.97 | 0.5662 | -0.171331 | 0.036081 | 0.538448 | 660258.8287 | 6805569.036 | 46.508448 |
| point 5 | 659833 | 6806026 | 51.15 | 3.216063 | 2.569526 | -0.008278 | -1.934044 | 659835.5693 | 6806025.992 | 49.215956 |

Potter Creek

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|------------|
| point 1 | 349036 | 6771728 | 9.023 | 1.086042 | -0.383701 | -0.351489 | 0.953266 | 349035.6163 | 6771727.649 | 9.976266 |
| point 2 | 349226 | 6771352 | 23.958 | 0.597508 | -0.022336 | -0.050438 | 0.594956 | 349225.9777 | 6771351.95 | 24.552956 |
| point 3 | 350130 | 6771953 | 210.281 | 0.174141 | 0.052312 | -0.16323 | -0.030735 | 350130.0523 | 6771952.837 | 210.250265 |
| point 4 | 350255 | 6772171 | 233.6 | 1.228356 | -0.124355 | 0.151873 | 1.212571 | 350254.8757 | 6772171.152 | 234.812571 |
| point 5 | 350320 | 6771874 | 236.692 | 0.447985 | -0.373006 | -0.053509 | 0.242268 | 350319.6271 | 6771873.946 | 236.934268 |
| point 6 | 349909 | 6771845 | 174.484 | 1.175373 | -0.05376 | 0.341578 | -1.12336 | 349908.9462 | 6771845.342 | 173.36064 |
| point 7 | 349490 | 6771981 | 81.315 | 0.535427 | 0.411071 | -0.337605 | -0.061036 | 349490.411 | 6771980.662 | 81.253964 |
| point 8 | 349686 | 6771722 | 118.864 | 1.063752 | 0.420163 | -0.367805 | -0.9054 | 349686.4201 | 6771721.632 | 117.9586 |
| point 9 | 349211 | 6772027 | 58.626 | 0.735923 | 0.210584 | 0.592112 | -0.382937 | 349211.2106 | 6772027.592 | 58.243063 |
| point 10 | 349518 | 6771845 | 85.061 | 0.57053 | -0.136703 | 0.238289 | -0.500035 | 349517.8633 | 6771845.238 | 84.560965 |

Vine Road

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|---------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|------------|
| point 1 | 361739 | 6828448 | 99.22 | 0.528369 | -0.015359 | 0.126202 | 0.512846 | 361738.9846 | 6828448.126 | 99.732846 |
| point 2 | 361429 | 6828864 | 105.37 | 0.827792 | 0.284306 | -0.461463 | 0.625669 | 361429.2843 | 6828863.539 | 105.995669 |
| point 3 | 362210 | 6828847 | 103.459 | 0.359426 | 0.190933 | 0.293014 | 0.082916 | 362210.1909 | 6828847.293 | 103.541916 |
| point 4 | 361854 | 6829317 | 105.279 | 1.053284 | -0.139904 | 0.834342 | 0.627461 | 361853.8601 | 6829317.834 | 105.906461 |
| point 5 | 361786 | 6829041 | 109.93 | 0.989517 | 0.561402 | -0.464052 | -0.669797 | 361786.5613 | 6829040.536 | 109.260203 |
| point 6 | 362077 | 6828842 | 103.54 | 0.504548 | -0.382676 | -0.323253 | 0.060291 | 362076.6174 | 6828841.677 | 103.600291 |
| point 7 | 361641 | 6828830 | 104.16 | 1.249522 | 0.132994 | 0.44291 | -1.160797 | 361641.133 | 6828830.443 | 102.999203 |
| point 8 | 361964 | 6828771 | 106.25 | 0.778748 | -0.632206 | -0.447892 | -0.078469 | 361963.3679 | 6828770.552 | 106.171531 |

Pittman Road

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|---------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|------------|
| point 1 | 360368 | 6830693 | 96.879 | 0.982863 | -0.286654 | 0.389976 | -0.855434 | 360367.7134 | 6830693.39 | 96.023566 |
| point 2 | 360382 | 6831252 | 99.98 | 1.057681 | 0.333668 | 0.667222 | 0.749779 | 360382.3336 | 6831252.667 | 100.729779 |
| point 3 | 360165 | 6832117 | 101.31 | 1.556541 | -1.003161 | 1.181871 | 0.140246 | 360163.997 | 6832118.182 | 101.450245 |
| point 4 | 360376 | 6832473 | 101.45 | 1.02877 | 0.458509 | 0.853269 | -0.346508 | 360376.4584 | 6832473.853 | 101.103492 |
| point 5 | 360295 | 6831630 | 101.02 | 0.804586 | -0.340553 | -0.372563 | -0.626562 | 360294.6595 | 6831629.628 | 100.393438 |
| point 6 | 360071 | 6832370 | 92.46 | 2.036623 | 0.601828 | -1.92026 | 0.313433 | 360071.6017 | 6832368.08 | 92.773433 |
| point 7 | 360469 | 6830815 | 98.9 | 1.042144 | 0.236454 | -0.799574 | 0.625167 | 360469.2364 | 6830814.201 | 99.525167 |

Ship Creek Road

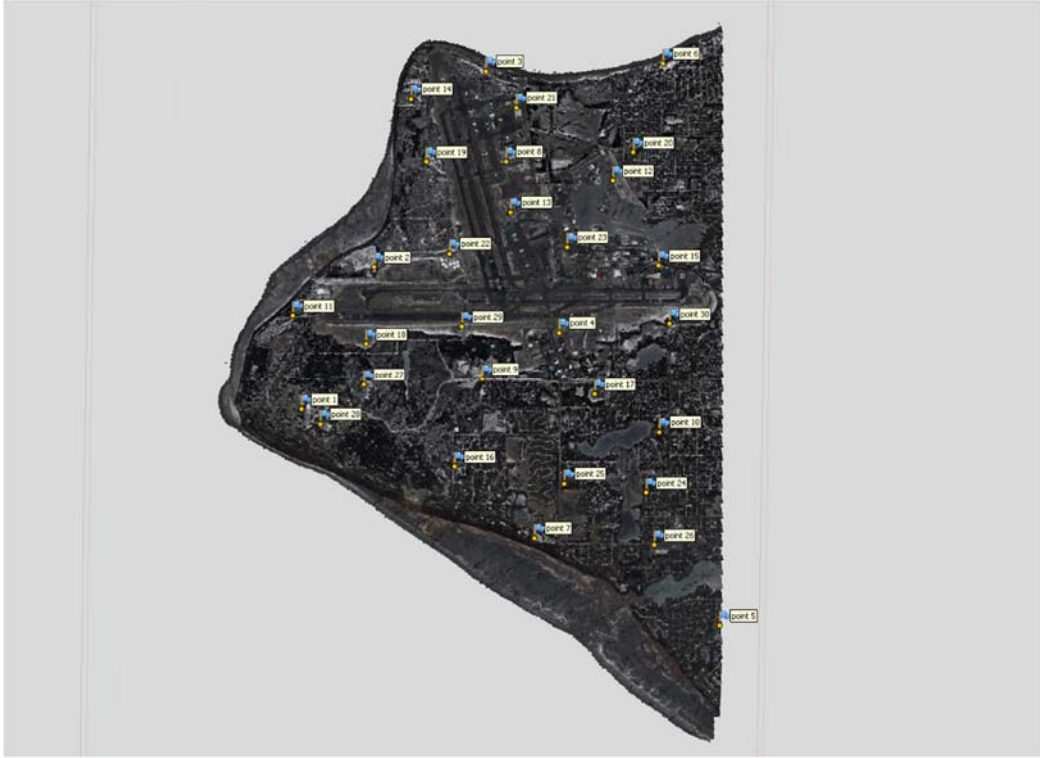
| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|---------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|------------|
| point 1 | 358403 | 6790663 | 151.9 | 1.650722 | 0.003445 | 0.666542 | -1.510164 | 358403.0034 | 6790663.666 | 150.389836 |
| point 2 | 358440 | 6790526 | 162.973 | 2.164852 | 1.758621 | 0.145885 | 1.254015 | 358441.7583 | 6790526.146 | 164.227015 |
| point 3 | 358088 | 6790772 | 141.239 | 3.534344 | -3.182982 | -0.940421 | -1.214835 | 358084.8176 | 6790771.06 | 140.024164 |
| point 4 | 357744 | 6791042 | 146.894 | 1.868494 | 1.620688 | 0.321181 | 0.872629 | 357745.6204 | 6791042.321 | 147.766628 |
| point 5 | 358712 | 6790634 | 165.081 | 0.662291 | -0.196658 | -0.192795 | 0.602317 | 358711.8034 | 6790633.807 | 165.683317 |

EauClaire Place

| #Label | X/Easting | Y/Northing | Z/Altitude | Error_(m) | X_error | Y_error | Z_error | X_est | Y_est | Z_est |
|---------|-----------|------------|------------|-----------|-----------|-----------|-----------|-------------|-------------|-----------|
| point 1 | 346850 | 6786530 | 43.058 | 0.350197 | -0.190802 | -0.129485 | 0.263564 | 346849.8092 | 6786529.871 | 43.321564 |
| point 2 | 346479 | 6786446 | 38.066 | 0.237545 | 0.151352 | -0.171333 | -0.06454 | 346479.1513 | 6786445.829 | 38.00146 |
| point 3 | 346073 | 6786368 | 40.025 | 0.646001 | 0.452189 | 0.263289 | 0.378841 | 346073.4521 | 6786368.263 | 40.403841 |
| point 4 | 346497 | 6786147 | 40.443 | 0.41168 | 0.085273 | -0.267092 | -0.301447 | 346497.0853 | 6786146.733 | 40.141553 |
| point 5 | 346258 | 6786748 | 38.947 | 0.645448 | -0.49777 | 0.304611 | -0.275754 | 346257.5023 | 6786748.305 | 38.671246 |

APPENDIX 3. CONTROL/CHECKPOINTS (MAPPED)

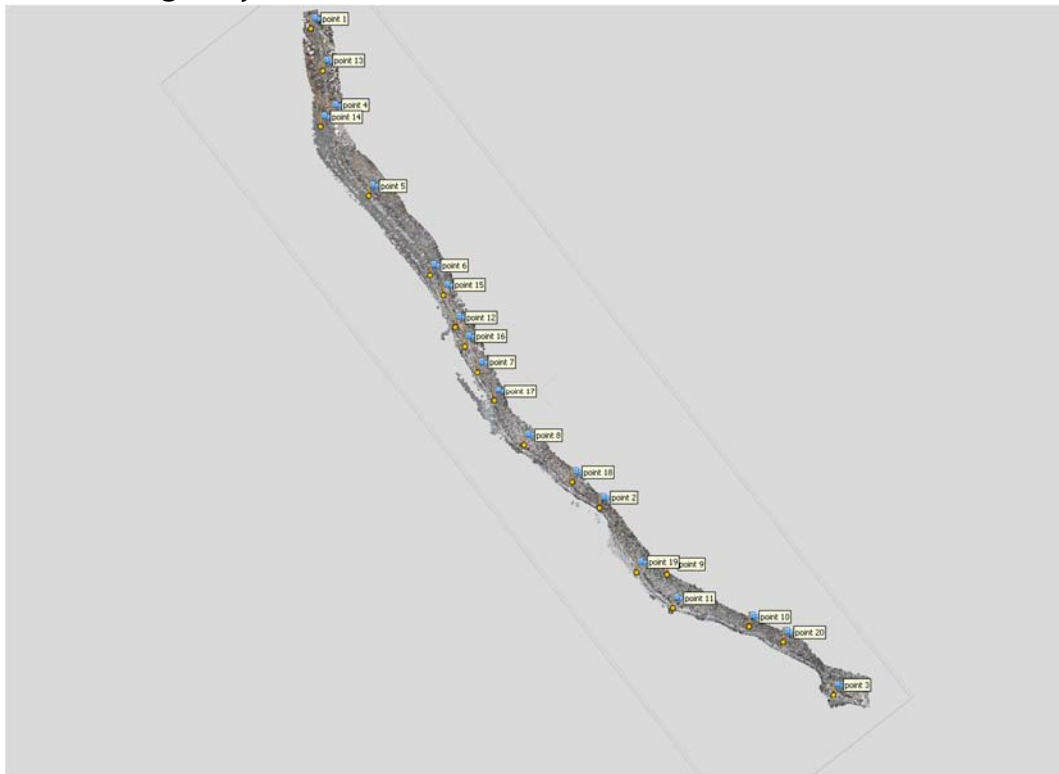
Ted Stevens Anchorage International Airport



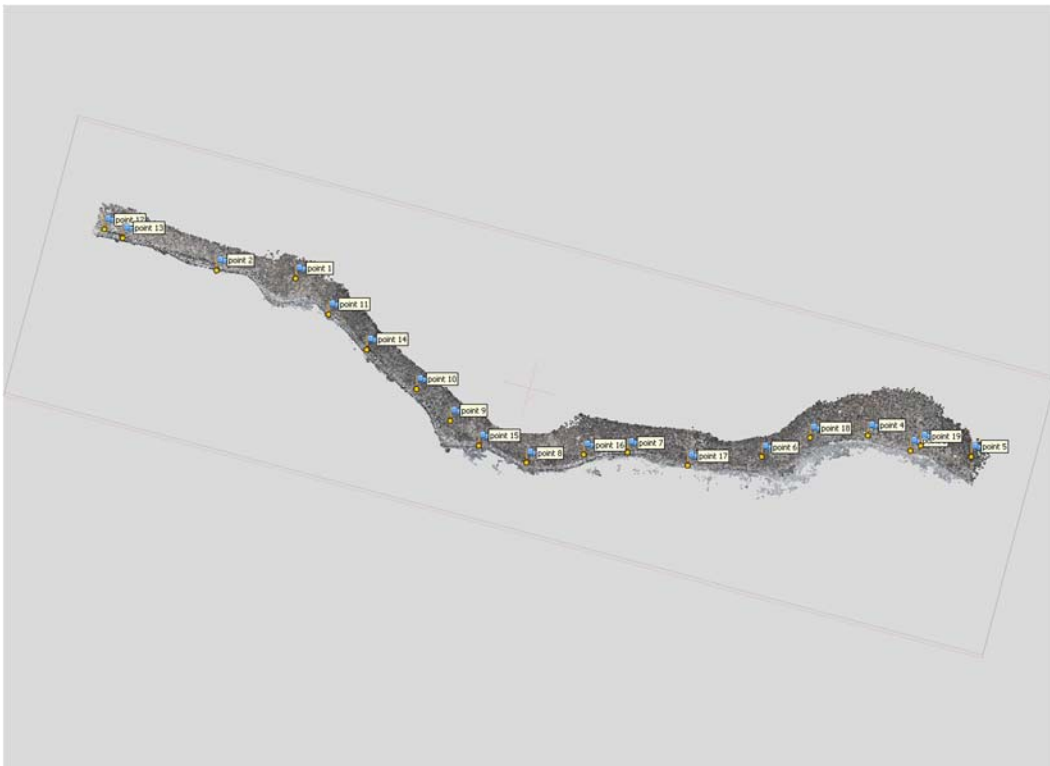
Glenn Highway



Seward Highway 1



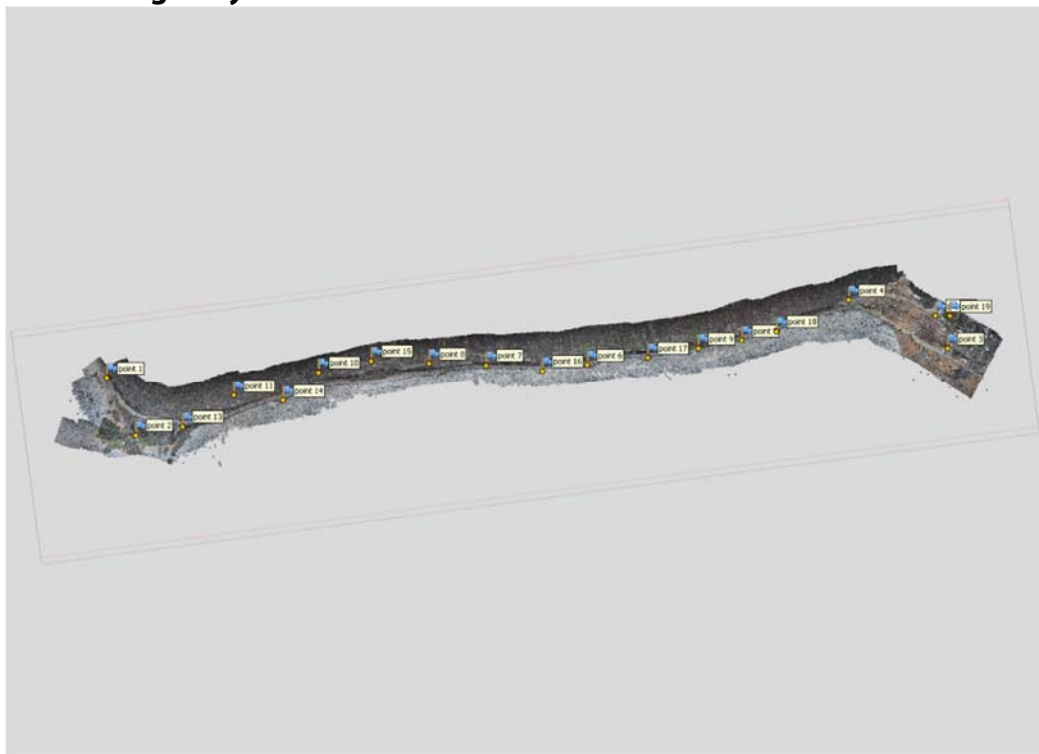
Seward Highway 2



Seward Highway 3



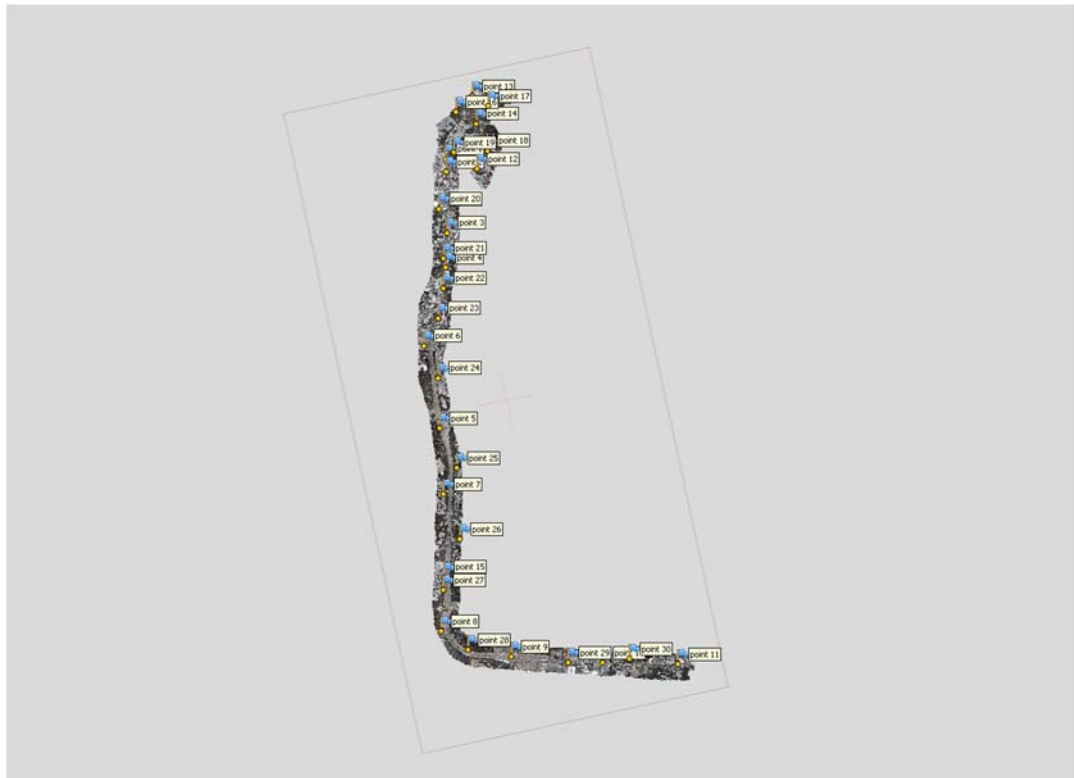
Seward Highway 4



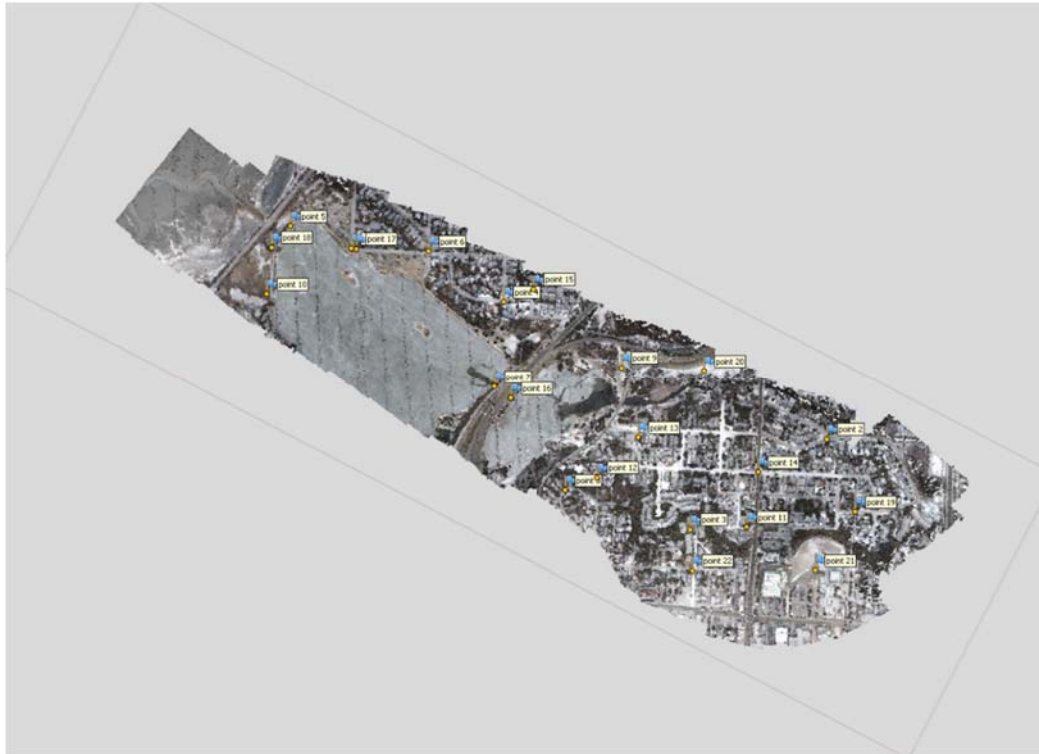
Eklutna Lake



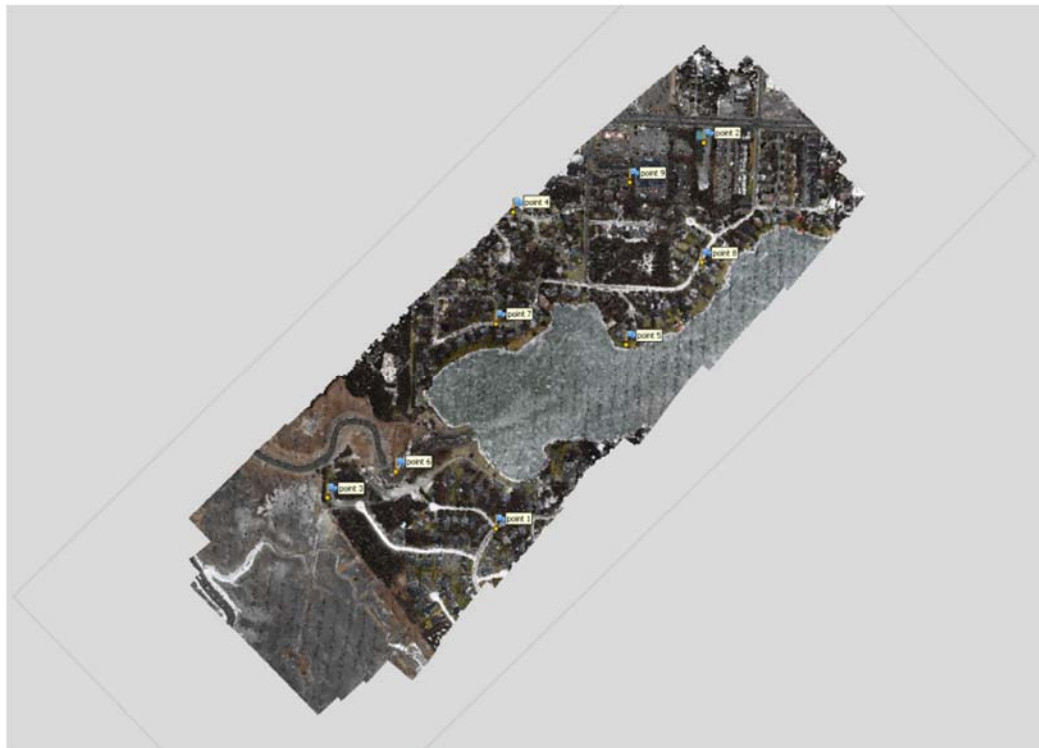
Minnesota Drive



Westchester Lagoon



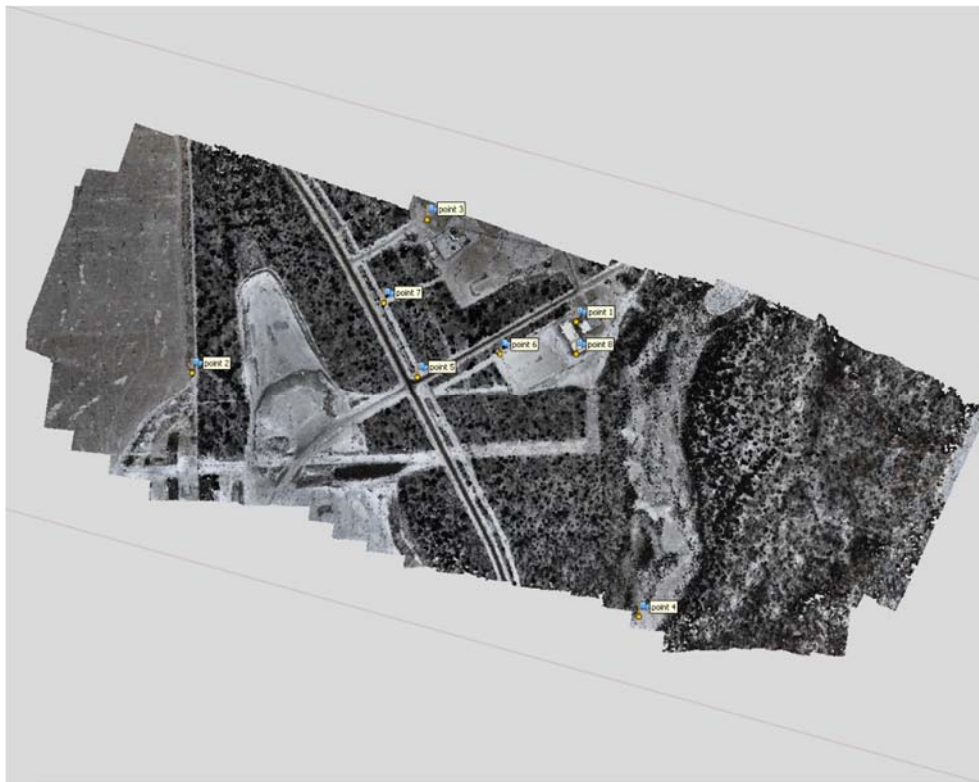
Campbell Lake Dam



Lake O the Hills neighborhood



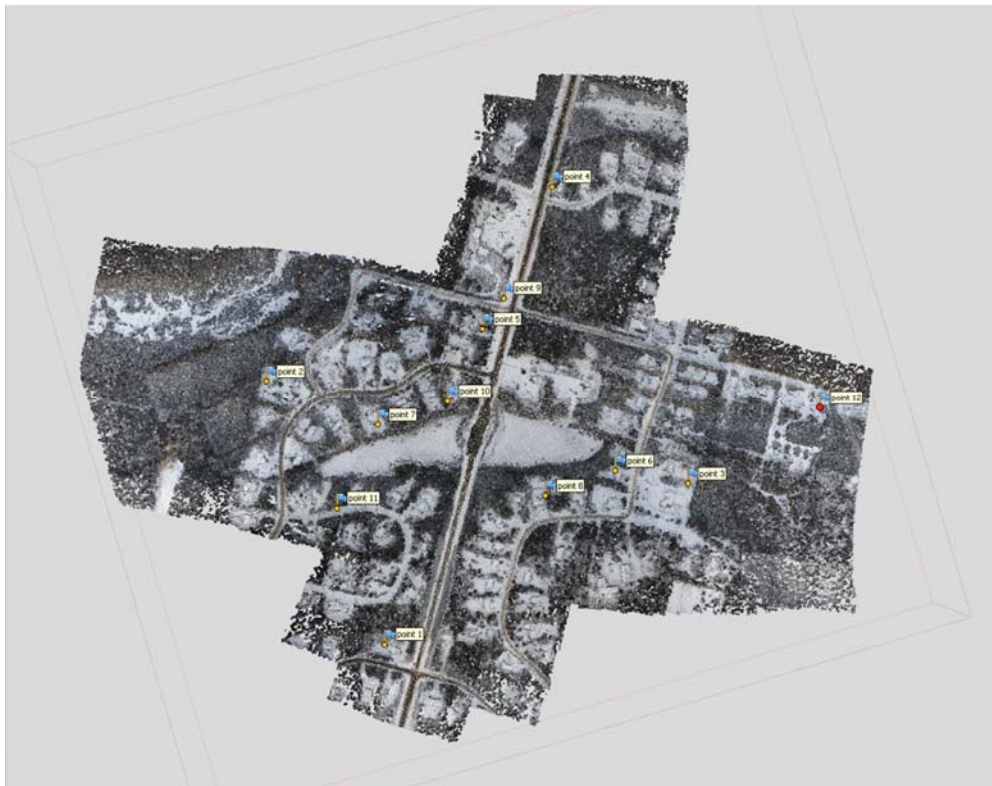
Mackenzie Road



Potter Creek



Vine Road



Pittman Road



Ship Creek Dam



EauClaire Place

