South San Francisco Bay 2004 Topographic Lidar Survey: Data Overview and Preliminary Quality Assessment

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Abstract

Tidal wetlands in South San Francisco Bay (South Bay) have decreased by over 80% in the past 150 years. The California Coastal Conservancy, in conjunction with other state and federal agencies, is collaboratively managing an effort to restore approximately 61 km^2 (15,100 acres) of commercial salt evaporation ponds in South Bay to mixed intertidal habitat. In order to best develop restoration strategies, as well as to track morphologic change throughout the restoration process, a topographic lidar survey was conducted in May of 2004. The survey collected more than 250 million elevation points in a 334 km^2 area extending from just south of the San Francisco and Oakland airports to the Alviso salt ponds.

This report details the collection of lidar in South Bay, the ground-truthing efforts, preliminary accuracy assessments, and known limitations of the data set. We describe the data generated from the survey and how to obtain it. In addition, we present maps and sample imagery that provides a revealing look into the intricate topographic features of South Bay.

Introduction

The San Francisco Bay area has changed dramatically since the first settlers arrived in the mid-1700's (Nichols, 1986). From the gold rush of 1849 to the tech boom of Silicon Valley, this urbanized estuary has been dredged, filled, diked, and degraded. Over 80% of the historic tidal marshes of South San Francisco Bay (South Bay) have been lost due to urbanization, agriculture, and commercial salt production (Foxgrover *et al*., 2004). Despite numerous anthropogenic alterations, this ecosystem remains a crucial habitat for wildlife and waterfowl as well as a popular recreational destination for the millions of people that live in surrounding communities.

In an effort to enhance this precious estuary, the California State Coastal Conservancy, in conjunction with U.S. Fish and Wildlife Service and the California Department of Fish and Game, has undertaken a monumental project to restore 61 km^2 of commercial salt evaporation ponds in South Bay to mixed intertidal habitat (Fig. 1).

A crucial component to planning a successful restoration project is to determine the baseline conditions. To meet this goal, the U.S. Geological Survey (USGS) contracted an airborne topographic lidar survey that was flown in the spring of 2004. The survey covers approximately 334 km^2 and extends south of the San Francisco and Oakland airports, covering tidal flats, marsh, levees, and surrounding areas including the 100-year flood plain (Fig. 2). This is the first time that such a highly detailed, comprehensive topographic data set of the South Bay region has been collected.

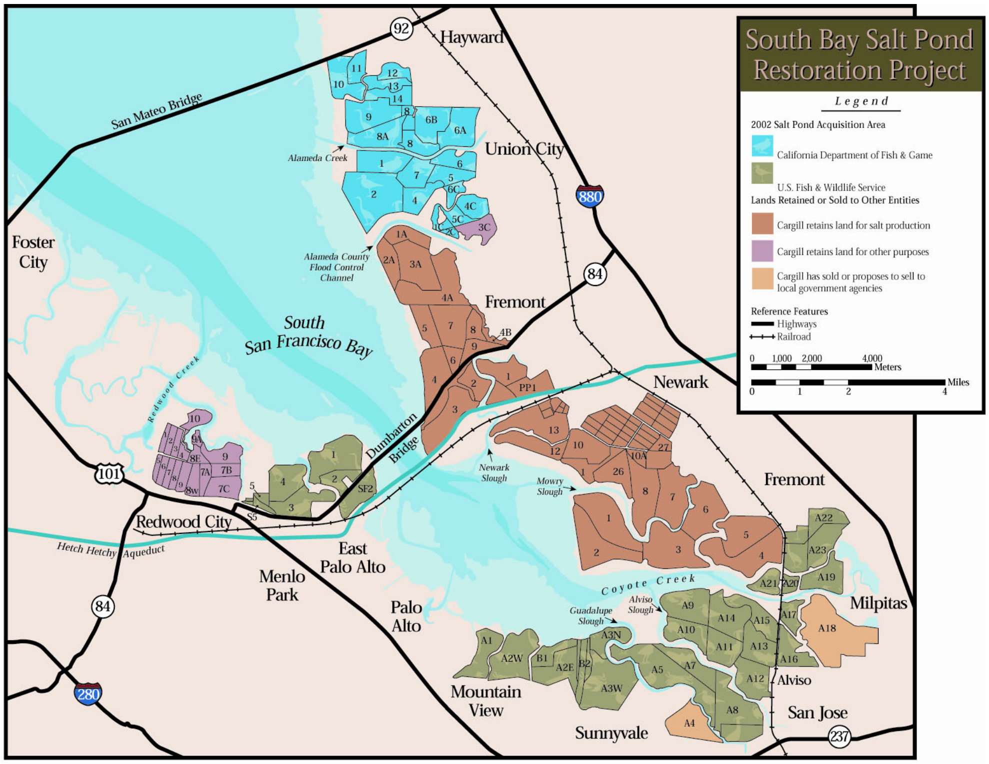

Figure 1. Image of salt pond restoration site. (Image Source: *www.southbayrestoration.org*.)

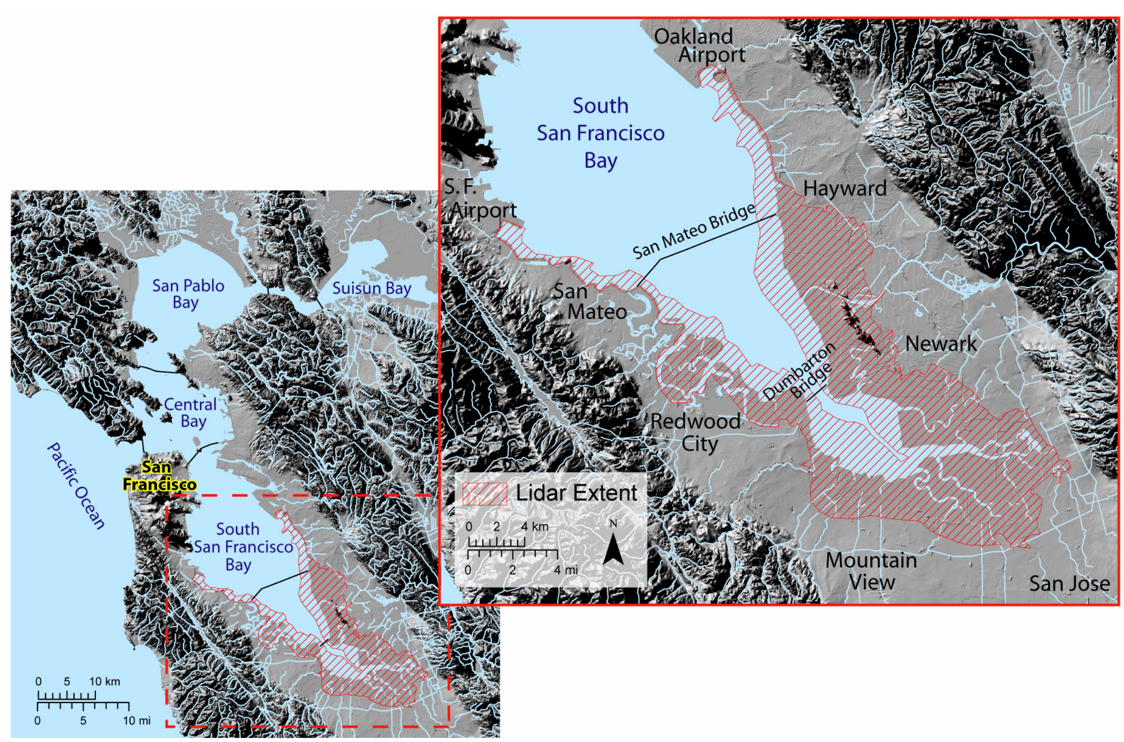

Figure 2. Map of the study area. Hachured area indicates extent of the lidar survey.

South Bay Lidar Survey

The South San Francisco Bay lidar survey was conducted by TerraPoint from May 5th to May 21st, 2004. The timing of the survey was selected to correspond with extreme low tides during daylight hours so that the tidal flats would be exposed and so video could be collected during data acquisition (Fig. 3). Nominal flight line spacing was 99 meters, providing an overlap of 51% between adjacent flight lines resulting in the collection of over 250 million returns and a data density greater than one point per square meter.

Local agencies (e.g., Alameda County Public Works Agency, the City of San Jose, Philip Williams & Associates) have collected elevation data in the past for specific sites of interest within this study area however, traditional surveying methods are not practical given the large area of interest and diversity of terrain. Lidar enables the creation of a very high-resolution digital elevation model (DEM) spanning a variety of terrain while providing an unobtrusive means for collecting elevations in sensitive habitats such as tidal flats and marsh.

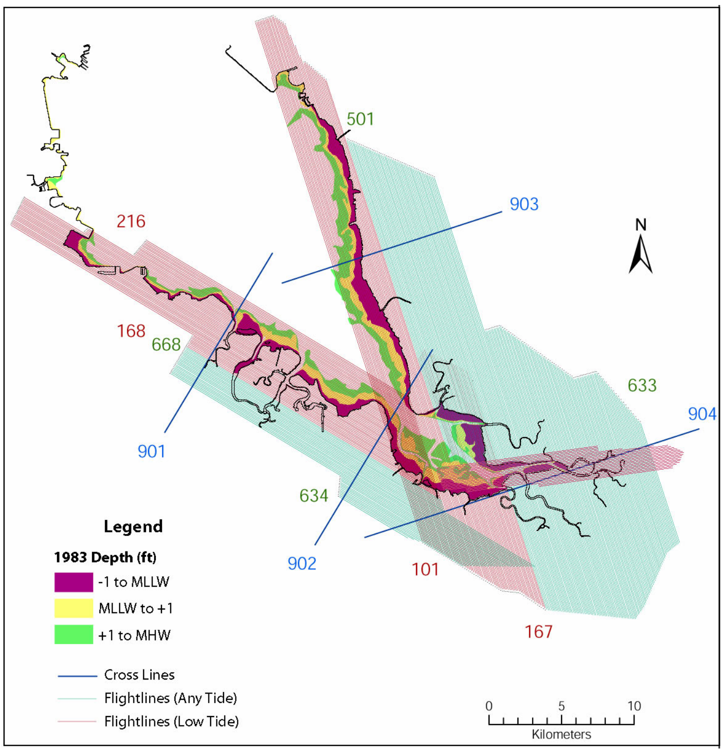

Figure 3. Flight lines for lidar survey. Red colored lines were flown only within specified time windows during daylight hours when the tide was below mean lower low water (MLLW). Teal colored lines were flown during any tide level during daylight hours.

Lidar System

Lidar (LIght Detection And Ranging) is a remote sensing method where a laser emits and receives thousands of laser pulses per second for the purpose of calculating the distance to an object. The lidar system (in this instance mounted to a fixed wing aircraft) consists of three main components; 1) a scanning laser rangefinder 2) a differential Global Positioning System (GPS), and 3) an Inertial Motion Unit (IMU). Surface elevations are determined using two-way travel time of the laser pulse in combination with positioning and orientation information obtained from the onboard GPS and IMU and the GPS base stations on land.

Although hydrographic lidar systems with the ability to penetrate water for bathymetric readings are available, such systems would not work well in the turbid, muddy water of South San Francisco Bay. For this project a topographic lidar system which does not penetrate water was selected. The South Bay survey used TerraPoint's ALMIS (Airborne Laser Mapping Imaging System). The ALMIS consists of a 60-degree full angle Riegel laser with a rotation polygon mirror, a Novatel GPS receiver, and a Honeywell IMU unit. The ALMIS was mounted to a Partenavia P68 twin-engine aircraft flown at an altitude of approximately 245 meters above ground level during the survey. The size of the surface illuminated by the Riegel laser, also referred to as the footprint or spot size, was approximately 0.75 m in diameter. The lidar was set to pulse at 10 kHz in an alternating pulse mode that alternates between recording the first and last returns of the signal. The scan pattern produces parallel lines that are perpendicular to the flight line and have a spacing of 1.4 m in the across-swath direction and 1.1 m in the along-swath direction. The first/last return system results in a pattern of first returns approximately every 3-meters in the across-swath direction and every meter in the along-swath. This sampling scheme was chosen to facilitate detection and removal of vegetation and structures. The first returns can either be from the top of vegetation (or structures) or bare earth when vegetation or structures are not present. The last returns will be bare earth in instances where either the lidar is able to penetrate vegetation or structures or they are not present. The 51% side overlap between adjacent swaths ensures that all areas are covered twice (except in areas of water).

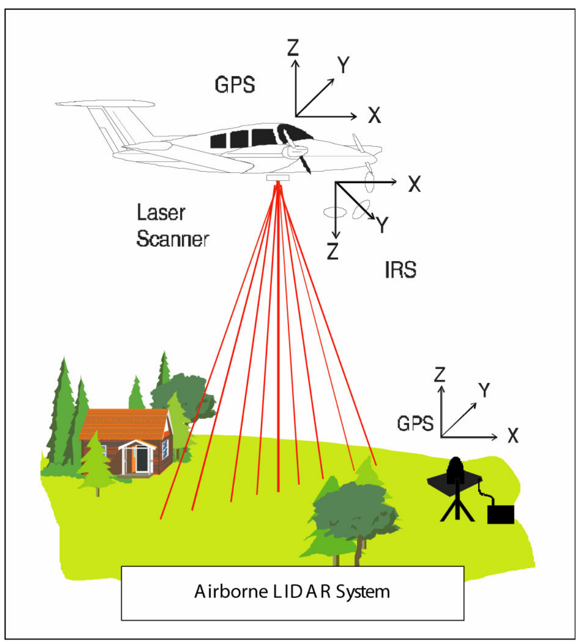

Figure 4. Schematic diagram of lidar collection system. (Image Source: Mosaic Mapping, 2001).

A control network comprised of four GPS base stations was established for differential GPS calculations (Fig. 5). Two base stations were used for each flight to ensure accurate positioning during flight missions. The lidar data is referenced to the UTM coordinate system, horizontal datum NAD83, vertical datum NAVD88.

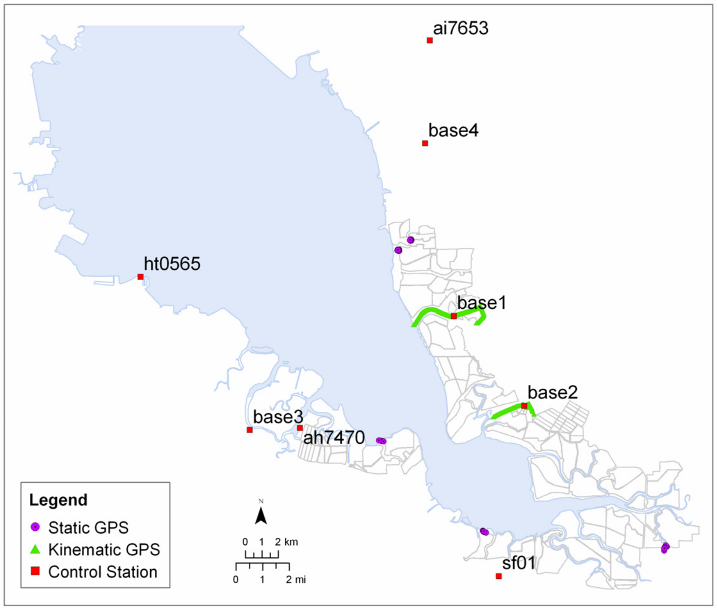

Figure 5. Location map of base stations and ground-truthing locations.

Data from the onboard instruments and GPS base stations were post-processed to determine surface elevations. An additional processing step was required by TerraPoint to correct for a roll error which was introduced as a result of a loose component within the ALMIS. Once the proper boresight correction values were applied to the data, the data met the accuracy criteria in Tables 1 and 2.

Accuracy

Lidar accuracy is a function of errors in position and orientation of the laser and the characteristics of the surface being illuminated. Uncertainty in the orientation of the laser is the primary factory influencing horizontal accuracy. Errors in differential GPS solutions and uncertainty in elevations of the ground surface on steep terrain also degrade horizontal accuracy. Absolute positional (horizontal) accuracy at the 2σ level is 20 to 60 cm on all but extremely hilly terrain (Table 2).

Uncertainty in orientation of the laser and differences in elevation of the illuminated surface are the primary factors determining vertical accuracy. Ground elevations of steep slopes, such as the sides of levees, are less accurate than elevations on flat surfaces (Table 3). The vertical accuracy of this system on low sloping, hard surfaces is 10 to 15 cm at the 95% (2σ) confidence level (Table 1).

Table 1. Absolute vertical accuracy.

2σ Error (cm)	Terrain Description
+/- 10 – 15	Hard Surfaces (roads and buildings)
+/- 15 – 25	Soft/Vegetated Surfaces (flat to rolling terrain)
+/- 25 – 40	Soft/Vegetated Surfaces (hilly terrain)

Table 2. Absolute horizontal accuracy.

2σ Error (cm)	Terrain Description
+/- 20 – 60	All locations except extremely hilly terrain.

Ground-truth

Over 650 ground-truth measurements were taken in seven areas to evaluate lidar performance (Fig. 5). Ground-truth locations were selected to include the variety of surface types within the study area and included tidal flats, levees, and marshes. Marsh ground-truthing was difficult because our access was restricted to avoid disturbing endangered nesting birds. We were limited in potential marsh sample areas to those that could be reached from overlying PG&E boardwalks or sites which were known not to be populated by endangered species.

Ground-truthing included static GPS measurements throughout the study area and kinematic GPS surveys on paved roads. Elevations of the static and kinematic GPS ground-truthing points have an accuracy relative to the GPS control network of 2 cm in three dimensions, at the 95% confidence interval (see appendix).

A total of 165 static ground-truth points were collected in a variety of terrain to evaluate how well lidar was estimating bare earth elevations in differing vegetations, slopes, and on soft surfaces (tidal flats). Along with each GPS measurement, notes were collected on the description of the terrain, and if present, the type, density, and height of vegetation. The information was analyzed to estimate the lidar error in varying terrain, and to determine if the system was able to penetrate vegetation densities typical of the study area. To do so, a one-meter resolution DEM was generated from the bare earth lidar data points. The ground-truth GPS elevations were then subtracted from the bare earth DEM cell value at that location to determine the difference between the lidar value and the GPS elevations.

For static ground-truth points, the average difference between the lidar and ground-truth elevations was 3.6 cm and 95% (2σ) of the lidar elevations were within 28 cm of ground-truth elevations (see appendix). However, a more detailed look at the accuracy can be taken by separating the statistics into surface types (Table 3). Lidar estimates of the bare earth surface in areas of pickleweed (*salicornia virginica*) marsh were good with a 2σ error of 18 cm while in the bulrush *(Scirpus californicus or Scirpus maritimus)*, lidar performed poorly with a 2σ error of 192 cm. Based upon our limited number of bulrush ground-truth locations, we believe the high error is the result of the very dense vegetation that was impenetrable by the lidar. Gently sloping areas such as those sampled containing pickleweed, tidal flats, or the center of the levees performed relatively well, while the edges of the levees did not. The higher error of measurements at either the top edges of the levees or at the base of the levee banks is a result of the size of the laser footprint and the steep slope of the levees. The laser footprint is approximately 0.75 m in diameter and with typical levee slopes of 10 to 20 degrees; the lidar is unable to resolve the steep slopes with the same accuracy of gently sloping terrain.

In addition to the 165 static ground-truth points, 593 check points were collected using a kinematic surveying method in which the GPS is mounted to an automobile and set to collect data every second. The kinematic ground-truth points were collected along two separate stretches of paved roads totaling 10 km in length and compared to the bare earth lidar surface to evaluate absolute accuracy. For the entire set of these points, the average difference between lidar and ground-truth elevations was -1.9 cm and 95% of the lidar elevations were within 13.2 cm of ground-truth elevations (see appendix).

Table 3. Differences between lidar values and ground-truth elevations classified by surface type.

Location	Number of Samples	Min	Max	Mean	RMSE	2σ Difference
Center of Levee	19	-29	26	-6	13	25
Edges of Levee[1]	49	-81	114	4	31	61
Pickleweed Marsh	42	-7	29	6	9	18
Tidal Flat	14	-18	25	2	11	21
Bulrush Marsh	3	82	121	96	98	192

[1]edges of levee includes both the top outer edges of the levee and base of levee banks

Lidar Limitations

The 2004 South Bay lidar survey collected elevation data from a variety of surfaces including bare earth, vegetation, structures, and water. The primary limitation to using the data set is the uncertainty in the type of surface the return is from. For example, in tidal flat settings, is the return from the tidal flat or from water? In marsh settings, is the return from the bare earth or from vegetation? These determinations are possible, but time consuming, and not always 100% accurate. Below we discuss three of the most common difficulties in interpreting this lidar data set; 1) discriminating tidal flats from water returns, 2) discriminating bare earth from vegetation, and 3) discriminating wet salt ponds from dry ponds.

The problem of discriminating tidal flats from water can be addressed using the intensity and spatial pattern of lidar returns. When lidar is collected over water or very dark surfaces, rather than receiving the typical full-swath return, the laser beam is only reflected back to the receiver in a in a very narrow range close to nadir (Puget Sound Lidar Consortium Web Site, C. Vickers, Mosaic Mapping Systems Inc., personal communication). This phenomenon results in a limited swath return approximately 30 to 50 m wide as opposed to the anticipated full swath return of 245 m over a solid surface. Without the full swath return, data from adjacent flight lines do not overlap, resulting in striped pattern of narrow bands of data alternating between bands of no data (Fig. 6). These values are not an accurate reflection of water levels and must be removed prior to generating a terrain model (Puget Sound Lidar Consortium Web Site).

Unfortunately, there is not a simple automated way of identifying these over-water returns and manually delineating them can be quite laborious. This data set was collected over a time span of three weeks and due to the complex nature of tides in South Bay, it is impossible to determine a single elevation under which all returns would be classified as over-water returns. Although geo-referenced video was collected at the time of the flights, it has proven difficult to distinguish tidally influenced areas of shallow water from the mudflats, which both appear brown in the video. Therefore, independently, the video does not serve as a reliable source for identifying over-water returns.

The technique which proved most reliable in this instance was using a combination of high-resolution satellite imagery, exaggerated hill-shaded images of the lidar, and lidar return intensity to manually delineate and remove over-water returns. One-meter resolution IKONOS satellite imagery collected in May of 2004 was available for the majority of the project area. The IKONOS proved useful in determining areas of standing water that remained relatively constant from the time the imagery was collected and throughout the collection of the lidar. Areas such as levied ponds could be delineated using the IKONOS but this imagery could not be used to identify continually changing tidal inundation levels such as those in the tidal flats. To determine the bay-ward extent of the tide or to identify small puddles of water within the tidal flats, lidar intensity in conjunction with exaggerated hill-shades of the full feature return lidar data set was best suited for distinguishing these false returns from valid surface elevation returns. Areas of water tend to give a strong lidar return intensity directly at nadir relative to surrounding tidal flats and marsh (Fig. 6). Polygons delineating areas containing water were manually digitized based upon the interpretation of these three data sets. The preliminary water-mask polygons generated using this technique can be obtained as an ArcInfo shapefile by contacting Eric Zhang (ericz@sfei.org or 510-746-7361). Although this is a somewhat subjective technique, the results appear to be promising.

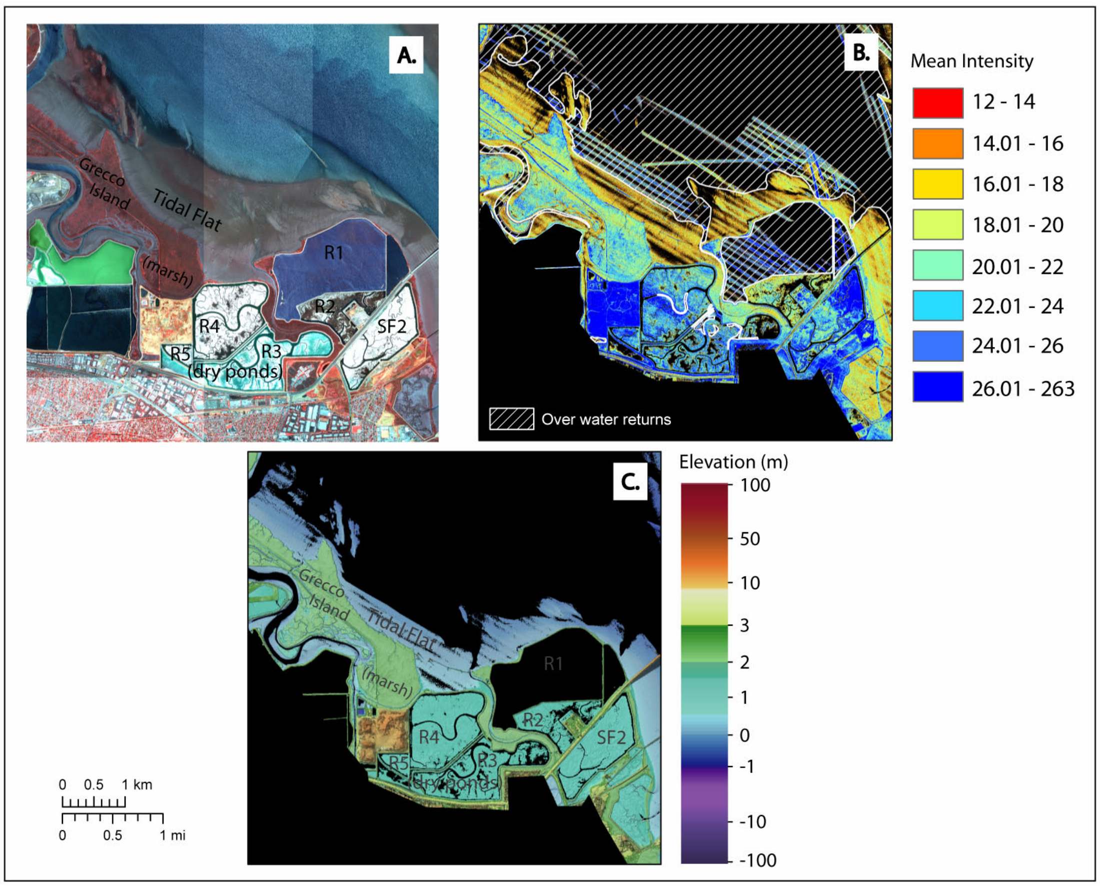

Figure 6. Sample of how IKONS satellite imagery in conjunction with lidar return intensity can be used to mask out over-water returns. (A) IKONOS false color composite satellite imagery (1 m resolution) of the area just northwest of the Dumbarton bridge (B) full feature lidar returns shaded according to average return intensity (averaged over 3x3 m neighborhood) hachured area indicates data that was removed because the returns were over water surfaces (C) resultant DEM with over-water returns eliminated, hill-shaded by elevation.

An additional challenge in generating an accurate bare earth model is determining if the lidar was able to penetrate vegetation. TerraPoint removes vegetation using an automated algorithm that iteratively evaluates local slopes (constrained by iteration distance and building size parameters) to determine if the returns meet the criteria of bare earth elevation values (see appendix). This step is followed by a manual quality control process to correct any errors that occurred during the automated process.

We evaluated the vegetation removal process that TerraPoint uses by comparing the lidar elevations with the static ground-truth elevations and vegetation surveys that were collected while the lidar was being flown (Table 3). The lidar was able to penetrate sparse vegetation such a pickleweed to obtain accurate ground measurements. However, in areas of very thick vegetation, such as bulrush, the lidar did not measure ground elevations.

Our field observations of bulrush suggest that the lidar partially penetrates this very dense vegetation and does not measure bare earth elevation. At the three locations where we were able to collect GPS readings and vegetation height measurements, the lidar readings were near the top of the vegetation for the first return values, however, the last return values were from approximately half way down the height of the vegetation, where the bulrush became too dense to penetrate. An additional complication is that the bulrush may grow upon a levee bank adjacent to a channel (as can be found in South Bay). TerraPoint's automated vegetation removal algorithm does not recognize both the first and last returns as vegetation in such circumstances. For instance, on a sloping levee bank, returns reflected from a height mid-way down the stalk of the bulrush (where vegetation becomes too thick to penetrate) could result in an elevation return similar to that of the top of the levee, and could therefore be misinterpreted as a ground return (Fig. 7). In this situation we have been unable to develop a way to identify such returns and encourage the users of this data to be familiar with their particular area of focus and the potential for mis-classifications in areas of extremely dense vegetation.

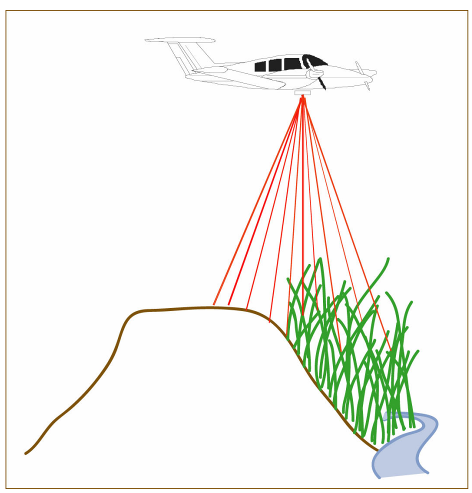

Figure 7. Schematic diagram depicting complications of lidar collection in dense bulrush located along levee banks.

A third challenge in interpreting lidar data is partially dry salt ponds. We have determined that under typical water conditions the lidar will return a narrow swath of high intensity returns or no return at all. However, these salt ponds are a unique environment and it is uncertain how lidar would reflect upon puddles of highly saline (which may appear white or red in color) water. It is possible that the particulate matter (salt, algae, etc.) floating at the surface of such ponds would return a reading that could be misinterpreted as bare earth. In the case of these partially dry salt ponds we encourage the end user to look at the ponds in detail before making any assumptions regarding this data.

Available Data

To make this enormous data set manageable for various end users, all of the deliverables (except hill-shaded images) are partitioned into both 1 x 1 km and 2 x 2 km tiles with 25-meters of overlap between adjacent tiles (Table 4). The bare earth and full feature (all return) point data are available as ASCII comma delimited text files. TerraPoint also generated a bare earth grid of last returns at 1 m resolution, in ASCII format. The gridded bare earth data is also available at 1 m and 25 m resolution in an ArcInfo ASCII format for easy import into a GIS. Contours generated at a 50 cm nominal contour interval are available in AutoCAD (DWG) format. One-meter resolution hill-shaded images of both the bare earth and full feature data sets are available GeoTIFF format. In addition to the elevation data, digital video imagery was collected at 2 frames per second during all flight missions. The geo-referenced video files are in AVI format with accompanying *.GPS files designed for viewing with Trident 3D Vision software.

Table 4. Table of data available from the 2004 South Bay lidar survey.

Available Data	File Format	Data Partitions
Full Feature Points	ASCII text	1 km & 2 km tiles
Bare Earth Points	ASCII text	1 km & 2 km tiles
1 m Bare Earth Grids	ASCII text	1 km & 2 km tiles
1 m Bare Earth Grids	ArcInfo ASCII text	2 km tiles
25 m Bare Earth Grids	ArcInfo ASCII text	2 km tiles
Full Feature Hill-Shaded Image	GeoTIFF	3 large regions
Bare Earth Hill-Shaded Image	GeoTIFF	3 large regions
Contours (50cm interval)	AutoCAD DWG	1 km & 2 km tiles
Digital Video Imagery	AVI	collected at 2 frames per second (sorted by Julian day and flight number)

The San Francisco Estuary Institute is responsible for maintaining and distributing this data. Contact Eric Zhang (ericz@sfei.org or 510-746-7361) to obtain the data.

Sample Maps and Imagery

This exceptional topographic data set of the South Bay provides an unprecedented view of the region. In this section we will present a large overview map highlighting the subtle relief of the terrain surrounding the bay, the location of the salt ponds slated for restoration, and provide context of the bay within the larger geologic setting (Fig. 8). This map is followed up by some close-up perspective views of Newark Slough, Coyote Creek, and the Palo Alto regions (Figs. 9, 10, 11, respectively). The close-up shaded-relief images accentuate the great detail with which the lidar captures the subtle morphologic features found in the marsh, tidal flats, as well as man-made structures. The perspective views are followed by a sequence of high resolution aerial photographs of Alviso, Bair Island, and the Shoreline Amphitheater displayed adjacent to the shaded-relief image of that particular area as captured through the lidar (Figs. 12, 13, 14, respectively). These phenomenal images provide an excellent context for viewing and evaluating the hill-shaded images.

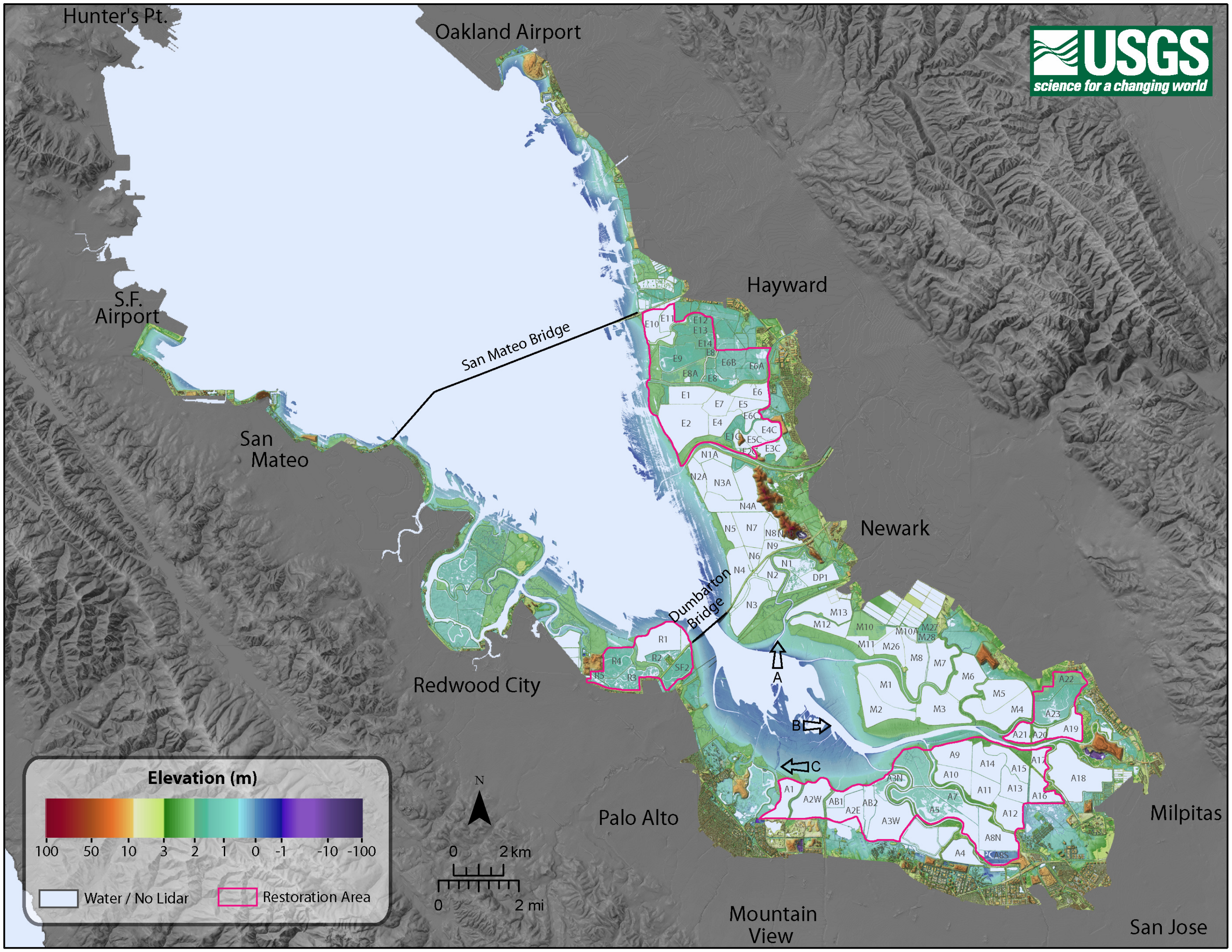

Figure 8. DEM of the South San Francisco Bay area. Full-feaure lidar data gridded at 2 m resolution and colored by elevation (over-water returns removed). The lidar is overlying a USGS 30 m gray-shaded DEM of the surrounding areas (Graham and Pike, 1997). Ponds are labeled as reference points. Arrows within the bay south of the Dumbarton Bridge indicate the orientation and location of the following perspective views (A - Figure 9, B - Figure 10, and C - Figure11).

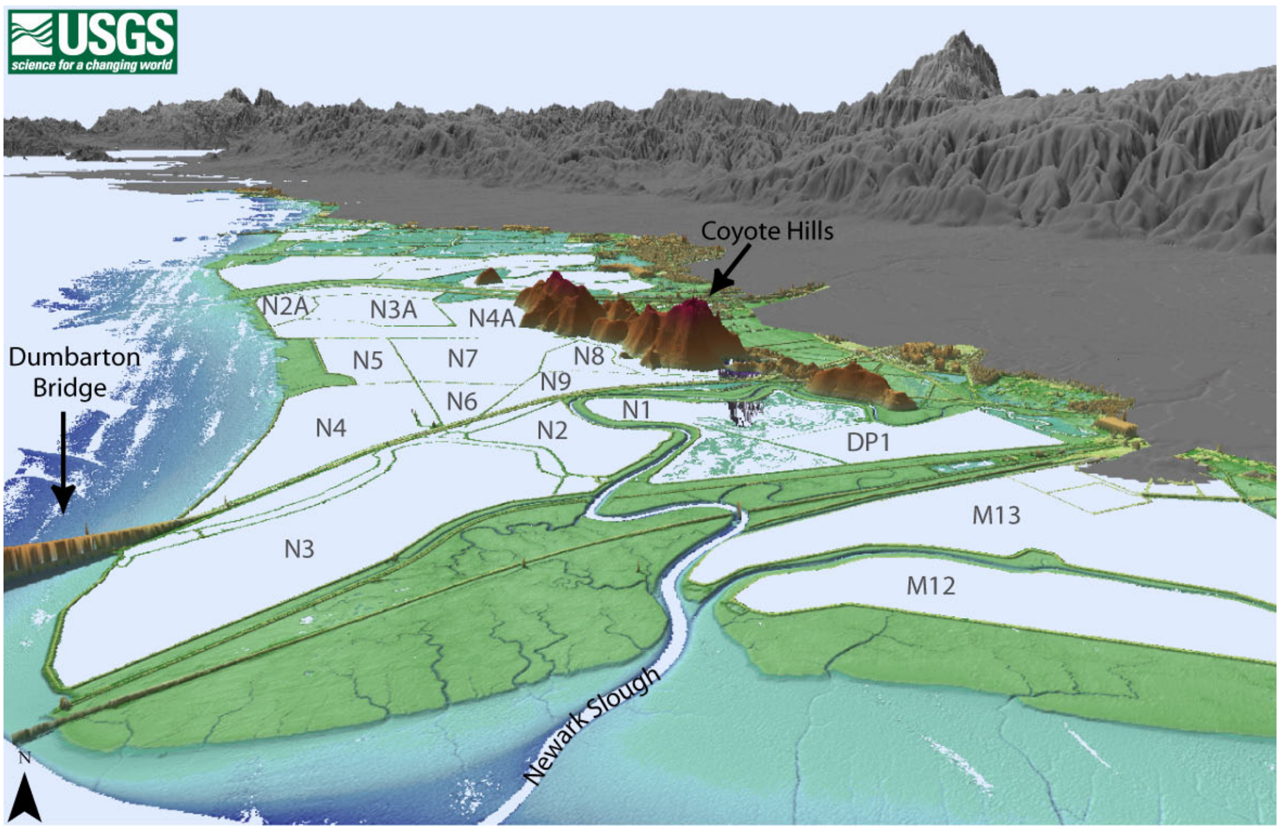

Figure 9. Shaded relief map of full feature lidar colored by elevation. Perspective view is looking north towards Newark Slough and Coyote Hills. The distance across the bottom of the image is approximately 4 km with a vertical exaggeration of 5x.

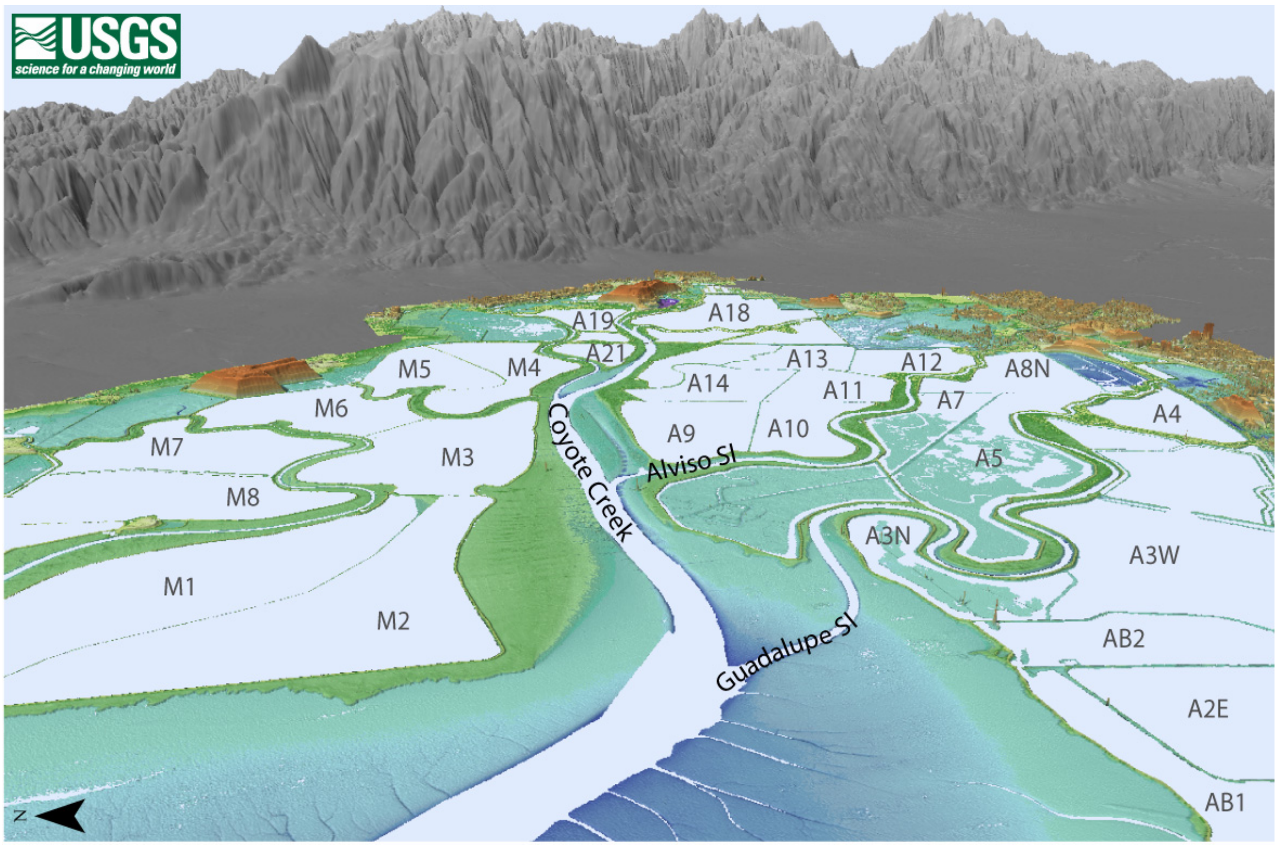

Figure 10. Shaded relief map of full feature lidar colored by elevation. Perspective view is looking east towards Coyote Creek. The distance across the bottom of the image is approximately 4.5 km with a vertical exaggeration of 5x.

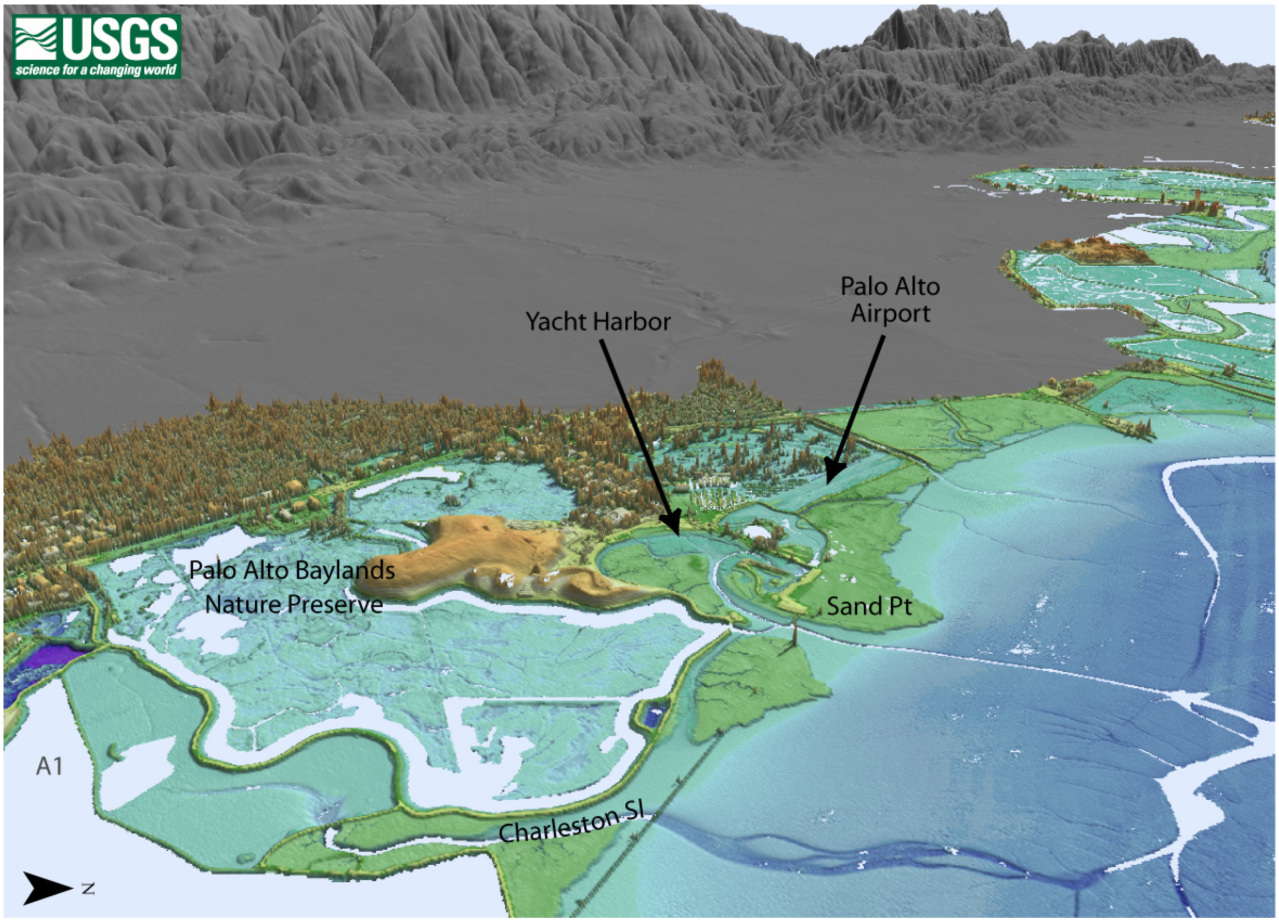

Figure 11. Shaded relief map of full feature lidar colored by elevation. Perspective view is looking west towards Palo Alto. The distance across the bottom of the image is approximately 3.5 km with a vertical exaggeration of 5x.

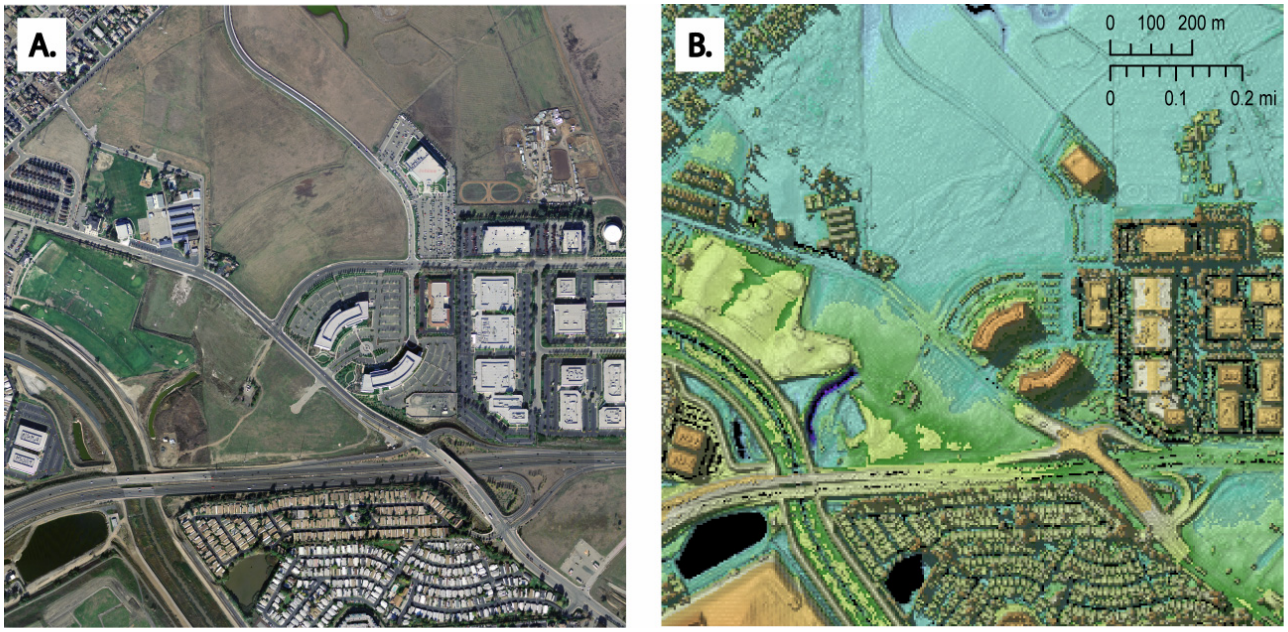

Figure 12. (A) National Geospatial Intelligence Agency (NGA) imagery of intersection of Highway 237 and North 1st Avenue in Alviso. (B) Full feature hill-shaded image of the same location.

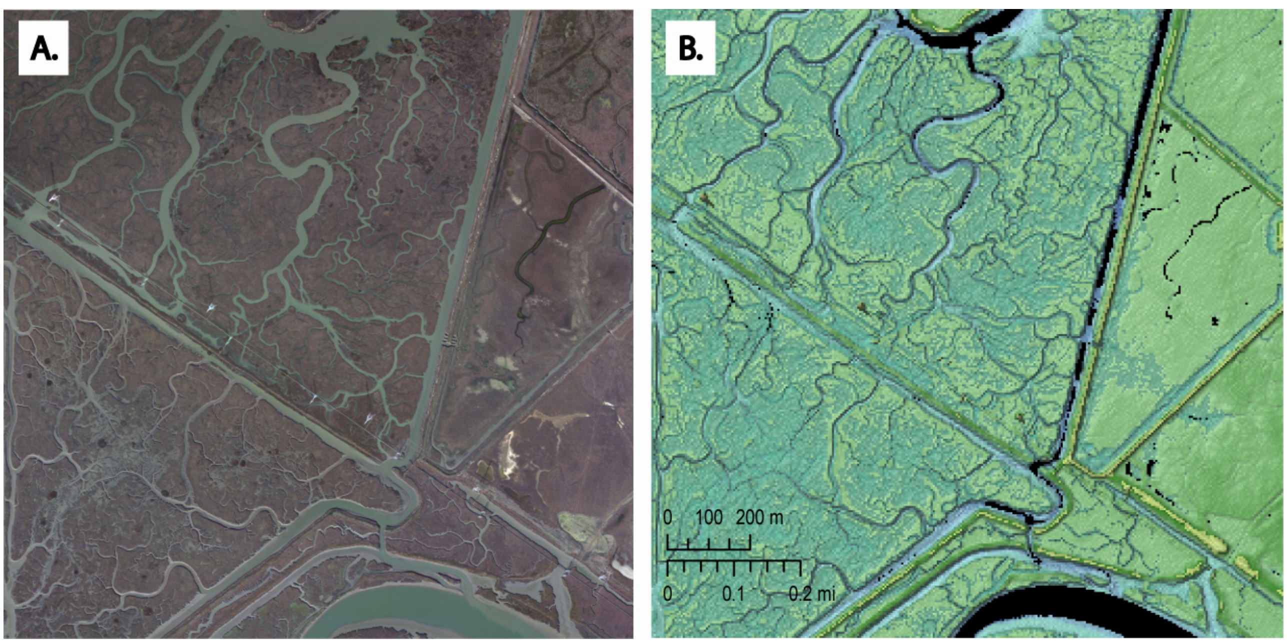

Figure 13. (A) NGA imagery of marsh and channels in Bair Island. (B) Full feature hill-shaded image of the same location.

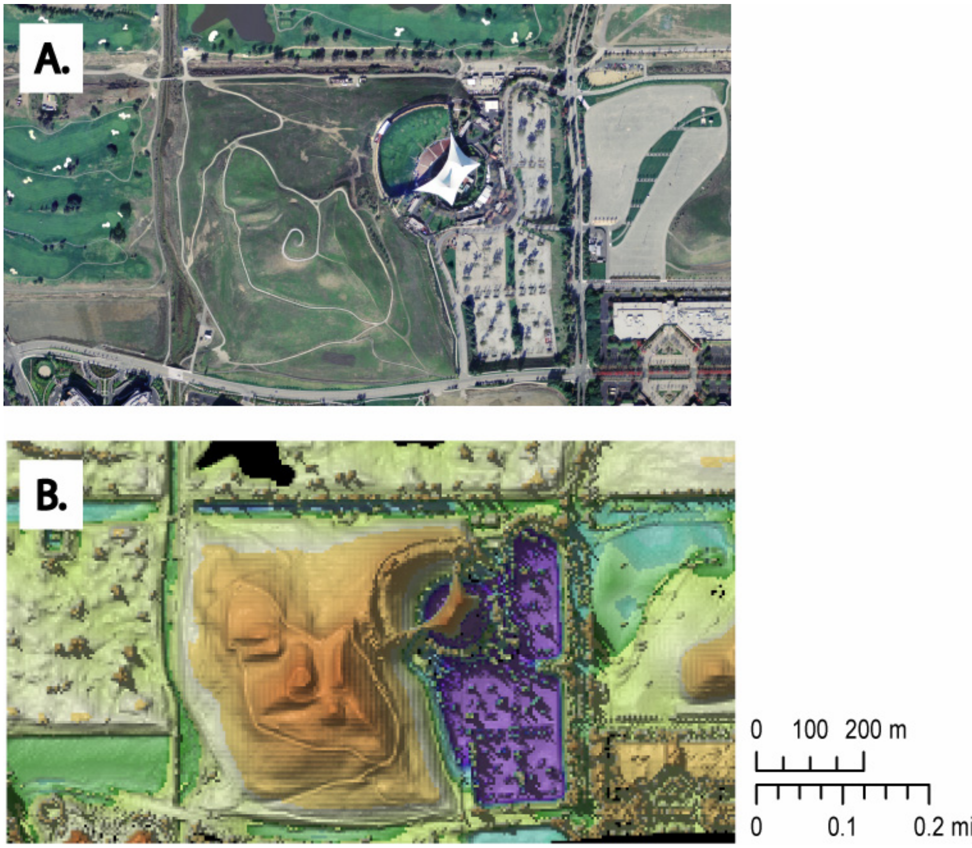

Figure 14. (A) NGA imagery of the Shoreline Amphitheater (and surrounding area) in Mountain View. (B) Full feature hill-shaded image of the same location.

Future Work

The collection of topographic lidar of South Bay is one component of a very comprehensive long term planning process which seeks to best understand the biological, physical, and social implications of marsh restoration. This topographic survey will soon be merged with recently collected bathymetric data of the bay and salt ponds to create a continuous DEM of the bay and surrounding areas that will be used as the basis for numerous models and scientific studies. In addition to providing a baseline for evaluating effectiveness of restoration efforts, the combined data set will be used to model processes and formulate approaches that will improve the success of restoration.

Acknowledgments

The authors would like to thank Ralph Haugerud (USGS) for his immense assistance in analyzing the lidar accuracy and suggestions on processing methods to improve the data quality. Thanks to Pete Darnell, Gerry Hatcher, and Joshua Logan (all of the USGS) for contributing their GIS and lidar expertise. Tim Hayes, City of San Jose, provided the IKONOS satellite imagery. The National Geospatial-Intelligence Agency and the USGS supplied the high-resolution aerial photographs. The City of San Jose, Alamada County Public Works Agency, and Philip Williams & Associates provided elevation data used for preliminary accuracy analyses. Nicole Athearn, (USGS) and John Krause (CA Department of Fish and Game) collected vegetation measurements for ground-truthing. Clyde Morris, (U.S. Fish & Wildlife Service), provided access to ponds and marsh for lidar ground-truthing. Lastly, we would like to acknowledge the staff at TerraPoint and Mosaic Mapping (especially Claude Vickers, Simon Newby, and Alan Dodson) for their role in completing this project.

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For details on the South Bay Salt Pond Restoration Project visit:
http://www.southbayrestoration.org/

Appendix

February 2, 2005

Project Report

USGS – South Bay Restoration Project

Contract #2206-H

TerraPoint USA

Report Presented to:

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1.Project Overview

Field Crew:

The Terrapoint field crew consisted of Roger Shreenan and Al Greatrex, who alternated as field project managers and Barry Kaiser. The Aspen Helicopters Incorporated aircraft crew consisted of Kevin Kintz, Diana Feddersohn and Richard E. Saenz (pilots).

Post Processing Crew:

Roger Shreenan completed the processing of GPS data. Kresimir Kusevic, Alan Dodson, Roger Shreenan and Claude Vickers carried out data validation and boresight corrections. Vegetation removal and final product generation were completed the Ottawa processing team: Alan Dodson, Andrew Magnan, Krista Helman, Bruce Adey, Shaun Perry, Josh Beaton and Claude Vickers. Claude Vickers and Alan Dodson coordinated the Ottawa processing.

Size of Project:

The South Bay restoration project covered approximately 334 square kilometers.

Location:

The project consisted and the mud flats and associated salt ponds of San Francisco Bay and surrounding 100-year flood plain.

Project Type:

The purpose of this project is to provide a high quality DEM for drainage mapping and salt pond restoration for the USGS.

Approximate Duration of Project:

The field data collection took place from May 5 to May 21, 2004. The control network and check point surveys were established from April 30 to May 20, 2004.

Boresight correction, vegetation removal and product generation took place from June 3 to October 27, 2004.

Number of Flights:

Twenty-five flights were required to cover the project area with approximately one hundred thirty six flight lines.

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Coordinate System(s) Used:

All horizontal coordinate data was collected and referenced to NAD83 and NAVD88 as Universal Transverse Mercator Zone 10. GEOID03 grid #5 for CONUS (24-42N, 230-249E) was applied to the vertical component of all deliverables.

Survey Measurement Units Used/Delivered:

All surveys were conducted and products delivered in the metric system.

Processing Software Used:

The following software was used to reduce the GPS kinematic data, compute the 3-D laser points, classify and edit laser points, produce shaded relief images and transform the ellipsoidal heights to Orthometric:

- ArcView
- Flykin
- Microstation
- TerraScan
- TerraModeler
- TerraModel
- Terrapoint Proprietary LiDAR processing software

Capsule Review of Ground Control Survey(s) and Adjustment(s)

Terrapoint's field crew acquired and adjusted the ground control survey information. Terrapoint collected all of their LiDAR data referenced to points BASE1, BASE2, BASE3 and BASE4. Please see the base coordinates and associated control in table 1 below. Kinematic GPS profiles and static GPS check points were acquired as discrete x, y, z check points were collected as part of the ground truthing activities. A plot of these check points and control are located in Map A.

Table 1: Control and Base Coordinate

NAME	Latitude			Longitude			Orthometric Elevations (Geoid03)
ah7470	37	30	28.76286	-122	12	39.08903	3.521
ai7653	37	43	11.04196	-122	7	9.20686	149.986
BASE1	37	34	7.35898	-122	6	16.12822	3.18
BASE2	37	31	8.79511	-122	3	23.68627	10.62
BASE3	37	30	26.18105	-122	14	42.72399	3.468
BASE4	37	39	48.1243	-122	7	23.05579	9.272
HS2851	37	26	10.03157	-122	54	24.8923	4.805
HT0565	37	35	28.63886	-122	19	9.92157	13.999
SF01	37	25	32.53794	-122	4	30.56896	18.616

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2. Health and Safety

Following Terrapoint's safety procedures, the field crew conducted a safety meeting upon arrival at the project site.

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3. Equipment Used

Aircraft Type:

A Partenavia P68 twin-engine aircraft (N300LF) was used for this project. The aircraft was based out of Oxnard, California. The Partenavia P-68 has a maximum flight range of approximately 1740km, and was typically flying at an altitude of 245 meters AGL (above ground level) for the duration of the survey.

Sensors Used:

The Airborne LiDAR survey was conducted using Terrapoint's ALMIS (Airborne Laser Mapping Imaging System), flying at an optimum height of 245 meters AGL at 100 knots. The system consists of a 60-degree full angle Riegl laser, a Novatel GPS receiver and a Honeywell IMU unit. The nominal flight line spacing was 99 meters, providing overlap of 51% between flight lines.

GPS Type(s):

Two Trimble 4000ssi dual frequency GPS receivers were used on the ground to support the airborne operations on this project.

4. Accuracy

The following list itemizes the accuracy attainable over the project area, as a function of terrain type and vegetation cover. Note that the accuracy quoted is the accuracy of the attainable DEM, once it is processed and edited to this stage. All data accuracies quoted relate to post processed GPS/IMU/LiDAR solutions.

Accuracy is as follows, quoted at the 95% confidence level (2 sigma),

1. Absolute Vertical Accuracy:

   +/- 10-15 centimeters on Hard Surfaces (roads and buildings)
   +/- 15-25 centimeters on Soft/Vegetated Surfaces (flat to rolling terrain)
   +/- 25-40 centimeters on Soft/Vegetated Surfaces (hilly terrain)

2. Absolute Horizontal Accuracy:

   +/- 20 – 60 centimeters on all but extremely hilly terrain.

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To verify that the accuracy criteria were being achieved, the kinematic and static checkpoints were compared with a triangulated surface generated from the bald earth LiDAR points. The statistical comparisons can be found in Appendix A for the kinematic points and Appendix B for the static points.

593 kinematic check points compared to the LiDAR bald earth surface on paved surfaces found that the average error was –1.9 centimeters and that 95% (2 sigma) of the checkpoints were within 13.2 centimeters of true values. An overview of the results from the kinematic GPS checkpoints follows in table 2.

Table 2: Kinematic Survey Results	
Summary Statistics	Centimeters
Sample Size	593 pts.
Average Error	-1.191
RMSE (1 Sigma)	6.47
NSSDA (2 Sigma)	13.21
Standard Deviation	6.47
Error Range	-30.0 to +12.0

165 Static check points compared to the LiDAR bald earth surface on soft surfaces with varying vegetation cover found that the average error was 3.6 centimeters and that 95% (2 sigma) of the check points were within 28 centimeters of true values. An overview of the results from the kinematic GPS checkpoints follows in table 3.

Table 3: Static Survey Results	
Summary Statistics	Centimeters
Sample Size	145 pts.
Average Error	3.19
RMSE (1 Sigma)	13.37
NSSDA (2 Sigma)	26.21
Standard Deviation	13.03
Error Range	-39.0 to +53.0

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5. Quality Control

Quality control of the data was ongoing throughout the process. Following data acquisition, preliminary GPS processing was conducted in the field to ensure completeness and integrity.

The GPS and inertial data were processed in tandem to achieve the best positional result. Once the position and attitude of the aircraft were known at each epoch (1-second intervals), then these data were integrated with the laser ranges to provide a position for each data point on the ground. The data were then processed using TerraPoint's proprietary laser processing software suite to produce coordinates.

Each flight involved setting up two base stations to collect data. Utilizing two base stations ensures GPS data collection in the event that the main base station fails. For all flights the GPS data were of high quality. This minimized the absolute error for the aircraft position.

The primary quality control tool for the laser ranges is the percentage of returns that are received back at the laser after it has emitted a signal. The acceptable range for returns, typically between 90% and 95% was met for this project. Lower percentages are normal over water and other poor reflectivity surfaces such as the dark, wet surfaces typical of the project area's mud flats.

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6. Point Generation

The points are generated as Terrascan binary Format using Terrapoint's proprietary Laser Postprocessor Software. This software combines the Raw Laser file and GPS/IMU information to generate a point cloud for each individual flight.

All the point cloud files encompassing the project area were then divided into 2 kilometer by 2-kilometer tiles. The referencing system of these tiles is based upon the project boundary minimum and maximums. This process is carried out in Terrascan. The tile index graphics are represented in Map B.

The bald earth is subsequently extracted from the raw LiDAR points using Terrascan in a Microstation environment. The automated vegetation removal process takes place by building an iterative surface model. This surface model is generated using three main parameters: Building size, Iteration angle and Iteration distance.

The initial model is based upon low points selected by a roaming window and are assumed to be ground points. The size of this roaming window is determined by the building size parameter. These low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the Iteration angle and distance constraints (fig. 1). This process is repeated until no additional points are added within an iteration.

There is also a maximum terrain angle constraint that determines the maximum terrain angle allowed within the model.

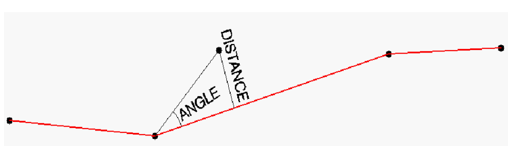

Figure 1: Terrascan iteration methodology.

(Image Source: Terrascan User's Guide, www.terrasolid.fi)

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7. Quality Control

Once the data setup has taken place the manual quality control of the surface occurs. This process consists of visually examining the LiDAR points within Terrascan and correcting errors that occurred during the automated process. These corrections include verifying that all non ground elements, such as vegetation and buildings are removed from the ground model and that all small terrain undulations such as road beds, dykes, rock cuts and hill tops are present within the model.

This process is done with the help of hillshades, contours, profiles and cross-sections. To correct misclassifications, a full suite of Terrascan and custom in-house data tools are used.

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8. Deliverables

Below is a list of the deliverables for this project:

All LiDAR Data Products were delivered on DVD–ROM. Three copies were provided. All products other than hill-shade data were provided in 1k and 2k tiles with a 25-meter buffer. Hill-shades were delivered in three large areas.

Full Feature or All Return Point Data

Data delivered in ASCII, comma delimited files with one record per return containing data columns as defined in Table 4. The records are ordered sequentially according to Easting with no duplicate records. The individual returns are classified into the following categories: ground or water, above ground (low), above ground (high), building and NADIR as defined in Table 5. This ASCII product was generated using an in house custom utility. The process involved extracting a Terrascan Binary file packed with the scan angle and the extra precision required for the for a unique time stamp.

Bare Earth Point Data

Data delivered in ASCII, comma delimited files with one record per return containing data columns as defined in Table 4. The records are ordered sequentially according to Easting with no duplicate records. This product is a subset of the full feature or all return point data product containing only code 3, ground points, as described in table 5 below. This ASCII product was generated using an in house custom utility. The process involved extracting a Terrascan Binary file packed with the scan angle and the extra precision required for the for a unique time stamp.

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Bare Earth and Full Feature Hill-Shade Image

Data delivered in GeoTIFF format with a TFW file. The image resolution is 1m. This product was generated in ArcView.

Gridded Bare Earth Point Data

Bare earth Digital Elevation Model (DEM) using last return, with vegetation and building elevations removed. The data was gridded at 1m postings, and delivered in ASCII format. This product was generated in Terrascan.

Contour Data

Data is delivered at 50cm nominal contour interval, 2.5m labeled index contours in AutoCAD format. This product was generated using a combination of TerraModeler and Microstation.

Table 4: Individual laser return (point cloud) data product specifications

Specification	Description	Notes
Data Field 1: Time	GPS time	Reported to nearest microsecond
Data Field 2: x,y location	Geographic location of return	NAD83-92, to nearest 0.01m
Data Field 3: Elevation	Elevation of return	NAVD-88, to nearest 0.01m
Data Field 4: Return classification	Return classification of this return	First or last return
Data Field 5: Off Nadir Angle	Angle between nadir and transmitted pulse	Reported to nearest 0.01 degrees
Data Field 6: Return Intensity	Intensity of return	
Data Field 7: Classification Code	Classification of return	According to Table 4

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Table 5: Return Classification System		
Code	Description	Notes
3	Ground or water	-Bare Earth surface
10	Above Ground – Low *	-Located 0 – 1.5 m above ground
5	Above Ground – High *	-Non-ground points, 1.51 m up to 60 m above ground
7	Buildings *	-Manually extracted LiDAR hits corresponding to buildings from codes 10 and 5
13	Strong return at nadir	-Returns having intensity values greater than or equal to 40 at nadir. -Can correspond to any features from the above feature codes

NOTE: * Codes 10 and 5 capture all above ground features not deemed to be building – i.e. vegetation and other man made structures

Please note that all products, other than the hillshade products were delivered in 2 kilometer tiles (Map B) and 1 kilometer tiles (Map C).

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9. Problems, Resolutions and Conclusions

Boresight

Our laser encountered some technical difficulties during acquisition. The laser manufacturer, Riegl, was unable to pin point the problem on the bench due to the small magnitude of the error. Riegl anticipated this result due to the limits of testing within a lab setting. As a precaution to eliminate any possible source of error, the laser angle encoder unit and the bearings were replaced. As an additional precaution, an extra screw was added during the inspection to improve the mounting of encoder mechanism. The unit belt was eliminated as the source of the problem. As a result of this malfunction, the boresight values for each flight had to be thoroughly reviewed. This manual process took approximately three weeks to resolve for the appropriate boresight corrections. The majority of the flights required a single roll correction of 0.097 degrees while others required an adjustment of 0.068 or 0.142 degrees. Certain flights required two-roll corrections.

Unfortunately, this boresight problem caused by equipment malfunction was only discovered after initially delivering the project — this was principally due to a shortcoming in our QC methodology that did not reveal mechanical problems such as those encountered with our scanning laser. It should be noted that the laser deployed for this project had previously operated without error on approximately 200 missions. We therefore consider the problems encountered with the South Bay project to be an outlier. Nevertheless, our processing flow has now been modified to identify such outliers by performing more quality control checks on the data prior to entering production. These include: profiles, full feature hill-shades, GPS checks and distance grids. The distance grids are quite beneficial as they visually display relative elevation error between flightlines. Please note that we attempted to perform distance grids on all the tiles, but were successful on only 127 of 145 tiles due to lack of overlap in open water or tiles containing a great deal of flightlines causing the application to crash. Close attention was paid to these tiles in particular during the second round of production as to ensure the quality was good. The distance images were captured as screengrabs from the application and are located on the accompanying disk.

The late discovery of this problem proved to be special challenge, as the processing team had spent the majority of the initial filtering run extracting the buildings from the point cloud. To deliver this project in a rapid manner, we opted to maintain the building classifications as to minimize

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the amount of reprocessing. Therefore we could not reprocess the point cloud with the boresight compensation values. An additional problem ensued; two GPS week rollovers occurred during acquisition. Due to software limitations we are unable to store GPS week, only GPS time, therefore, there is a strong likelihood of having multiple identical GPS times within the dataset. This situation leads to the possibility of associating the LiDAR data to the wrong trajectory and applying an incorrect roll compensation factor based upon aircraft position and required correction. To overcome these obstacles we developed a new procedure using existing software and custom applications. Once applied, these corrections were verified with the aforementioned distance grids. This issue is being addressed in future projects by allowing the LiDAR operator to tag flight lines with an attribute during acquisition.

As a result of applying the roll compensation the overall quality of the dataset increased significantly allowing the project to meet the set accuracy guidelines. Upon the discovery of this problem by the USGS a few selected distance grids were generated. These grids indicated an average error of 30 centimeters while a few areas indicated errors of 45-50 centimeters. Once the boresight corrections were applied, all but a few areas are now within the range of +/- 15 centimeters. A few areas remain as outliers in the 15 to 30 cm range.

A benefit of the correction was the elimination of “false vegetation”. The error was more evident in flat open areas of the mud flats. The error manifested itself to look like isolated areas of low scrub. Once corrected these were reduced significantly to meet specification or eliminated all together. Vegetation removal also proved to be tricky as quite often the bulrush directly adjoining dikes masked themselves as extensions to the dikes. Pickle weed and other forms of low vegetation shorter than 20 cm also tended blend very well into the mudflats. Particular attention had to be paid to these areas and the assistance of the USGS proved to be a valuable asset in discerning valid ground from vegetation.

Building Extraction

As mentioned above, one of the obstacles encountered was the high concentration of buildings for extraction. The lack of a reliable automated extraction tool for buildings caused a great impediment to delivering the project within the original time frame. Constant development is undertaken by the manufacturer of Terrascan to streamline the difficult process of building extraction.

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Storage Format

Our standard point storage format, Terrascan Binary, also proved to be a hindrance to completing this project due to the inability to store the required scan angle and time stamp to the microsecond. We are investigating using LAS binary as our standard storage in the future.

High Tide Versus Low Tide

One of the acquisition constraints set for this project was that certain areas were to be acquired at low tide level. Although these guidelines were followed, Terrapoint's ALMIS system acquires data at all times when flying and does not have flight line logging abilities. Therefore on many occasions transit lines were flown at high tide over areas requiring low tide coverage. This proved to be only a minor issue in processing as the majority of the high tide lines were classified as code 10 (not ground or water). Some points were not removed in the automated filtering process and were classified as code 10 or eliminated during the manual quality control process.

Conclusion

In conclusion, all parties have learned a great from this project. New measures are being put forth at Terrapoint to allow us in the future to deliver a better product in a shorter time frame.

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Appendix A. Kinematic GPS Statistical Comparisons

All tests done with maximum triangle length of 1.5 meters and maximum slope of 60 degrees

Section 1 of 1 (Hard Surface)

Point Number	Location Description	Easting	Northing	Known Z	Laser Z	Dz	$(Dz)^2$
310	Tiles 48, 49 & 50	579086.32	4158336.57	3.03	3.06	0.03	0.0009
311	Tiles 48, 49 & 50	579086.36	4158336.58	3.03	3.06	0.03	0.0009
312	Tiles 48, 49 & 50	579086.65	4158336.62	3.02	3.09	0.07	0.0049
313	Tiles 48, 49 & 50	579087.10	4158336.68	3.02	3.09	0.07	0.0049
321	Tiles 48, 49 & 50	579112.68	4158341.72	3.15	3.16	0.01	0.0001
326	Tiles 48, 49 & 50	579144.58	4158354.23	3.27	3.33	0.06	0.0036
327	Tiles 48, 49 & 50	579151.52	4158357.77	3.19	3.20	0.01	0.0001
328	Tiles 48, 49 & 50	579158.69	4158361.32	3.11	3.12	0.01	0.0001
330	Tiles 48, 49 & 50	579173.87	4158367.92	2.93	2.92	-0.01	0.0001
331	Tiles 48, 49 & 50	579182.02	4158370.81	2.85	2.81	-0.04	0.0016
334	Tiles 48, 49 & 50	579208.14	4158378.87	2.70	2.73	0.03	0.0009
337	Tiles 48, 49 & 50	579235.37	4158386.82	2.72	2.81	0.09	0.0081
338	Tiles 48, 49 & 50	579244.59	4158389.54	2.70	2.77	0.07	0.0049
342	Tiles 48, 49 & 50	579282.06	4158400.78	2.60	2.67	0.07	0.0049
354	Tiles 48, 49 & 50	579394.72	4158434.12	2.71	2.68	-0.03	0.0009
355	Tiles 48, 49 & 50	579404.21	4158436.95	2.71	2.72	0.01	0.0001
359	Tiles 48, 49 & 50	579441.75	4158448.58	2.59	2.59	0.00	0.0000
366	Tiles 48, 49 & 50	579509.45	4158467.52	2.49	2.51	0.02	0.0004
368	Tiles 48, 49 & 50	579530.12	4158473.55	2.59	2.55	-0.04	0.0016
369	Tiles 48, 49 & 50	579540.62	4158476.76	2.56	2.57	0.01	0.0001
371	Tiles 48, 49 & 50	579561.77	4158482.98	2.60	2.62	0.02	0.0004
373	Tiles 48, 49 & 50	579583.16	4158489.31	2.61	2.60	-0.01	0.0001
379	Tiles 48, 49 & 50	579649.81	4158509.54	2.55	2.56	0.01	0.0001
389	Tiles 48, 49 & 50	579762.61	4158544.33	2.50	2.48	-0.02	0.0004
390	Tiles 48, 49 & 50	579773.68	4158547.71	2.59	2.58	-0.01	0.0001
396	Tiles 48, 49 & 50	579837.31	4158567.52	2.63	2.56	-0.07	0.0049
401	Tiles 48, 49 & 50	579887.67	4158582.87	2.65	2.61	-0.04	0.0016
402	Tiles 48, 49 & 50	579897.43	4158585.76	2.66	2.62	-0.04	0.0016
404	Tiles 48, 49 & 50	579916.77	4158591.56	2.61	2.58	-0.03	0.0009
406	Tiles 48, 49 & 50	579936.28	4158597.48	2.56	2.61	0.05	0.0025
407	Tiles 48, 49 & 50	579946.18	4158600.48	2.52	2.57	0.05	0.0025
413	Tiles 48, 49 & 50	580005.23	4158618.70	2.69	2.65	-0.04	0.0016
414	Tiles 48, 49 & 50	580015.22	4158621.79	2.69	2.70	0.01	0.0001
415	Tiles 48, 49 & 50	580025.19	4158624.93	2.67	2.60	-0.07	0.0049
416	Tiles 48, 49 & 50	580035.13	4158628.08	2.67	2.61	-0.06	0.0036

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417	Tiles 48, 49 & 50	580045.06	4158631.24	2.70	2.69	-0.01	0.0001
418	Tiles 48, 49 & 50	580054.97	4158634.55	2.77	2.78	0.01	0.0001
419	Tiles 48, 49 & 50	580064.91	4158638.02	2.78	2.80	0.02	0.0004
440	Tiles 48, 49 & 50	580290.63	4158708.50	2.82	2.78	-0.04	0.0016
441	Tiles 48, 49 & 50	580301.66	4158711.77	2.80	2.77	-0.03	0.0009
442	Tiles 48, 49 & 50	580312.68	4158715.03	2.85	2.85	0.00	0.0000
443	Tiles 48, 49 & 50	580323.68	4158718.31	2.90	2.92	0.02	0.0004
446	Tiles 48, 49 & 50	580356.77	4158728.62	3.00	2.97	-0.03	0.0009
447	Tiles 48, 49 & 50	580367.74	4158732.45	3.08	3.05	-0.03	0.0009
448	Tiles 48, 49 & 50	580378.55	4158736.75	3.08	3.08	0.00	0.0000
452	Tiles 48, 49 & 50	580419.34	4158758.23	3.25	3.29	0.04	0.0016
453	Tiles 48, 49 & 50	580429.36	4158763.97	3.25	3.28	0.03	0.0009
456	Tiles 48, 49 & 50	580459.30	4158781.66	3.18	3.22	0.04	0.0016
460	Tiles 48, 49 & 50	580499.22	4158804.20	3.19	3.26	0.07	0.0049
461	Tiles 48, 49 & 50	580509.14	4158809.88	3.21	3.30	0.09	0.0081
462	Tiles 48, 49 & 50	580518.95	4158815.57	3.29	3.33	0.04	0.0016
463	Tiles 48, 49 & 50	580528.75	4158821.28	3.25	3.29	0.04	0.0016
464	Tiles 48, 49 & 50	580538.55	4158827.08	3.20	3.28	0.08	0.0064
465	Tiles 48, 49 & 50	580548.35	4158832.96	3.19	3.27	0.08	0.0064
466	Tiles 48, 49 & 50	580558.21	4158838.79	3.19	3.19	0.00	0.0000
467	Tiles 48, 49 & 50	580568.12	4158844.64	3.20	3.24	0.04	0.0016
468	Tiles 48, 49 & 50	580578.13	4158850.46	3.17	3.24	0.07	0.0049
469	Tiles 48, 49 & 50	580588.16	4158856.31	3.13	3.21	0.08	0.0064
470	Tiles 48, 49 & 50	580598.24	4158862.16	3.13	3.19	0.06	0.0036
471	Tiles 48, 49 & 50	580608.31	4158868.06	3.13	3.18	0.05	0.0025
472	Tiles 48, 49 & 50	580618.29	4158873.93	3.11	3.12	0.01	0.0001
477	Tiles 48, 49 & 50	580664.65	4158900.71	3.02	2.94	-0.08	0.0064
481	Tiles 48, 49 & 50	580690.58	4158912.06	3.03	3.03	0.00	0.0000
482	Tiles 48, 49 & 50	580695.85	4158911.27	3.03	2.99	-0.04	0.0016
483	Tiles 48, 49 & 50	580700.88	4158909.28	2.94	2.86	-0.08	0.0064
487	Tiles 48, 49 & 50	580721.74	4158896.51	3.41	3.36	-0.05	0.0025
489	Tiles 48, 49 & 50	580729.58	4158884.50	3.69	3.56	-0.13	0.0169
494	Tiles 48, 49 & 50	580747.37	4158842.88	3.70	3.57	-0.13	0.0169
495	Tiles 48, 49 & 50	580751.10	4158834.15	3.70	3.63	-0.07	0.0049
497	Tiles 48, 49 & 50	580758.61	4158816.64	3.71	3.72	0.01	0.0001
499	Tiles 48, 49 & 50	580766.28	4158798.84	3.70	3.63	-0.07	0.0049
500	Tiles 48, 49 & 50	580770.28	4158789.76	3.73	3.65	-0.08	0.0064
524	Tiles 48, 49 & 50	580868.43	4158565.91	3.35	3.16	-0.19	0.0361
526	Tiles 48, 49 & 50	580876.19	4158548.31	3.37	3.26	-0.11	0.0121
528	Tiles 48, 49 & 50	580883.20	4158530.75	3.39	3.21	-0.18	0.0324
534	Tiles 48, 49 & 50	580905.35	4158479.68	3.44	3.32	-0.12	0.0144
536	Tiles 48, 49 & 50	580909.87	4158463.00	3.47	3.23	-0.24	0.0576
540	Tiles 48, 49 & 50	580907.38	4158430.29	3.56	3.39	-0.17	0.0289
544	Tiles 48, 49 & 50	580898.70	4158397.36	3.29	3.24	-0.05	0.0025
547	Tiles 48, 49 & 50	580888.96	4158372.87	3.48	3.37	-0.11	0.0121
548	Tiles 48, 49 & 50	580885.75	4158364.63	3.53	3.40	-0.13	0.0169
562	Tiles 48, 49 & 50	580836.94	4158256.09	3.60	3.66	0.06	0.0036
565	Tiles 48, 49 & 50	580819.61	4158240.15	3.68	3.73	0.05	0.0025

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566	Tiles 48, 49 & 50	580813.13	4158235.17	3.61	3.64	0.03	0.0009
567	Tiles 48, 49 & 50	580806.56	4158230.45	3.55	3.59	0.04	0.0016
568	Tiles 48, 49 & 50	580800.15	4158225.89	3.51	3.56	0.05	0.0025
578	Tiles 48, 49 & 50	580740.18	4158179.08	3.43	3.42	-0.01	0.0001
579	Tiles 48, 49 & 50	580733.94	4158173.64	3.39	3.44	0.05	0.0025
580	Tiles 48, 49 & 50	580727.76	4158167.71	3.37	3.36	-0.01	0.0001
582	Tiles 48, 49 & 50	580715.82	4158154.25	3.40	3.43	0.03	0.0009
583	Tiles 48, 49 & 50	580709.80	4158146.92	3.43	3.44	0.01	0.0001
586	Tiles 48, 49 & 50	580690.61	4158123.18	3.36	3.39	0.03	0.0009
590	Tiles 48, 49 & 50	580663.76	4158089.33	3.38	3.42	0.04	0.0016
591	Tiles 48, 49 & 50	580657.00	4158080.81	3.40	3.42	0.02	0.0004
592	Tiles 48, 49 & 50	580650.22	4158072.20	3.35	3.37	0.02	0.0004
593	Tiles 48, 49 & 50	580643.28	4158063.62	3.32	3.38	0.06	0.0036
597	Tiles 48, 49 & 50	580614.49	4158030.01	3.18	3.23	0.05	0.0025
598	Tiles 48, 49 & 50	580607.11	4158021.76	3.16	3.17	0.01	0.0001
599	Tiles 48, 49 & 50	580599.78	4158013.40	3.13	3.21	0.08	0.0064
600	Tiles 48, 49 & 50	580592.56	4158005.04	3.14	3.08	-0.06	0.0036
601	Tiles 48, 49 & 50	580585.56	4157996.70	3.08	3.07	-0.01	0.0001
602	Tiles 48, 49 & 50	580578.72	4157988.51	3.03	3.10	0.07	0.0049
607	Tiles 48, 49 & 50	580545.71	4157950.23	2.81	2.83	0.02	0.0004
609	Tiles 48, 49 & 50	580532.72	4157936.84	2.81	2.83	0.02	0.0004
611	Tiles 48, 49 & 50	580519.57	4157924.63	2.80	2.80	0.00	0.0000
612	Tiles 48, 49 & 50	580512.51	4157919.04	2.84	2.85	0.01	0.0001
613	Tiles 48, 49 & 50	580505.19	4157913.95	2.90	2.95	0.05	0.0025
614	Tiles 48, 49 & 50	580497.74	4157909.71	2.96	2.99	0.03	0.0009
615	Tiles 48, 49 & 50	580490.46	4157906.40	3.03	3.05	0.02	0.0004
616	Tiles 48, 49 & 50	580483.45	4157903.91	3.06	3.03	-0.03	0.0009
619	Tiles 48, 49 & 50	580466.84	4157899.48	3.02	3.03	0.01	0.0001
624	Tiles 48, 49 & 50	580448.32	4157898.88	2.95	3.01	0.06	0.0036
625	Tiles 48, 49 & 50	580444.45	4157899.60	2.95	3.01	0.06	0.0036
627	Tiles 48, 49 & 50	580438.04	4157901.71	2.97	3.02	0.05	0.0025
628	Tiles 48, 49 & 50	580435.65	4157902.84	2.98	3.00	0.02	0.0004
629	Tiles 48, 49 & 50	580433.91	4157903.87	3.00	3.02	0.02	0.0004
630	Tiles 48, 49 & 50	580432.96	4157904.46	3.00	3.01	0.01	0.0001
631	Tiles 48, 49 & 50	580432.60	4157904.67	3.00	3.02	0.02	0.0004
632	Tiles 48, 49 & 50	580432.59	4157904.68	3.00	3.02	0.02	0.0004
633	Tiles 48, 49 & 50	580432.90	4157904.49	3.00	3.01	0.01	0.0001
634	Tiles 48, 49 & 50	580433.65	4157904.04	3.00	3.00	0.00	0.0000
636	Tiles 48, 49 & 50	580436.12	4157902.49	2.99	3.00	0.01	0.0001
637	Tiles 48, 49 & 50	580437.78	4157901.41	2.98	3.02	0.04	0.0016
639	Tiles 48, 49 & 50	580441.40	4157899.40	2.97	3.03	0.06	0.0036
641	Tiles 48, 49 & 50	580444.50	4157898.16	2.98	3.04	0.06	0.0036
642	Tiles 48, 49 & 50	580446.27	4157897.65	2.98	3.01	0.03	0.0009
643	Tiles 48, 49 & 50	580447.76	4157897.27	2.98	2.98	0.00	0.0000
644	Tiles 48, 49 & 50	580449.03	4157896.97	2.98	2.92	-0.06	0.0036
645	Tiles 48, 49 & 50	580450.54	4157896.55	2.95	3.00	0.05	0.0025
646	Tiles 48, 49 & 50	580452.02	4157895.99	2.88	2.98	0.10	0.0100
664	Tiles 48, 49 & 50	580465.43	4157899.70	3.04	3.06	0.02	0.0004

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666	Tiles 48, 49 & 50	580475.52	4157901.45	3.04	3.03	-0.01	0.0001
668	Tiles 48, 49 & 50	580487.23	4157905.15	3.06	3.07	0.01	0.0001
670	Tiles 48, 49 & 50	580500.60	4157911.30	2.94	2.99	0.05	0.0025
671	Tiles 48, 49 & 50	580507.43	4157915.40	2.88	2.91	0.03	0.0009
672	Tiles 48, 49 & 50	580514.17	4157920.18	2.83	2.85	0.02	0.0004
674	Tiles 48, 49 & 50	580527.12	4157931.41	2.80	2.78	-0.02	0.0004
675	Tiles 48, 49 & 50	580533.44	4157937.61	2.81	2.83	0.02	0.0004
677	Tiles 48, 49 & 50	580545.99	4157950.45	2.82	2.83	0.01	0.0001
684	Tiles 48, 49 & 50	580586.16	4157997.26	3.09	3.08	-0.01	0.0001
685	Tiles 48, 49 & 50	580591.96	4158004.20	3.13	3.14	0.01	0.0001
686	Tiles 48, 49 & 50	580597.93	4158011.12	3.12	3.17	0.05	0.0025
687	Tiles 48, 49 & 50	580604.00	4158018.03	3.13	3.13	0.00	0.0000
688	Tiles 48, 49 & 50	580610.12	4158024.99	3.17	3.20	0.03	0.0009
689	Tiles 48, 49 & 50	580616.29	4158032.01	3.19	3.25	0.06	0.0036
693	Tiles 48, 49 & 50	580641.18	4158060.70	3.30	3.27	-0.03	0.0009
694	Tiles 48, 49 & 50	580647.27	4158068.21	3.33	3.35	0.02	0.0004
695	Tiles 48, 49 & 50	580653.34	4158075.79	3.38	3.41	0.03	0.0009
696	Tiles 48, 49 & 50	580659.44	4158083.41	3.39	3.40	0.01	0.0001
697	Tiles 48, 49 & 50	580665.46	4158091.02	3.39	3.38	-0.01	0.0001
701	Tiles 48, 49 & 50	580689.14	4158121.00	3.34	3.36	0.02	0.0004
702	Tiles 48, 49 & 50	580695.03	4158128.32	3.37	3.41	0.04	0.0016
704	Tiles 48, 49 & 50	580706.65	4158142.92	3.42	3.41	-0.01	0.0001
705	Tiles 48, 49 & 50	580712.61	4158150.14	3.43	3.49	0.06	0.0036
706	Tiles 48, 49 & 50	580718.77	4158157.23	3.38	3.43	0.05	0.0025
707	Tiles 48, 49 & 50	580725.08	4158164.17	3.36	3.41	0.05	0.0025
709	Tiles 48, 49 & 50	580738.19	4158177.12	3.41	3.44	0.03	0.0009
710	Tiles 48, 49 & 50	580745.02	4158182.95	3.48	3.56	0.08	0.0064
720	Tiles 48, 49 & 50	580803.12	4158227.88	3.52	3.48	-0.04	0.0016
721	Tiles 48, 49 & 50	580808.74	4158232.05	3.56	3.61	0.05	0.0025
722	Tiles 48, 49 & 50	580814.39	4158236.14	3.64	3.65	0.01	0.0001
725	Tiles 48, 49 & 50	580830.98	4158249.56	3.65	3.69	0.04	0.0016
734	Tiles 48, 49 & 50	580866.45	4158313.47	3.59	3.61	0.02	0.0004
740	Tiles 48, 49 & 50	580886.72	4158366.03	3.52	3.51	-0.01	0.0001
741	Tiles 48, 49 & 50	580890.11	4158374.76	3.46	3.36	-0.10	0.0100
745	Tiles 48, 49 & 50	580902.86	4158409.25	3.40	3.18	-0.22	0.0484
751	Tiles 48, 49 & 50	580910.02	4158463.03	3.48	3.24	-0.24	0.0576
753	Tiles 48, 49 & 50	580905.41	4158479.97	3.44	3.31	-0.13	0.0169
755	Tiles 48, 49 & 50	580898.10	4158496.05	3.48	3.41	-0.07	0.0049
763	Tiles 48, 49 & 50	580869.21	4158564.49	3.36	3.12	-0.24	0.0576
764	Tiles 48, 49 & 50	580865.27	4158573.37	3.38	3.15	-0.23	0.0529
766	Tiles 48, 49 & 50	580857.05	4158591.21	3.44	3.29	-0.15	0.0225
768	Tiles 48, 49 & 50	580848.94	4158609.33	3.46	3.35	-0.11	0.0121
773	Tiles 48, 49 & 50	580828.81	4158655.29	3.26	3.18	-0.08	0.0064
780	Tiles 48, 49 & 50	580801.25	4158718.51	3.62	3.32	-0.30	0.0900
789	Tiles 48, 49 & 50	580767.73	4158796.02	3.71	3.65	-0.06	0.0036
791	Tiles 48, 49 & 50	580760.32	4158813.09	3.72	3.66	-0.06	0.0036
798	Tiles 48, 49 & 50	580735.43	4158872.07	3.78	3.69	-0.09	0.0081
802	Tiles 48, 49 & 50	580721.35	4158897.00	3.39	3.36	-0.03	0.0009

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804	Tiles 48, 49 & 50	580710.29	4158905.01	2.93	2.87	-0.06	0.0036
806	Tiles 48, 49 & 50	580698.00	4158910.77	3.01	2.92	-0.09	0.0081
807	Tiles 48, 49 & 50	580691.55	4158911.37	3.02	3.00	-0.02	0.0004
811	Tiles 48, 49 & 50	580665.07	4158900.98	3.02	2.98	-0.04	0.0016
817	Tiles 48, 49 & 50	580613.06	4158871.40	3.11	3.18	0.07	0.0049
818	Tiles 48, 49 & 50	580603.26	4158865.64	3.12	3.16	0.04	0.0016
819	Tiles 48, 49 & 50	580593.18	4158859.74	3.12	3.16	0.04	0.0016
820	Tiles 48, 49 & 50	580582.87	4158853.79	3.13	3.17	0.04	0.0016
821	Tiles 48, 49 & 50	580572.36	4158847.76	3.16	3.19	0.03	0.0009
822	Tiles 48, 49 & 50	580561.81	4158841.53	3.19	3.17	-0.02	0.0004
823	Tiles 48, 49 & 50	580551.23	4158835.25	3.17	3.21	0.04	0.0016
824	Tiles 48, 49 & 50	580540.60	4158828.93	3.19	3.23	0.04	0.0016
825	Tiles 48, 49 & 50	580529.92	4158822.63	3.22	3.22	0.00	0.0000
827	Tiles 48, 49 & 50	580508.52	4158810.11	3.20	3.26	0.06	0.0036
833	Tiles 48, 49 & 50	580446.21	4158774.12	3.16	3.19	0.03	0.0009
835	Tiles 48, 49 & 50	580426.09	4158762.58	3.25	3.25	0.00	0.0000
838	Tiles 48, 49 & 50	580396.65	4158746.40	3.14	3.17	0.03	0.0009
840	Tiles 48, 49 & 50	580376.98	4158736.97	3.03	3.03	0.00	0.0000
841	Tiles 48, 49 & 50	580366.86	4158732.87	3.04	3.05	0.01	0.0001
842	Tiles 48, 49 & 50	580356.51	4158729.11	2.97	2.95	-0.02	0.0004
844	Tiles 48, 49 & 50	580335.30	4158722.30	2.88	2.86	-0.02	0.0004
846	Tiles 48, 49 & 50	580313.75	4158715.77	2.85	2.85	0.00	0.0000
848	Tiles 48, 49 & 50	580291.95	4158709.21	2.79	2.83	0.04	0.0016
869	Tiles 48, 49 & 50	580063.77	4158637.91	2.77	2.74	-0.03	0.0009
870	Tiles 48, 49 & 50	580053.16	4158634.28	2.75	2.72	-0.03	0.0009
871	Tiles 48, 49 & 50	580042.47	4158630.77	2.67	2.63	-0.04	0.0016
872	Tiles 48, 49 & 50	580031.75	4158627.36	2.66	2.61	-0.05	0.0025
873	Tiles 48, 49 & 50	580021.15	4158624.07	2.67	2.71	0.04	0.0016
875	Tiles 48, 49 & 50	580000.55	4158617.85	2.69	2.66	-0.03	0.0009
882	Tiles 48, 49 & 50	579929.45	4158596.00	2.57	2.49	-0.08	0.0064
884	Tiles 48, 49 & 50	579908.60	4158589.43	2.66	2.70	0.04	0.0016
885	Tiles 48, 49 & 50	579897.92	4158586.12	2.67	2.67	0.00	0.0000
886	Tiles 48, 49 & 50	579887.05	4158582.91	2.65	2.63	-0.02	0.0004
888	Tiles 48, 49 & 50	579865.30	4158576.37	2.62	2.62	0.00	0.0000
892	Tiles 48, 49 & 50	579822.94	4158563.13	2.67	2.62	-0.05	0.0025
896	Tiles 48, 49 & 50	579782.34	4158550.68	2.63	2.67	0.04	0.0016
897	Tiles 48, 49 & 50	579772.05	4158547.54	2.58	2.58	0.00	0.0000
898	Tiles 48, 49 & 50	579761.56	4158544.41	2.49	2.46	-0.03	0.0009
899	Tiles 48, 49 & 50	579750.96	4158541.30	2.42	2.40	-0.02	0.0004
916	Tiles 48, 49 & 50	579561.44	4158483.53	2.59	2.56	-0.03	0.0009
917	Tiles 48, 49 & 50	579550.29	4158480.15	2.57	2.61	0.04	0.0016
919	Tiles 48, 49 & 50	579528.13	4158473.52	2.59	2.60	0.01	0.0001
931	Tiles 48, 49 & 50	579398.56	4158435.68	2.70	2.73	0.03	0.0009
932	Tiles 48, 49 & 50	579387.49	4158432.28	2.73	2.73	0.00	0.0000
946	Tiles 48, 49 & 50	579234.94	4158387.03	2.71	2.81	0.10	0.0100
947	Tiles 48, 49 & 50	579224.67	4158384.10	2.72	2.77	0.05	0.0025
948	Tiles 48, 49 & 50	579214.59	4158381.04	2.71	2.77	0.06	0.0036
949	Tiles 48, 49 & 50	579204.57	4158377.92	2.69	2.73	0.04	0.0016

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950	Tiles 48, 49 & 50	579194.53	4158374.93	2.73	2.82	0.09	0.0081
952	Tiles 48, 49 & 50	579174.89	4158368.21	2.91	2.94	0.03	0.0009
954	Tiles 48, 49 & 50	579156.19	4158359.89	3.12	3.12	0.00	0.0000
955	Tiles 48, 49 & 50	579147.07	4158355.50	3.25	3.29	0.04	0.0016
956	Tiles 48, 49 & 50	579137.95	4158351.14	3.26	3.27	0.01	0.0001
966	Tiles 48, 49 & 50	579043.47	4158328.67	2.84	2.85	0.01	0.0001
971	Tiles 48, 49 & 50	579000.81	4158313.90	2.95	2.99	0.04	0.0016
973	Tiles 48, 49 & 50	578984.83	4158309.31	3.19	3.13	-0.06	0.0036
974	Tiles 48, 49 & 50	578977.41	4158307.20	3.36	3.36	0.00	0.0000
977	Tiles 48, 49 & 50	578963.69	4158302.72	3.91	3.92	0.01	0.0001
989	Tiles 48, 49 & 50	578908.21	4158306.90	5.35	5.32	-0.03	0.0009
990	Tiles 48, 49 & 50	578899.61	4158310.13	5.35	5.27	-0.08	0.0064
992	Tiles 48, 49 & 50	578881.03	4158317.04	5.30	5.20	-0.10	0.0100
1008	Tiles 48, 49 & 50	578721.50	4158376.94	5.49	5.46	-0.03	0.0009
1011	Tiles 48, 49 & 50	578689.95	4158388.41	5.25	5.30	0.05	0.0025
1024	Tiles 48, 49 & 50	578547.49	4158441.20	4.75	4.70	-0.05	0.0025
1029	Tiles 48, 49 & 50	578491.88	4158462.02	4.86	4.88	0.02	0.0004
1030	Tiles 48, 49 & 50	578480.73	4158466.44	4.93	4.88	-0.05	0.0025
1031	Tiles 48, 49 & 50	578469.63	4158470.93	4.98	4.96	-0.02	0.0004
1037	Tiles 48, 49 & 50	578401.36	4158502.50	4.86	4.69	-0.17	0.0289
1039	Tiles 48, 49 & 50	578378.00	4158513.61	4.93	4.80	-0.13	0.0169
1044	Tiles 48, 49 & 50	578318.99	4158541.85	4.66	4.66	0.00	0.0000
1051	Tiles 48, 49 & 50	578234.77	4158581.99	4.64	4.61	-0.03	0.0009
1056	Tiles 48, 49 & 50	578177.20	4158609.45	4.58	4.59	0.01	0.0001
1057	Tiles 48, 49 & 50	578165.89	4158614.94	4.41	4.37	-0.04	0.0016
1062	Tiles 48, 49 & 50	578109.67	4158641.66	4.58	4.44	-0.14	0.0196
1064	Tiles 48, 49 & 50	578087.03	4158651.97	4.85	4.85	0.00	0.0000
1066	Tiles 48, 49 & 50	578063.64	4158661.90	4.69	4.55	-0.14	0.0196
1078	Tiles 48, 49 & 50	577925.11	4158706.06	4.29	4.19	-0.10	0.0100
1082	Tiles 48, 49 & 50	577878.97	4158715.50	4.21	4.16	-0.05	0.0025
1085	Tiles 48, 49 & 50	577844.43	4158721.12	4.30	4.14	-0.16	0.0256
1172	Tiles 48, 49 & 50	577000.78	4158355.47	3.90	3.62	-0.28	0.0784
1193	Tiles 48, 49 & 50	576891.01	4158184.94	3.62	3.54	-0.08	0.0064
1299	Tiles 48, 49 & 50	576892.05	4158185.96	3.60	3.49	-0.11	0.0121
1303	Tiles 48, 49 & 50	576914.31	4158221.23	3.67	3.51	-0.16	0.0256
1363	Tiles 48, 49 & 50	577310.03	4158626.08	4.09	4.10	0.01	0.0001
1372	Tiles 48, 49 & 50	577393.41	4158665.07	4.22	4.22	0.00	0.0000
1375	Tiles 48, 49 & 50	577423.42	4158676.35	4.25	4.27	0.02	0.0004
1412	Tiles 48, 49 & 50	577800.39	4158725.88	4.31	4.28	-0.03	0.0009
1417	Tiles 48, 49 & 50	577851.65	4158720.07	4.39	4.37	-0.02	0.0004
1418	Tiles 48, 49 & 50	577861.84	4158718.42	4.33	4.07	-0.26	0.0676
1420	Tiles 48, 49 & 50	577882.71	4158714.81	4.24	4.23	-0.01	0.0001
1424	Tiles 48, 49 & 50	577924.55	4158705.96	4.27	4.10	-0.17	0.0289
1427	Tiles 48, 49 & 50	577953.82	4158698.65	4.42	4.43	0.01	0.0001
1435	Tiles 48, 49 & 50	578033.07	4158673.28	4.56	4.58	0.02	0.0004
1437	Tiles 48, 49 & 50	578053.87	4158665.31	4.60	4.48	-0.12	0.0144
1443	Tiles 48, 49 & 50	578115.10	4158638.65	4.54	4.34	-0.20	0.0400
1444	Tiles 48, 49 & 50	578125.11	4158633.84	4.45	4.34	-0.11	0.0121

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1448	Tiles 48, 49 & 50	578164.79	4158615.43	4.39	4.33	-0.06	0.0036
1451	Tiles 48, 49 & 50	578194.31	4158601.11	4.62	4.52	-0.10	0.0100
1452	Tiles 48, 49 & 50	578204.24	4158596.45	4.66	4.48	-0.18	0.0324
1453	Tiles 48, 49 & 50	578214.13	4158591.61	4.71	4.66	-0.05	0.0025
1455	Tiles 48, 49 & 50	578234.34	4158582.02	4.64	4.63	-0.01	0.0001
1457	Tiles 48, 49 & 50	578254.66	4158572.44	4.59	4.51	-0.08	0.0064
1458	Tiles 48, 49 & 50	578264.80	4158567.66	4.62	4.49	-0.13	0.0169
1469	Tiles 48, 49 & 50	578370.39	4158516.91	4.96	4.92	-0.04	0.0016
1471	Tiles 48, 49 & 50	578389.41	4158507.91	4.89	4.80	-0.09	0.0081
1474	Tiles 48, 49 & 50	578419.38	4158493.44	4.94	4.90	-0.04	0.0016
1480	Tiles 48, 49 & 50	578480.81	4158466.27	4.92	4.90	-0.02	0.0004
1481	Tiles 48, 49 & 50	578491.14	4158462.15	4.86	4.86	0.00	0.0000
1482	Tiles 48, 49 & 50	578501.51	4158458.21	4.90	4.85	-0.05	0.0025
1484	Tiles 48, 49 & 50	578522.21	4158450.43	4.83	4.88	0.05	0.0025
1486	Tiles 48, 49 & 50	578542.85	4158442.78	4.70	4.68	-0.02	0.0004
1500	Tiles 48, 49 & 50	578680.79	4158391.30	5.22	5.16	-0.06	0.0036
1501	Tiles 48, 49 & 50	578689.83	4158387.96	5.25	5.27	0.02	0.0004
1503	Tiles 48, 49 & 50	578707.18	4158381.57	5.44	5.40	-0.04	0.0016
1512	Tiles 48, 49 & 50	578779.26	4158354.22	5.19	5.19	0.00	0.0000
1522	Tiles 48, 49 & 50	578859.65	4158324.85	5.16	5.15	-0.01	0.0001
1524	Tiles 48, 49 & 50	578876.91	4158318.60	5.26	5.28	0.02	0.0004
1528	Tiles 48, 49 & 50	578911.21	4158305.91	5.36	5.30	-0.06	0.0036
1530	Tiles 48, 49 & 50	578925.60	4158300.28	5.38	5.38	0.00	0.0000
1534	Tiles 48, 49 & 50	578947.66	4158297.57	4.78	4.71	-0.07	0.0049
1536	Tiles 48, 49 & 50	578957.21	4158300.27	4.20	4.18	-0.02	0.0004
1538	Tiles 48, 49 & 50	578963.49	4158302.39	3.96	3.94	-0.02	0.0004
1542	Tiles 48, 49 & 50	578976.26	4158306.79	3.37	3.40	0.03	0.0009
1546	Tiles 48, 49 & 50	578999.09	4158313.94	2.97	2.96	-0.01	0.0001
1548	Tiles 48, 49 & 50	579013.19	4158318.52	2.93	2.95	0.02	0.0004
1552	Tiles 48, 49 & 50	579041.10	4158328.25	2.85	2.85	0.00	0.0000
1553	Tiles 48, 49 & 50	579047.97	4158330.28	2.83	2.95	0.12	0.0144
1560	Tiles 48, 49 & 50	579082.94	4158336.62	3.02	3.08	0.06	0.0036
2443	Tiles 79, 80 & 81	583035.95	4152883.72	8.30	8.18	-0.12	0.0144
2446	Tiles 79, 80 & 81	583006.39	4152880.28	8.09	8.04	-0.05	0.0025
2447	Tiles 79, 80 & 81	582996.56	4152878.23	7.87	7.79	-0.08	0.0064
2449	Tiles 79, 80 & 81	582977.31	4152872.41	7.40	7.36	-0.04	0.0016
2451	Tiles 79, 80 & 81	582958.66	4152865.48	7.09	7.02	-0.07	0.0049
2452	Tiles 79, 80 & 81	582949.54	4152861.85	6.86	6.77	-0.09	0.0081
2453	Tiles 79, 80 & 81	582940.44	4152858.39	6.64	6.53	-0.11	0.0121
2456	Tiles 79, 80 & 81	582913.68	4152848.64	6.17	6.07	-0.10	0.0100
2458	Tiles 79, 80 & 81	582895.97	4152842.35	5.64	5.57	-0.07	0.0049
2459	Tiles 79, 80 & 81	582887.11	4152839.19	5.51	5.41	-0.10	0.0100
2463	Tiles 79, 80 & 81	582852.50	4152826.13	5.19	5.01	-0.18	0.0324
2465	Tiles 79, 80 & 81	582835.46	4152819.36	5.30	5.18	-0.12	0.0144
2466	Tiles 79, 80 & 81	582826.92	4152815.98	5.35	5.31	-0.04	0.0016
2467	Tiles 79, 80 & 81	582818.32	4152812.45	5.34	5.34	0.00	0.0000
2469	Tiles 79, 80 & 81	582801.15	4152804.98	5.27	5.25	-0.02	0.0004
2470	Tiles 79, 80 & 81	582792.58	4152801.11	5.26	5.25	-0.01	0.0001

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2471	Tiles 79, 80 & 81	582783.90	4152797.14	5.38	5.33	-0.05	0.0025
2473	Tiles 79, 80 & 81	582766.24	4152789.25	5.67	5.64	-0.03	0.0009
2474	Tiles 79, 80 & 81	582757.15	4152785.33	5.61	5.51	-0.10	0.0100
2475	Tiles 79, 80 & 81	582748.01	4152781.33	5.53	5.41	-0.12	0.0144
2484	Tiles 79, 80 & 81	582665.21	4152746.56	5.27	5.09	-0.18	0.0324
2485	Tiles 79, 80 & 81	582656.39	4152742.91	5.37	5.15	-0.22	0.0484
2486	Tiles 79, 80 & 81	582647.79	4152739.29	5.32	5.25	-0.07	0.0049
2487	Tiles 79, 80 & 81	582639.29	4152735.73	5.29	5.26	-0.03	0.0009
2488	Tiles 79, 80 & 81	582630.96	4152732.08	5.29	5.08	-0.21	0.0441
2489	Tiles 79, 80 & 81	582622.78	4152728.19	5.38	5.26	-0.12	0.0144
2490	Tiles 79, 80 & 81	582614.62	4152724.36	5.33	5.34	0.01	0.0001
2492	Tiles 79, 80 & 81	582597.81	4152716.83	5.11	4.96	-0.15	0.0225
2495	Tiles 79, 80 & 81	582571.52	4152705.70	5.03	4.92	-0.11	0.0121
2508	Tiles 79, 80 & 81	582459.53	4152659.78	3.79	3.81	0.02	0.0004
2509	Tiles 79, 80 & 81	582451.41	4152657.35	3.62	3.59	-0.03	0.0009
2510	Tiles 79, 80 & 81	582443.36	4152654.78	3.56	3.54	-0.02	0.0004
2511	Tiles 79, 80 & 81	582435.33	4152651.97	3.53	3.48	-0.05	0.0025
2512	Tiles 79, 80 & 81	582427.15	4152648.96	3.48	3.49	0.01	0.0001
2514	Tiles 79, 80 & 81	582410.73	4152642.41	3.38	3.31	-0.07	0.0049
2515	Tiles 79, 80 & 81	582402.57	4152638.96	3.42	3.36	-0.06	0.0036
2516	Tiles 79, 80 & 81	582394.42	4152635.44	3.43	3.42	-0.01	0.0001
2517	Tiles 79, 80 & 81	582386.33	4152631.89	3.47	3.43	-0.04	0.0016
2518	Tiles 79, 80 & 81	582378.32	4152628.33	3.53	3.49	-0.04	0.0016
2521	Tiles 79, 80 & 81	582354.58	4152617.35	3.62	3.68	0.06	0.0036
2525	Tiles 79, 80 & 81	582323.17	4152603.84	4.11	4.18	0.07	0.0049
2526	Tiles 79, 80 & 81	582315.47	4152600.41	4.08	3.96	-0.12	0.0144
2527	Tiles 79, 80 & 81	582307.81	4152596.89	3.95	3.94	-0.01	0.0001
2528	Tiles 79, 80 & 81	582300.01	4152593.47	3.87	3.90	0.03	0.0009
2531	Tiles 79, 80 & 81	582276.39	4152583.72	3.75	3.73	-0.02	0.0004
2533	Tiles 79, 80 & 81	582260.56	4152576.99	3.64	3.64	0.00	0.0000
2534	Tiles 79, 80 & 81	582252.66	4152573.65	3.63	3.54	-0.09	0.0081
2535	Tiles 79, 80 & 81	582244.93	4152570.23	3.59	3.58	-0.01	0.0001
2536	Tiles 79, 80 & 81	582237.32	4152566.81	3.60	3.58	-0.02	0.0004
2537	Tiles 79, 80 & 81	582229.70	4152563.45	3.59	3.67	0.08	0.0064
2538	Tiles 79, 80 & 81	582221.93	4152560.14	3.50	3.41	-0.09	0.0081
2539	Tiles 79, 80 & 81	582214.07	4152556.78	3.44	3.39	-0.05	0.0025
2540	Tiles 79, 80 & 81	582206.15	4152553.38	3.44	3.50	0.06	0.0036
2541	Tiles 79, 80 & 81	582198.08	4152549.87	3.50	3.44	-0.06	0.0036
2544	Tiles 79, 80 & 81	582174.14	4152538.98	3.72	3.66	-0.06	0.0036
2548	Tiles 79, 80 & 81	582141.81	4152525.23	3.75	3.72	-0.03	0.0009
2549	Tiles 79, 80 & 81	582133.84	4152521.69	3.79	3.68	-0.11	0.0121
2550	Tiles 79, 80 & 81	582125.79	4152518.29	3.79	3.77	-0.02	0.0004
2552	Tiles 79, 80 & 81	582109.59	4152511.19	3.64	3.62	-0.02	0.0004
2554	Tiles 79, 80 & 81	582093.53	4152504.01	3.65	3.63	-0.02	0.0004
2555	Tiles 79, 80 & 81	582085.51	4152500.41	3.62	3.52	-0.10	0.0100
2558	Tiles 79, 80 & 81	582060.78	4152489.37	3.79	3.77	-0.02	0.0004
2559	Tiles 79, 80 & 81	582052.31	4152485.68	3.83	3.80	-0.03	0.0009
2560	Tiles 79, 80 & 81	582043.68	4152482.05	3.81	3.81	0.00	0.0000

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2561	Tiles 79, 80 & 81	582034.93	4152478.31	3.79	3.77	-0.02	0.0004
2562	Tiles 79, 80 & 81	582026.04	4152474.57	3.82	3.82	0.00	0.0000
2565	Tiles 79, 80 & 81	581999.46	4152463.27	3.90	3.88	-0.02	0.0004
2567	Tiles 79, 80 & 81	581982.21	4152455.49	3.87	3.85	-0.02	0.0004
2570	Tiles 79, 80 & 81	581956.15	4152443.96	3.93	3.84	-0.09	0.0081
2573	Tiles 79, 80 & 81	581929.12	4152432.25	3.66	3.64	-0.02	0.0004
2574	Tiles 79, 80 & 81	581919.95	4152428.30	3.67	3.70	0.03	0.0009
2575	Tiles 79, 80 & 81	581910.82	4152424.17	3.72	3.74	0.02	0.0004
2576	Tiles 79, 80 & 81	581901.78	4152420.03	3.78	3.79	0.01	0.0001
2580	Tiles 79, 80 & 81	581865.78	4152403.38	3.58	3.63	0.05	0.0025
2581	Tiles 79, 80 & 81	581856.53	4152399.39	3.69	3.72	0.03	0.0009
2585	Tiles 79, 80 & 81	581820.29	4152383.03	3.72	3.67	-0.05	0.0025
2588	Tiles 79, 80 & 81	581791.99	4152369.40	3.62	3.58	-0.04	0.0016
2589	Tiles 79, 80 & 81	581782.40	4152364.76	3.57	3.60	0.03	0.0009
2590	Tiles 79, 80 & 81	581772.95	4152359.90	3.60	3.61	0.01	0.0001
2593	Tiles 79, 80 & 81	581744.51	4152344.61	3.67	3.67	0.00	0.0000
2594	Tiles 79, 80 & 81	581735.08	4152339.43	3.66	3.69	0.03	0.0009
2595	Tiles 79, 80 & 81	581725.73	4152334.30	3.71	3.72	0.01	0.0001
2596	Tiles 79, 80 & 81	581716.61	4152329.01	3.72	3.73	0.01	0.0001
2597	Tiles 79, 80 & 81	581707.50	4152323.65	3.72	3.77	0.05	0.0025
2598	Tiles 79, 80 & 81	581698.24	4152318.32	3.76	3.79	0.03	0.0009
2599	Tiles 79, 80 & 81	581688.79	4152313.04	3.77	3.80	0.03	0.0009
2601	Tiles 79, 80 & 81	581669.58	4152302.70	3.78	3.90	0.12	0.0144
2606	Tiles 79, 80 & 81	581622.38	4152277.64	3.59	3.68	0.09	0.0081
2610	Tiles 79, 80 & 81	581584.83	4152257.82	3.32	3.31	-0.01	0.0001
2611	Tiles 79, 80 & 81	581575.74	4152252.44	3.37	3.45	0.08	0.0064
2686	Tiles 79, 80 & 81	581610.14	4152271.28	3.49	3.54	0.05	0.0025
2690	Tiles 79, 80 & 81	581640.16	4152287.03	3.71	3.73	0.02	0.0004
2694	Tiles 79, 80 & 81	581670.74	4152303.20	3.78	3.87	0.09	0.0081
2697	Tiles 79, 80 & 81	581694.12	4152316.00	3.77	3.81	0.04	0.0016
2698	Tiles 79, 80 & 81	581702.00	4152320.44	3.73	3.79	0.06	0.0036
2699	Tiles 79, 80 & 81	581709.91	4152325.00	3.71	3.77	0.06	0.0036
2700	Tiles 79, 80 & 81	581717.85	4152329.56	3.71	3.68	-0.03	0.0009
2701	Tiles 79, 80 & 81	581725.88	4152334.13	3.70	3.73	0.03	0.0009
2702	Tiles 79, 80 & 81	581734.06	4152338.75	3.67	3.75	0.08	0.0064
2705	Tiles 79, 80 & 81	581759.49	4152352.62	3.60	3.58	-0.02	0.0004
2707	Tiles 79, 80 & 81	581776.82	4152361.75	3.59	3.58	-0.01	0.0001
2708	Tiles 79, 80 & 81	581785.65	4152366.18	3.57	3.63	0.06	0.0036
2709	Tiles 79, 80 & 81	581794.55	4152370.56	3.64	3.60	-0.04	0.0016
2710	Tiles 79, 80 & 81	581803.48	4152374.92	3.68	3.73	0.05	0.0025
2712	Tiles 79, 80 & 81	581821.53	4152383.52	3.72	3.73	0.01	0.0001
2717	Tiles 79, 80 & 81	581866.66	4152403.94	3.57	3.58	0.01	0.0001
2718	Tiles 79, 80 & 81	581875.56	4152407.85	3.54	3.54	0.00	0.0000
2721	Tiles 79, 80 & 81	581901.93	4152420.02	3.79	3.79	0.00	0.0000
2722	Tiles 79, 80 & 81	581910.85	4152424.15	3.72	3.74	0.02	0.0004
2723	Tiles 79, 80 & 81	581919.77	4152428.23	3.67	3.69	0.02	0.0004
2724	Tiles 79, 80 & 81	581928.74	4152432.17	3.65	3.63	-0.02	0.0004
2730	Tiles 79, 80 & 81	581982.28	4152455.48	3.88	3.86	-0.02	0.0004

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2732	Tiles 79, 80 & 81	582000.18	4152463.46	3.90	3.82	-0.08	0.0064
2733	Tiles 79, 80 & 81	582009.07	4152467.33	3.89	3.87	-0.02	0.0004
2735	Tiles 79, 80 & 81	582026.93	4152474.97	3.81	3.84	0.03	0.0009
2737	Tiles 79, 80 & 81	582045.01	4152482.59	3.80	3.78	-0.02	0.0004
2739	Tiles 79, 80 & 81	582063.38	4152490.60	3.77	3.83	0.06	0.0036
2740	Tiles 79, 80 & 81	582072.48	4152494.60	3.67	3.72	0.05	0.0025
2741	Tiles 79, 80 & 81	582081.53	4152498.62	3.61	3.61	0.00	0.0000
2742	Tiles 79, 80 & 81	582090.47	4152502.66	3.64	3.65	0.01	0.0001
2744	Tiles 79, 80 & 81	582108.27	4152510.52	3.62	3.60	-0.02	0.0004
2745	Tiles 79, 80 & 81	582117.03	4152514.44	3.69	3.73	0.04	0.0016
2746	Tiles 79, 80 & 81	582125.67	4152518.22	3.78	3.79	0.01	0.0001
2747	Tiles 79, 80 & 81	582134.25	4152521.90	3.78	3.74	-0.04	0.0016
2749	Tiles 79, 80 & 81	582151.34	4152529.16	3.73	3.75	0.02	0.0004
2750	Tiles 79, 80 & 81	582159.83	4152532.74	3.75	3.79	0.04	0.0016
2752	Tiles 79, 80 & 81	582176.65	4152540.09	3.70	3.73	0.03	0.0009
2754	Tiles 79, 80 & 81	582193.37	4152547.50	3.58	3.56	-0.02	0.0004
2755	Tiles 79, 80 & 81	582201.58	4152551.28	3.47	3.49	0.02	0.0004
2756	Tiles 79, 80 & 81	582209.77	4152554.95	3.41	3.47	0.06	0.0036
2758	Tiles 79, 80 & 81	582225.95	4152561.96	3.53	3.52	-0.01	0.0001
2759	Tiles 79, 80 & 81	582233.96	4152565.30	3.60	3.62	0.02	0.0004
2760	Tiles 79, 80 & 81	582241.97	4152568.75	3.60	3.61	0.01	0.0001
2761	Tiles 79, 80 & 81	582249.86	4152572.34	3.60	3.59	-0.01	0.0001
2762	Tiles 79, 80 & 81	582257.67	4152575.74	3.64	3.63	-0.01	0.0001
2763	Tiles 79, 80 & 81	582265.35	4152578.96	3.69	3.72	0.03	0.0009
2764	Tiles 79, 80 & 81	582272.87	4152582.15	3.71	3.71	0.00	0.0000
2766	Tiles 79, 80 & 81	582287.46	4152588.23	3.86	3.89	0.03	0.0009
2768	Tiles 79, 80 & 81	582301.50	4152594.04	3.87	3.90	0.03	0.0009
2769	Tiles 79, 80 & 81	582308.37	4152596.99	3.96	3.94	-0.02	0.0004
2770	Tiles 79, 80 & 81	582315.07	4152600.04	4.07	4.10	0.03	0.0009
2771	Tiles 79, 80 & 81	582321.78	4152603.04	4.14	4.18	0.04	0.0016
2772	Tiles 79, 80 & 81	582328.56	4152606.06	4.07	4.11	0.04	0.0016
2776	Tiles 79, 80 & 81	582358.13	4152618.96	3.58	3.67	0.09	0.0081
2779	Tiles 79, 80 & 81	582382.05	4152630.17	3.48	3.43	-0.05	0.0025
2780	Tiles 79, 80 & 81	582390.37	4152633.91	3.42	3.42	0.00	0.0000
2781	Tiles 79, 80 & 81	582398.73	4152637.43	3.41	3.42	0.01	0.0001
2782	Tiles 79, 80 & 81	582407.10	4152640.86	3.39	3.38	-0.01	0.0001
2784	Tiles 79, 80 & 81	582423.76	4152647.53	3.46	3.43	-0.03	0.0009
2785	Tiles 79, 80 & 81	582431.88	4152650.67	3.50	3.48	-0.02	0.0004
2786	Tiles 79, 80 & 81	582439.98	4152653.52	3.55	3.51	-0.04	0.0016
2787	Tiles 79, 80 & 81	582448.07	4152656.13	3.60	3.64	0.04	0.0016
2788	Tiles 79, 80 & 81	582456.09	4152658.62	3.70	3.65	-0.05	0.0025
2789	Tiles 79, 80 & 81	582463.91	4152661.14	4.01	3.99	-0.02	0.0004
2808	Tiles 79, 80 & 81	582621.58	4152728.09	5.35	5.21	-0.14	0.0196
2809	Tiles 79, 80 & 81	582629.73	4152731.89	5.30	5.08	-0.22	0.0484
2810	Tiles 79, 80 & 81	582637.96	4152735.57	5.29	5.17	-0.12	0.0144
2811	Tiles 79, 80 & 81	582646.24	4152739.08	5.30	5.25	-0.05	0.0025
2812	Tiles 79, 80 & 81	582654.51	4152742.56	5.36	5.16	-0.20	0.0400
2816	Tiles 79, 80 & 81	582688.06	4152756.42	5.37	5.21	-0.16	0.0256

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2820	Tiles 79, 80 & 81	582723.49	4152770.75	5.21	5.18	-0.03	0.0009
2821	Tiles 79, 80 & 81	582732.49	4152774.43	5.27	5.24	-0.03	0.0009
2822	Tiles 79, 80 & 81	582741.36	4152778.15	5.43	5.37	-0.06	0.0036
2823	Tiles 79, 80 & 81	582750.13	4152781.91	5.55	5.48	-0.07	0.0049
2824	Tiles 79, 80 & 81	582758.92	4152785.78	5.62	5.65	0.03	0.0009
2827	Tiles 79, 80 & 81	582785.56	4152797.94	5.34	5.33	-0.01	0.0001
2828	Tiles 79, 80 & 81	582794.73	4152802.13	5.25	5.18	-0.07	0.0049
2832	Tiles 79, 80 & 81	582831.82	4152817.84	5.32	5.32	0.00	0.0000
2838	Tiles 79, 80 & 81	582887.30	4152839.16	5.51	5.41	-0.10	0.0100
2839	Tiles 79, 80 & 81	582896.66	4152842.48	5.64	5.58	-0.06	0.0036
2841	Tiles 79, 80 & 81	582915.06	4152849.08	6.21	6.10	-0.11	0.0121
2845	Tiles 79, 80 & 81	582950.63	4152862.01	6.87	6.80	-0.07	0.0049
2846	Tiles 79, 80 & 81	582959.26	4152865.20	7.09	7.02	-0.07	0.0049
2852	Tiles 79, 80 & 81	583012.89	4152881.31	8.20	8.15	-0.05	0.0025
2854	Tiles 79, 80 & 81	583032.02	4152883.27	8.30	8.31	0.01	0.0001
2858	Tiles 79, 80 & 81	583070.54	4152887.52	8.41	8.28	-0.13	0.0169
2914	Tiles 79, 80 & 81	583398.35	4152894.98	5.49	5.49	0.00	0.0000
2915	Tiles 79, 80 & 81	583404.98	4152894.60	5.03	5.09	0.06	0.0036
2917	Tiles 79, 80 & 81	583418.79	4152894.39	4.66	4.70	0.04	0.0016
2919	Tiles 79, 80 & 81	583432.69	4152895.65	4.26	4.27	0.01	0.0001
2922	Tiles 79, 80 & 81	583454.05	4152902.12	3.51	3.48	-0.03	0.0009
2925	Tiles 79, 80 & 81	583474.51	4152913.96	3.52	3.52	0.00	0.0000
2926	Tiles 79, 80 & 81	583481.08	4152918.25	3.55	3.50	-0.05	0.0025
2928	Tiles 79, 80 & 81	583494.31	4152927.90	3.45	3.46	0.01	0.0001
2933	Tiles 79, 80 & 81	583531.98	4152950.36	3.45	3.49	0.04	0.0016
2936	Tiles 79, 80 & 81	583556.92	4152961.49	3.33	3.42	0.09	0.0081
2939	Tiles 79, 80 & 81	583581.65	4152974.85	3.26	3.28	0.02	0.0004
2940	Tiles 79, 80 & 81	583589.45	4152979.71	3.27	3.22	-0.05	0.0025
2942	Tiles 79, 80 & 81	583604.53	4152989.39	3.23	3.25	0.02	0.0004
2947	Tiles 79, 80 & 81	583637.35	4153011.59	3.08	3.09	0.01	0.0001
2948	Tiles 79, 80 & 81	583642.08	4153015.18	3.05	2.97	-0.08	0.0064
2949	Tiles 79, 80 & 81	583646.92	4153017.79	3.01	3.03	0.02	0.0004
2958	Tiles 79, 80 & 81	583683.15	4152978.37	3.20	3.16	-0.04	0.0016
2959	Tiles 79, 80 & 81	583686.93	4152969.84	3.21	3.11	-0.10	0.0100
2960	Tiles 79, 80 & 81	583690.82	4152961.02	3.20	3.07	-0.13	0.0169
2961	Tiles 79, 80 & 81	583694.78	4152951.98	3.19	3.20	0.01	0.0001
2962	Tiles 79, 80 & 81	583698.78	4152942.78	3.25	3.16	-0.09	0.0081
2963	Tiles 79, 80 & 81	583702.83	4152933.44	3.32	3.38	0.06	0.0036
2964	Tiles 79, 80 & 81	583706.76	4152923.90	3.29	3.21	-0.08	0.0064
2971	Tiles 79, 80 & 81	583732.92	4152857.48	3.13	3.00	-0.13	0.0169
2977	Tiles 79, 80 & 81	583770.54	4152806.30	3.16	3.12	-0.04	0.0016
2981	Tiles 79, 80 & 81	583796.18	4152770.88	2.99	2.89	-0.10	0.0100
2982	Tiles 79, 80 & 81	583801.44	4152761.60	2.99	2.97	-0.02	0.0004
2983	Tiles 79, 80 & 81	583806.16	4152752.06	3.02	2.91	-0.11	0.0121
2984	Tiles 79, 80 & 81	583810.18	4152742.30	3.06	3.04	-0.02	0.0004
2986	Tiles 79, 80 & 81	583816.41	4152722.33	3.08	3.07	-0.01	0.0001
2987	Tiles 79, 80 & 81	583818.77	4152712.13	3.01	3.00	-0.01	0.0001
3122	Tiles 79, 80 & 81	583963.75	4152345.88	3.69	3.66	-0.03	0.0009

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3158	Tiles 79, 80 & 81	583846.40	4152594.10	3.02	2.93	-0.09	0.0081
3163	Tiles 79, 80 & 81	583828.36	4152644.19	3.05	2.93	-0.12	0.0144
3164	Tiles 79, 80 & 81	583826.15	4152655.16	3.04	3.00	-0.04	0.0016
3167	Tiles 79, 80 & 81	583821.91	4152688.89	3.05	3.07	0.02	0.0004
3169	Tiles 79, 80 & 81	583818.71	4152711.23	3.00	3.01	0.01	0.0001
3170	Tiles 79, 80 & 81	583816.38	4152722.07	3.08	3.05	-0.03	0.0009
3173	Tiles 79, 80 & 81	583805.92	4152752.62	3.03	2.92	-0.11	0.0121
3174	Tiles 79, 80 & 81	583801.11	4152762.00	3.00	2.97	-0.03	0.0009
3175	Tiles 79, 80 & 81	583795.69	4152771.13	2.99	2.91	-0.08	0.0064
3185	Tiles 79, 80 & 81	583733.46	4152857.62	3.13	3.06	-0.07	0.0049
3186	Tiles 79, 80 & 81	583728.79	4152866.57	3.18	3.07	-0.11	0.0121
3191	Tiles 79, 80 & 81	583709.89	4152916.03	3.25	3.15	-0.10	0.0100
3192	Tiles 79, 80 & 81	583705.74	4152926.13	3.30	3.31	0.01	0.0001
3193	Tiles 79, 80 & 81	583701.49	4152936.19	3.29	3.24	-0.05	0.0025
3198	Tiles 79, 80 & 81	583679.26	4152985.57	3.29	3.25	-0.04	0.0016
3201	Tiles 79, 80 & 81	583667.85	4153009.78	3.24	3.18	-0.06	0.0036
3205	Tiles 79, 80 & 81	583647.34	4153018.18	3.03	3.00	-0.03	0.0009
3206	Tiles 79, 80 & 81	583641.89	4153015.43	3.05	2.98	-0.07	0.0049
3207	Tiles 79, 80 & 81	583636.23	4153011.32	3.08	3.03	-0.05	0.0025
3208	Tiles 79, 80 & 81	583629.97	4153006.51	3.10	3.03	-0.07	0.0049
3209	Tiles 79, 80 & 81	583623.03	4153001.47	3.12	3.08	-0.04	0.0016
3214	Tiles 79, 80 & 81	583581.11	4152974.99	3.26	3.27	0.01	0.0001
3217	Tiles 79, 80 & 81	583553.83	4152960.64	3.32	3.31	-0.01	0.0001
3219	Tiles 79, 80 & 81	583536.17	4152952.66	3.41	3.43	0.02	0.0004
3223	Tiles 79, 80 & 81	583502.79	4152934.95	3.45	3.41	-0.04	0.0016
3225	Tiles 79, 80 & 81	583488.59	4152924.10	3.50	3.51	0.01	0.0001
3226	Tiles 79, 80 & 81	583482.98	4152917.82	3.55	3.58	0.03	0.0009
3228	Tiles 79, 80 & 81	583476.63	4152903.48	3.86	3.85	-0.01	0.0001
3229	Tiles 79, 80 & 81	583476.20	4152895.51	4.21	4.22	0.01	0.0001
3230	Tiles 79, 80 & 81	583477.46	4152887.47	4.58	4.58	0.00	0.0000
3231	Tiles 79, 80 & 81	583480.52	4152879.44	4.96	4.89	-0.07	0.0049
3232	Tiles 79, 80 & 81	583484.84	4152871.48	5.27	5.18	-0.09	0.0081
3234	Tiles 79, 80 & 81	583493.74	4152855.77	5.81	5.86	0.05	0.0025
3235	Tiles 79, 80 & 81	583497.77	4152847.87	6.06	6.07	0.01	0.0001
3238	Tiles 79, 80 & 81	583508.76	4152825.73	5.61	5.59	-0.02	0.0004
3239	Tiles 79, 80 & 81	583512.54	4152818.76	5.03	5.06	0.03	0.0009
3240	Tiles 79, 80 & 81	583516.32	4152811.59	4.68	4.65	-0.03	0.0009
3243	Tiles 79, 80 & 81	583522.41	4152791.37	5.98	5.89	-0.09	0.0081
3244	Tiles 79, 80 & 81	583521.81	4152785.12	6.58	6.54	-0.04	0.0016
3245	Tiles 79, 80 & 81	583519.83	4152779.34	7.00	7.04	0.04	0.0016
3248	Tiles 79, 80 & 81	583510.26	4152766.66	7.37	7.35	-0.02	0.0004
3255	Tiles 79, 80 & 81	583498.78	4152760.92	7.08	7.06	-0.02	0.0004
3258	Tiles 79, 80 & 81	583496.20	4152763.16	7.05	6.98	-0.07	0.0049
3259	Tiles 79, 80 & 81	583495.70	4152764.70	7.01	6.96	-0.05	0.0025
3260	Tiles 79, 80 & 81	583495.78	4152766.25	6.95	6.90	-0.05	0.0025
3261	Tiles 79, 80 & 81	583496.38	4152767.68	6.90	6.89	-0.01	0.0001
3262	Tiles 79, 80 & 81	583497.31	4152768.81	6.92	6.85	-0.07	0.0049
3263	Tiles 79, 80 & 81	583498.59	4152769.60	6.95	6.91	-0.04	0.0016

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3264	Tiles 79, 80 & 81	583500.06	4152769.84	7.02	6.99	-0.03	0.0009
3265	Tiles 79, 80 & 81	583501.87	4152769.77	7.09	7.09	0.00	0.0000
3266	Tiles 79, 80 & 81	583503.93	4152769.58	7.19	7.18	-0.01	0.0001
3267	Tiles 79, 80 & 81	583506.16	4152769.54	7.29	7.26	-0.03	0.0009
3268	Tiles 79, 80 & 81	583508.50	4152769.68	7.33	7.27	-0.06	0.0036
3269	Tiles 79, 80 & 81	583511.10	4152770.16	7.33	7.32	-0.01	0.0001
3271	Tiles 79, 80 & 81	583516.70	4152773.07	7.30	7.33	0.03	0.0009
3274	Tiles 79, 80 & 81	583522.59	4152784.57	6.66	6.61	-0.05	0.0025
3276	Tiles 79, 80 & 81	583522.48	4152796.44	5.41	5.37	-0.04	0.0016
3278	Tiles 79, 80 & 81	583517.78	4152809.31	4.65	4.63	-0.02	0.0004
3280	Tiles 79, 80 & 81	583511.58	4152820.77	5.17	5.17	0.00	0.0000
3281	Tiles 79, 80 & 81	583508.64	4152825.95	5.63	5.60	-0.03	0.0009
3282	Tiles 79, 80 & 81	583505.93	4152831.16	5.99	6.05	0.06	0.0036
3284	Tiles 79, 80 & 81	583500.66	4152842.67	6.19	6.17	-0.02	0.0004
3285	Tiles 79, 80 & 81	583497.85	4152849.18	6.06	6.02	-0.04	0.0016
3286	Tiles 79, 80 & 81	583494.74	4152855.89	5.85	5.79	-0.06	0.0036
3287	Tiles 79, 80 & 81	583491.24	4152862.46	5.63	5.51	-0.12	0.0144
3288	Tiles 79, 80 & 81	583487.54	4152868.63	5.41	5.44	0.03	0.0009
3289	Tiles 79, 80 & 81	583483.91	4152874.47	5.18	5.17	-0.01	0.0001
3290	Tiles 79, 80 & 81	583480.73	4152880.25	4.93	4.91	-0.02	0.0004
3291	Tiles 79, 80 & 81	583478.36	4152886.18	4.68	4.63	-0.05	0.0025
3292	Tiles 79, 80 & 81	583477.01	4152892.00	4.38	4.37	-0.01	0.0001
3293	Tiles 79, 80 & 81	583476.62	4152897.61	4.14	4.09	-0.05	0.0025
3294	Tiles 79, 80 & 81	583476.42	4152902.38	3.91	3.94	0.03	0.0009
3296	Tiles 79, 80 & 81	583472.92	4152908.55	3.73	3.75	0.02	0.0004
3297	Tiles 79, 80 & 81	583469.53	4152909.53	3.49	3.44	-0.05	0.0025
3298	Tiles 79, 80 & 81	583465.26	4152908.63	3.42	3.40	-0.02	0.0004
3299	Tiles 79, 80 & 81	583460.02	4152905.96	3.46	3.42	-0.04	0.0016
3300	Tiles 79, 80 & 81	583453.75	4152902.71	3.50	3.51	0.01	0.0001
3303	Tiles 79, 80 & 81	583430.10	4152895.77	4.34	4.42	0.08	0.0064

Statistics (Meters)	
Average Dz	-0.0191
Average $(Dz)^2$	0.0045
Sum of $(Dz)^2$	2.6936
Standard Deviation	0.0647
RMSE	0.0674
NSSDA	0.1321

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Appendix B. Static GPS Statistical Comparisons

Project 2206, South San Francisco Bay
GPS / LiDAR Comparisons

Static GPS Checks

Comparisons constrained to a maximum triangle length of 3 metres and maximum slope of 60 degrees

Section 1 of 5

Point Number	Location Description	Easting	Northing	Known Z	Laser Z	Dz	$(Dz)^2$
1	Tile 88	574824	4150721	1.98	2.16	0.18	0.0324
2	Tile 88	574788.9	4150726	1.92	2.17	0.25	0.0625
3	Tile 88	574759.7	4150731	1.99	2.22	0.23	0.0529
4	Tile 88	574730.5	4150736	2.03	2.17	0.14	0.0196
5	Tile 88	574688.9	4150743	2.05	2.35	0.30	0.0900
6	Tile 88	574660.8	4150747	1.95	2.25	0.30	0.0900
7	Tile 88	574621.2	4150754	2.01	2.21	0.20	0.0400
8	Tile 88	574591.6	4150758	2	2.26	0.26	0.0676
9	Tile 88	574548.8	4150765	1.89	2	0.11	0.0121
10	Tile 88	574547.3	4150769	1.69	1.63	-0.06	0.0036
11	Tile 88	574547.4	4150770	1.75	1.86	0.11	0.0121
12	Tile 88	574570.2	4150764	1.89	2.18	0.29	0.0841
13	Tile 88	574607.5	4150758	2.03	2.27	0.24	0.0576
14	Tile 88	574642.7	4150752	2.1	2.21	0.11	0.0121
15	Tile 88	574689.4	4150744	2.1	2.33	0.23	0.0529
16	Tile 88	574730.1	4150737	2.03	2.25	0.22	0.0484
17	Tile 88	574761.1	4150733	1.98	2.2	0.22	0.0484
19	Tile 88	574809.7	4150725	2.05	2.16	0.11	0.0121
20	Tile 88	574830.1	4150720	3.04	3.16	0.12	0.0144
21	Tile 88	574537.3	4150768	0.36	0.39	0.03	0.0009
22	Tile 88	574534	4150768	0.28	0.37	0.09	0.0081
23	Tile 88	574534	4150768	0.29	0.37	0.08	0.0064
25	Tile 88	574537.8	4150769	0.37	0.35	-0.02	0.0004
26	Tile 88	574534.7	4150769	0.5	0.38	-0.12	0.0144

Statistics (Metres)	
Average Dz	0.1508
Average $(Dz)^2$	0.0351
Sum of $(Dz)^2$	0.8430
Standard Deviation	0.1136
RMSE	0.1874
NSSDA	0.3673

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Point Number	Location Description	Easting	Northing	Known Z	Laser Z	Dz	$(Dz)^2$
27	Tiles 112 & 123	580893.8	4145208	1.24	1.15	-0.09	0.0081
36	Tiles 112 & 123	580995.6	4145178	3.25	3.2	-0.05	0.0025
37	Tiles 112 & 123	580996.3	4145180	3.4	3.39	-0.01	0.0001
38	Tiles 112 & 123	580997.2	4145183	3.27	3.13	-0.14	0.0196
40	Tiles 112 & 123	581043.3	4145159	3.15	3.2	0.05	0.0025
41	Tiles 112 & 123	581044.3	4145162	3.38	3.29	-0.09	0.0081
42	Tiles 112 & 123	581045.7	4145165	3.1	3.09	-0.01	0.0001
43	Tiles 112 & 123	580909	4145212	3.31	3.18	-0.13	0.0169
44	Tiles 112 & 123	580911.4	4145219	2.54	2.81	0.27	0.0729
46	Tiles 112 & 123	580914.2	4145240	2.26	2.54	0.28	0.0784
47	Tiles 112 & 123	580903.7	4145247	2.28	2.3	0.02	0.0004
48	Tiles 112 & 123	580891.8	4145254	2.02	2.18	0.16	0.0256
57	Tiles 112 & 123	580884.5	4145260	1.7	1.7	0.00	0.0000
58	Tiles 112 & 123	580906	4145247	2.18	2.37	0.19	0.0361

Statistics (Metres)	
Average Dz	0.0321
Average $(Dz)^2$	0.0181
Sum of $(Dz)^2$	0.2713
Standard Deviation	0.1406
RMSE	0.1345
NSSDA	0.2636

Section 3 of 5

Point Number	Location Description	Easting	Northing	Known Z	Laser Z	Dz	$(Dz)^2$
62	Tile 129	592010.2	4144301	3.45	3.71	0.26	0.0676
63	Tile 129	592010.2	4144301	3.45	3.71	0.26	0.0676
67	Tile 129	591987.8	4144325	3.55	3.57	0.02	0.0004
68	Tile 129	591990	4144327	3.76	3.81	0.05	0.0025
69	Tile 129	591992.8	4144329	3.59	3.63	0.04	0.0016
72	Tile 129	591966	4144362	3.91	3.92	0.01	0.0001
73	Tile 129	591966.1	4144362	3.94	3.93	-0.01	0.0001
74	Tile 129	591968.5	4144364	3.85	3.97	0.12	0.0144
76	Tile 129	591947.4	4144387	3.67	3.77	0.10	0.0100
77	Tile 129	591949.2	4144388	3.84	3.89	0.05	0.0025
79	Tile 129	591871.8	4144255	1.77	1.84	0.07	0.0049
80	Tile 129	591872.1	4144251	2.94	2.95	0.01	0.0001
81	Tile 129	591872	4144249	3.15	3.08	-0.07	0.0049
83	Tile 129	591863.2	4144207	0.5	0.65	0.15	0.0225
84	Tile 129	591859.1	4144188	0.41	0.57	0.16	0.0256
86	Tile 129	591851.6	4144095	0.29	0.43	0.14	0.0196
88	Tile 129	591858.3	4144058	0.41	0.74	0.33	0.1089

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91	Tile 129	591859.7	4144203	0.34	0.43	0.09	0.0081
92	Tile 129	591861	4144203	0.87	0.48	-0.39	0.1521
93	Tile 129	591862.5	4144213	0.52	0.51	-0.01	0.0001

Statistics (Metres)	
Average Dz	0.0690
Average $(Dz)^2$	0.0245
Sum of $(Dz)^2$	0.5136
Standard Deviation	0.1484
RMSE	0.1564
NSSDA	0.3065

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Point Number	Location Description	Easting	Northing	Known Z	Laser Z	Dz	$(Dz)^2$
94	Tile 26 (South)	575773.9	4162371	1.57	1.49	-0.08	0.0064
95	Tile 26 (South)	575764.9	4162371	2.19	2.12	-0.07	0.0049
96	Tile 26 (South)	575760.9	4162371	3.33	3.21	-0.12	0.0144
97	Tile 26 (South)	575758.3	4162371	3.54	3.44	-0.10	0.0100
98	Tile 26 (South)	575754.3	4162372	3.41	3.3	-0.11	0.0121
99	Tile 26 (South)	575750.1	4162373	2.51	2.36	-0.15	0.0225
100	Tile 26 (South)	575734.3	4162374	2.03	2.02	-0.01	0.0001
101	Tile 26 (South)	575718.3	4162375	2.04	2.11	0.07	0.0049
102	Tile 26 (South)	575699.3	4162375	2.1	2.13	0.03	0.0009
103	Tile 26 (South)	575680.5	4162372	1.73	2.26	0.53	0.2809
104	Tile 26 (South)	575681.3	4162360	2.12	2.24	0.12	0.0144
105	Tile 26 (South)	575694.8	4162358	2.09	1.96	-0.13	0.0169
106	Tile 26 (South)	575716.7	4162358	2.06	2.03	-0.03	0.0009
107	Tile 26 (South)	575735.7	4162357	2.06	2.02	-0.04	0.0016
108	Tile 26 (South)	575749.8	4162357	2.29	2.31	0.02	0.0004
109	Tile 26 (South)	575754.4	4162358	3.09	3.04	-0.05	0.0025
110	Tile 26 (South)	575757.9	4162357	3.41	3.3	-0.11	0.0121
111	Tile 26 (South)	575761.7	4162357	3.18	3.1	-0.08	0.0064
112	Tile 26 (South)	575764.3	4162357	2.31	2.39	0.08	0.0064
113	Tile 26 (South)	575773.3	4162356	1.53	1.52	-0.01	0.0001
115	Tile 26 (South)	575766.8	4162329	2.11	2.12	0.01	0.0001
116	Tile 26 (South)	575763.1	4162328	3.39	3.27	-0.12	0.0144
117	Tile 26 (South)	575759.7	4162328	3.47	3.24	-0.23	0.0529
118	Tile 26 (South)	575756.1	4162328	3.33	3.18	-0.15	0.0225
119	Tile 26 (South)	575752.5	4162328	2.25	2.19	-0.06	0.0036
120	Tile 26 (South)	575733.5	4162328	2.01	2.07	0.06	0.0036
121	Tile 26 (South)	575713	4162329	2.01	2.1	0.09	0.0081
122	Tile 26 (South)	575685.7	4162330	2.07	1.99	-0.08	0.0064
123	Tile 26 (South)	575665.9	4162331	2.11	2.09	-0.02	0.0004
124	Tile 26 (South)	575657.2	4162304	2.08	2.14	0.06	0.0036
125	Tile 26 (South)	575679.6	4162299	2.06	2.12	0.06	0.0036
126	Tile 26 (South)	575707.3	4162297	2.08	2.08	0.00	0.0000

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127	Tile 26 (South)	575733.3	4162295	2.04	2.03	-0.01	0.0001
128	Tile 26 (South)	575753.9	4162295	2.16	2.13	-0.03	0.0009
129	Tile 26 (South)	575758.9	4162295	3.3	3.24	-0.06	0.0036
130	Tile 26 (South)	575761.4	4162295	3.41	3.29	-0.12	0.0144
131	Tile 26 (South)	575774.8	4162296	1.55	1.45	-0.10	0.0100
132	Tile 26 (South)	575775.6	4162274	1.5	1.36	-0.14	0.0196
133	Tile 26 (South)	575768.9	4162274	2.14	2.04	-0.10	0.0100
137	Tile 26 (South)	575754.9	4162274	2.15	2.3	0.15	0.0225
138	Tile 26 (South)	575739.3	4162281	2.09	2.11	0.02	0.0004
139	Tile 26 (South)	575709.9	4162293	2.07	2.13	0.06	0.0036
140	Tile 26 (South)	575681.6	4162306	2.07	2.17	0.10	0.0100
141	Tile 26 (South)	575657	4162315	2.09	2.14	0.05	0.0025
142	Tile 26 (South)	575683	4162329	2.05	2.11	0.06	0.0036
143	Tile 26 (South)	575710.8	4162344	2.07	2.02	-0.05	0.0025

Statistics (Metres)	
Average Dz	-0.0183
Average $(Dz)^2$	0.0087
Sum of $(Dz)^2$	0.2084
Standard Deviation	0.0933
RMSE	0.0932
NSSDA	0.1826

Section 5 of 5

Point Number	Location Description	Easting	Northing	Known Z	Laser Z	Dz	$(Dz)^2$
144	Tile 26 (North)	576507.6	4162903	1.83	1.72	-0.11	0.0121
145	Tile 26 (North)	576500.2	4162906	2.4	2.42	0.02	0.0004
147	Tile 26 (North)	576489.8	4162910	3.52	3.54	0.02	0.0004
148	Tile 26 (North)	576483.8	4162912	1.99	2	0.01	0.0001
150	Tile 26 (North)	576489.4	4162930	1.95	2.01	0.06	0.0036
151	Tile 26 (North)	576494.5	4162929	3.37	3.2	-0.17	0.0289
153	Tile 26 (North)	576500.6	4162926	3.32	3.25	-0.07	0.0049
154	Tile 26 (North)	576507	4162924	2.39	2.33	-0.06	0.0036
155	Tile 26 (North)	576514.5	4162924	1.96	1.71	-0.25	0.0625
157	Tile 26 (North)	576512.4	4162945	2.48	2.5	0.02	0.0004
158	Tile 26 (North)	576505.8	4162948	3.41	3.36	-0.05	0.0025
160	Tile 26 (North)	576501	4162949	3.15	3.16	0.01	0.0001
161	Tile 26 (North)	576496.8	4162952	2.03	2.17	0.14	0.0196
162	Tile 26 (North)	576513.5	4162976	3.35	3.32	-0.03	0.0009
164	Tile 26 (North)	576468.6	4162905	1.97	2	0.03	0.0009
165	Tile 26 (North)	576436.1	4162928	1.89	1.96	0.07	0.0049
166	Tile 26 (North)	576441.7	4162942	1.89	2.01	0.12	0.0144
168	Tile 26 (North)	576487.4	4162938	1.98	2.04	0.06	0.0036
169	Tile 26 (North)	576475.5	4162945	1.9	1.95	0.05	0.0025
170	Tile 26 (North)	576463.8	4162952	1.85	1.87	0.02	0.0004
171	Tile 26 (North)	576448.4	4162959	1.83	1.96	0.13	0.0169

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172	Tile 26 (North)	576454.3	4162977	1.91	2	0.09	0.0081
173	Tile 26 (North)	576464.8	4162970	1.85	1.75	-0.10	0.0100
174	Tile 26 (North)	576478.1	4162964	1.93	1.99	0.06	0.0036
175	Tile 26 (North)	576494.3	4162958	1.99	2	0.01	0.0001
176	Tile 26 (North)	576495.6	4162978	2	2.05	0.05	0.0025
177	Tile 26 (North)	576480.6	4162986	1.93	1.94	0.01	0.0001
178	Tile 26 (North)	576467.7	4162991	1.85	1.79	-0.06	0.0036
179	Tile 26 (North)	576457.8	4162994	1.87	1.97	0.10	0.0100
180	Tile 26 (North)	576430.5	4162923	1.88	1.98	0.10	0.0100
181	Tile 26 (North)	576419.1	4162931	3.32	3.23	-0.09	0.0081
182	Tile 26 (North)	576415.4	4162932	3.14	2.99	-0.15	0.0225
183	Tile 26 (North)	576424.3	4162950	3.23	3.34	0.11	0.0121
184	Tile 26 (North)	576427.2	4162948	3.38	3.3	-0.08	0.0064
185	Tile 26 (North)	576431.1	4162946	3	2.96	-0.04	0.0016
186	Tile 26 (North)	576436	4162944	2.03	2.14	0.11	0.0121
188	Tile 26 (North)	576435.3	4162931	1.85	1.87	0.02	0.0004
189	Tile 26 (North)	576430.6	4162934	2.12	2.18	0.06	0.0036
190	Tile 26 (North)	576426.9	4162936	3.04	2.92	-0.12	0.0144
191	Tile 26 (North)	576422.7	4162939	3.33	3.3	-0.03	0.0009
192	Tile 26 (North)	576418.5	4162940	3.14	3.04	-0.10	0.0100

Statistics (Metres)	
Average Dz	0.0087
Average $(Dz)^2$	0.0068
Sum of $(Dz)^2$	0.1635
Standard Deviation	0.0838
RMSE	0.0825
NSSDA	0.1618

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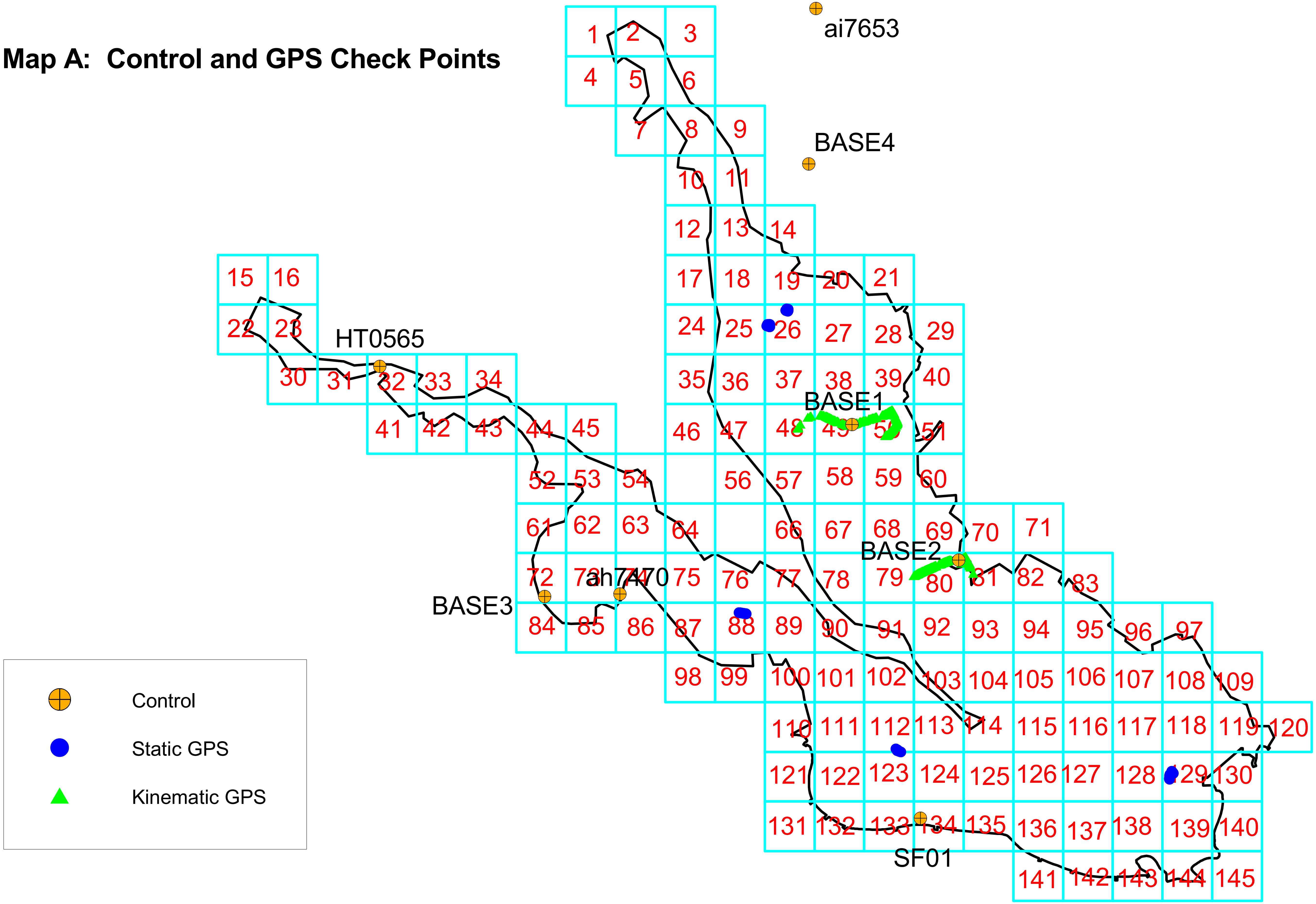
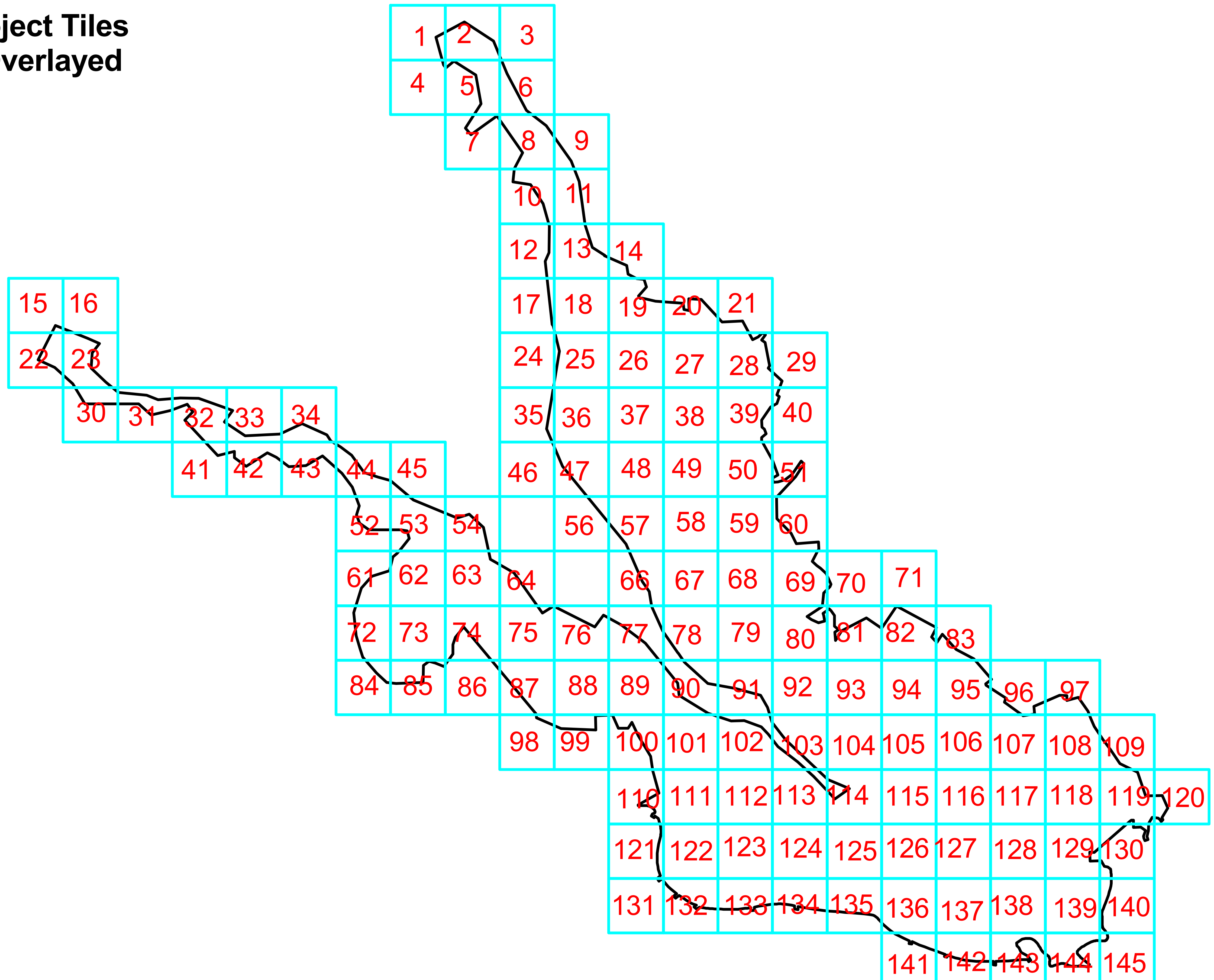
Map A: Control and GPS Check Points



Map B: 2Km Project Tiles with Boundary Overlayed



Map C: 1Km Project Tiles with Boundary Overlayed