LiDAR Quality Assessment Report

The USGS National Geospatial Technical Operations Center, Data Operations Branch is responsible for conducting reviews of all Light Detection and Ranging (LiDAR) point-cloud data and derived products delivered by a data supplier before it is approved for inclusion in the National Elevation Dataset and the Center for LiDAR Information Coordination and Knowledge. The USGS recognizes the complexity of LiDAR collection and processing performed by the data suppliers and has developed this Quality Assessment (QA) procedure to accommodate USGS collection and processing specifications with flexibility. The goal of this process is to assure LiDAR data are of sufficient quality for database population and scientific analysis. Concerns regarding the assessment of these data should be directed to the Chief, Data Operations Branch, 1400 Independence Road, Rolla, Missouri 65401 or NGTOCoperations@usgs.gov.

Materials Received:
10/06/2011-02/29/2012

Project ID:
ARRA-CA_GoldenGate_2010

Project Alias(es):
N/A

Project Type: ARRA Partnership

Project Description:
Golden Gate LiDAR

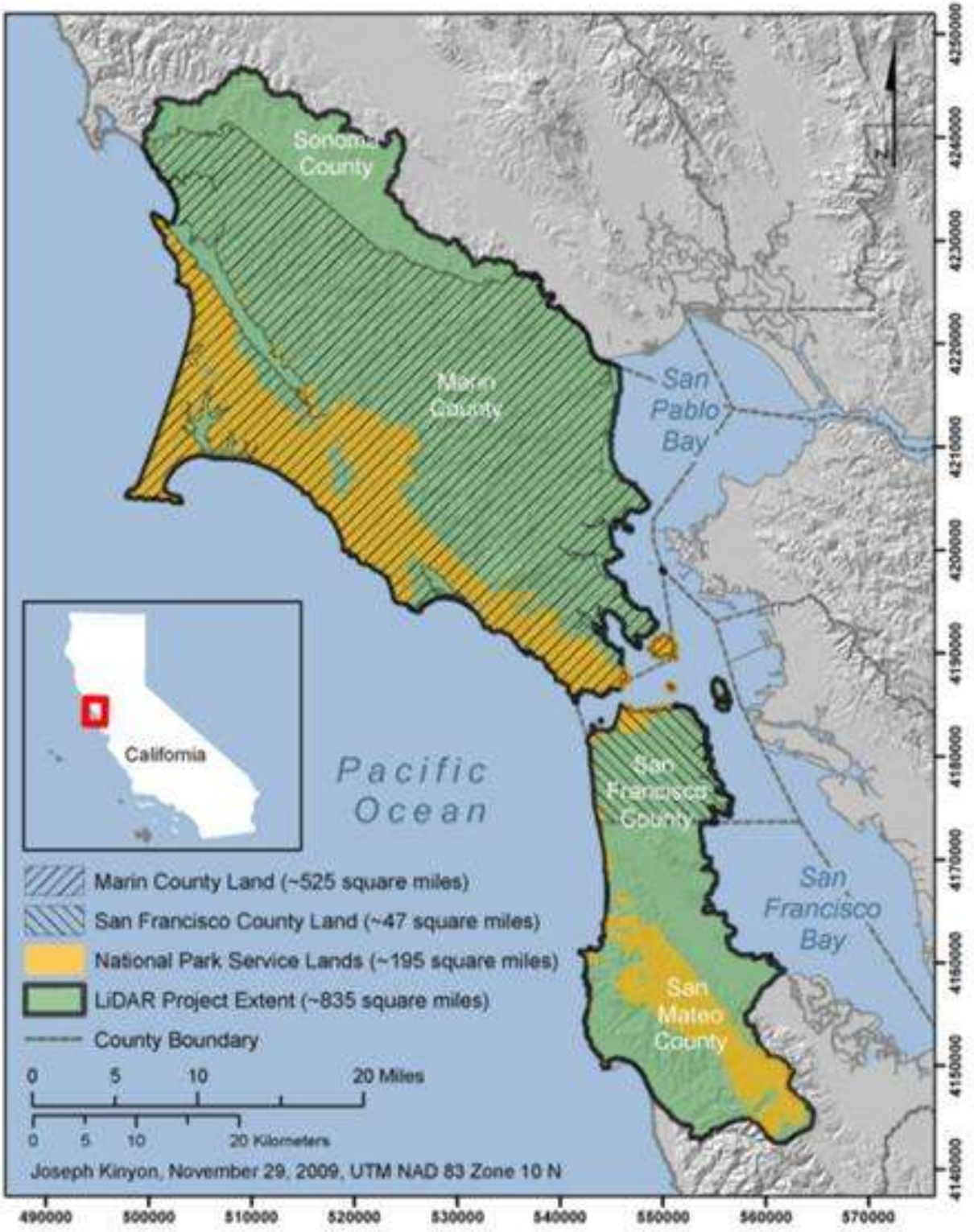
Year of Collection: 2010

Lot 1 of 1 lots.

Project Extent:
☑ Project Extent image?

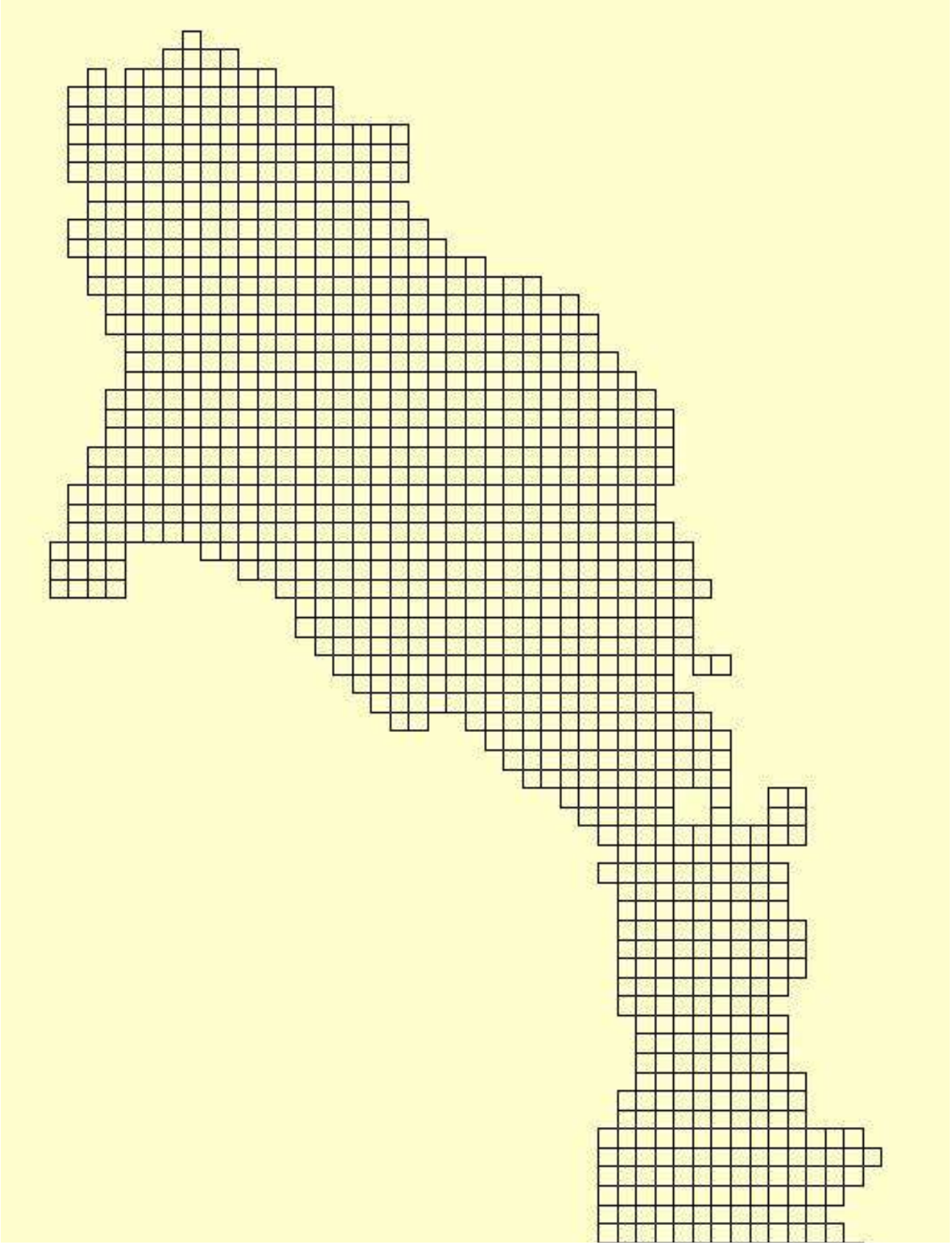
Golden Gate LiDAR Project Area of Acquistion

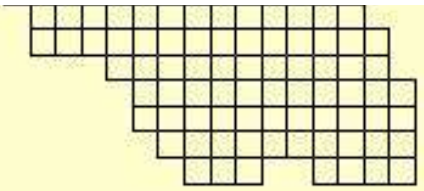
San Francisco State University



Project Tiling Scheme:

☑ Project Tiling Scheme image?





Contractor:
San Francisco State University

Applicable Specification:
V13

Licensing Restrictions:

☐ Third Party Performed QA?

Project Points of Contact:

POC Name	Type	Primary Phone	E-Mail
Teresa Dean	ARRA	703-648-4825	tdean@usgs.gov

Project Deliverables

All project deliverables must be supplied according to collection and processing specifications. The USGS will postpone the QA process when any of the required deliverables are missing. When deliverables are missing, the Contracting Officer Technical Representative (COTR) will be contacted by the Elevation/Orthoimagery Section supervisor and informed of the problem. Processing will resume after the COTR has coordinated the deposition of remaining deliverables.

- ☑ Collection Report
- ☑ Survey Report
- ☑ Processing Report
- ☑ QA/QC Report
- ☐ Control and Calibration Points
- ☑ Project Shapefile/Geodatabase
- ☑ Project Tiling Scheme Shapefile/Gdb
- ☐ Control Point Shapefile/Gdb
- ☑ Breakline Shapefile/Gdb
- ☐ Project XML Metadata

Multi-File Deliverables

File Type	Quantity
☑ Swath LAS Files ☑ Required? ☑ XML Metadata?	309
☑ Intensity Image Files ☑ Required?	1,160
☑ Tiled LAS Files ☑ Required? ☑ XML Metadata?	3,483
☑ Breakline Files ☑ Required? ☐ XML Metadata?	4
☑ Bare-Earth DEM Files ☑ Required? ☑ XML Metadata?	1,158

Additional Deliverables

	Item
☑	LAS 1.3 waveform packets
☑	Control points used in calibration delivered to reviewer in Excel format.

Errors, Anomalies, Other Issues to document? ◉ Yes ○ No

XML Metadata delivered to reviewer at NGTOC on 02/20/2012.

Swath LAS files delivered to reviewer at NGTOC on 02/29/2012.

Vector data including breakline, project boundary, and project tiling scheme shapefiles delivered to reviewer at NGTOC on 02/06/2012.

Project Geographic Information

Areal Extent: 835 Sq Mi
Grid Size: 1 meters
Tile Size: 1500 meters
Nominal Pulse Spacing: 2 meters
Vertical Datum: NAVD88 meters
Horizontal Datum: NAD83 meters

Project Projection/Coordinate Reference System: UTM Zone 10 N meters.

This Projection Coordinate Reference System is consistent across the following deliverables:

☑ Project Shapefile/Geodatabase
☐ Breaklines XML Metadata File
☑ Project Tiling Scheme Shapefile/Gdb
☑ Bare-Earth DEM XML Metadata File

- [ ] Checkpoints Shapefile/Geodatabase
- [ ] Project XML Metadata File
- [x] Swath LAS XML Metadata File
- [x] Classified LAS XML Metadata File
- [x] Swath LAS Files
- [x] Classified LAS Files
- [x] Breaklines Files
- [x] Bare-Earth DEM Files

Check Point Shapefile/Geodatabase CRS

No checkpoint shapefile delivered to reviewer at NGTOC.

Project XML Metadata CRS

No project xml metadata delivered to reviewer at NGTOC.

Breakline XML Metadata CRS

No breakline xml metadata delivered to reviewer at NGTOC.

Review Cycle

This section documents who performed the QA Review on a project as well as when QA reviews were started, actions passed, received, and completed.

Reviewer:

H. Boggs

Review Start Date:

10/06/2011,02/29/2(

Action to Contractor Date	Issue Description	Return Date
10/17/2011	QA completed by reviewer at NGTOC on 10/17/2011. On 02/06/2012 a phone call was arranged for the NGTOC reviewer, SFSU representative Ellen Hines, and Teresa Dean to clarify issues with data. Vector data was delivered via email on 02/06/2012. XML metadata was received by reviewer at NGTOC on 02/20/2012. Swath LAS files were received by reviewer at NGTOC on 02/29/2012.	2/29/2012

Review Complete: 3/6/2012

Metadata Review

Provided metadata files have been parsed using 'mp' metadata parser. Any errors generated by the parser are documented below for reference and/or corrective action.

The Project XML Metadata file parsed with errors.

No project xml metadata delivered to the reviewer at NGTOC.

The Swath LAS XML Metadata file parsed with errors.

```
Executing: mp
G:\LiDAR\Projects\California\GoldenGate_REDO\xml\GoldenGateLidarProject_Uncl
assified_flightlines.xml # # #
Start Time: Thu Feb 23 14:21:13 2012
Running script mp...
"C:\ArcGIS\bin\mp.exe"
GoldenGateLidarProject_Unclassified_flightlines.xml   2>&1
mp GoldenGateLidarProject_Unclassified_flightlines.xml
: mp 2.9.6 - Peter N. Schweitzer (U.S. Geological Survey)
: Info: input file = GoldenGateLidarProject_Unclassified_flightlines.xml
: Error (line 40): Misplaced text in XML before element placekt, will be
discarded
: Error (line 117): Misplaced text in XML before element srccite, will be
discarded
: Error (line 118): Misplaced text in XML before element citeinfo, will be
discarded
: Error (line 133): Misplaced text in XML before element timeinfo, will be
discarded
: Error (line 246): Misplaced text in XML before element mapprojn, will be
discarded
: Error (line 116): Source_Contribution is required in Source_Information
: Error (line 130): improper value for Source_Scale_Denominator
: Error (line 142): Source_Contribution is required in Source_Information
: Error (line 151): improper value for Publication_Date
: Error (line 155): improper value for Source_Scale_Denominator
: Error (line 160): improper value for Calendar_Date
: Error (line 210): Source_Contribution is required in Source_Information
: Error (line 214): improper value for Publication_Date
: Error (line 223): improper value for Source_Scale_Denominator
: Error (line 228): improper value for Calendar_Date
: Error (line 329): too many Contact_Information found in Distributor
: Error (line 373): too many Contact_Information found in Metadata_Contact
: 12 errors: 2 too_many, 3 missing, 7 bad_value
Completed script mp...
Executed (mp) successfully.
     End Time: Thu Feb 23 14:21:13 2012 (Elapsed Time: 0.00 seconds)
```

Reviewer at NGTOC fixed as many errors as possible and created a new xml file named:

GoldenGateLidarProject_Unclassified_flightlines_usgs.xml

This file is located in the METADATA-Documents folder. This xml file created at NGTOC was also run through the USGS metadata parser and the results are shown below.

```
Executing: mp
G:\LiDAR\Projects\California\GoldenGate_REDO\USGS_xml\GoldenGateLidarProject
_Unclassified_flightlines_usgs.xml # # #
Start Time: Fri Feb 24 11:14:45 2012
Running script mp...
"C:\ArcGIS\bin\mp.exe"
GoldenGateLidarProject_Unclassified_flightlines_usgs.xml   2>&1
mp GoldenGateLidarProject_Unclassified_flightlines_usgs.xml
: mp 2.9.6 - Peter N. Schweitzer (U.S. Geological Survey)
: Info: input file =
GoldenGateLidarProject_Unclassified_flightlines_usgs.xml
: 2 errors: 2 empty
Completed script mp...
Executed (mp) successfully.
End Time: Fri Feb 24 11:14:45 2012 (Elapsed Time: 0.00 seconds)
```

The Classified LAS XML Metadata file parsed with errors.

```
Executing: mp
G:\LiDAR\Projects\California\GoldenGate_REDO\xml\GoldenGateLidarProject_Clas
sified_Tiles.xml # # #
Start Time: Thu Feb 23 14:20:12 2012
Running script mp...
"C:\ArcGIS\bin\mp.exe" GoldenGateLidarProject_Classified_Tiles.xml   2>&1
mp GoldenGateLidarProject_Classified_Tiles.xml
: mp 2.9.6 - Peter N. Schweitzer (U.S. Geological Survey)
: Info: input file = GoldenGateLidarProject_Classified_Tiles.xml
: Error (line 39): Misplaced text in XML before element placekt, will be
discarded
: Error (line 116): Misplaced text in XML before element srccite, will be
discarded
: Error (line 117): Misplaced text in XML before element citeinfo, will be
discarded
: Error (line 132): Misplaced text in XML before element timeinfo, will be
discarded
: Error (line 142): Misplaced text in XML before element srccite, will be
discarded
: Error (line 143): Misplaced text in XML before element citeinfo, will be
discarded
: Error (line 245): Misplaced text in XML before element mapprojn, will be
discarded
: Error (line 115): Source_Contribution is required in Source_Information
: Error (line 129): improper value for Source_Scale_Denominator
: Error (line 141): Source_Contribution is required in Source_Information
: Error (line 150): improper value for Publication_Date
: Error (line 154): improper value for Source_Scale_Denominator
: Error (line 159): improper value for Calendar_Date
: Error (line 209): Source_Contribution is required in Source_Information
```

```
 : Error (line 213): improper value for Publication_Date
 : Error (line 222): improper value for Source_Scale_Denominator
 : Error (line 227): improper value for Calendar_Date
 : Error (line 328): too many Contact_Information found in Distributor
 : Error (line 372): too many Contact_Information found in Metadata_Contact
 : 12 errors: 2 too_many, 3 missing, 7 bad_value
 Completed script mp...
 Executed (mp) successfully.
End Time: Thu Feb 23 14:20:12 2012 (Elapsed Time: 0.00 seconds)
```

Reviewer at NGTOC fixed as many errors as possible and created a new xml file named:

GoldenGateLidarProject_Classified_Tiles_usgs.xml

This file is located in the METADATA-Documents folder. This xml file created at NGTOC was also run through the USGS metadata parser and the results are shown below.

```
 Executing: mp
 G:\LiDAR\Projects\California\GoldenGate_REDO\USGS_xml\GoldenGateLidarProject
 _Classified_Tiles_usgs.xml # # #
 Start Time: Fri Feb 24 10:40:47 2012
 Running script mp...
 "C:\ArcGIS\bin\mp.exe" GoldenGateLidarProject_Classified_Tiles_usgs.xml
 2>&1
 mp GoldenGateLidarProject_Classified_Tiles_usgs.xml
 : mp 2.9.6 - Peter N. Schweitzer (U.S. Geological Survey)
 : Info: input file = GoldenGateLidarProject_Classified_Tiles_usgs.xml
 : No errors
 Completed script mp...
 Executed (mp) successfully.
End Time: Fri Feb 24 10:40:47 2012 (Elapsed Time: 0.00 seconds)
```

The Bare-Earth DEM XML Metadata file parsed with errors.

```
 Executing: mp
 G:\LiDAR\Projects\California\GoldenGate_REDO\xml\GoldenGateLidarProject_Bare
 _earth_DEMs.xml # # #
 Start Time: Thu Feb 23 14:16:47 2012
 Running script mp...
 "C:\ArcGIS\bin\mp.exe" GoldenGateLidarProject_Bare_earth_DEMs.xml   2>&1
 mp GoldenGateLidarProject_Bare_earth_DEMs.xml
 : mp 2.9.6 - Peter N. Schweitzer (U.S. Geological Survey)
 : Info: input file = GoldenGateLidarProject_Bare_earth_DEMs.xml
```

```
: Error (line 39): Misplaced text in XML before element placekt, will be
discarded
: Error (line 116): Misplaced text in XML before element srccite, will be
discarded
: Error (line 117): Misplaced text in XML before element citeinfo, will be
discarded
: Error (line 142): Misplaced text in XML before element srccite, will be
discarded
: Error (line 143): Misplaced text in XML before element citeinfo, will be
discarded
: Error (line 210): Misplaced text in XML before element srccite, will be
discarded
: Error (line 211): Misplaced text in XML before element citeinfo, will be
discarded
: Error (line 245): Misplaced text in XML before element mapprojn, will be
discarded
: Error (line 115): Source_Contribution is required in Source_Information
: Error (line 129): improper value for Source_Scale_Denominator
: Error (line 141): Source_Contribution is required in Source_Information
: Error (line 150): improper value for Publication_Date
: Error (line 154): improper value for Source_Scale_Denominator
: Error (line 159): improper value for Calendar_Date
: Error (line 209): Source_Contribution is required in Source_Information
: Error (line 213): improper value for Publication_Date
: Error (line 222): improper value for Source_Scale_Denominator
: Error (line 227): improper value for Calendar_Date
: Error (line 328): too many Contact_Information found in Distributor
: Error (line 372): too many Contact_Information found in Metadata_Contact
: 13 errors: 2 too_many, 3 missing, 1 empty, 7 bad_value
Completed script mp...
Executed (mp) successfully.
End Time: Thu Feb 23 14:16:48 2012 (Elapsed Time: 1.00 seconds)
```

Reviewer at NGTOC fixed as many errors as possible and created a new xml file named:

ARRA-CA_GoldenGate_2010.xml

This is the best use metadata file and will serve as project level metadata. This file is located in the METADATA-Documents folder. This xml file created at NGTOC was also run through the USGS metadata parser and the results are shown below.

```
Executing: mp
G:\LiDAR\Projects\California\GoldenGate_REDO\USGS_xml\GoldenGateLidarProject
_Bare_earth_DEMs_usgs.xml # # #
Start Time: Fri Feb 24 10:40:21 2012
Running script mp...
"C:\ArcGIS\bin\mp.exe" GoldenGateLidarProject_Bare_earth_DEMs_usgs.xml
2>&1
mp GoldenGateLidarProject_Bare_earth_DEMs_usgs.xml
: mp 2.9.6 - Peter N. Schweitzer (U.S. Geological Survey)
: Info: input file = GoldenGateLidarProject_Bare_earth_DEMs_usgs.xml
: No errors
Completed script mp...
```

```
 Executed (mp) successfully.
End Time: Fri Feb 24 10:40:21 2012 (Elapsed Time: 0.00 seconds)
```

Project QA/QC Report Review

ASPRS recommends that checkpoint surveys be used to verify the vertical accuracy of LiDAR data sets. Checkpoints are to be collected by an independent survey firm licensed in the particular state(s) where the project is located. While subjective, checkpoints should be well distributed throughout the dataset. National Standards for Spatial Data Accuracy (NSSDA) guidance states that checkpoints may be distributed more densely in the vicinity of important features and more sparsely in areas that are of little or no interest. Checkpoints should be distributed so that points are spaced at intervals of at least ten percent of the diagonal distance across the dataset and at least twenty percent of the points are located in each quadrant of the dataset.

NSSDA and ASPRS require that a minimum of twenty checkpoints (thirty is preferred) are collected for each major land cover category represented in the LiDAR data. Checkpoints should be selected on flat terrain, or on uniformly sloping terrain in all directions from each checkpoint. They should not be selected near severe breaks in slope, such as bridge abutments, edges of roads, or near river bluffs. Checkpoints are an important component of the USGS QA process. There is the presumption that the checkpoint surveys are error free and the discrepancies are attributable to the LiDAR dataset supplied.

For this dataset, USGS checked the spatial distribution of checkpoints with an emphasis on the bare-earth (open terrain) points; the number of points per class; the methodology used to collect these points; and the relationship between the data supplier and checkpoint collector. When independent control data are available, USGS has incorporated this into the analysis.

Checkpoint Shapefile or Geodatabase:

☐ Checkpoint Distribution Image?

The following land cover classes are represented in this dataset (uncheck any that do not apply):

☐ Bare Earth

☐ Tall Weeds and Crops

☐ Brush Lands and Low Trees

☐ Forested Areas Fully Covered by Trees

☐ Urban Areas with Dense Man-Made Structures

There are a minimum of 20 checkpoints for each land cover class represented. Points within each class are uniformly distributed throughout the dataset. USGS was not able to locate independent checkpoints for this analysis. USGS accepts the quality of the checkpoint data for these LiDAR datasets.

Errors, Anomalies, Other Issues to document? ◉ Yes ○ No

☐ Image?

SFSU did not acquire independent check points to test vertical accuracy. This data will still be accepted as per direction of Teresa Dean on 02/06/2012. In the SFSU_LiDAR_Project_Report, SFSU reported vertical accuracy by adjusting 47 ground control points to the finished product.

Accuracy values are reported in terms of Fundamental Vertical Accuracy (FVA), Supplemental Vertical Accuracy(s) (SVA), and Consolidated Vertical Accuracy (CVA).

Accuracy values are reported in: centimeters

Required FVA Value is centimeters or less.
Target SVA Value is centimeters or less.
Required CVA Value is centimeters or less.

The reported FVA of the LAS Swath data is centimeters.

The reported FVA of the Bare-Earth DEM data is centimeters.

SVA are required for each land cover type present in the data set with the exception of bare-earth. SVA is calculated and reported as a 95th Percentile Error.

Land Cover Type	SVA Value	Units

Tall Weeds and Crops			centimeters
Brush Lands and Low Trees			centimeters
Forested Areas Fully Covered by Trees			centimeters
Urban Areas with Dense Man-Made Structur...			centimeters

The reported CVA of this data set is: centimeters.

LAS Swath File Review

LAS swath files or raw unclassified LiDAR data are reviewed to assess the quality control used by the data supplier during collection. Furthermore, LAS swath data are checked for positional accuracy. The data supplier should have calculated the Fundamental Vertical Accuracy using ground control checkpoints measured in clear open terrain. The following was determined for LAS swath data for this project:

LAS Version

(•) LAS 1.2 ( ) LAS1.3 ( ) LAS 1.4

Swath File Characteristics

[x] Separate folder for LAS swath files

[x] Each swath files <= 2GB

[ ] *If specified, *.wdp files for full waveform have been provided

The reported FVA of the LAS swath data is centimeters.

Based on this review, the USGS accepts the LAS swath file data.

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

[ ] Image?

SFSU did not acquire independent check points to test vertical accuracy. This data will still be accepted as per direction of Teresa Dean on 02/06/2012. In the SFSU_LiDAR_Project_Report, SFSU reported vertical accuracy by adjusting 47 ground control points to the finished product.

[ ] Image?

Swath las files received by reviewer at NGTOC on 02/29/12.

LAS Tile File Review

Classified LAS tile files are used to build digital terrain models using the points classified as ground. Therefore, it is important that the classified LAS are of sufficient quality to ensure that the derivative product accurately represents the landscape that was measured. The following was determined for classified LAS files for this project:

Classified LAS Tile File Characteristics

- [x] Separate folder for Classified LAS tile files
- [x] Classified LAS tile files conform to Project Tiling Scheme
- [x] Quantity of Classified LAS tile files conforms to Project Tiling Scheme
- [x] Classified LAS tile files do not overlap
- [x] Classified LAS tile files are uniform in size
- [x] Classified LAS tile files have no points classified as '12'

- [x] Point classifications are limited to the standard values listed below:

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
7	Noise (low or high, manually identified, if needed)
9	Water
10	Ignored ground (breakline proximity)
11	Withheld (if the "Withheld" bit is not implemented in processing software)

- [x] Buy up?

Additional classifications in this data set.

- [ ] 3 - Tall weeds and crops (low vegetation)
- [x] 4 - Brush lands and low trees (medium vegetation)
- [ ] 5 - Forested areas fully covered by trees
- [ ] 6 - Urban area with dense man-made structures

[x]	4	-	Includes vegetation and all man made objects; buildings, bridges, piers, etc.

Based on this review, the USGS accepts the classified LAS tile file data.

Errors, Anomalies, Other Issues to document? ○ Yes ◉ No

None.

Breakline File Review

Breaklines are vector feature classes that are used to hydro-flatten the bare earth Digital Elevation Models.

Breakline File Characteristics

- [x] Separate folder for breakline files
- [x] All breaklines captured as PolylineZ or PolygonZ features
- [x] No missing or misplaced breaklines

Based on this review, the USGS accepts the breakline files.

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

- [ ] Image for error?

Breaklines delivered to reviewer at NGTOC on 02/06/2012 via email in ArcMap 9.3 shapefile format.

Bare-Earth DEM Tile File Review

The derived bare-earth DEM file receives a review of the vertical accuracies provided by the data supplier, vertical accuracies calculated by USGS using supplied and independent checkpoints, and a manual check of the appearance of the DEM layer.

Bare-Earth DEM files provided in the following format: Erdas Imagine *.img

Bare-Earth DEM Tile File Characteristics

- [x] Separate folder for bare-earth DEM files
- [x] DEM files conform to Project Tiling Scheme
- [ ] Quantity of DEM files conforms to Project Tiling Scheme
- [x] DEM files do not overlap
- [x] DEM files are uniform in size
- [x] DEM files properly edge match

☐ Independent check points are well distributed

All accuracy values reported in centimeters.

Reported Accuracies

Land Cover Category	# of Points	Fundamental Vertical Accuracy @95% Confidence Interval ($Accuracy_z$) Required FVA = or less.	Supplemental Vertical Accuracy @95th Percentile Error Target SVA = or less.	Consolidated Vertical Accuracy @95th Percentile Error Required CVA = or less.
Open Terrain	20			
Tall Weeds and Crops				
Brush Lands and Low Trees				
Forested Areas Fully Covered by Trees				
Urban Areas with Dense Man-Made Structures				
Consolidated	20			

☐ QA performed Accuracy Calculations?

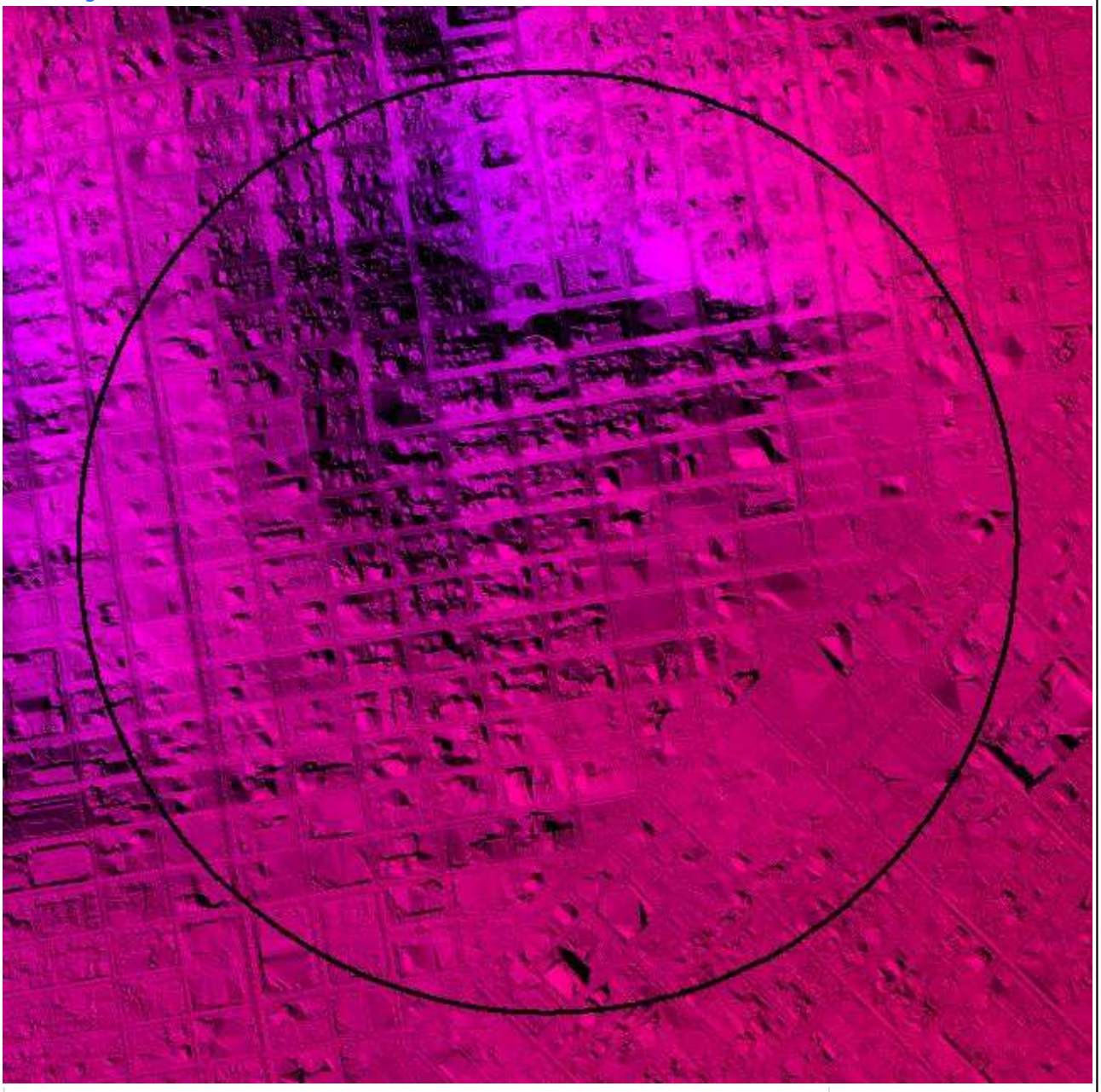
Based on this review, the USGS does not recommend the bare-earth DEM files for inclusion in the 1/3 Arc-Second National Elevation Dataset.

Based on this review, the USGS accepts the bare-earth DEM files.

Bare-Earth DEM Anomalies, Errors, Other Issues

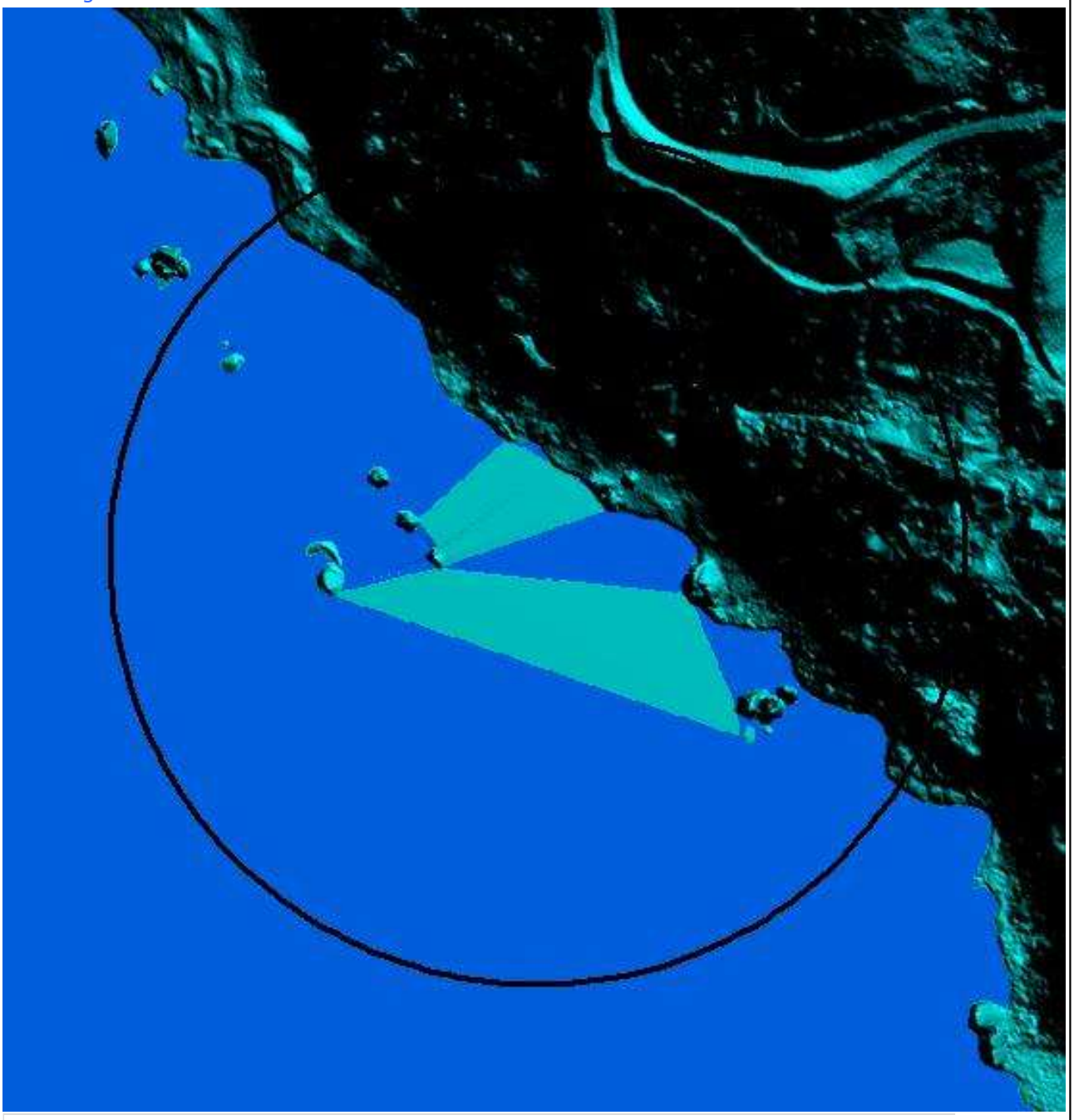
Errors, Anomalies, Other Issues to document? ◉ Yes ○ No

Image?



Buildings improperly removed, resulting in sinks. Scale 1:13,550

Image?

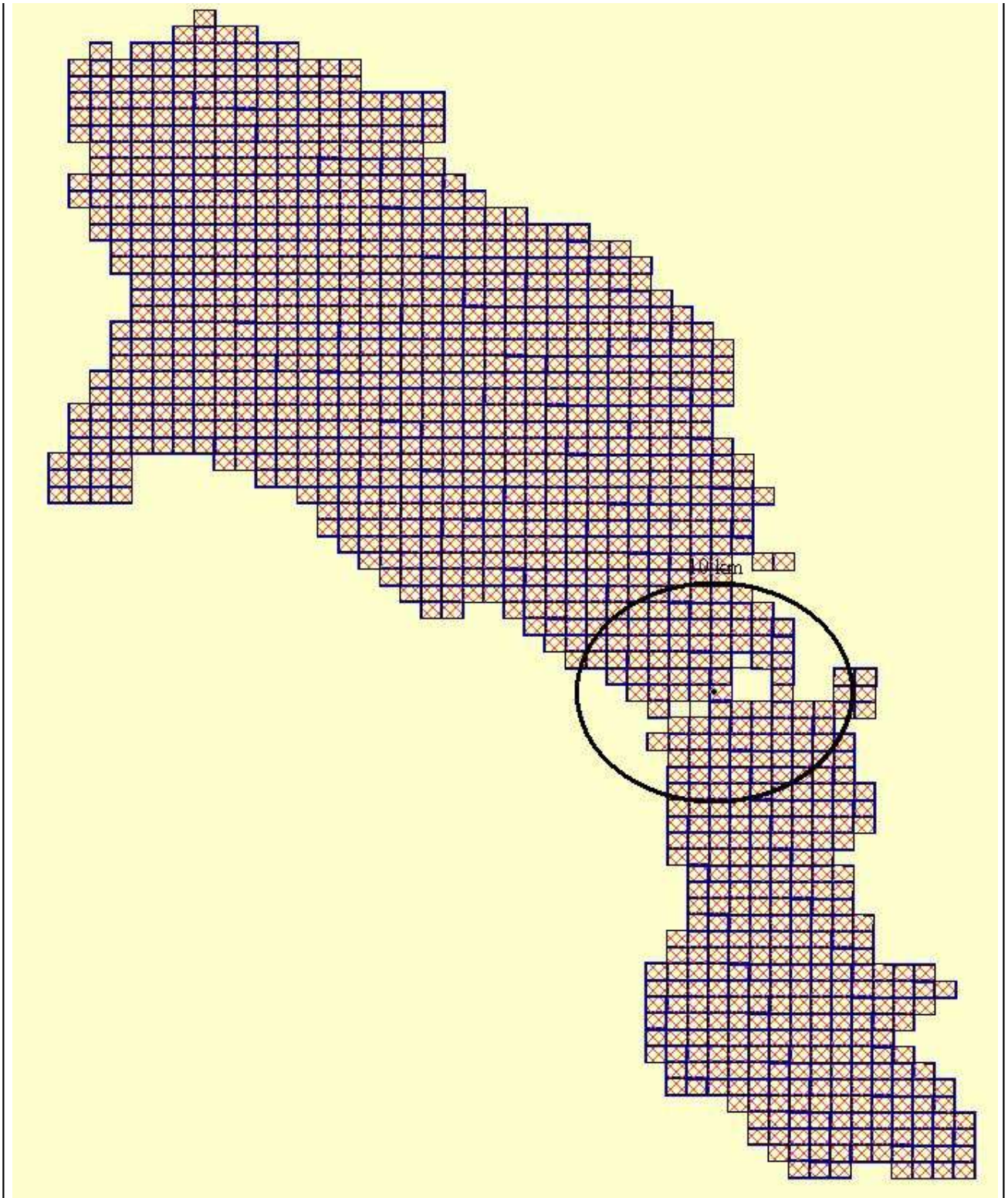


Waterbody classed as ground, results in tinning across water surface. Scale 1:4,239.

Image?

Bridge not removed. Scale 1:2,844.

Image?



Quantity of DEM tiles do not conform to project tiling scheme. Using the tiling scheme shapefile, reviewer at NGTOC identified cell numbers 44008400 and 47008850 as tiles that were not delivered as DEMs to NGTOC. SFSU confirmed that the identified DEM tiles were not generated or delivered to NGTOC. The corresponding classified las tiles contain no ground points.

☐ Image?

SFSU did not acquire independent check points to test vertical accuracy. This data will still be accepted as per direction of Teresa Dean on 02/06/2012. In the SFSU_LiDAR_Project_Report, SFSU reported vertical accuracy by adjusting 47 ground control points to the finished product.

Internal Note:

Vertical accuracy reported by SFSU as RMSE(z) ≤ 9.25cm

Internal Note:

Reviewer at NGTOC created a shapefile documenting errors found in the DEMs. This shapefile is located in the NED folder in the ERRORS folder and is named "errors.shp".

This is the end of the report.