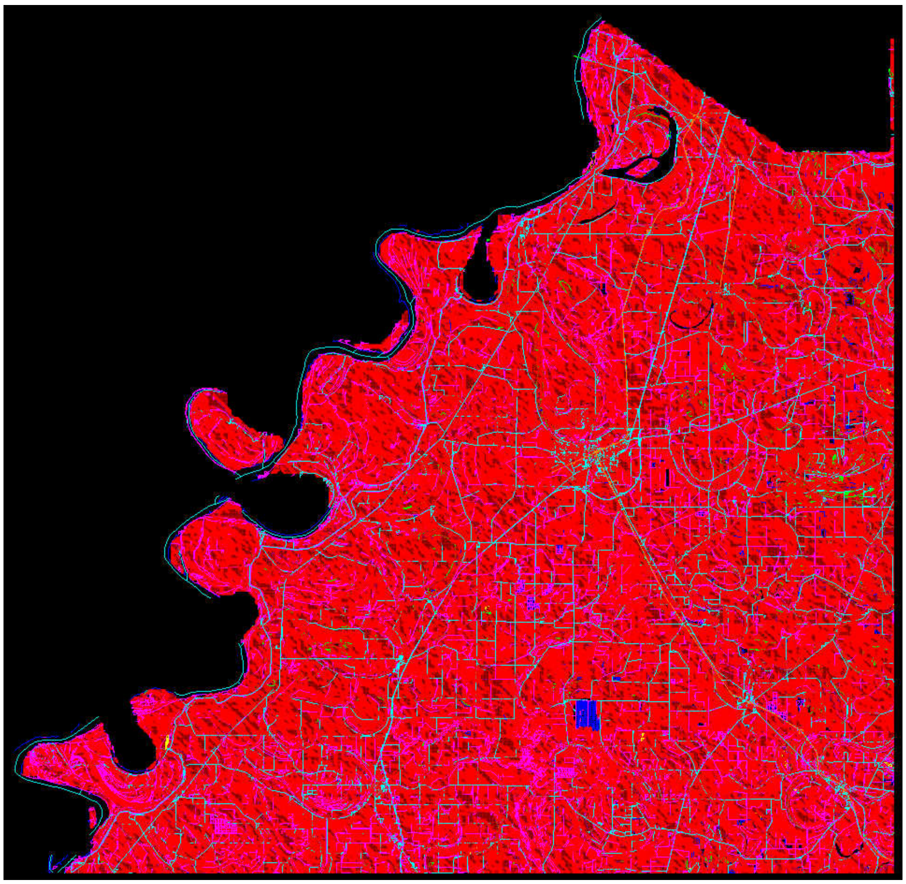
2009-2010 DTM Project, Mississippi

INDEPENDENT QUALITY CONTROL REPORT



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Independent Quality Control Report

1 Overview

The Qualitative and Quantitative Quality Assessment for the 2009-2010 DTM Project was performed by Mississippi Geographic Information (MGI) to validate data quality of Digital Terrain Models and 5 ft contours to American Society for Photogrammetry and Remote Sensing (ASPRS) Class II accuracy standards. Data deliverables for this project were derived from existing, 2 ft ground sample distance (GSD) orthophotography collected by the Mississippi Department of Environmental Quality (MDEQ). The method of collection for the source DTM for this project was stereo compilation using stereo image pairs generated from the existing orthophotography.

This report covers a pilot delivery and data deliveries received from Fugro EarthData, Inc. (FEDI) between September 8, 2009 and March 4, 2010 as well as all redeliveries of corrections applied.

1.1 Project Area

The Area of Interest (AOI) for the 2009-2010 DTM Project covered approximately 34,660 square miles throughout the state of Mississippi. The deliveries received from FEDI for this project were split into sub-blocks of data, delineated by primary block number and East or West State Plane projection. Figure 1 is an overview of the sub-block configuration for this project.

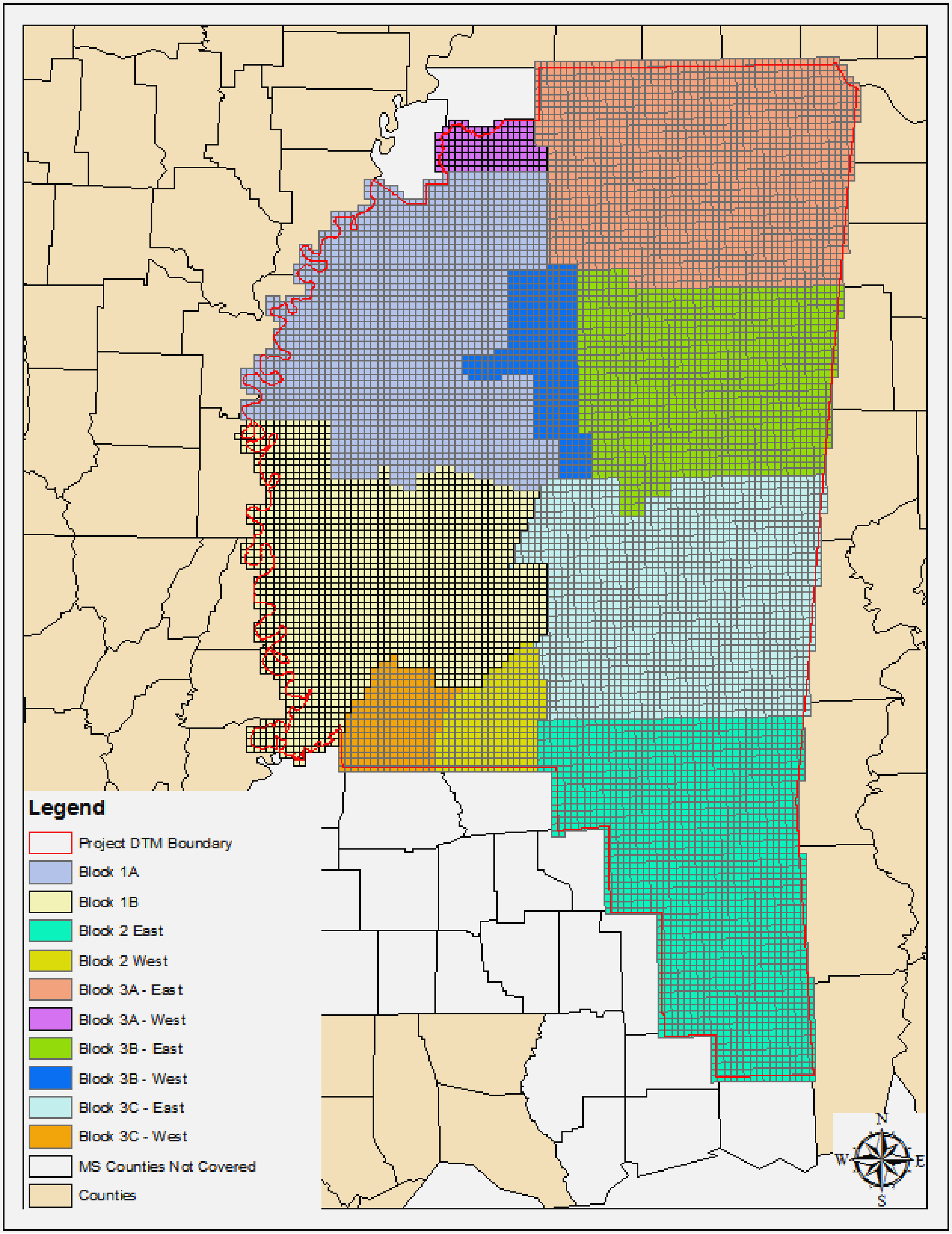


Figure 1 - Delivery block layout for 2009-2010 MS DTM Project

Deliveries related to these blocks were received in the following formats:

1. Aerotriangulation reports in Microsoft Word format
2. Source DTM files in Microstation .dgn format
3. Geodatabase files of masspoints and breaklines in ESRI .gdb format
4. Geodatabase files of 5 ft contours in ESRI .gdb format

1.2 Applicable Specifications and Guidelines

In addition, the following specifications/guidelines are applicable to this data inspection report:

A. Mississippi Geographic Information, Scope of Services for Mapping/GIS Data Development for the State of Mississippi, Attachment 1 to Work Order ED-10, March 26, 2009

B. FGDC-STD-007.3-1998: Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy (NSSDA) http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3

C. FGDC-STD-001-1998: Content Standard for Digital Geospatial Metadata (version 2.0) http://www.fgdc.gov/metadata/csdgm/

Note: ASPRS no longer maintains the "ASPRS Accuracy Standards for Large-Scale Maps" and has instead provided input to the latest NSSDA standards to correlate the older ASPRS standards with the latest methods.

2 Methodology

2.1 Qualitative Assessment

The following methods and tools were used by MGI to conduct the quality assessment of this delivery.

2.1.1 Software

The main software programs used by MGI in performing the qualitative assessment are as follows:

- *GeoCue:* a geospatial data/process management system especially suited to managing large geospatial data sets – used for vertical accuracy testing
- *Fugro Viewer:* a LiDAR viewing and analysis software provided by FEDI, used to view TINs and contours generated on the fly
- *Bently Microstation:* CAD software used to review, QA, and process the source DTM models mapped by FEDI
- *DAT/EM Summit Evolution:* a photogrammetric stereo workstation used to review DTM, contours, and other deliverables against the source stereo imagery

2.1.2 Process

The systematic QA approach for this project consisted of macro and micro QA checks for this project. Macro checks are designed to catch gross errors in the deliverable files before significant time is expended in the micro or detailed checks. Furthermore, it was decided that the source DTM files, consisting of Microstation files mapped from stereo models, would undergo a thorough QA before GDB files were produced.

It is important to note that while data consistency and coverage checks were conducted for 100% of the project deliverables, the more detailed micro checks were only conducted for 10% of the deliverables. The following steps were taken during QA:

2.1.2.1 Aerotriangulation QA

FEDI provided a total of 5 aerotriangulation (AT) reports outlining the methodology and results for each AT block. It is important to note that the AT blocks delineated for this project are independent of the production blocks and that AT was completed for Block 4 which was not included in this phase of DTM and contour development. Figure 2 depicts the layout of aerotriangulation blocks for this project:

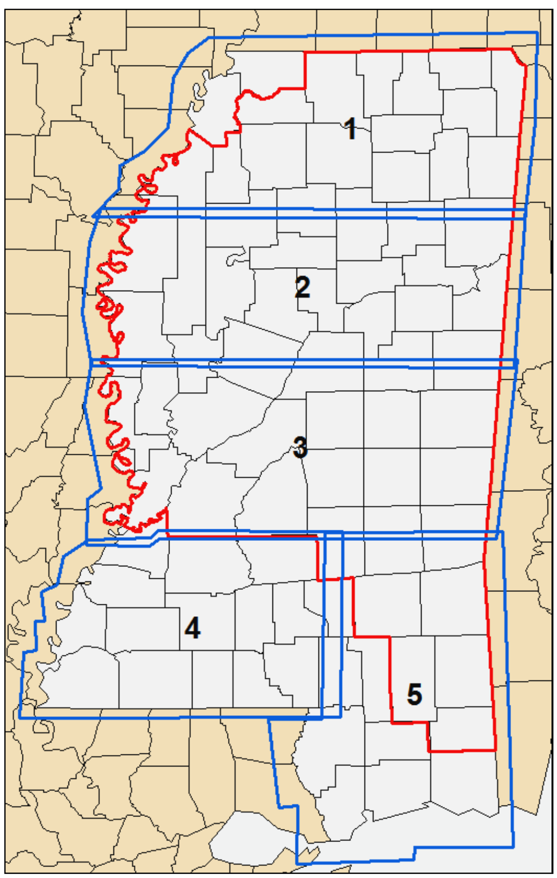


Figure 2 - AT blocks - blue polygons are AT blocks; red boundary is project limits

All five AT reports were reviewed for format, accuracy of the solutions, and inclusion of critical information such as the control point list, methodology, and attribution. Upon completion of each report review, a list of any errors and omissions was communicated to FEDI. Upon receipt of corrected reports, MGI reviewed the corrections and approved the final AT reports.

2.1.2.2 Source DTM QA

As each block of DTM source data was completed, they were submitted for QA before being approved for use in the development of the 5 ft contour deliverable and prior to inclusion in the final geodatabases. The source DTM files were received in Microstation .dgn format.

The following *macro* QA processes were followed when reviewing submitted DTM files.

1. Completeness of contents was checked on the deliverable media to ensure that all files relevant to the delivery were present
2. Deliveries were then copied to the local network as well as the photogrammetric workstation
3. Projection of data was converted. For this project, source data was provided in WGS84 and then converted to the project coordinate system for QA
4. A coverage/gap check was performed to ensure proper coverage of the DTM out to the project boundary; for the macro checks, this was accomplished by reviewing each file in its entirety.
5. Automated processes contained in the DAT/EM Summit Evolution Software were used to check source DTM file (.dgn files) for:
    a. Crossing breaklines
    b. Masspoints present on breaklines
    c. Anomalous elevation readings between nearest-neighbor points

    Figure 3 depicts an example of a crossing feature check used to search for vertical difference between nearest-neighbors or crossing features exceeding +/-3.32 ft.

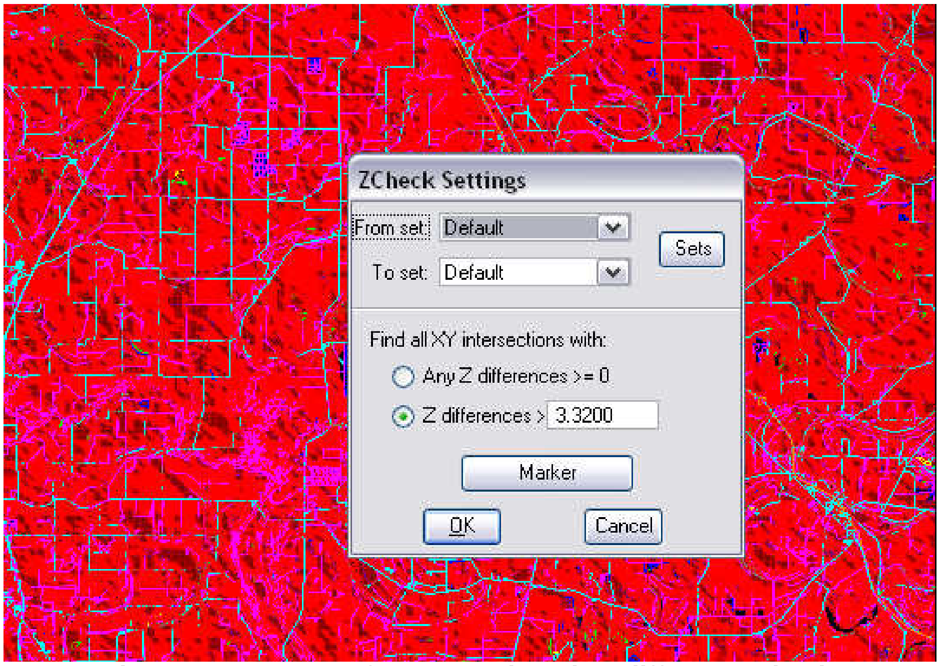


Figure 3 - Example of automated vertical difference check

6. Masspoint data was extracted from the Microstation .dgn files and converted to LiDAR LAS files to facilitate further analysis using more efficient software packages than Microstation.
7. TINs and rudimentary 2-ft contours were generated from the masspoints in LAS format and the products were checked for elevation steps, voids, and erroneous elevation points. Figure 4 is an example of a TIN generated from an LAS file derived from the supplied DTM file:

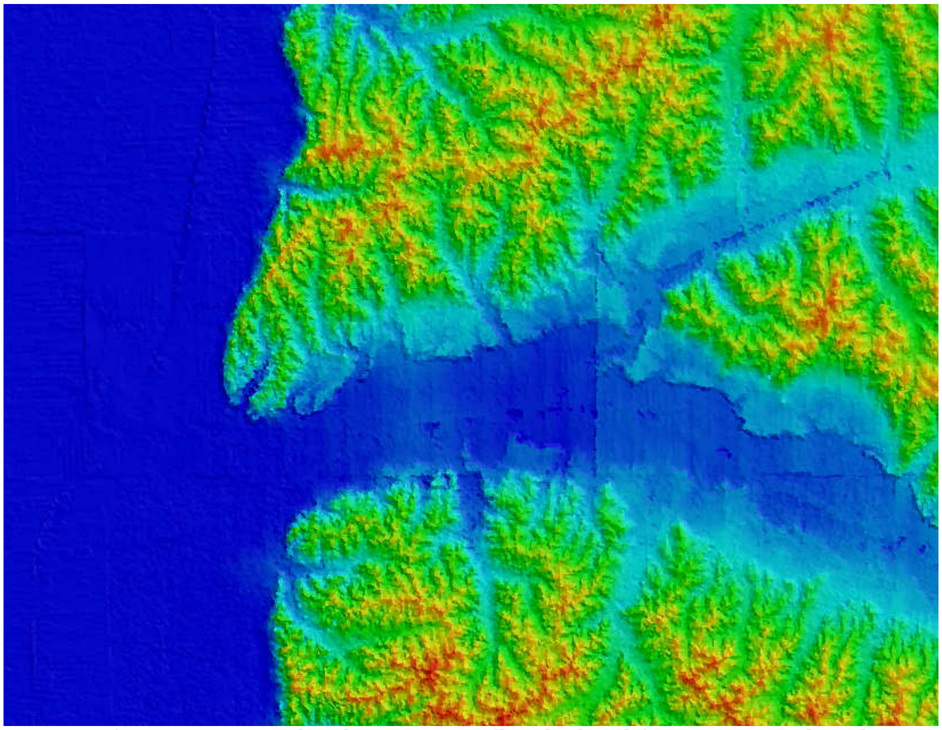


Figure 4 - Example of TIN generated using an LAS file derived from masspoints in DTM file

8. Any anomalies or errors found were documented for each delivery and communicated to FEDI for correction
9. All corrected DTM deliveries were resubmitted to MGI for a second QA and then approved for use in the development of final products

2.1.2.3 Final Deliverable QA

As final deliverable geodatabases were completed for each block, they were submitted for a thorough QA consisting of macro and micro checks. Because macro checks are designed to analyze a broad area of the project, 100% of the data delivered was subjected to these macro checks. Micro checks consisting of in-depth analysis of deliverables were conducted for 10% of the delivered area of the project.

The following macro check processes were used for this project:

1. Completeness of contents was checked on the deliverable media to ensure that all files relevant to the delivery were present.
2. Deliveries were then copied to the local network as well as the photogrammetric workstation.
3. Projection of data was verified to ensure that it meet project requirements of being delivered in the following where applicable:
    a. Mississippi State Plane **East**, NAD83/93 (HARN), NAVD88, US Survey Feet
    b. Mississippi State Plane **West**, NAD83/93 (HARN), NAVD88, US Survey Feet

4. A coverage/gap check was performed to ensure proper coverage of the DTM out to the project boundary for the macro checks; this was accomplished by reviewing each file in its entirety.
5. Deliveries were checked to ensure the inclusion of the required 500 ft buffer at county boundaries where the Mississippi State Plane East to West Zone change occurs.
6. A visual review of delivered blocks was conducted using ESRI ArcMap. Included in this review was a 100% review of ties along the boundaries of adjoining blocks to ensure that contours, breaklines, and other linear features were correctly tied and represented. Figure 5 is an example of such a review. Each block's contents are displayed in a different color to assist the reviewer. Nodes at tie points along the adjoining seam of the blocks are highlighted (pink nodes) in ArcMap to further assist the reviewer in identifying areas to QA.

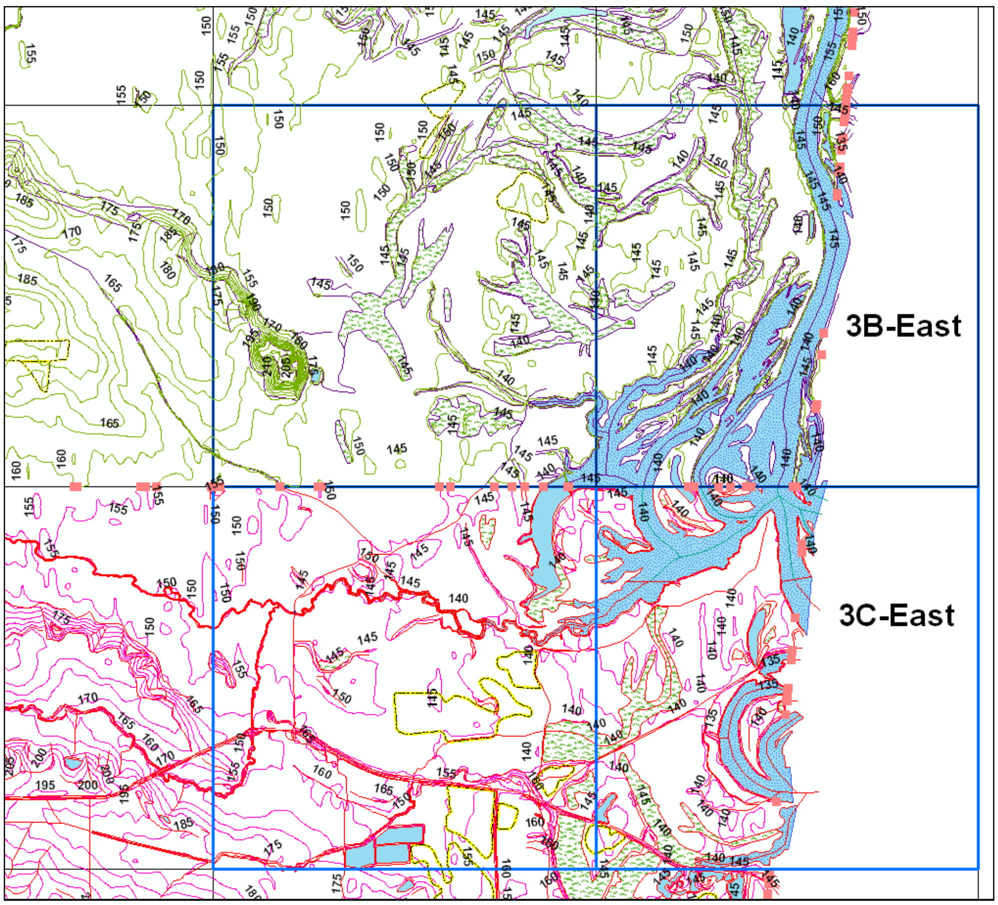


Figure 5- Example of macro review in ArcMap

7. At the conclusion of each macro review for a delivery, any errors or anomalies found were clearly identified using polygons in an ESRI shapefile format, attributed with comments.
8. Redeliveries of geodatabases were reviewed again to ensure that corrective actions were completed.

9. Upon approval of a delivery through the Macro check process, the approved delivered was sent to the Micro check process for final QA

The micro check process was used to QA 10% of the project tiles. To ensure that representative portions of the project were reviewed, MGI developed a micro check QA layout incorporating the following considerations:

- Land cover type
- Presence of major transportation features
- Presence of water features
- Seamlines between deliverable blocks and county boundaries

The layout developed for the 10% micro check of the deliverables is provided in Figure 6. The associated ESRI shapefiles were provided to MDEQ at the outset of the project.

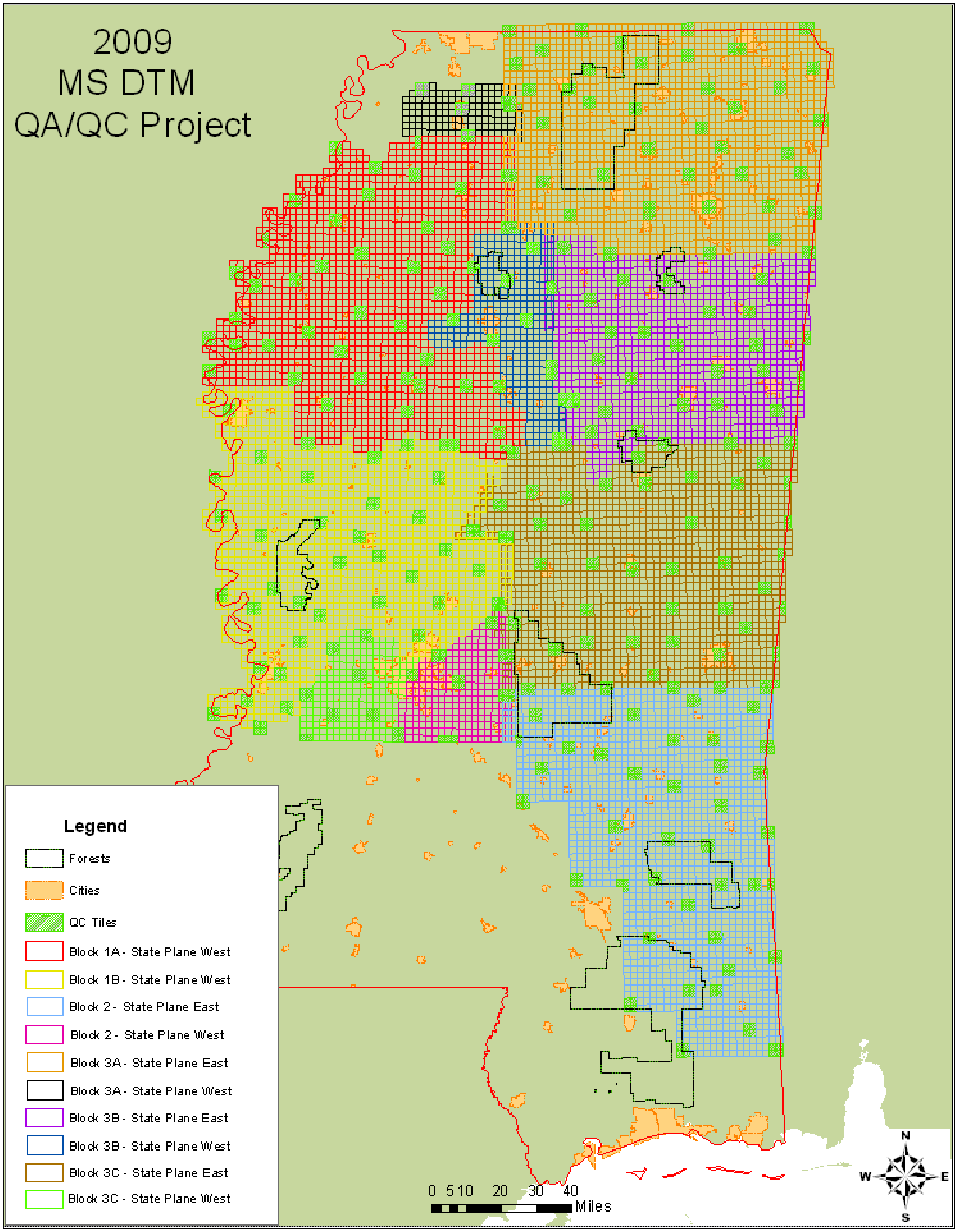


Figure 6 - Overview of 10% QA Micro check layout

Figure 7 is provided below to offer a detailed view of the layout:

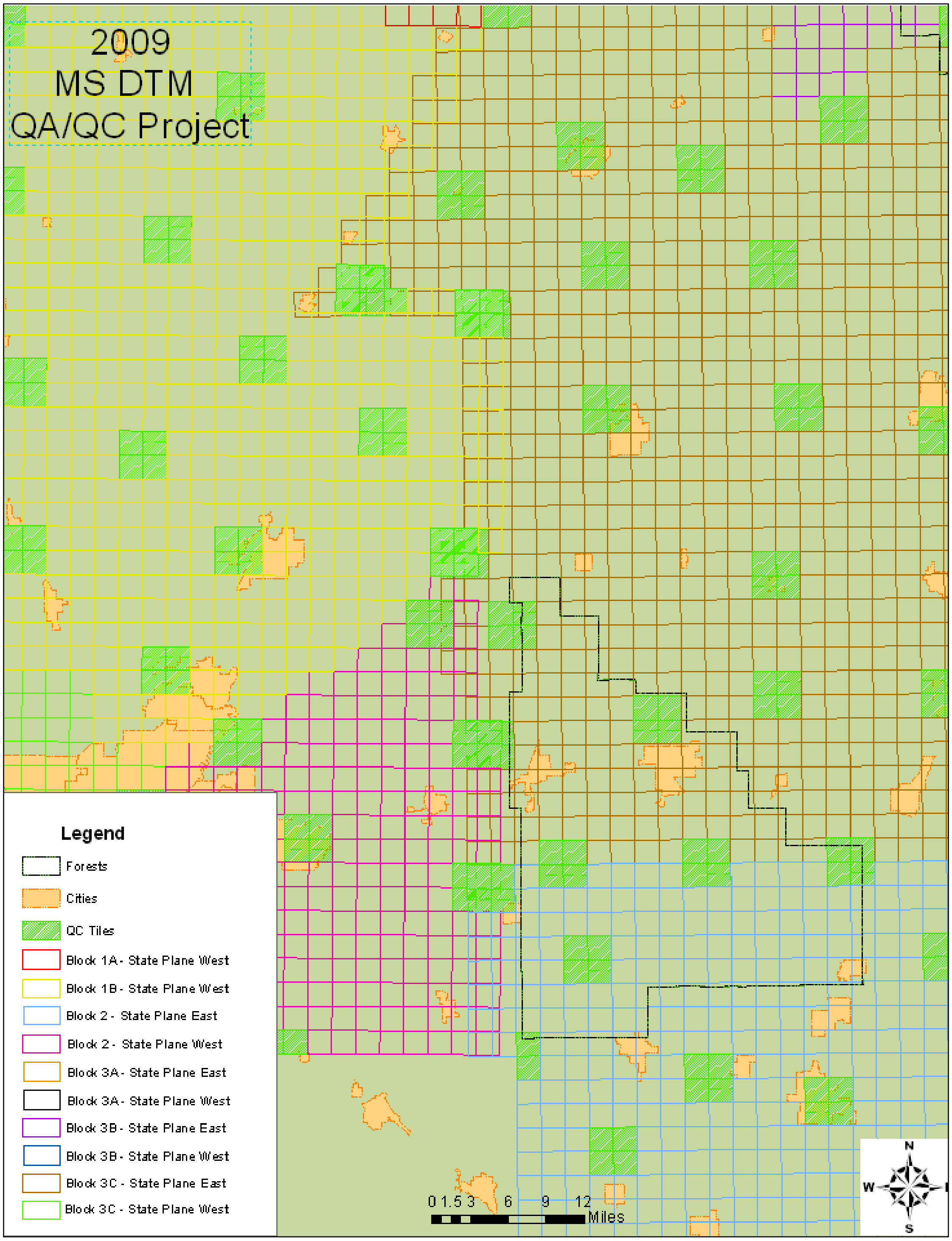


Figure 7 - Detailed view of 10% micro check layout

The following micro check processes were used for this project:

1. Upon approval of a delivery through the macro check process, the contents of each geodatabase were further reviewed in detail for 10% of the project tiles.
2. Breaklines and contours for each delivery were reviewed by inspecting:
    a. Joins between files
    b. Attribution
    c. Elevation labels (contours)
    d. Overall appearance of breakline and contours

Figure 8 illustrates four adjoining contour files colored by source file with nodes at joins highlighted. This method of review assisted the reviewer in checking joins and ensuring that the proper file was identified if an issue was found.

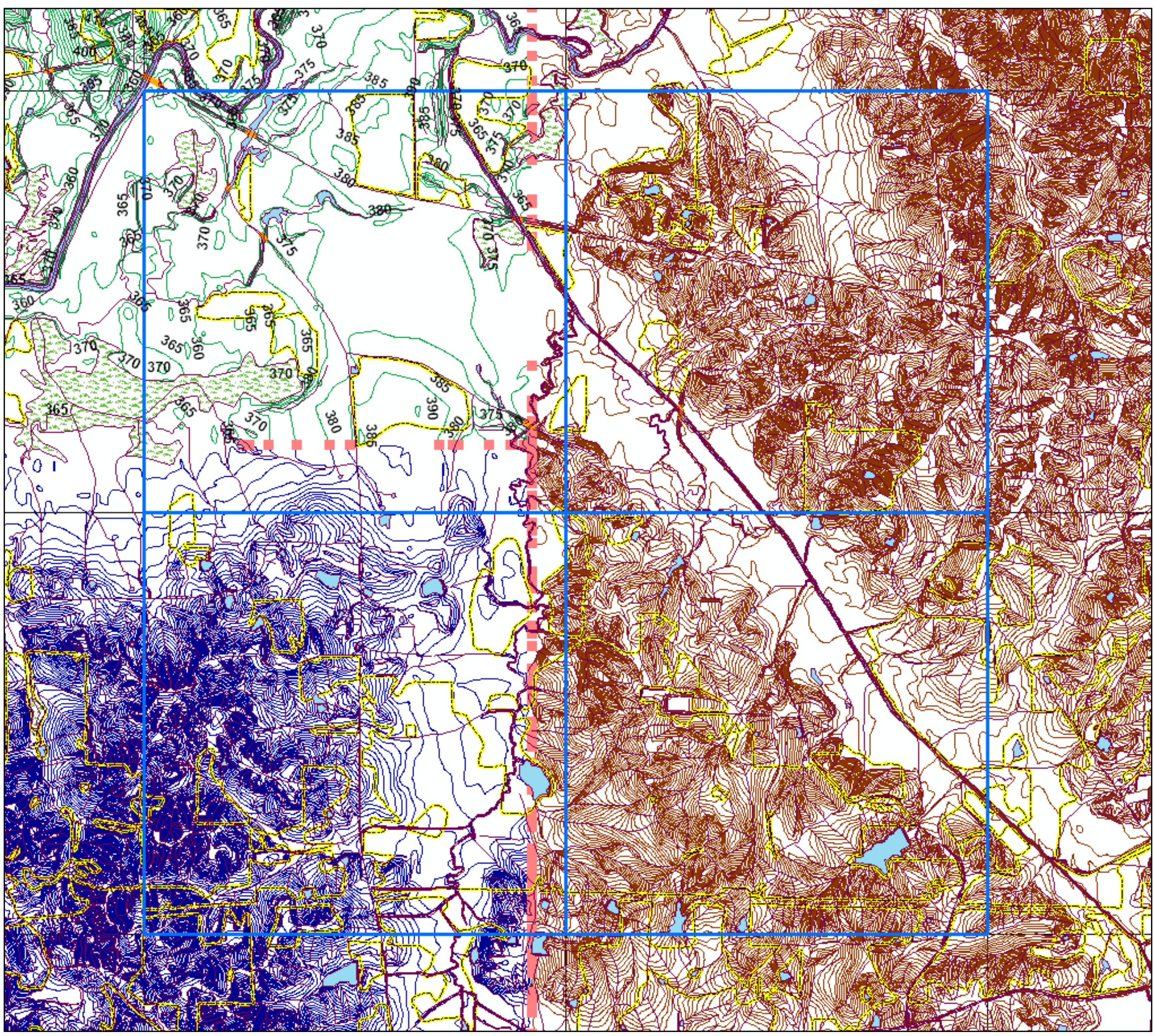


Figure 8 - Contour review - adjoining contour files colored by source file

Figure 9 illustrates a visual review with contours, contour labels, water features, breaklines, and bridges turned on to ensure that the various data features match and support proper depiction of the terrain.

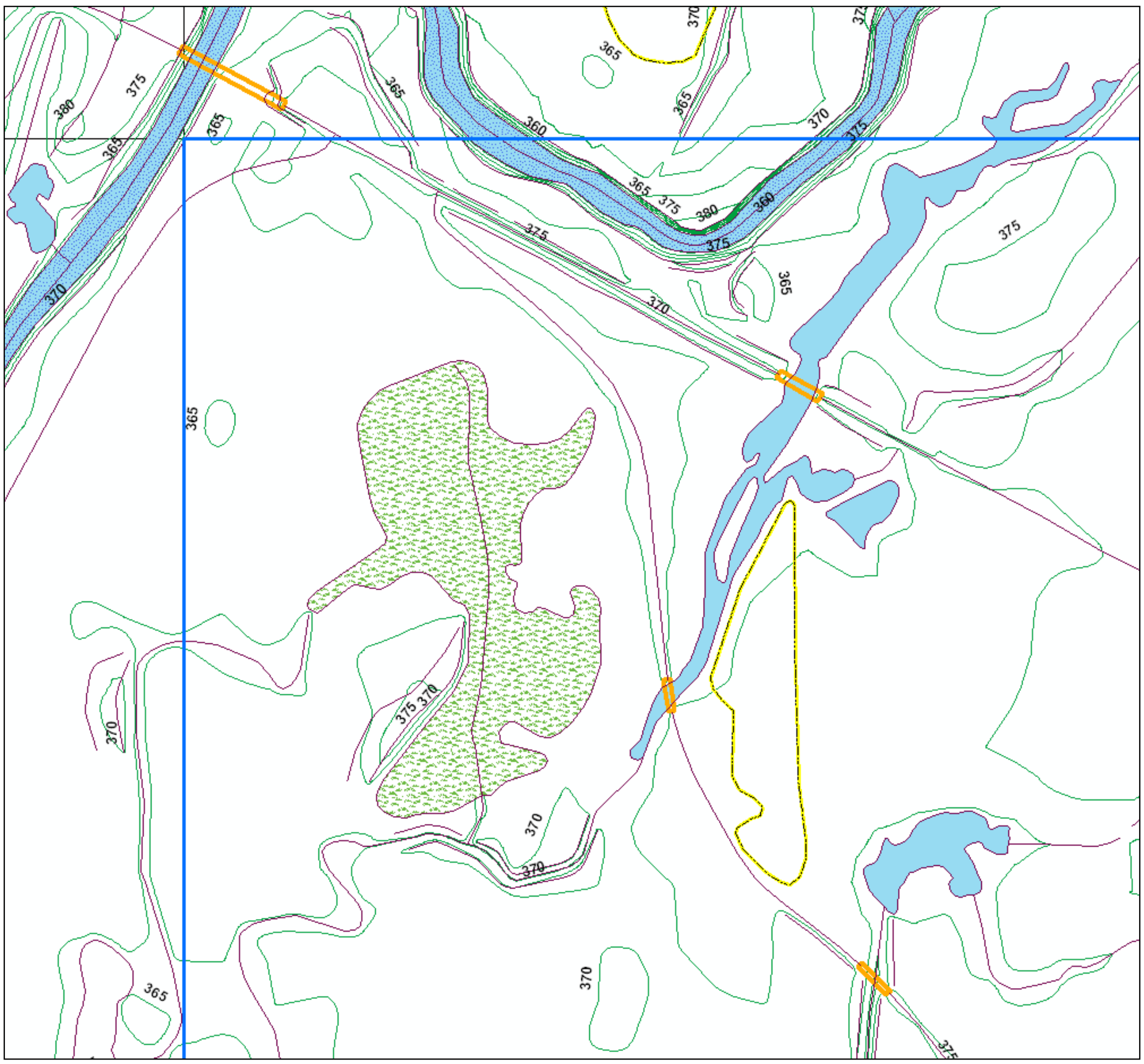
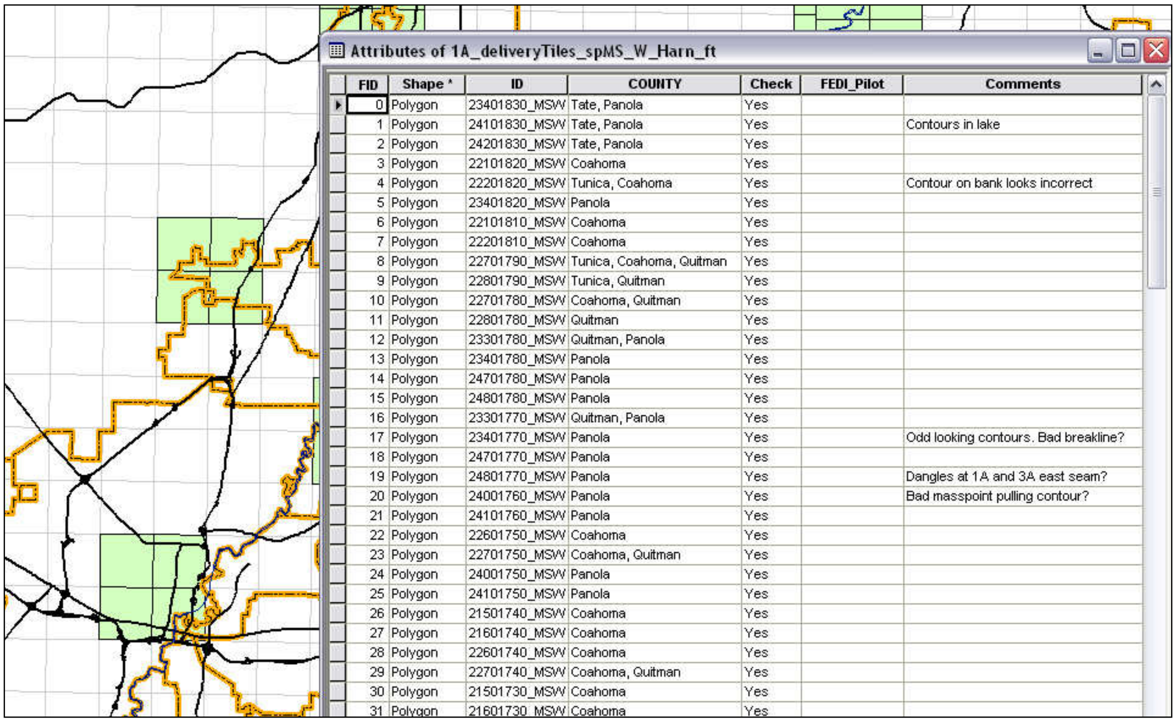


Figure 9 - Deliverable database review

3. Close attention was given to the breaklines and contours in the vicinity of water features such as streams and rivers due to the fact that temporal differences existed within the source aerial photography used as a base to collect this data.
4. All issues or anomalies found were documented using polygons in ESRI shapefile format and attributed with comments and communicated to FEDI.

Figure 10 is an example of an attribute table used to communicate issues for Block 1A-West. Calls are associated by tile name to allow for easy identification of source files.



Attributes of 1A_deliveryTiles_spMS_W_Harn_ft

FID	Shape *	ID	COUNTY	Check	FEDI_Pilot	Comments
0	Polygon	23401830_MSW	Tate, Panola	Yes		
1	Polygon	24101830_MSW	Tate, Panola	Yes		Contours in lake
2	Polygon	24201830_MSW	Tate, Panola	Yes		
3	Polygon	22101820_MSW	Coahoma	Yes		
4	Polygon	22201820_MSW	Tunica, Coahoma	Yes		Contour on bank looks incorrect
5	Polygon	23401820_MSW	Panola	Yes		
6	Polygon	22101810_MSW	Coahoma	Yes		
7	Polygon	22201810_MSW	Coahoma	Yes		
8	Polygon	22701790_MSW	Tunica, Coahoma, Quitman	Yes		
9	Polygon	22801790_MSW	Tunica, Quitman	Yes		
10	Polygon	22701780_MSW	Coahoma, Quitman	Yes		
11	Polygon	22801780_MSW	Quitman	Yes		
12	Polygon	23301780_MSW	Quitman, Panola	Yes		
13	Polygon	23401780_MSW	Panola	Yes		
14	Polygon	24701780_MSW	Panola	Yes		
15	Polygon	24801780_MSW	Panola	Yes		
16	Polygon	23301770_MSW	Quitman, Panola	Yes		
17	Polygon	23401770_MSW	Panola	Yes		Odd looking contours. Bad breakline?
18	Polygon	24701770_MSW	Panola	Yes		
19	Polygon	24801770_MSW	Panola	Yes		Dangles at 1A and 3A east seam?
20	Polygon	24001760_MSW	Panola	Yes		Bad masspoint pulling contour?
21	Polygon	24101760_MSW	Panola	Yes		
22	Polygon	22601750_MSW	Coahoma	Yes		
23	Polygon	22701750_MSW	Coahoma, Quitman	Yes		
24	Polygon	24001750_MSW	Panola	Yes		
25	Polygon	24101750_MSW	Panola	Yes		
26	Polygon	21501740_MSW	Coahoma	Yes		
27	Polygon	21601740_MSW	Coahoma	Yes		
28	Polygon	22601740_MSW	Coahoma	Yes		
29	Polygon	22701740_MSW	Coahoma, Quitman	Yes		
30	Polygon	21501730_MSW	Coahoma	Yes		
31	Polygon	21601730_MSW	Coahoma	Yes		

Figure 10 - Example of issue documentation for Block 1A-West

5. Upon receipt of a corrected geodatabase, the corrections were reviewed to ensure that the issues were properly addressed.

2.1.2.4 Review of Vertical Accuracy

For this project the vertical accuracy of the source DTM was required to support the generation of 5-ft contours to ASPRS Class II specifications. Per this specification,the product was required to meet vertical accuracy of ±3.32 ft RMSE according to ASPRS Class II specifications for a 4-ft contour interval.

Due to the significant area covered by the project (~34,660 square miles) it was deemed cost-prohibitive to collect new vertical/horizontal QA/QC checkpoints over such a large area. To facilitate the analysis of vertical accuracy, valid vertical points from the National Geodetic Survey (NGS) database were used to check the data as well as existing elevation data of higher resolution.

In response to initial comments and observations from MDEQ, FEDI conducted a full analysis of the vertical accuracy of the data entitled “Investigating the Quality of the DTM” which was provided to the MGI team as well as MDEQ. MGI conducted an independent confirmation of the results.

During the process of utilizing the NGS database, FEDI took the following measures to filter out invalid NGS points, as confirmed by an independent review of the points conducted by MGI:

1. Discarded points located on bridge, culvert, and overpass structures
2. Discarded points located on/within building structures
3. Discarded points located within areas under change/construction
4. Discarded points located within flooded areas/water bodies
5. Discarded points containing doubtful descriptions or high approximation of horizontal placement

After the NGS points were vetted for suitability, a total of 6,526 points were available and FEDI conducted a surface subtraction between the points and the surface derived from the DTM.

In addition to the surface subtraction, a comparison of the delivered data against existing projects with higher project accuracy specifications further verified the conclusion that the statewide data meets the proposed accuracies.

An independent confirmation of the results was conducted by MGI using the following methods:

- The vertical NGS points used by FEDI were imported into the GeoCue project as a photogrammetric layer
- Using the Z-probe program in GeoCue, survey checkpoint Δz's were generated. The Z-Probe works by projecting the control point into the elevation data and then taking a multiple of the GSD (Ground Sample Distance) of the masspoints and triangulating these. The program then looks for the most isosceles-like triangle (so as not to use slivers) that intersects the control point projection and compares the value of this surface to the control point.
- The results of the Z-probe analysis were reviewed compared against the results of the FEDI analysis

3 Results

The following are the results of the QA processes identified in Section 2 of this report. Any issues identified during the QA process were corrected and verified before final delivery of products.

3.1 Aerotriangulation QA Results

The following issues were noted and corrected by FEDI as a result of the AT QA:

1. Typographic errors contained within the reports

No other issues were found and the block adjustment results and residuals included in the report were within the specifications of the project.

3.2 Source DTM QA Results

The following issues were noted and corrected by FEDI as a result of the source DTM QA:

1. *Masspoints on breaklines* – upon completion of automated checks it was found that some DTM files contained masspoints located on breaklines. Due to the possibility of such masspoint elevations disagreeing with the breakline elevation, these points were identified and subsequently removed in the final DTM files by FEDI.
2. *Crossing breaklines* – upon completion of automated checks it was found that some DTM files contained low instances of crossing breaklines. Such breaklines were corrected in the final DTM files by FEDI.
3. *Elevation "steps"* – elevation steps were found throughout the project area, primarily along the seams of acquisition lifts and stereo model boundaries. These steps were initially identified when the first DTM files were used for modeling but subsequent steps were identified in the QA process after a revision was made to the QA process.

The table 1 outlines the elevation steps identified in the initial deliveries of source DTM files:

DTM File	General Range of Steps	Comments
1AW1	1-11 ft or greater	Numerous steps exceeding spec
1AW2	1-9 ft or greater	Numerous steps exceeding spec
1AW3	1-2 ft	No steps found exceeding 3.32 ft
1AW4	1-3 ft	Several seam lines are close to spec
1BW1	1-8 ft or greater	Several large steps
1BW2	1-5 ft or greater	Numerous steps
1BW3	1-11 ft or greater	Numerous steps
1BW4	1-8 ft or greater	Some steps present
3AW	1-7 ft or greater	Some steps present

Table 1 Identification of elevation steps in source DTM files

Figure 11 illustrates the visibility of the elevation steps using a simple TIN for review of the source DTM.

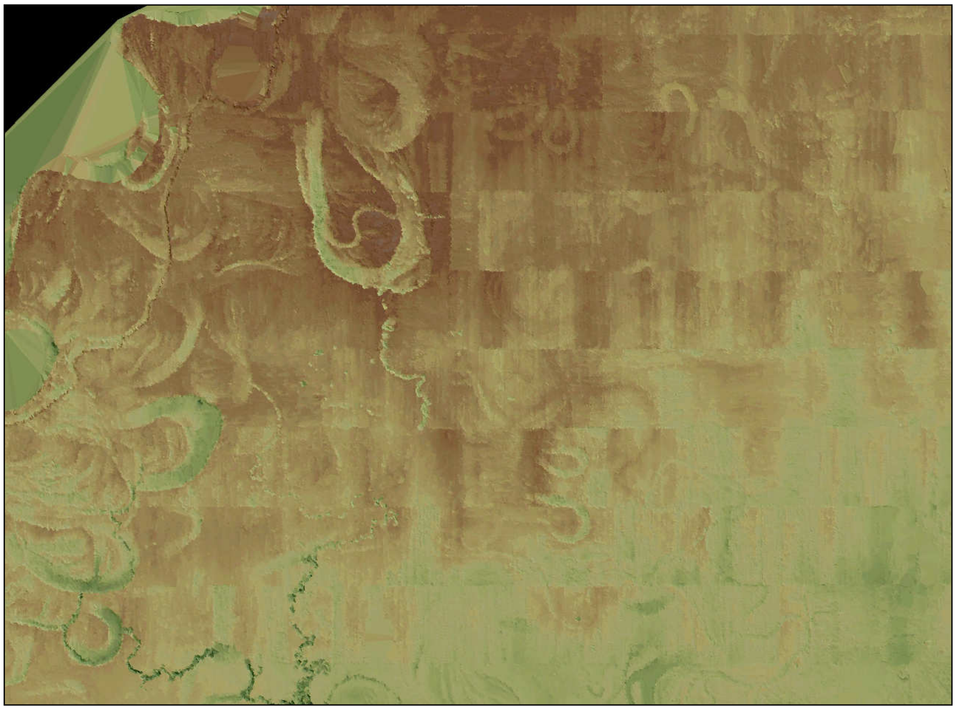


Figure 11- TIN surface of a block of source DTM files illustrating elevation steps

Cross sections such as the one in Figure 12 were used along identified seamlines to quantify the severity of each step and whether or not the vertical difference observed was within project specifications or not.

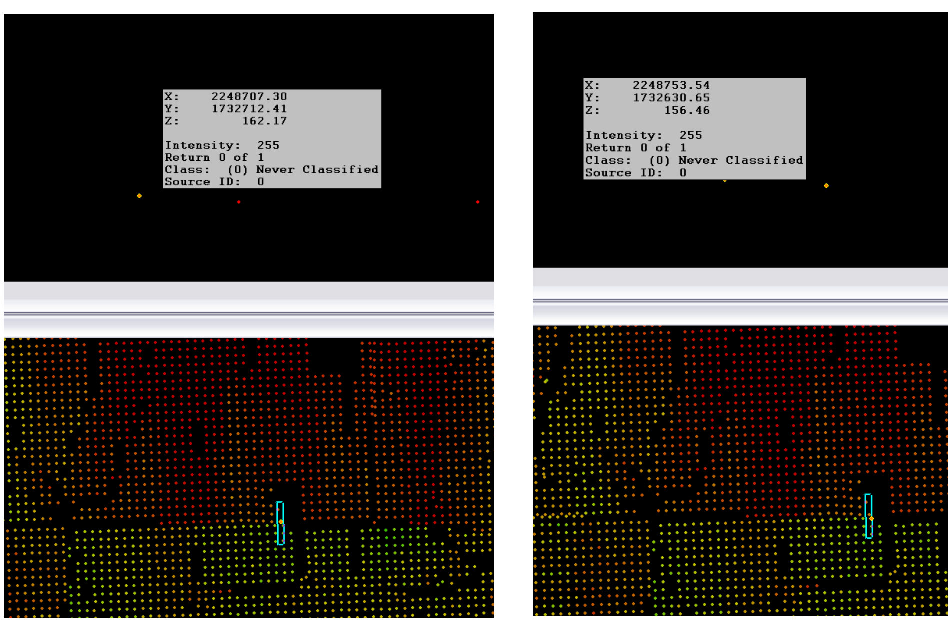


Figure 12 - Cross section showing a difference of ~5 ft between the top and bottom of the step

Issues identified during this QA process were corrected by FEDI and redeliveries were checked to verify the corrections.

3.3 Final Deliverables QA Results

The following issues were noted and corrected by FEDI as a result of the final deliverables QA:

1. *Anomalous contours* – reviews of the delivered geodatabases identified instances of anomalous looking contours which would indicate that the area is not correctly depicted by the contours and possibly the DTM. Figures 13-17 are examples of identified contour anomalies identified during the QA.

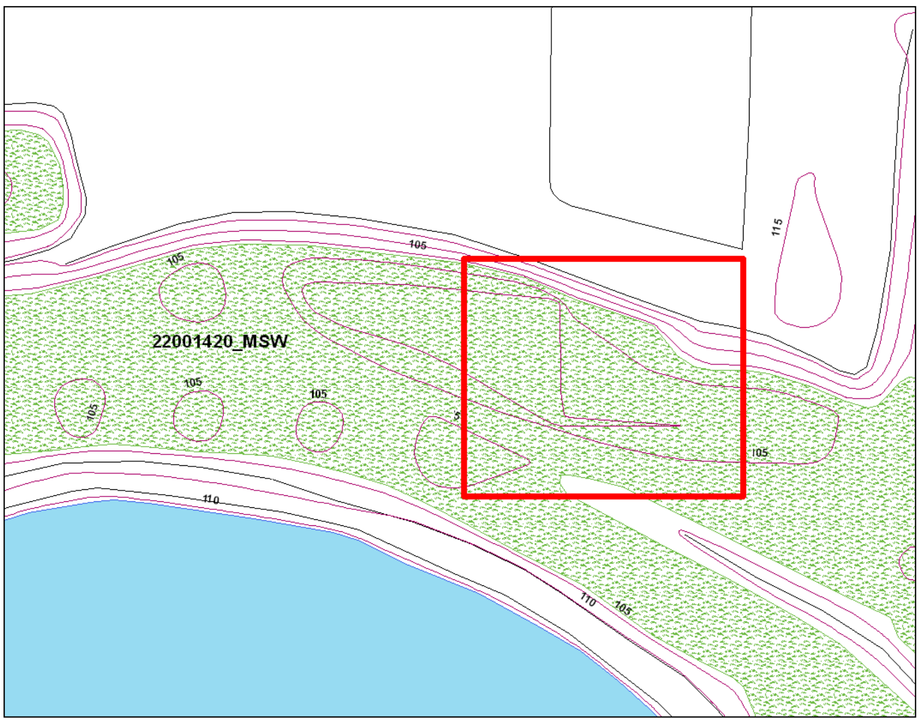


Figure 13 - Anomalous contour; tile 22001420_MSW

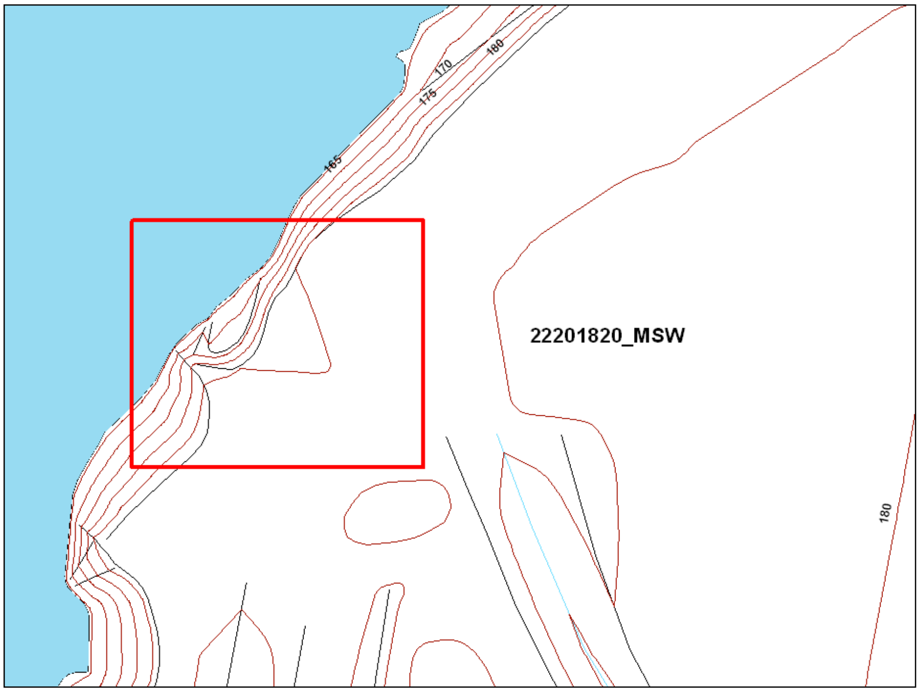


Figure 14 - Anomalous contour; tile 22201820_MSW

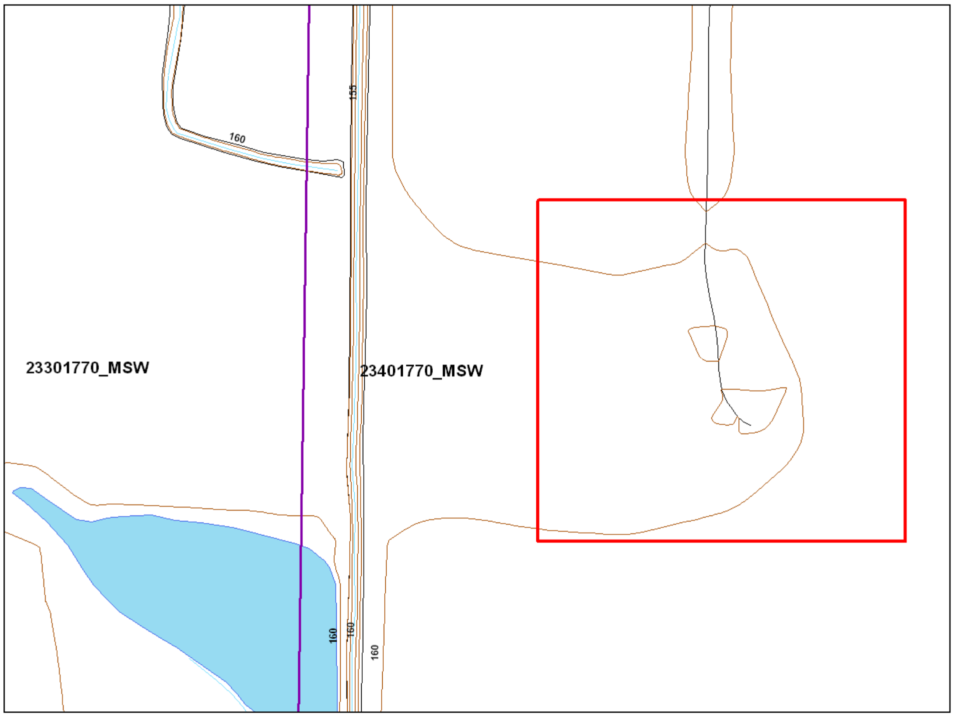


Figure 15 - Anomalous contours; tile 23401771_MSW

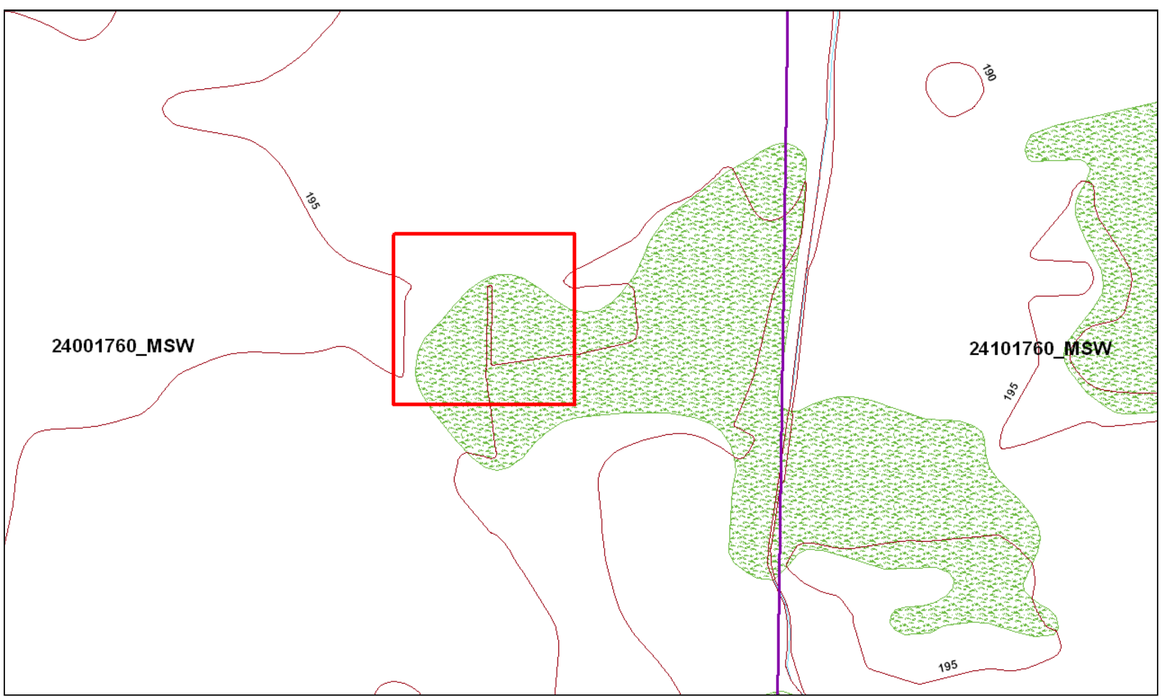


Figure 16 - Anomalous contour; tile 24001760_MSW

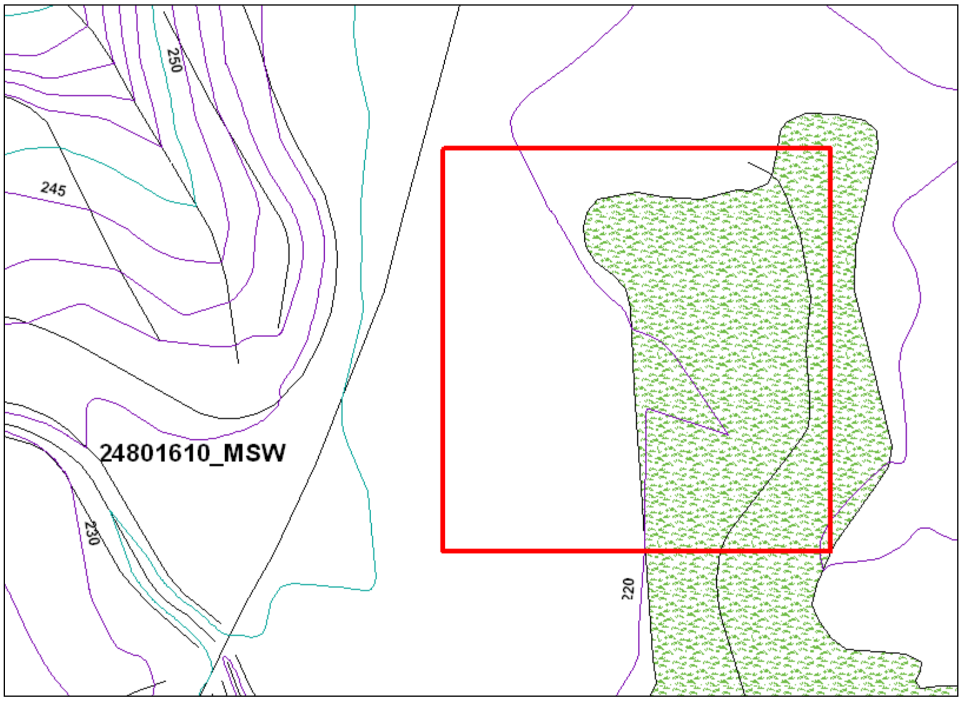


Figure 17 - Anomalous contour; tile 24801610_MSW

2. *Contours located within water bodies* – initial geodatabase deliveries contained errors in the contour files consisting of contour lines located within closed water bodies. Figures 18-20 are examples of this issue.

Figure 18 - Example of contour within closed water body; tile 08700780_MSW

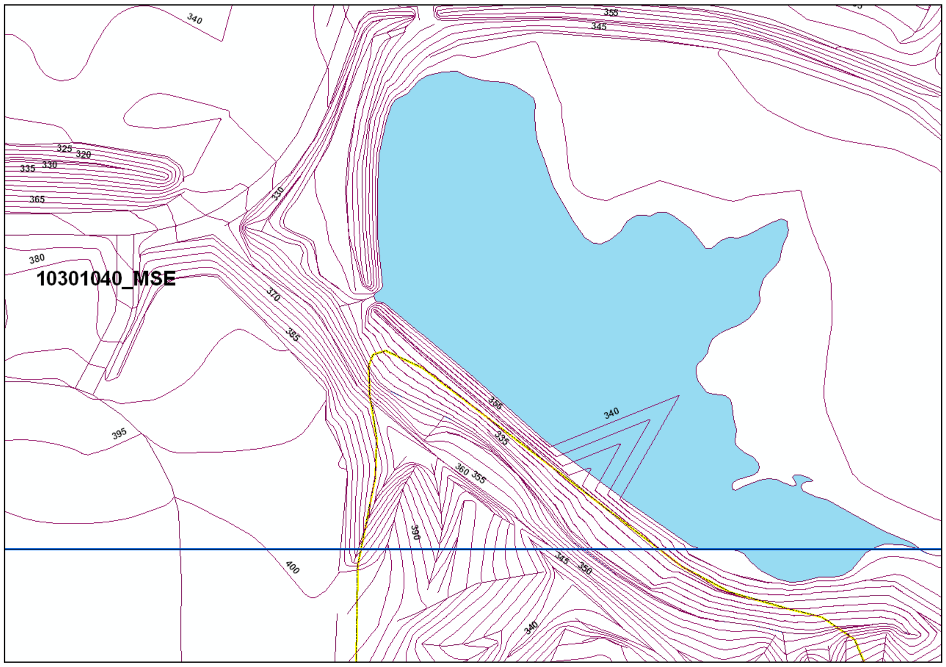


Figure 19 - Example of contours affected by improper elevations on breakline of closed water body; tile 10301040_MSE

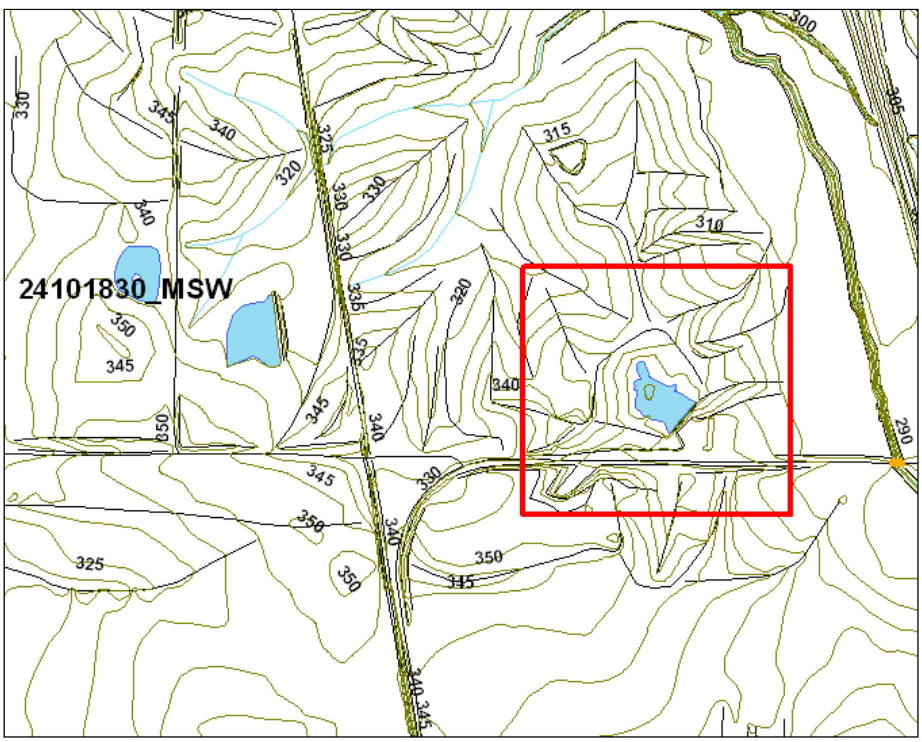


Figure 20 - Example of contour within closed water body; tile 24101830_MSW

3. *Double contours crossing rivers* – Double contours of varying elevations were found in several locations that would erroneously indicate a severe drop in

elevation at the crossing (such as a dam or waterfall). In some instances, these were identified as being caused by temporal differences in the imagery where flooding had occurred. However, some of the calls were valid as errors. Figures 21-22 are examples of this issue.

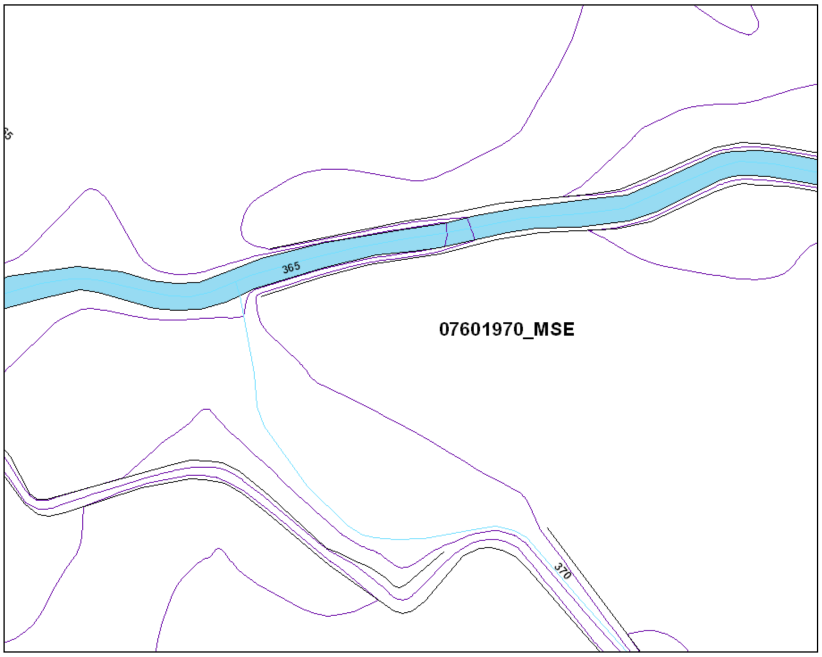


Figure 21 - Double contours crossing river; tile 07601970_MSE

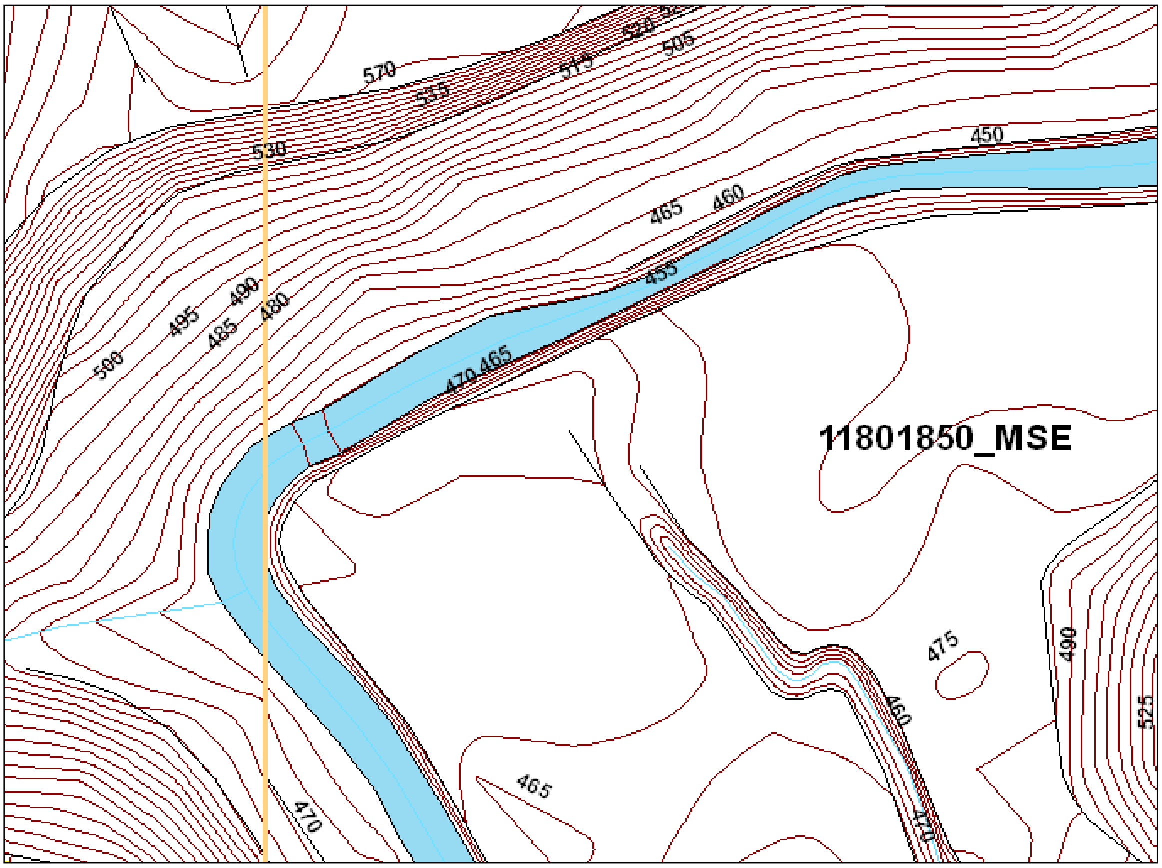


Figure 22 - Double contours crossing river; tile 11801850_MSE

4. *Overshoots/dangles and gaps in contours* - QA of the seamlines along adjoining blocks and contour files identified issues with the seamless transition of contours over the edges of blocks and/or files. These included:
   a. Overshoots/dangles - where the end of a contour from one area connects to but overshoots the identical contour in the adjoining area
   b. Gaps where a contour is broken by a block or file edge

Figures 23-24 illustrate examples of these issues.

Figure 23 - Example of contours containing overshoots/dangles. Yellow contours are from contour file adjoining the purple contours; tile 07101890_MSE

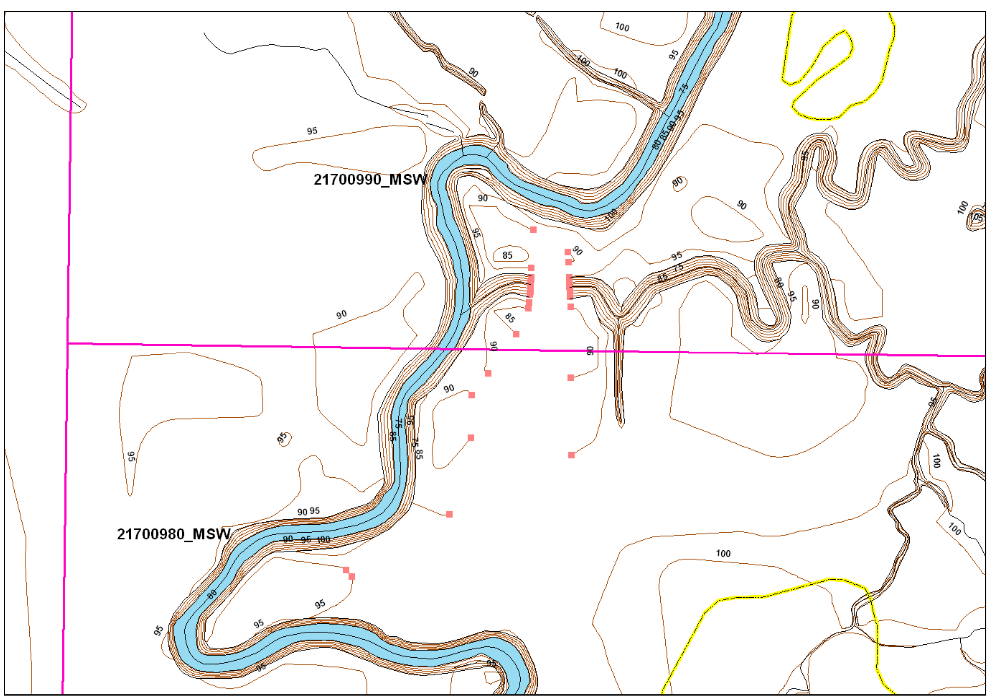


Figure 24 - Example of break in contours; tiles 21700990_MSW & 21700980_MSW

Issues identified during this QA process were corrected by FEDI and redeliveries were checked to verify the corrections.

3.4 Vertical Accuracy QA Results

Per the review described in Section 2.1.2.4 of this report, MGI verified the following statistics as reported by FEDI:

- The statistics represent a summary of the quality of fit of the delivered DTM to 6,167 NGS points throughout the state:

3.30’	**RMSE**
3.31’	**StDEV**
6,167	**Sample size**

MGI reviewed and agreed with the following conclusions outlined in FEDI’s report:

1. The NGS database does not contain sufficiently accurate positional locations to be used for data verification. Also, the vertical accuracy cannot be verified against a substantial number of NGS points without further field work.
2. Use of the 6,167 relatively accurate NGS points as a coarse check resulted in satisfactory results that support the validity of delivered mapping data.

Comparison of the delivered data against existing projects with higher project accuracy specifications further verify the conclusion that the statewide data meets the proposed accuracies.

4 Conclusions

Systemic issues were identified throughout the course of the project that indicated a need to strengthen internal QC processes during the production phase of each block of data. These issues were primarily limited to elevation steps in the source DTM files and incorrect contours. Though all issues were ultimately addressed, the project schedule was adversely impacted by the time needed to take corrective action and to recheck deliverables and source data.

Based on a review of the QA process, MGI made the following improvements to help facilitate a quicker identification of issues in the source data:

1. The use of additional resources to review the data in a shorter time period
2. The conversion of masspoints from the source DTM to an LAS format in order to use LiDAR QA tools that are designed for large project areas and datasets
3. The use of ancillary data sources to verify analysis such as data layers from the Mississippi Automated Resource Information System (MARIS), Google Earth, and other existing data sets

As a result of the QA process used during this project, the following recommendations are offered for future projects:

1. Prior to a kick-off meeting with MDEQ, internal production QC processes should be reviewed and revised as needed to ensure that possible issues are anticipated and measures are put into place to address if necessary.
2. From the above review, a QA Plan developed by the members of the MGI team working on the project should be submitted at the project kick-off meeting with MDEQ for review and comment.
3. The method of testing accuracy for the project should be well defined and agreed upon by MGI and MDEQ for the type of data being tested.

Based on the qualitative and quantitative assessment conducted by MGI on the initial data delivered as well as all redeliveries, the data for this project meets the applicable project specifications as set forth by Mississippi Geographic Information, Scope of Services for Mapping/GIS Data Development for the State of Mississippi, Attachment 1 to Work Order ED-10, March 26, 2009.

Quantitative Assessment and Qualitative Assessment Conducted by:

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