Bathymetry Basics

Gary Wilson
Missouri Water Science Center
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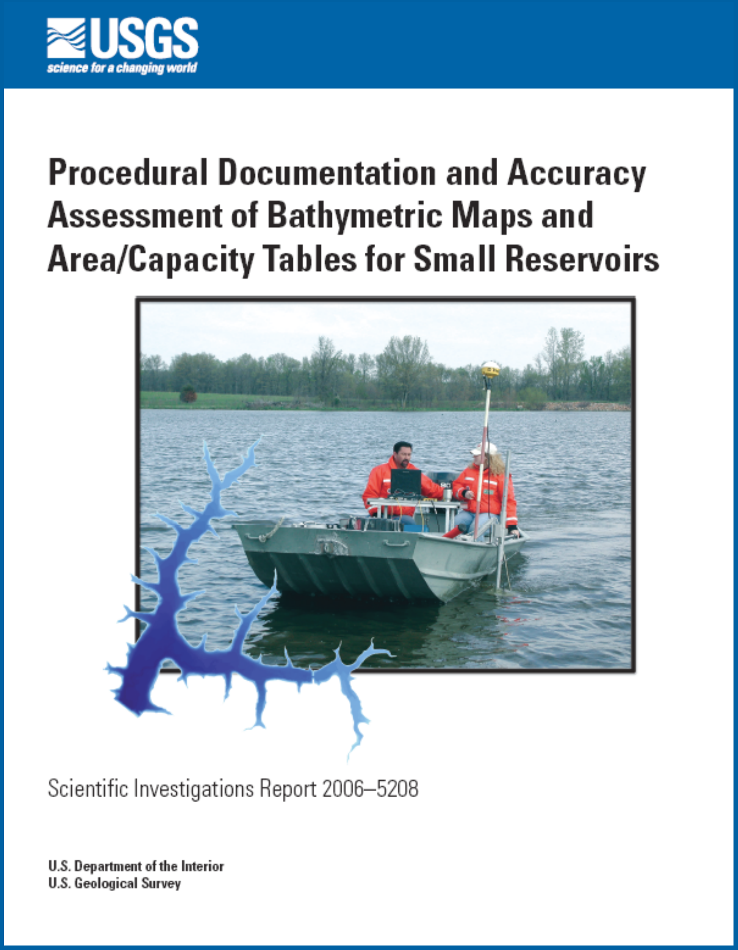
Topics

- Survey Set-up
  - Equipment/Software
  - Vertical Control
  - Office Preparation
- Data Collection
  - Field Preparation
  - Transects/Obliques
  - Target Points
  - Miscellaneous
- Data Processing
  - Surface creation
  - Map and Area/Capacity Table
  - Accuracy Assessment



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Reference to brand names does not constitute endorsement by the U.S. Geological Survey.

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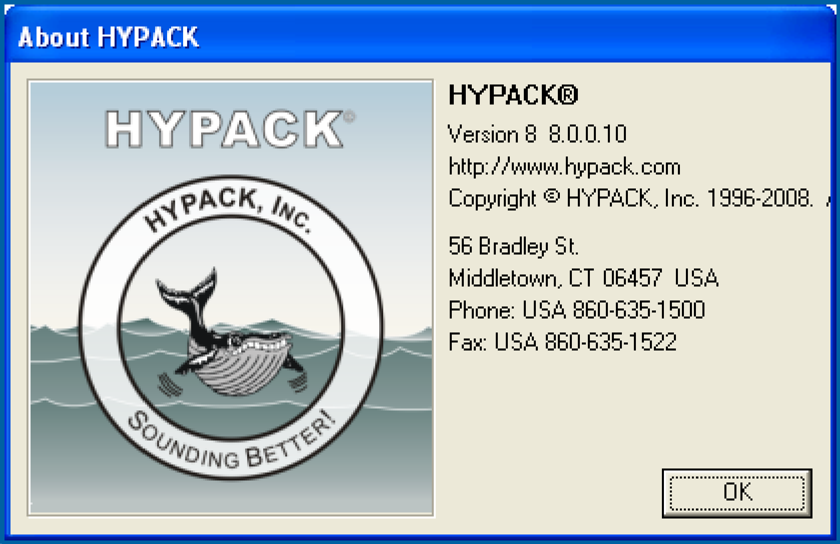
Equipment

- Boat
- Survey Grade Echosounder
  - ODE Bathy 500 Bathometer
    - 200 kHz Transducer 3^{o} Beam
- Trimble Ag GPS System
  - OMNI Star Differential Correction
- Trimble Survey GPS System

Software



- Hypack
  - Survey planning
  - Navigation
  - Bathymetry data collection
- Trimble Survey Office
  - DGPS pre-deployment data entry and post processing
- ArcGIS
  - Survey set-up
  - Bathymetry surface, map, area/capacity table creation and accuracy assessment

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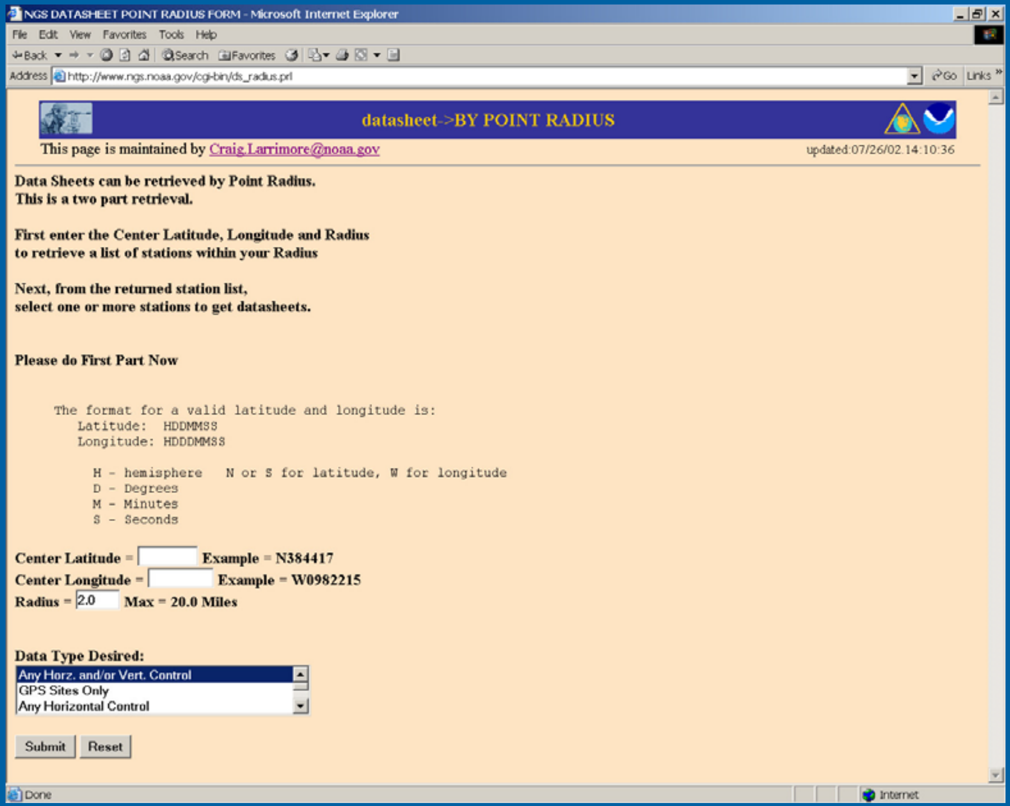
Vertical Control

- Bench Marks
  - www.ngs.noaa.gov/cgi-bin/ds_radius.prl



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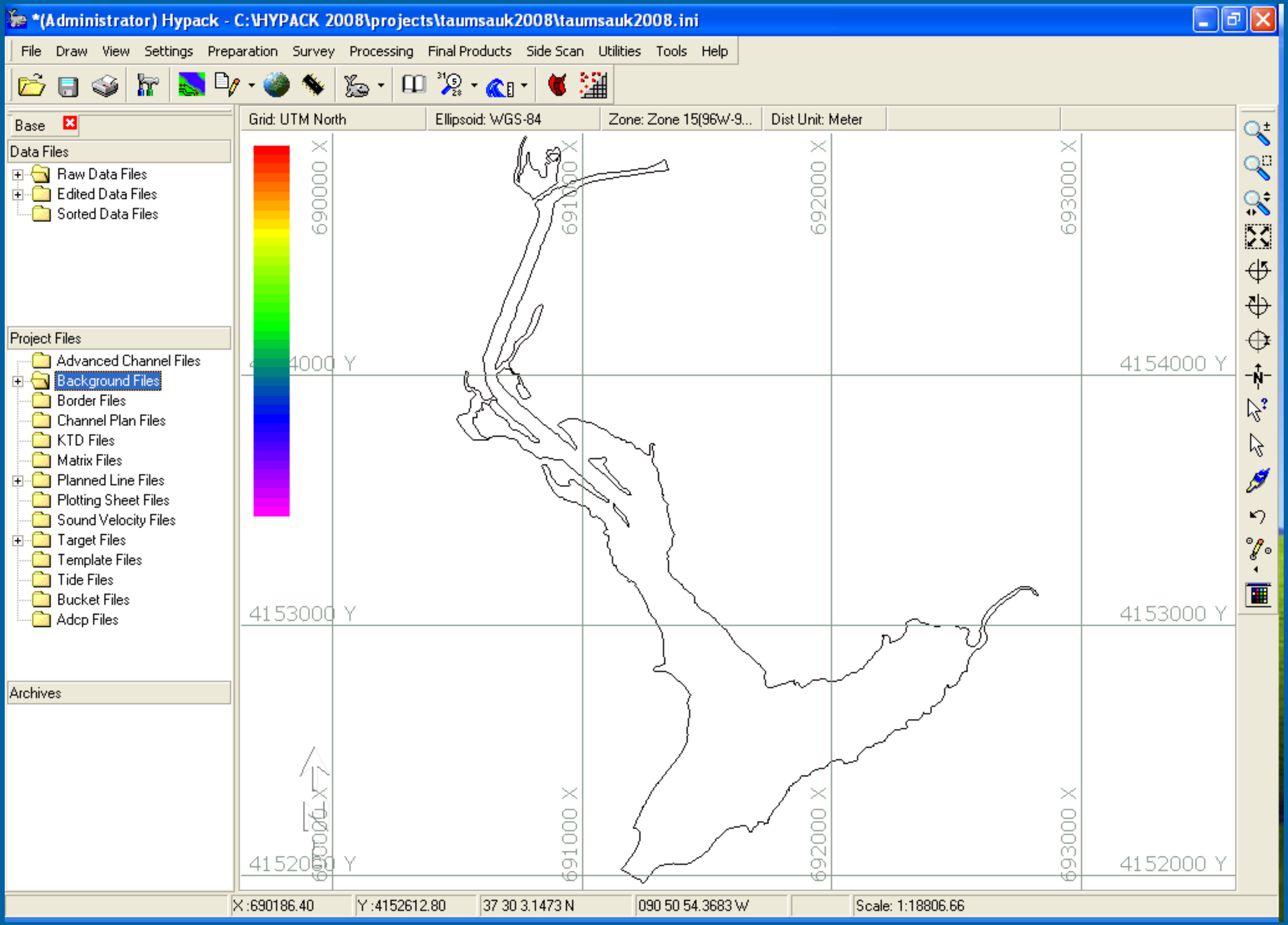
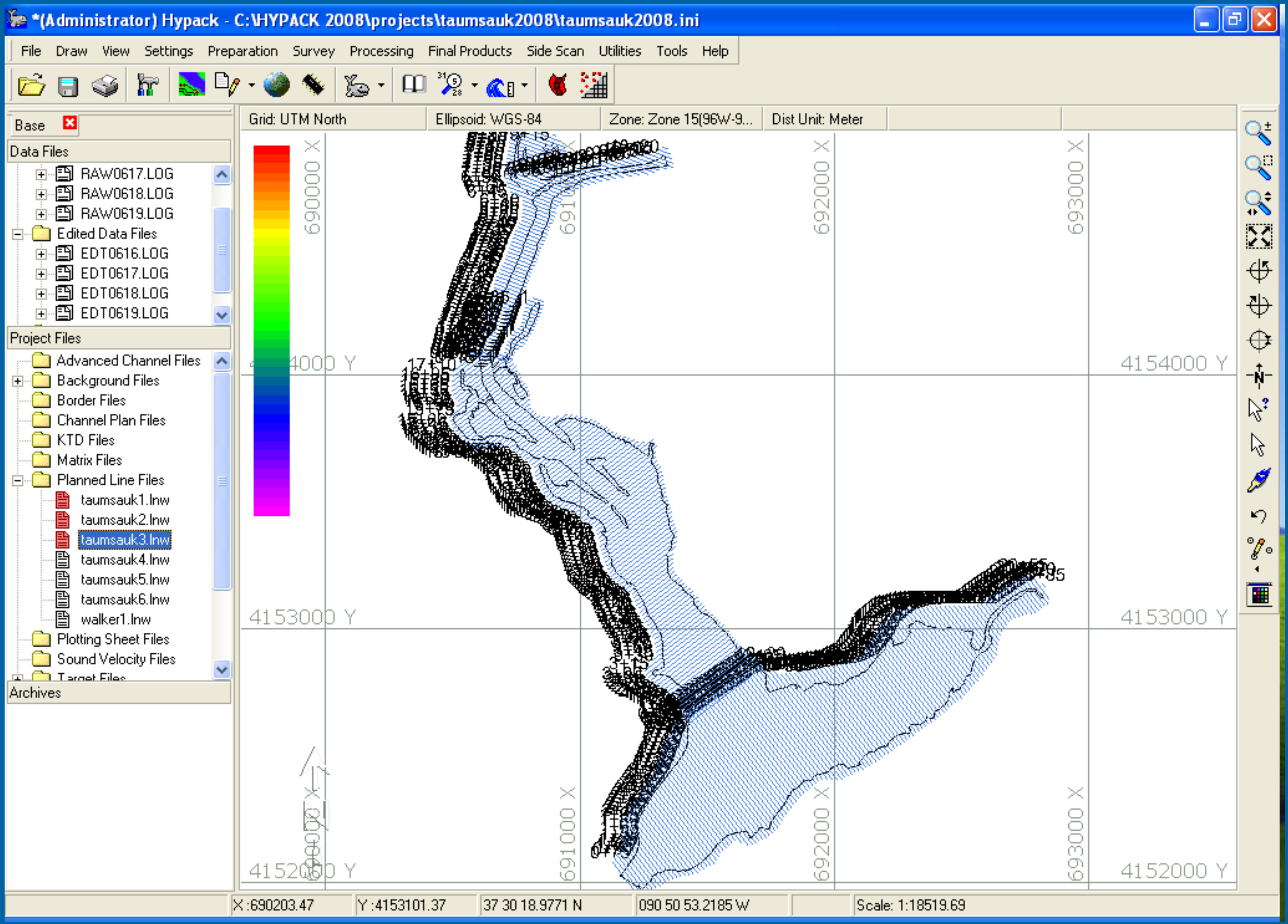
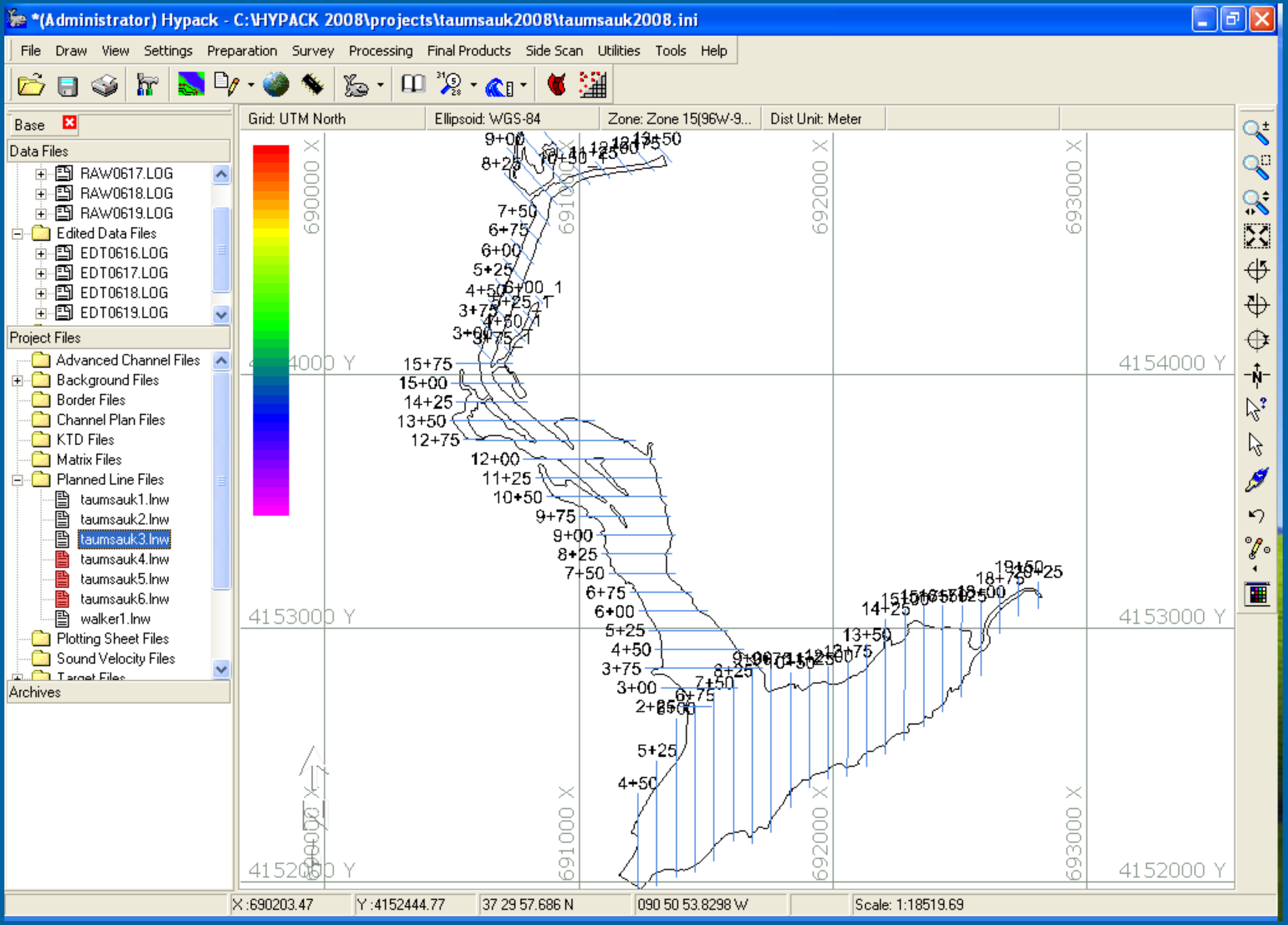
Lake boundary (best available)



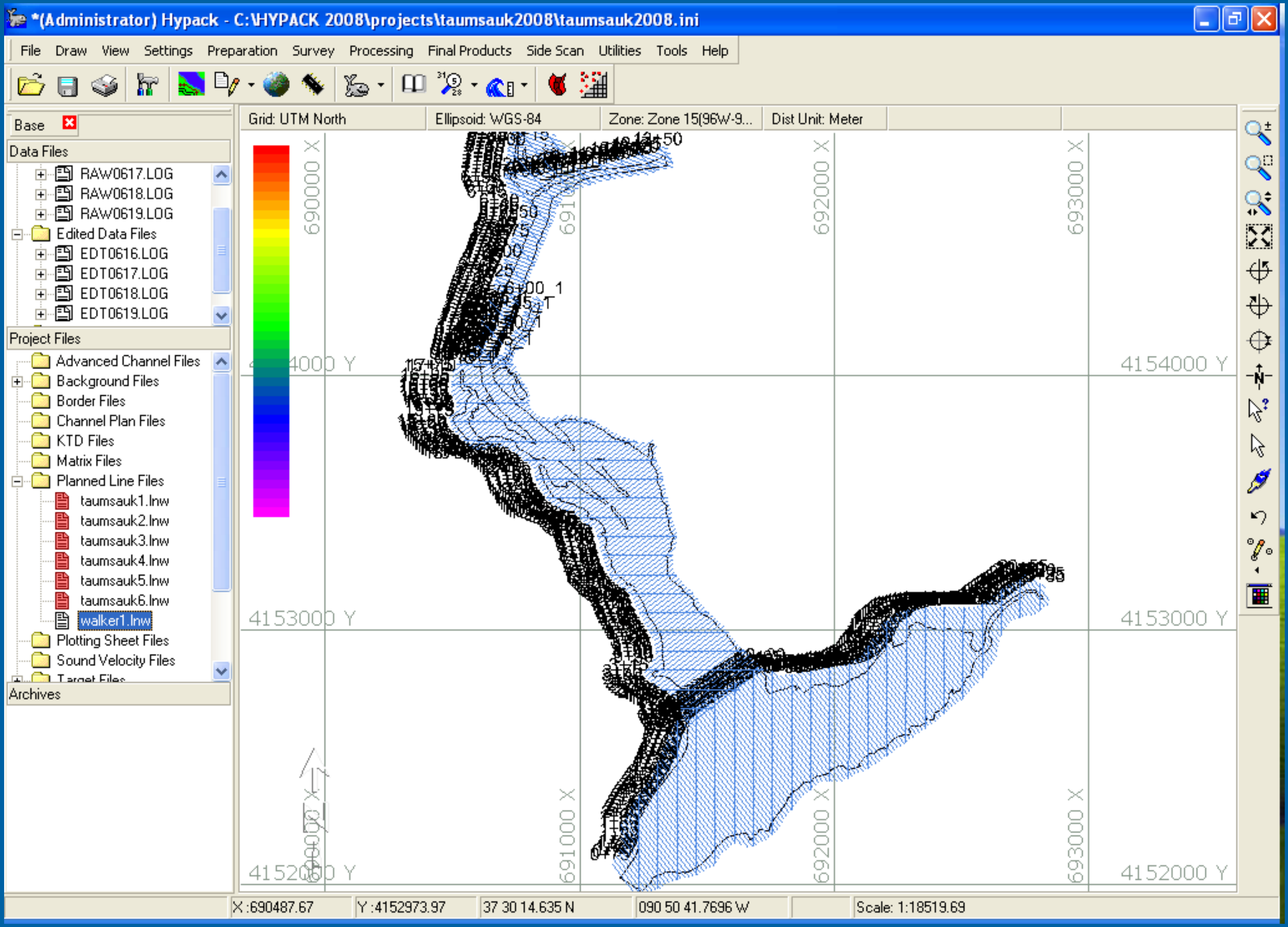
Survey plan lines (Transects)



Survey plan lines (Obliques)



Survey plan lines (all transects)



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Time estimates

- 1 day office preparation for technician
- 1 day office preparation for GIS person
- Minimum 1 day for crew to establish control at lake (depends on benchmark availability and location and location of lake)
- Survey time can be estimated by sum of transect lengths divided by avg. boat speed of 2.5 mph (this takes into account calibration and target points BUT does not take into account land based surveying)
- 1 week minimum processing time to create surface and area/capacity table
- Report time depends on author and additional information in the report

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Recent Example

- 360 acre lake surveyed in June
- Surveyed at 0.5% transect spacing
- Typical office prep
- 3.5 days lake surveying (12 hr days = 40 hrs)
- 1 week to create surface

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Establish vertical control at Lake

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Calibration of Echosounder (Bar Check)

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Following Survey Plan Lines

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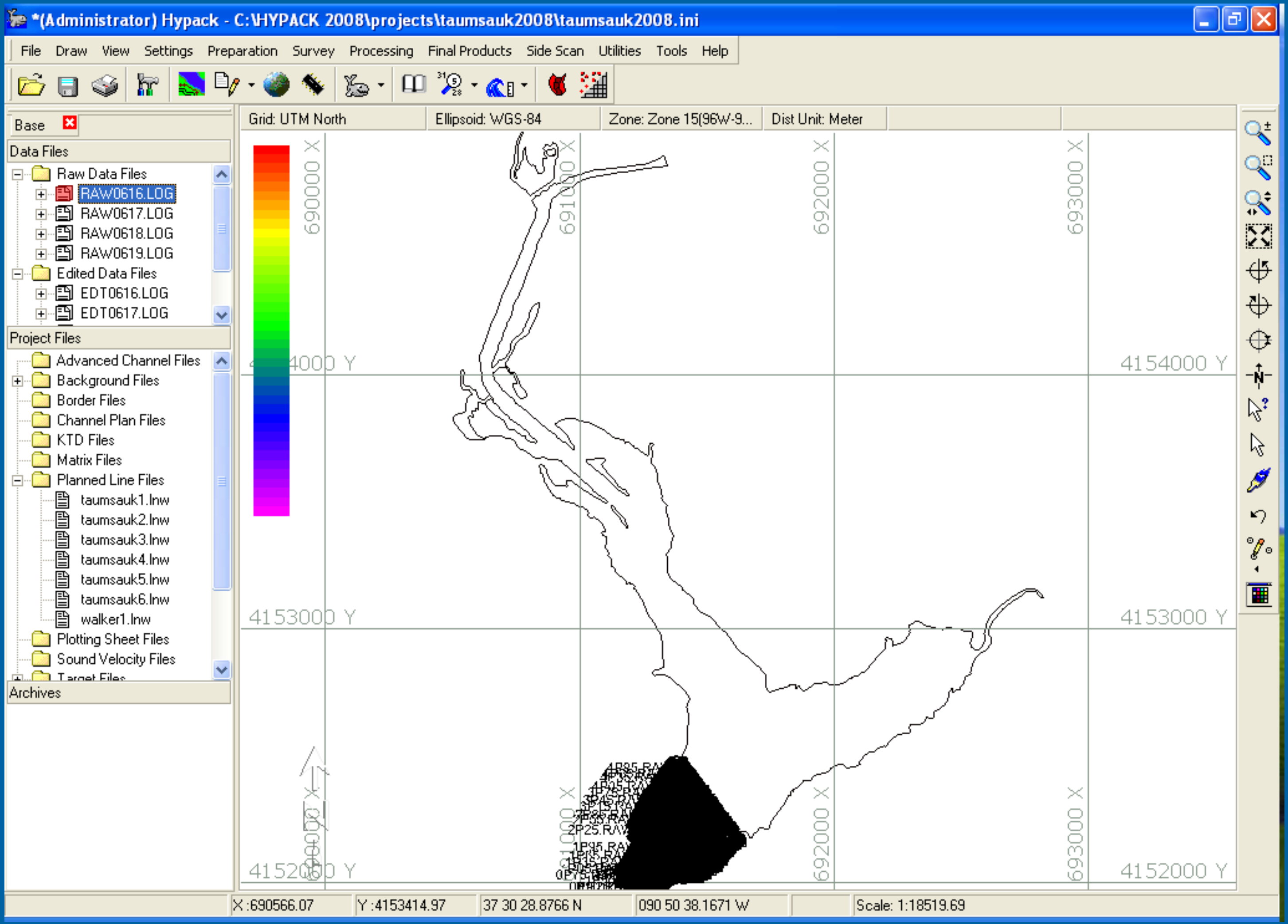
Survey Plan lines in HYPACK



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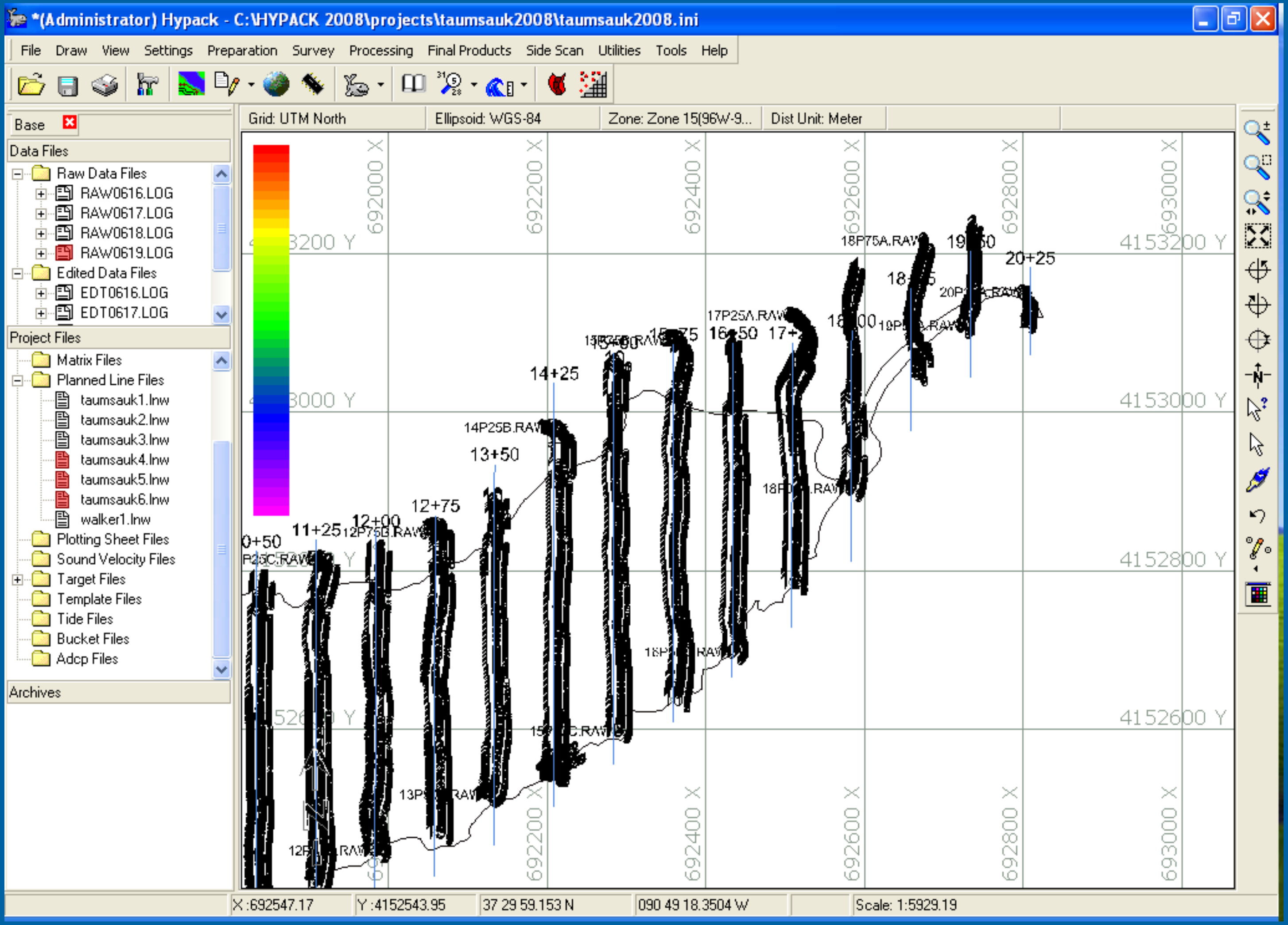
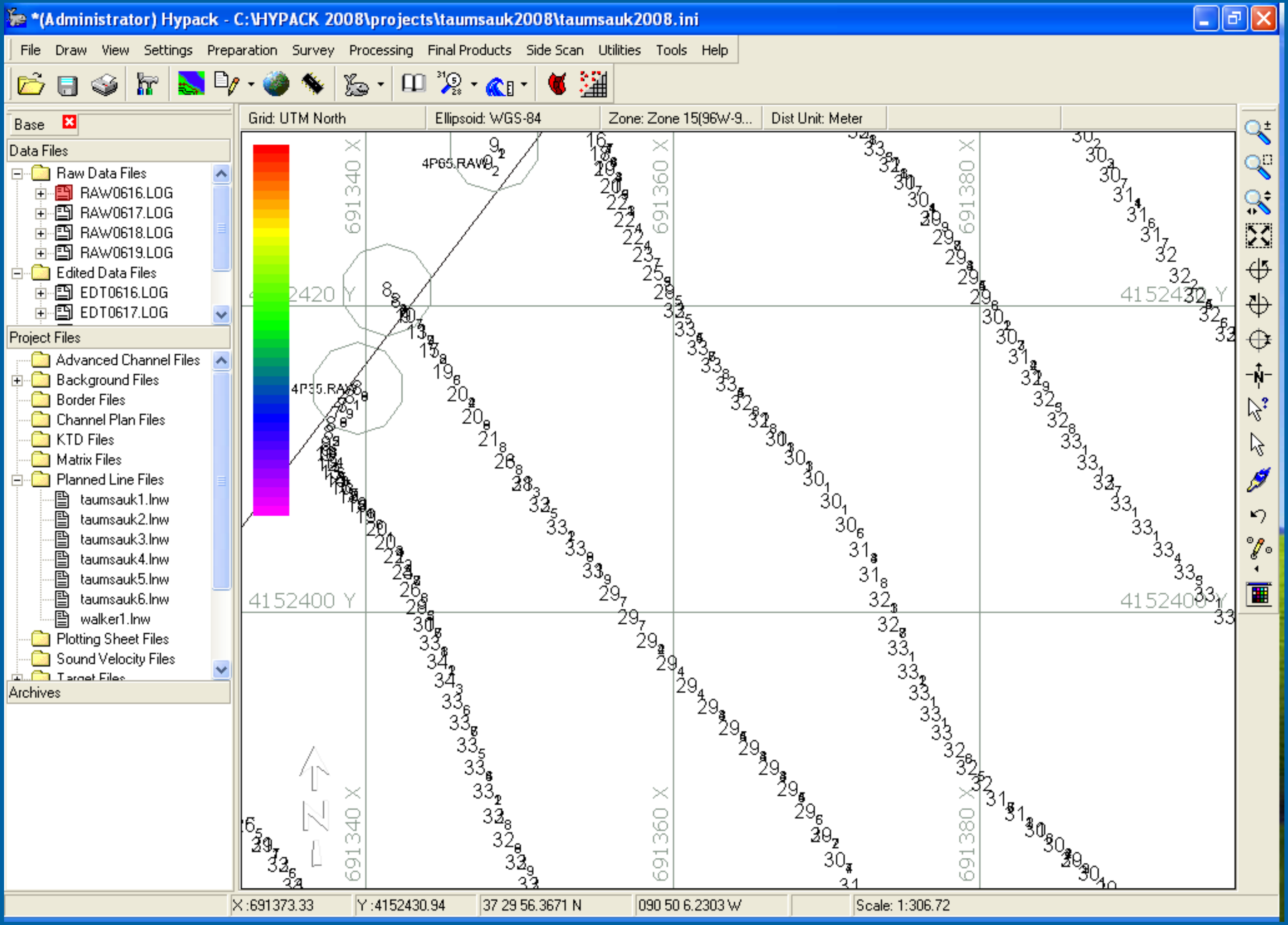
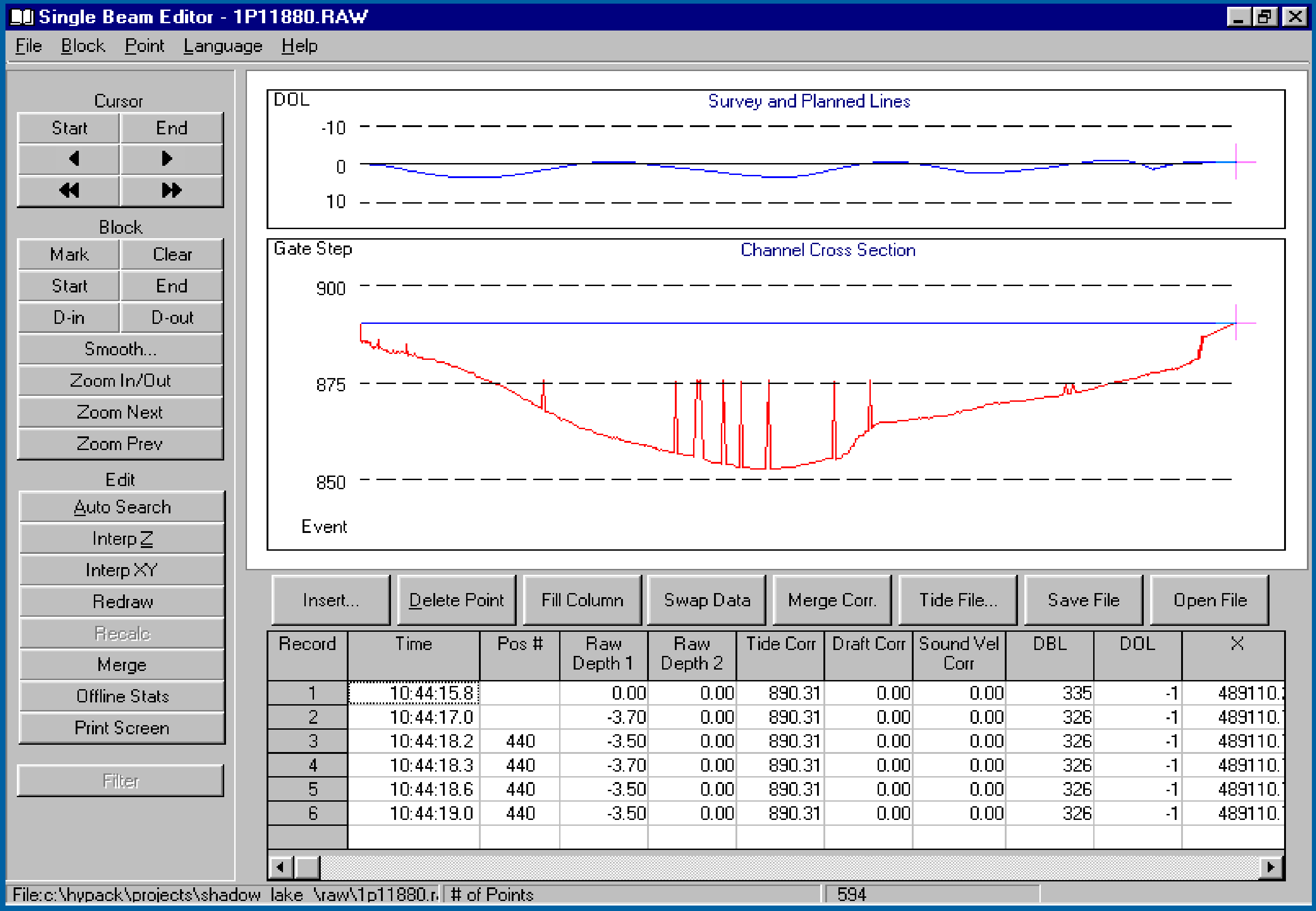


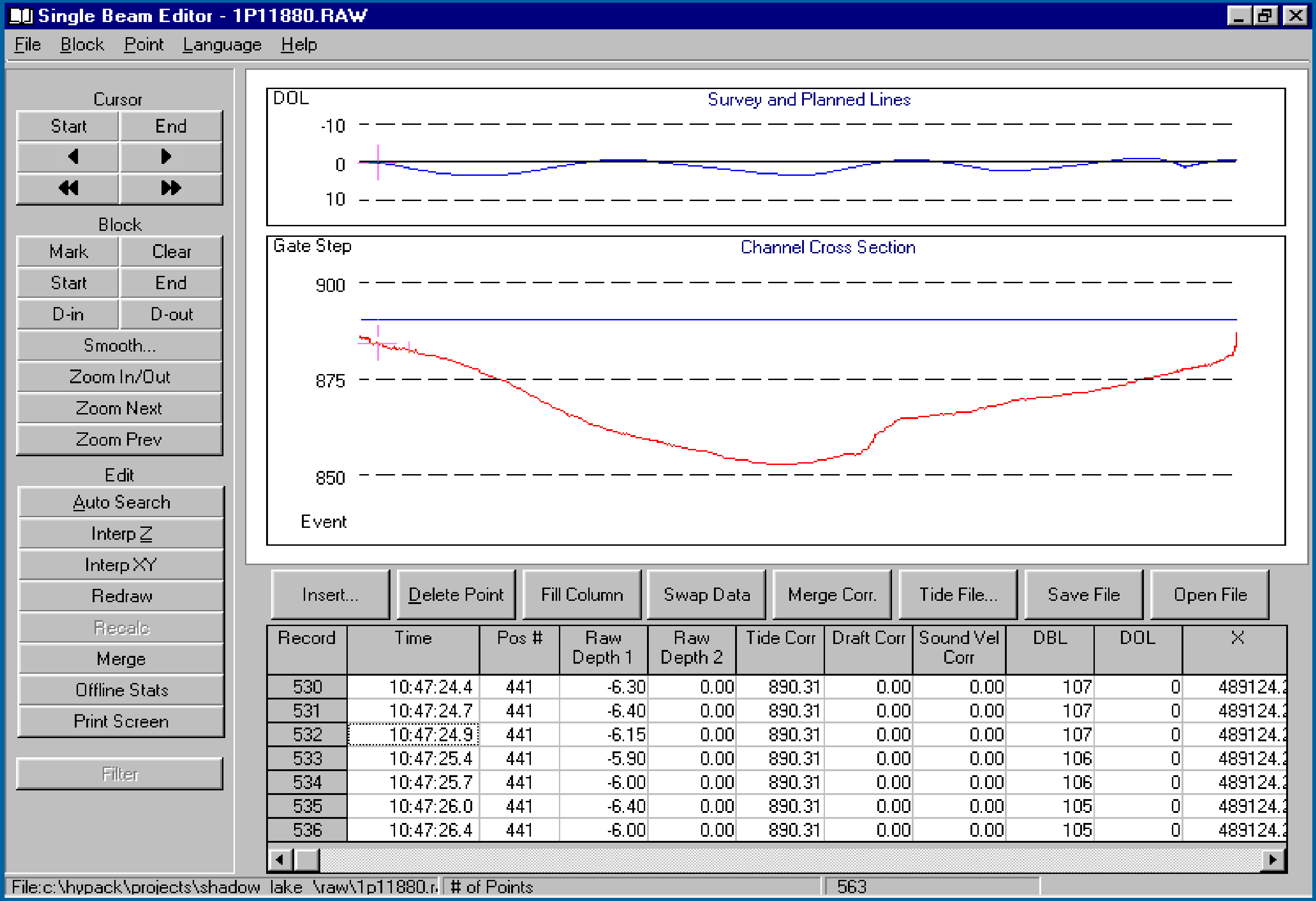
Survey Plan lines in HYPACK



Survey Plan Lines (cross-section view)



Editing cross-section



Record	Time	Pos #	Raw Depth 1	Raw Depth 2	Tide Corr	Draft Corr	Sound Vel Corr	DBL	DOL	X
530	10:47:24.4	441	-6.30	0.00	890.31	0.00	0.00	107	0	489124.
531	10:47:24.7	441	-6.40	0.00	890.31	0.00	0.00	107	0	489124.
532	10:47:24.9	441	-6.15	0.00	890.31	0.00	0.00	107	0	489124.
533	10:47:25.4	441	-5.90	0.00	890.31	0.00	0.00	106	0	489124.
534	10:47:25.7	441	-6.00	0.00	890.31	0.00	0.00	106	0	489124.
535	10:47:26.0	441	-6.40	0.00	890.31	0.00	0.00	105	0	489124.
536	10:47:26.4	441	-6.00	0.00	890.31	0.00	0.00	105	0	489124.

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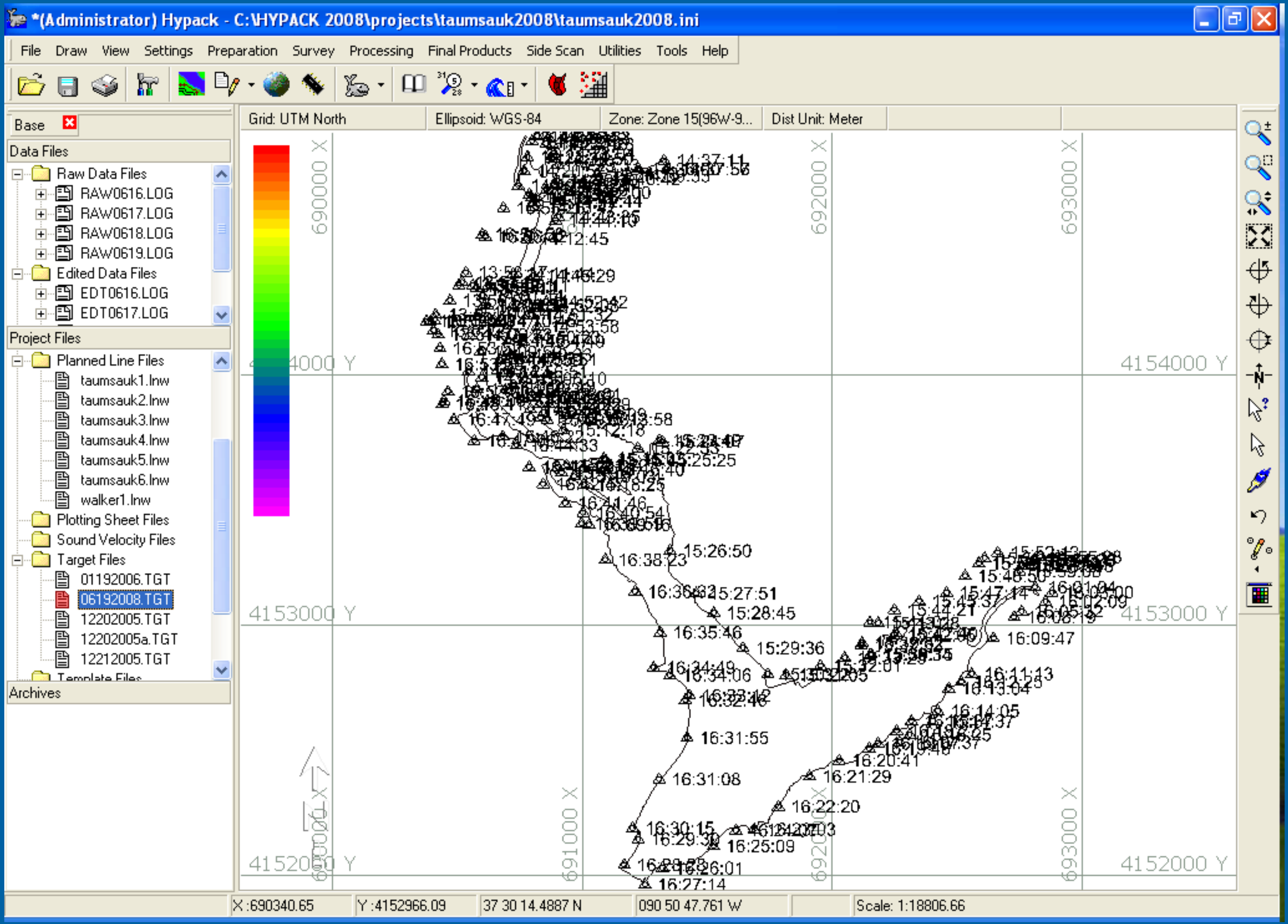
Water Surface edge points



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Target Points

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GPS DATA

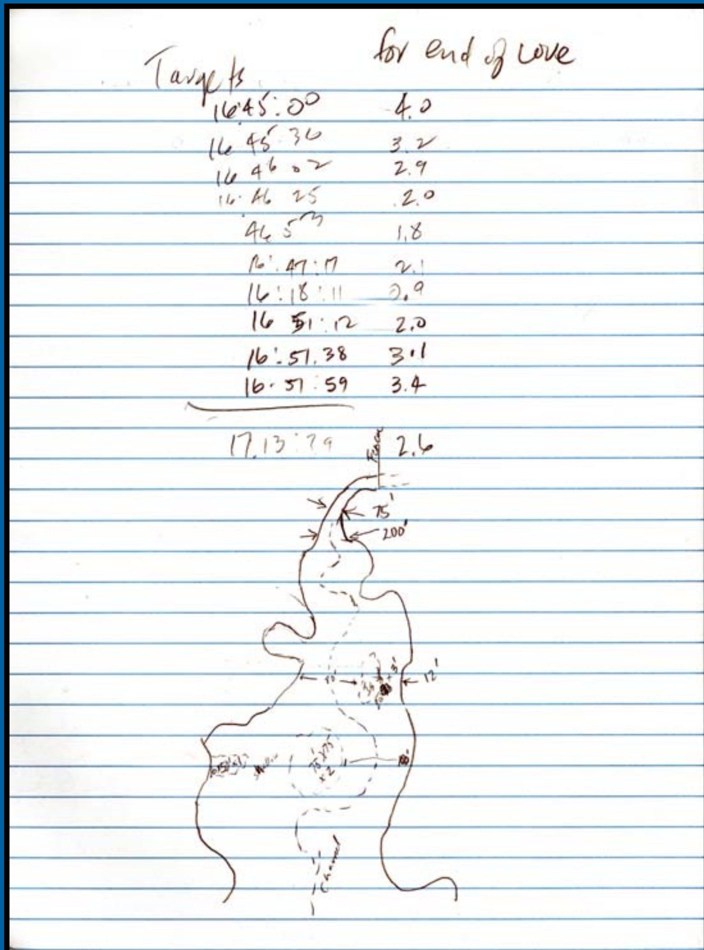
- Water surface elevations
- Spillway elevations (Primary and Emergency)
- Top of dam
- Bridge/Culvert details
- Land surface elevations

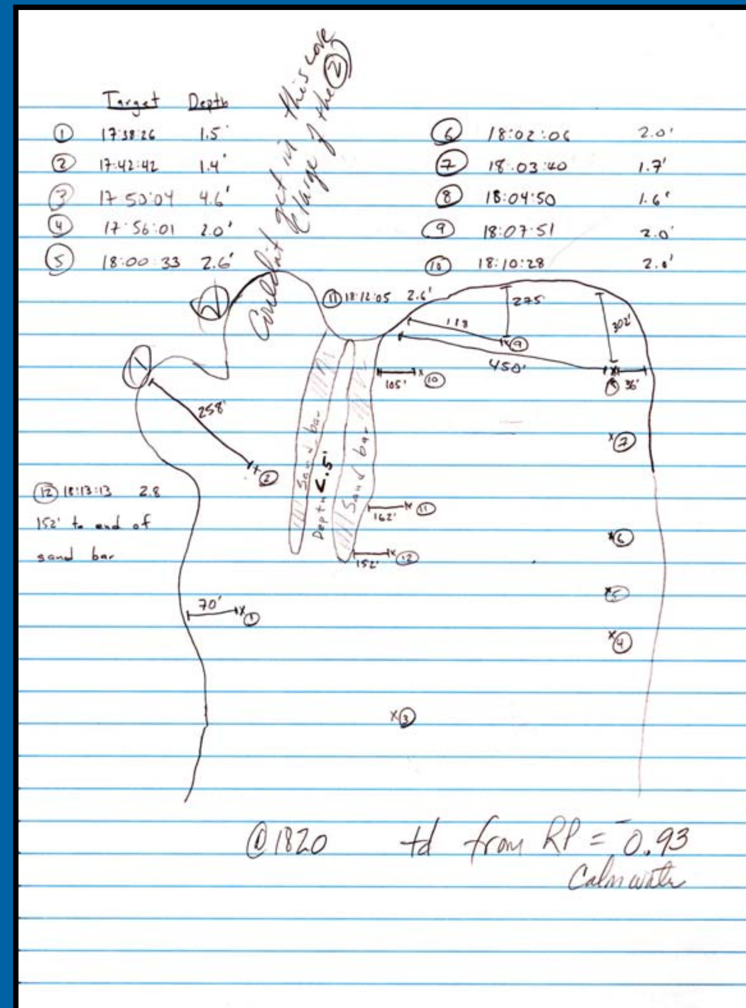
Spillway elevations

Dam elevations

Water surface elevations

Field Notes





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Photographs

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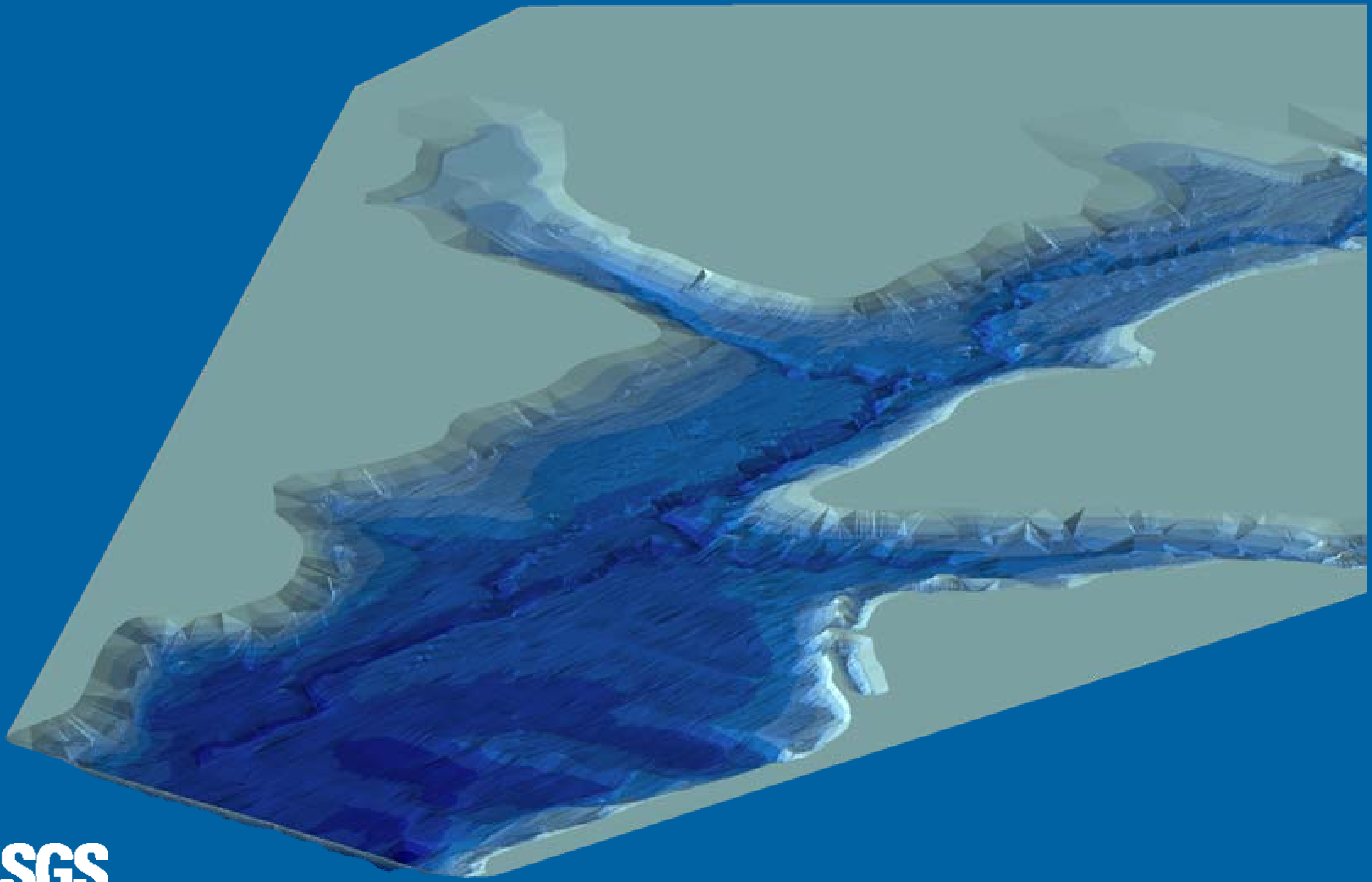
Bathymetry Surface (TIN)



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Bathymetric map creation

- Post process echosounder data with bathymetric mapping software
- Convert raw data to common projection and vertical datum
- Generate point data from raw data files
- Enforce ridge, drain, and bluff linearity in data set
- Convert point data to Triangulated Irregular Network (TIN)
- Contour TIN
- Inspect contours for errors
- Investigate errors and remove erroneous point data
- Regenerate new TIN
- Contour new TIN
- Cartographically edit contours for map production

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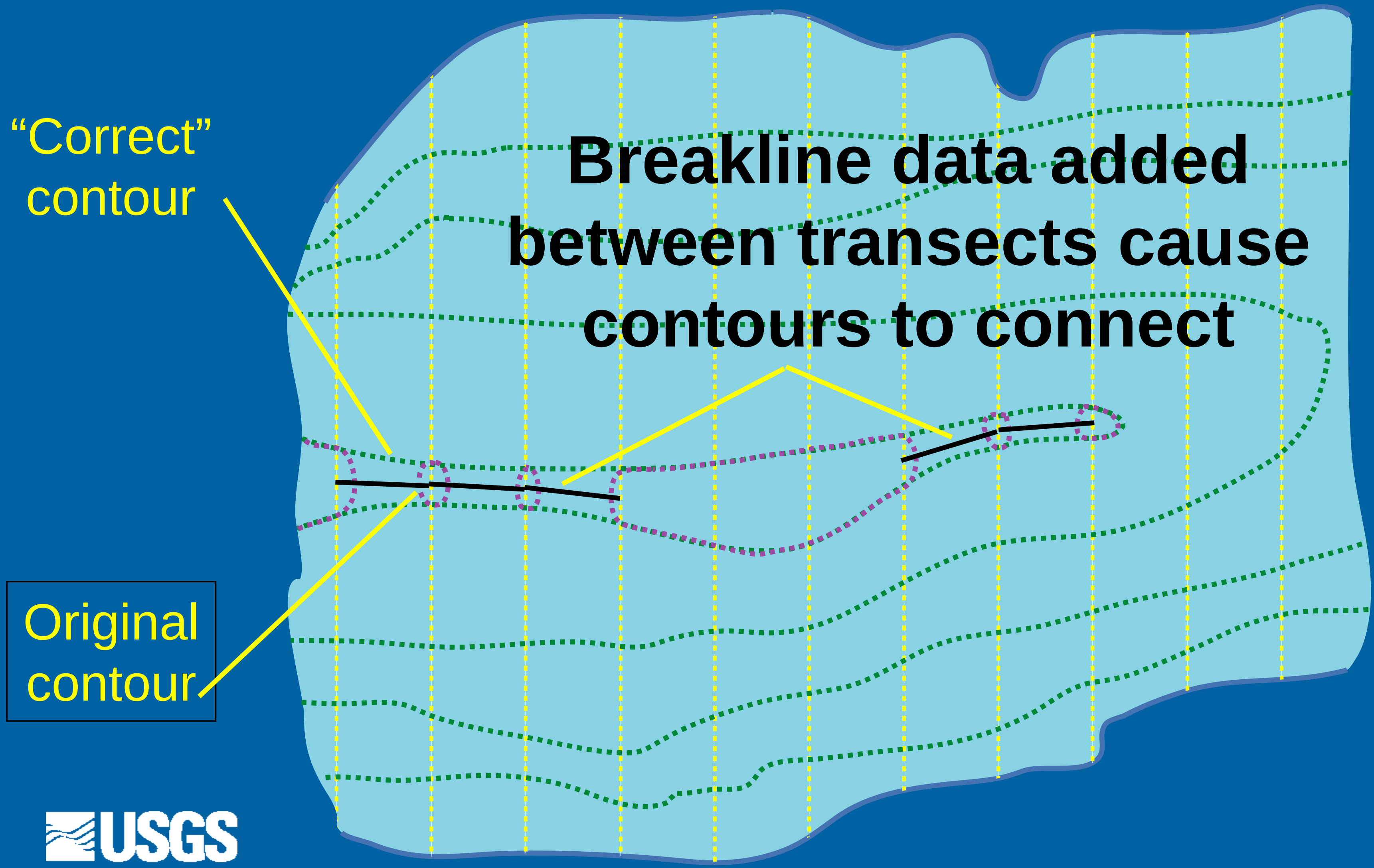
Linear Enforcement
(drain or ridge)



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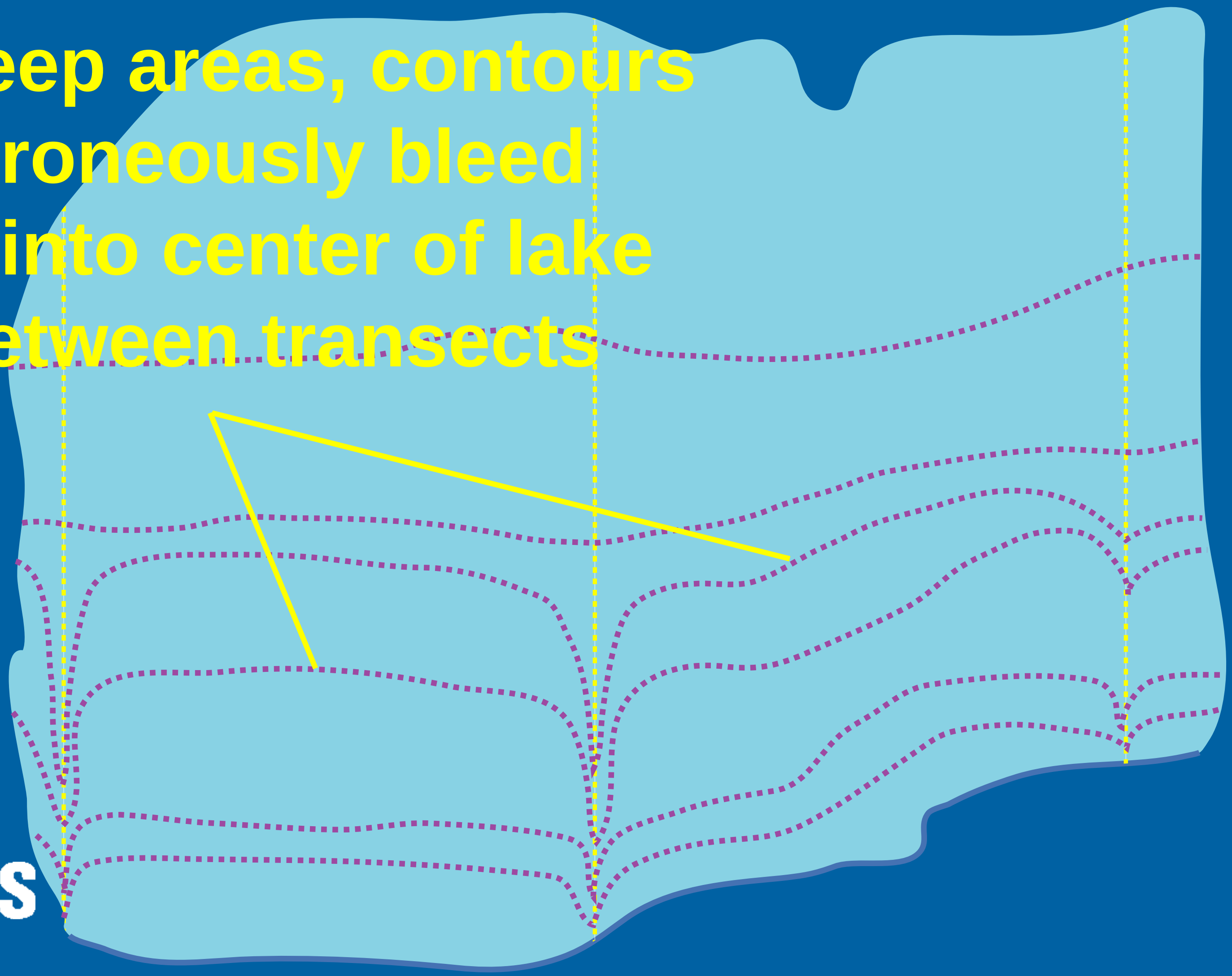
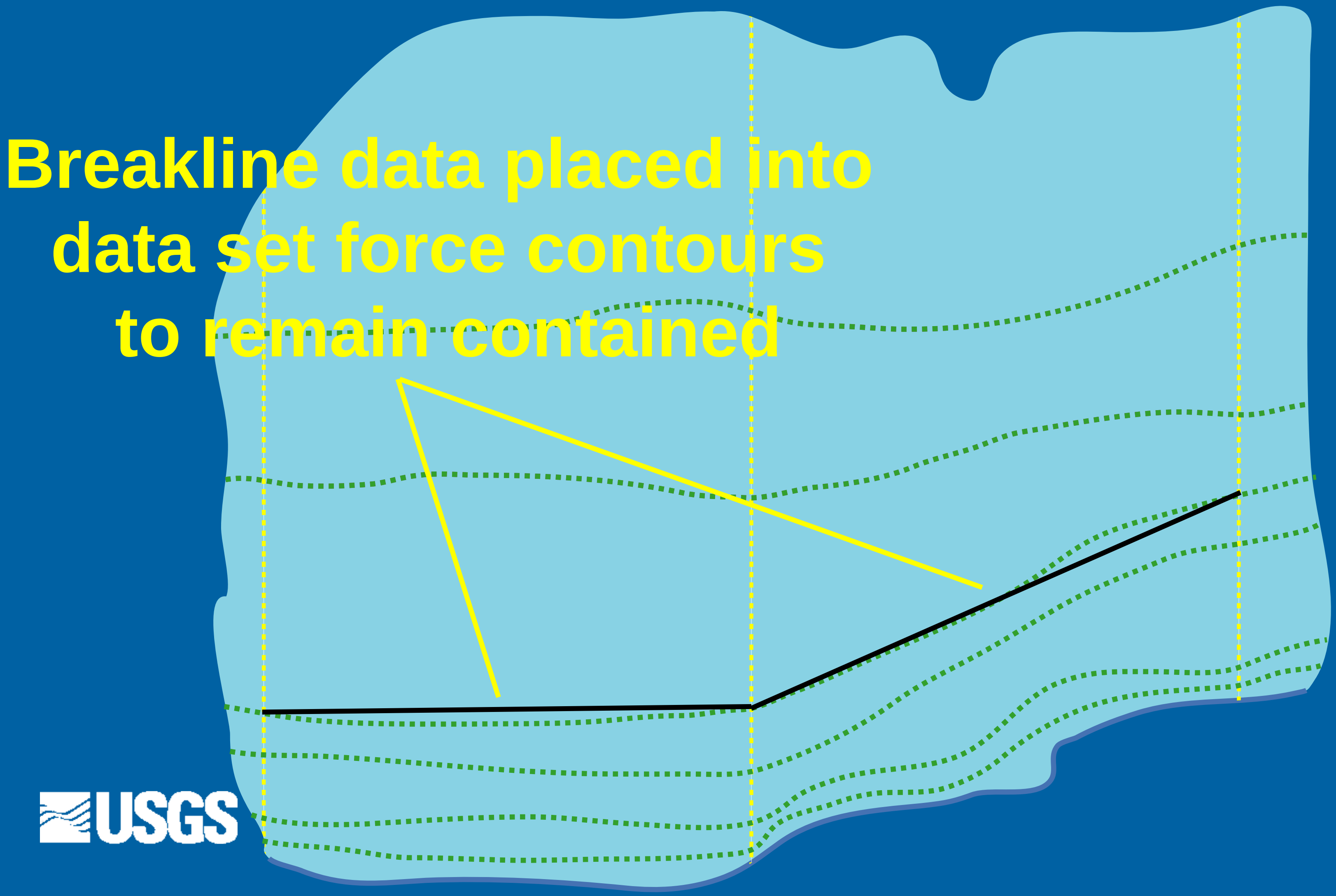
Linear Enforcement

(bluff)

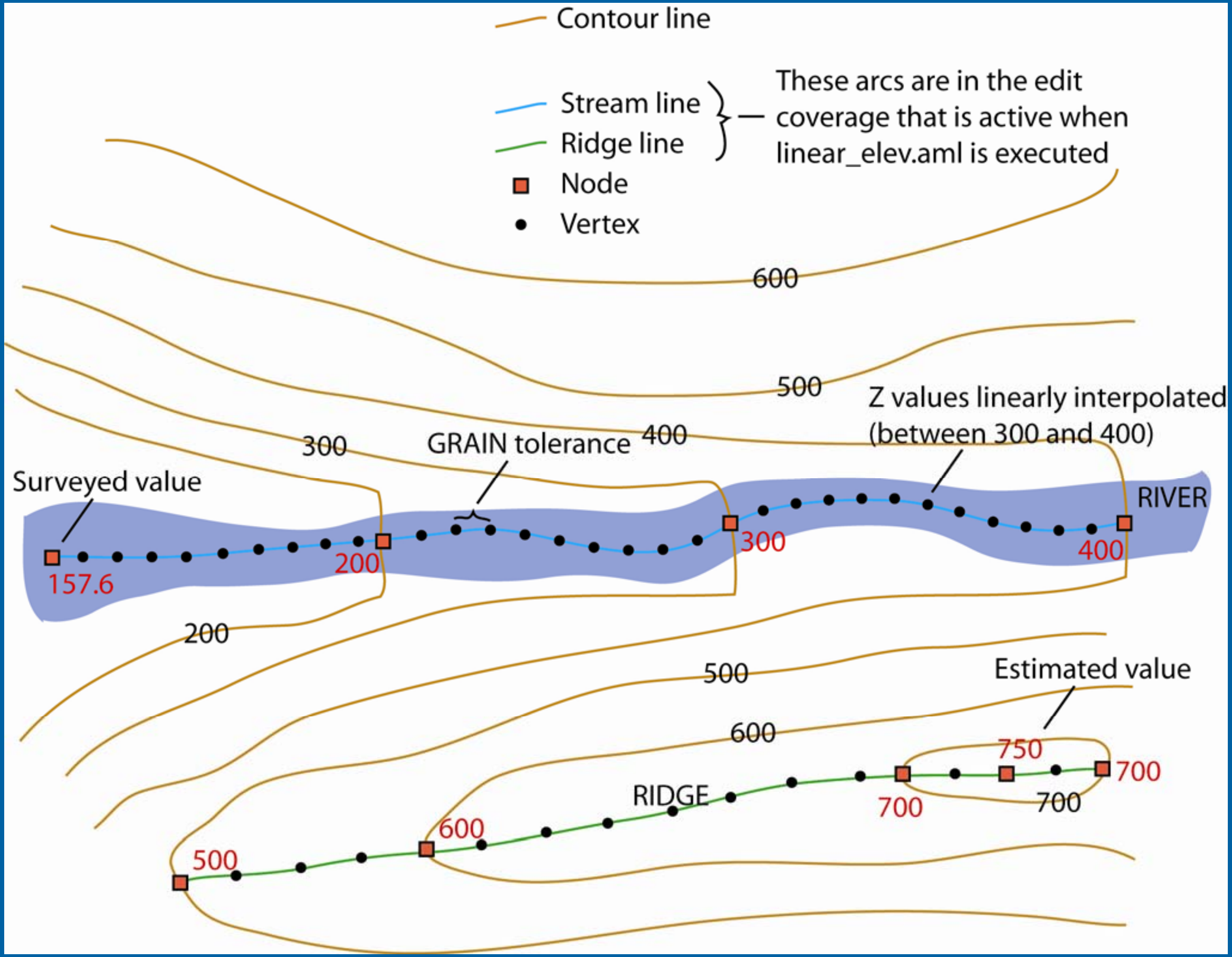
In steep areas, contours erroneously bleed out into center of lake between transects



Linear Enforcement
(bluff)



Usage of AML to create interpolated data



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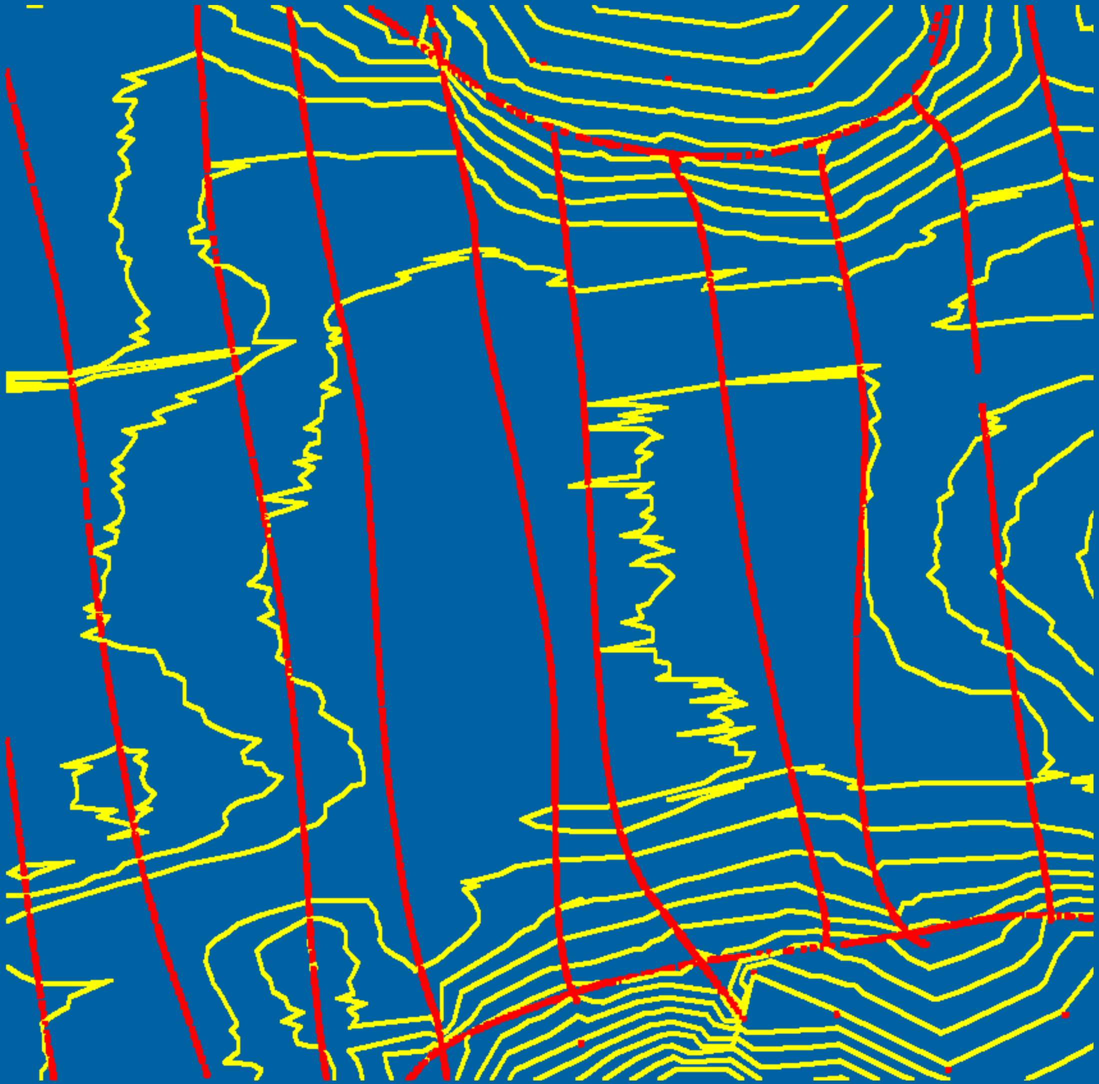
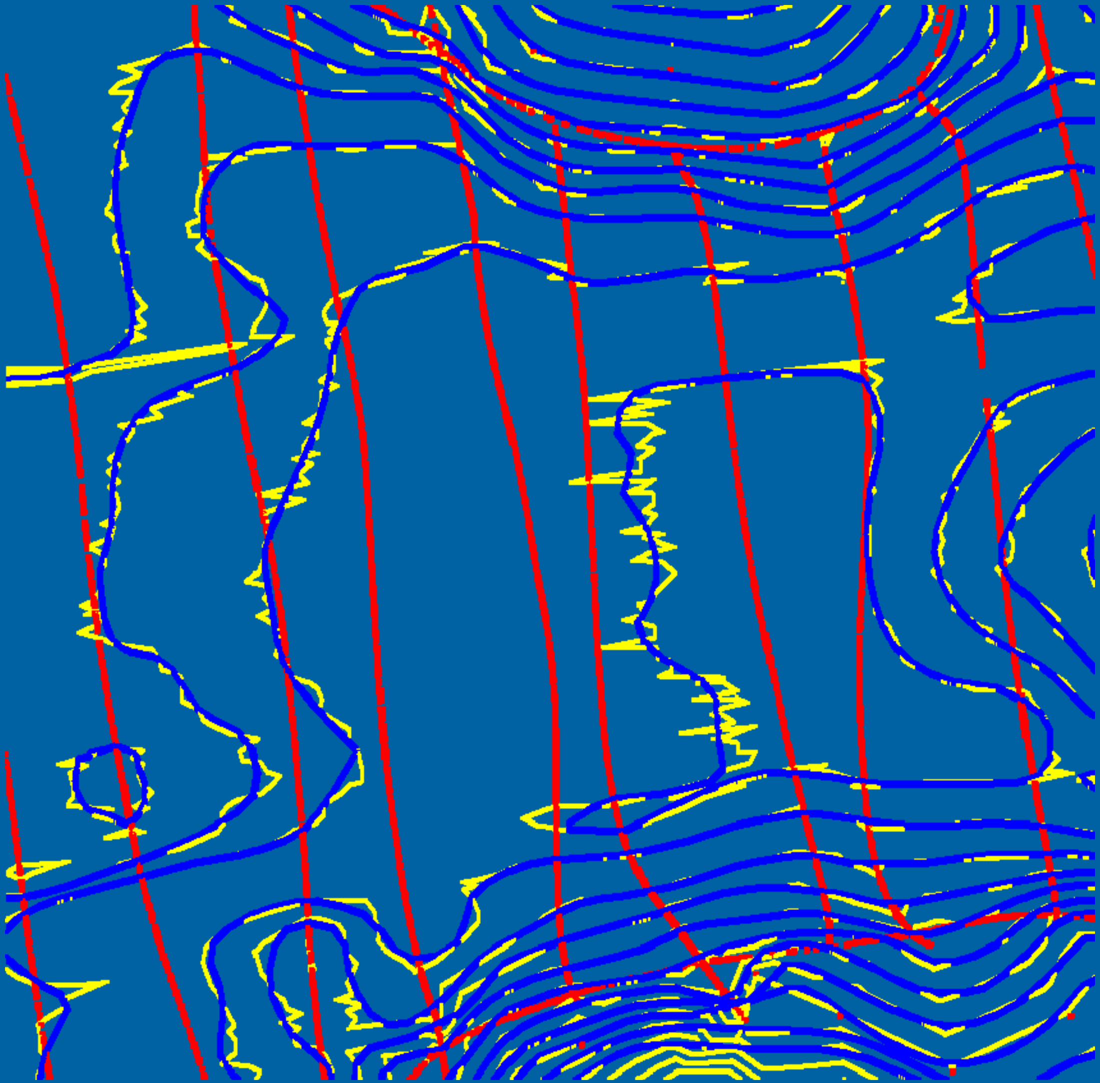
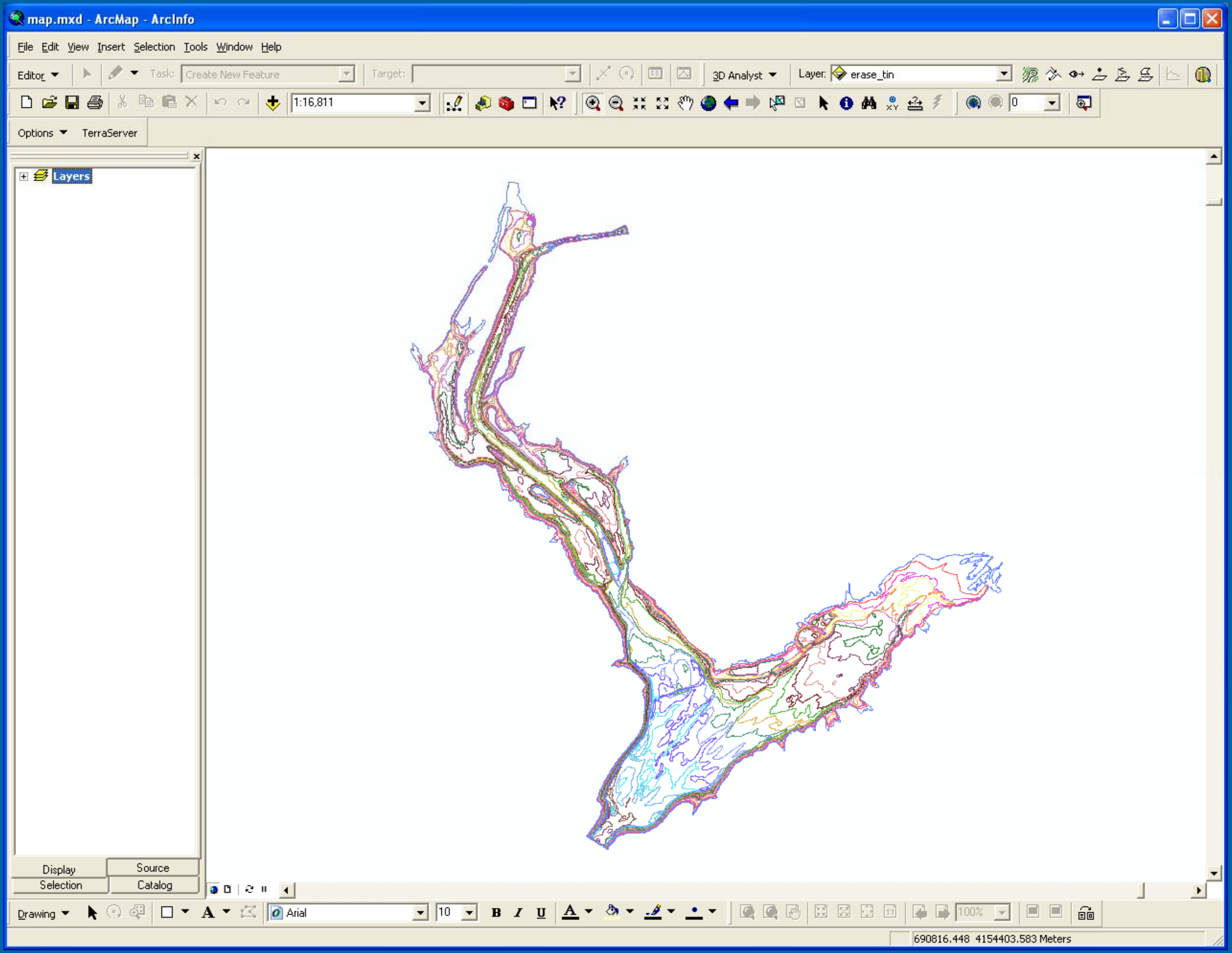
Initial output from surface can be “spiky”



Contours need "smoothed" for final map product (can be time intensive)



Final contours



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Area/Capacity Table

Elevation (feet)	Area (acres)	Volume (acre-ft)
1256.0	0.1	0.0
1258.0	0.5	0.5
1260.0	1.3	2.3
1262.0	2.5	6.1
1264.0	3.9	12.5
1266.0	5.4	21.7
1268.0	6.8	34.0
1270.0	8.5	49.3
1272.0	10	68.2
1274.0	12	91.0
1276.0	15	119
1278.0	18	151
1280.0	21	189
1282.0	26	235
1284.0	29	291
1285.0	31	321

Table 1. Lake elevations and respective surface areas and volumes. Approximate elevation of spillway structure is 1285 feet. Elevations referenced to North American Vertical Datum 1988 (NAVD 88).
Note: Volumes calculated from surface testing 1.17 feet vertical accuracy at 95 percent confidence level.

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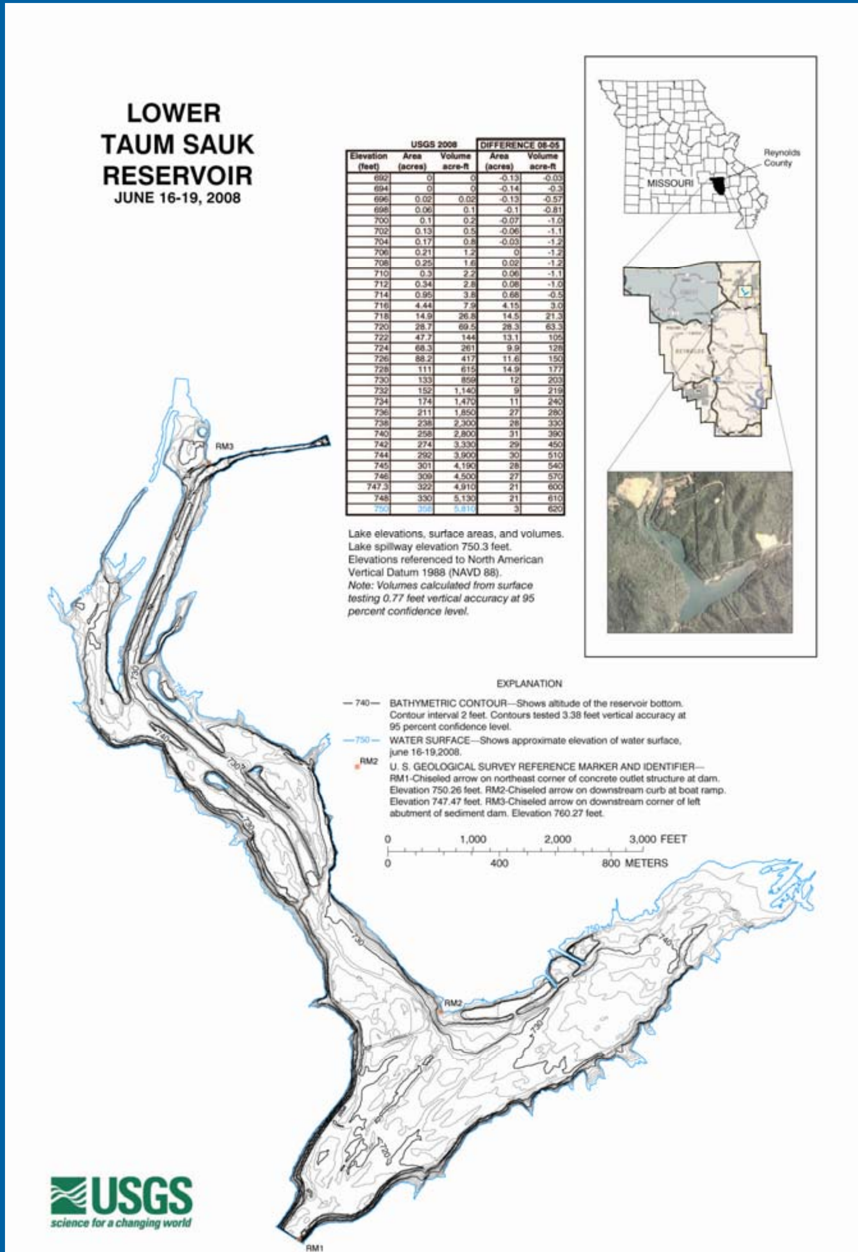
Final product (example from Missouri)



Bathymetric map for Lower Taum Sauk Reservoir near Lesterville, Missouri.

PROVISIONAL DATA SUBJECT TO REVISION - DO NOT QUOTE OR RELEASE

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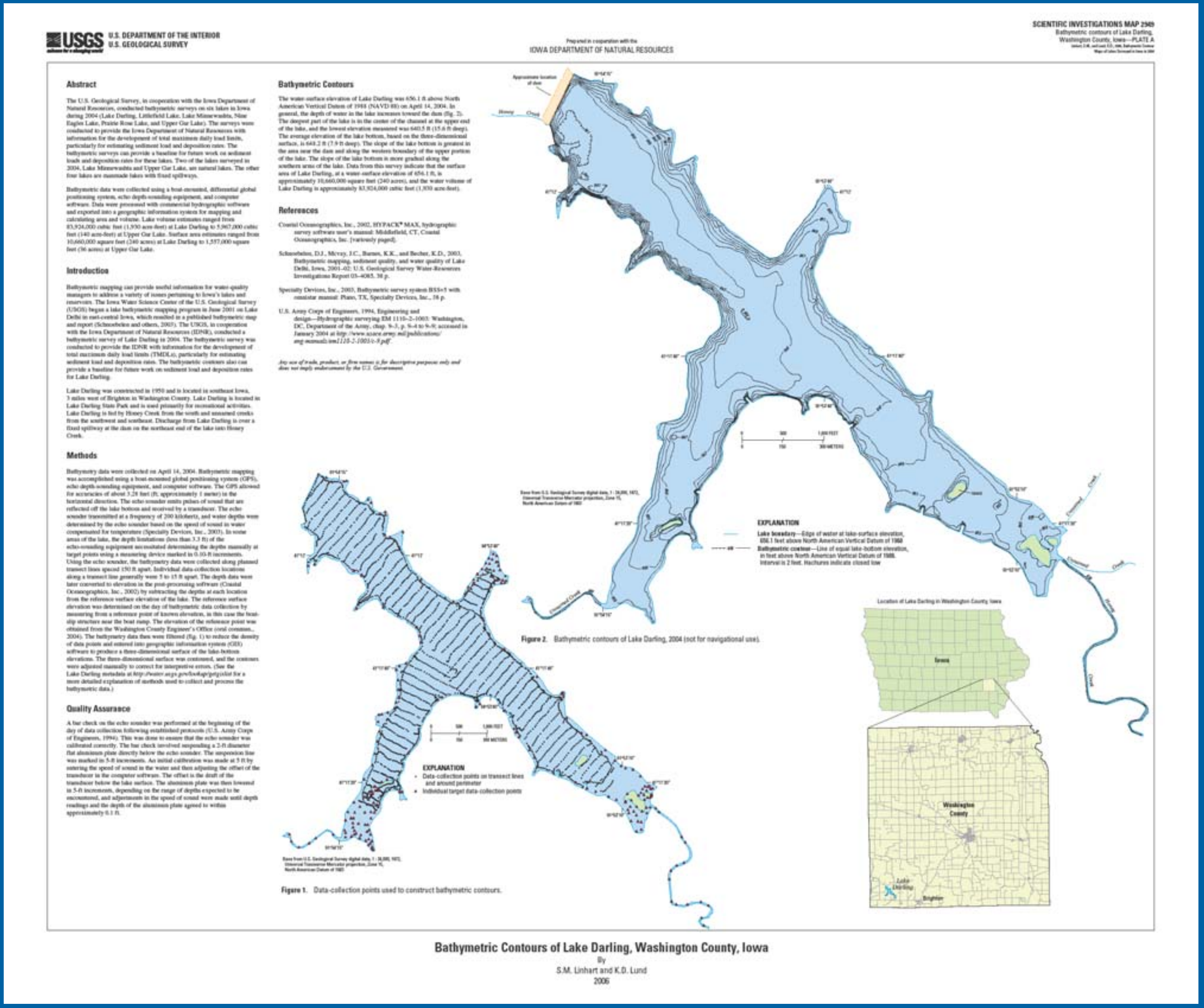
Final product (example from Iowa)



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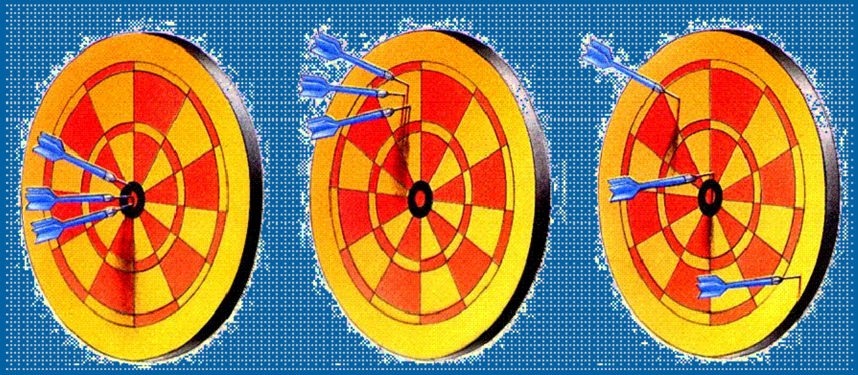
Accuracy Assessment

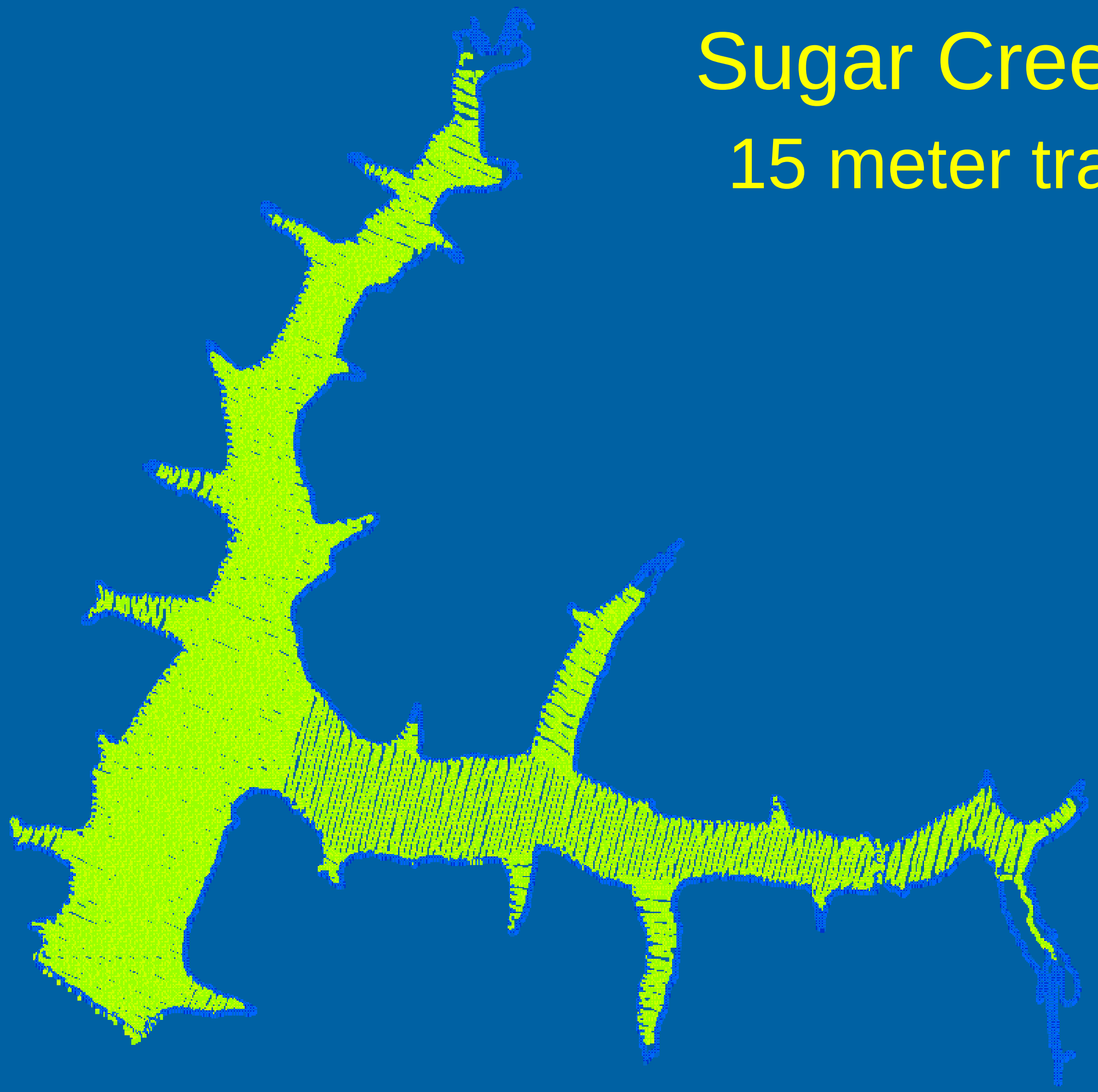
- **Echosounder**
- **Area/capacity Tables**
- **Bathymetric Maps**



Data Collection for Accuracy Assessment

- Sugar Creek Lake (~330 acres)
- Collected 15 meter transect spacing
  - Created area/capacity tables and maps for 15, 30, 60, 120, and 240 meter transect spacing
- Collected 150 meter oblique transects for checking accuracy of TINs and maps
- Collected echosounder and hand measurements of depth

Sugar Creek Lake
15 meter transects



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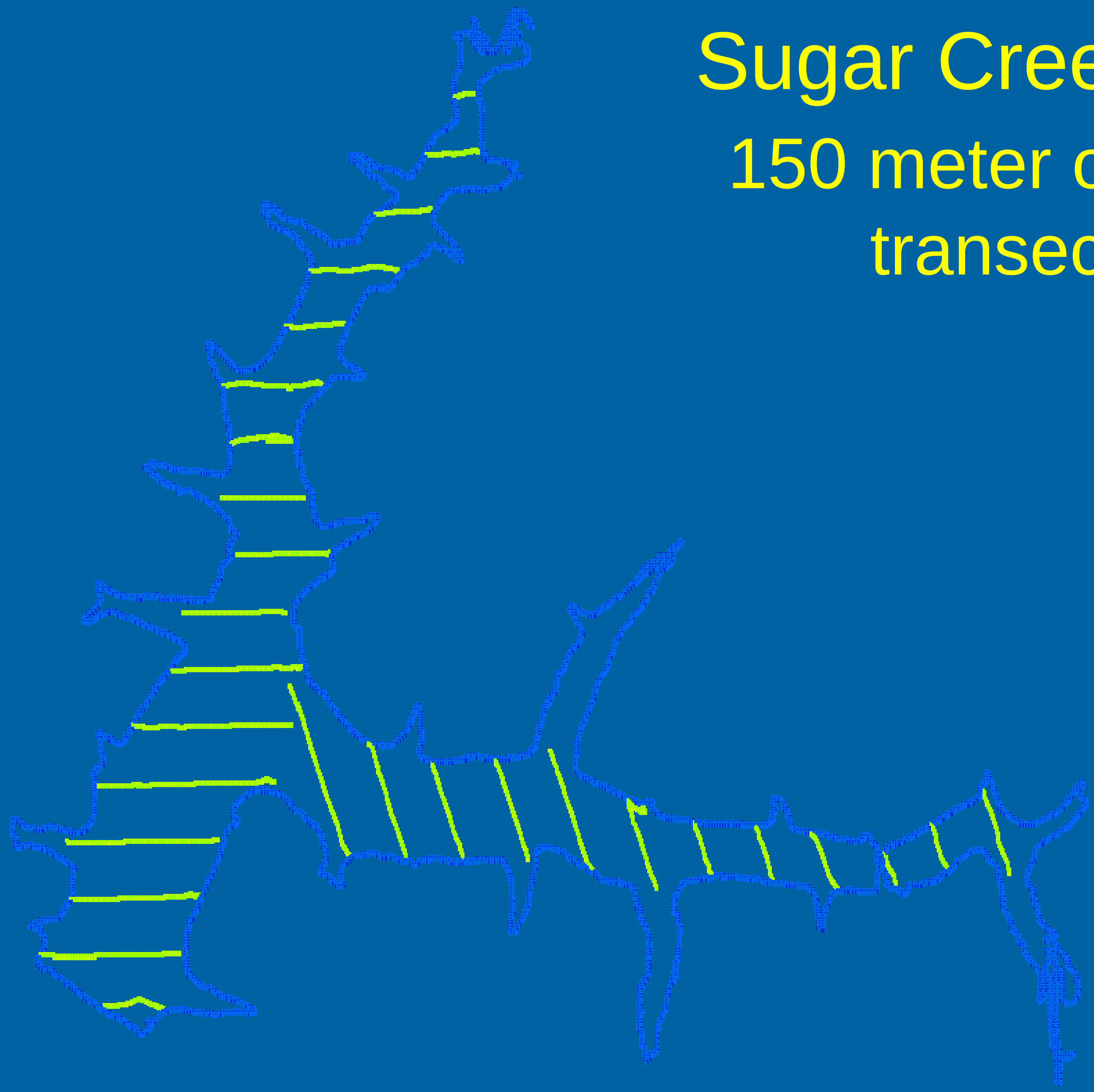
Sugar Creek Lake

150 meter oblique transects



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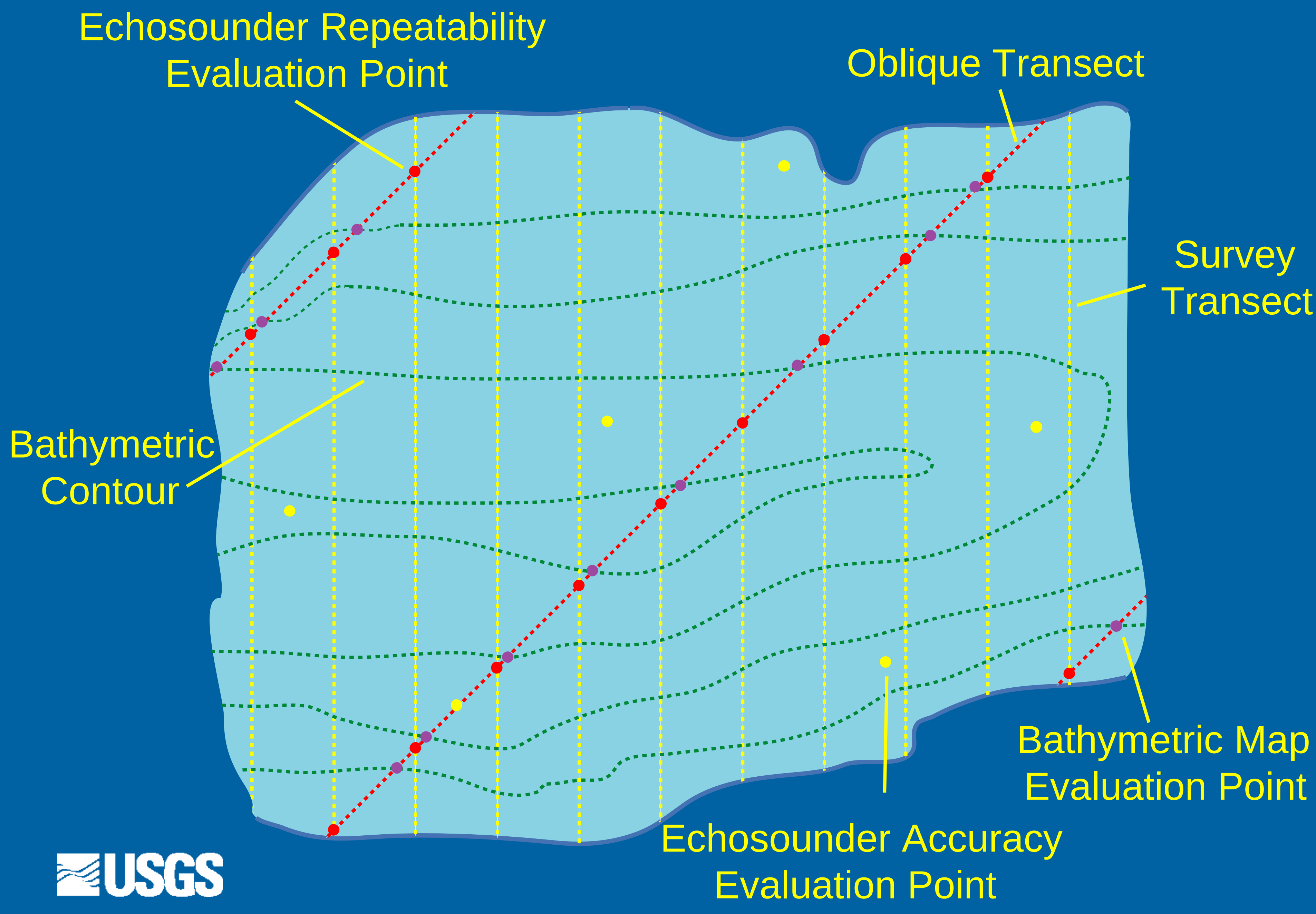
Echosounder Repeatability
Evaluation Point
Oblique Transect
Survey
Transect
Bathymetric
Contour
Bathymetric Map
Evaluation Point
Echosounder Accuracy
Evaluation Point

Echosounder Repeatability

- Evaluated the error where 15m transects intersected the oblique transects (points coincident within 0.1 meter)
- 105 points met the 0.1 meter requirement
- Minimum = -1.1 ft, Maximum = 1.0 ft, Median = -0.08, Mean = -0.06
- Vertical RMSE = 0.34 ft
- Vertical Accuracy (95% conf.) = 0.67 ft

Factors Effecting Horizontal Accuracy

- Global Positioning System (GPS) accuracy during echosounder data collection
- Accuracy of tie-in to National Spatial Reference System (horizontal control points)
- Vessel velocity (latency time)
- Vessel draft/index errors

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Factors Effecting Vertical Accuracy

- Type and quality of the depth measurement system
- Accuracy of tie-in to National Spatial Reference System (vertical control points)
- Vessel velocity, draft, and index errors
- Subsurface material density
- System calibration

Vertical Accuracy Standards

- National Map Accuracy Standard (NMAS)
  - Not more than 10% of the elevations tested shall be in error no more than one-half the contour interval
- National Standard for Spatial Data Accuracy (NSSDA)
  - Vertical component is a linear uncertainty value such that the true location of the point falls within +/- of that linear uncertainty value 95% of the time

NSSDA Vertical Accuracy

- Computed as a root mean square error (RMSE) from independent data set

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} \left(z_{\text{data}_i} - z_{\text{check}_i} \right)^2}{n}}$$

- Accuracy (95% conf.) = 1.960 * RMSE

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Comparison of NMAS/NSSDA Vertical Accuracy

NMAS Contour Interval	NMAS 90% conf.	NSSDA 95% conf. level
1 ft	0.5 ft	0.60 ft
2 ft	1 ft	1.19 ft
4 ft	2 ft	2.38 ft
5 ft	2.5 ft	2.98 ft
10 ft	5 ft	5.96 ft
20 ft	10 ft	11.92 ft

Vertical Accuracy of TINs for Sugar Creek Lake

Transect Interval	Accuracy 95% conf.	
	NO Linear enforcement	Linear enforcement
15 m	0.91 ft	0.91 ft
30 m	1.54 ft	1.46 ft
60 m	3.72 ft	2.83 ft
120 m	7.30 ft	3.95 ft
240 m	15.55 ft	5.83 ft

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Based on 21,647 check points

Vertical Accuracy of Bathymetric Maps for Sugar Creek Lake

Transect Interval	Accuracy (95% conf.)	Number of check points
15 m	1.51 ft	363
30 m	2.76 ft	387
60 m	4.54 ft	335
120 m	6.33 ft	325
240 m	7.30 ft	337

Accuracy Assessment - Conclusions

- Vertical accuracy of area/capacity table better than the bathymetric map
- Adding breakline data to survey data improves accuracy of area/capacity tables and bathymetric maps
- To evaluate the accuracy of the surveyed data, independent survey data must be collected

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Accuracy Assessment - Conclusions

- Large transect spacing causes loss of detail in the bathymetric maps
- Transect spacing of 1% of longitudinal length of length produces good results
- Regardless of transect spacing, a 1-foot interval area/capacity table or bathymetric map is unattainable because echosounder repeatability accuracy greater than 0.61 ft
- For Sugar Creek Lake data (15m), the best possible bathymetric contour map interval would be 3 ft

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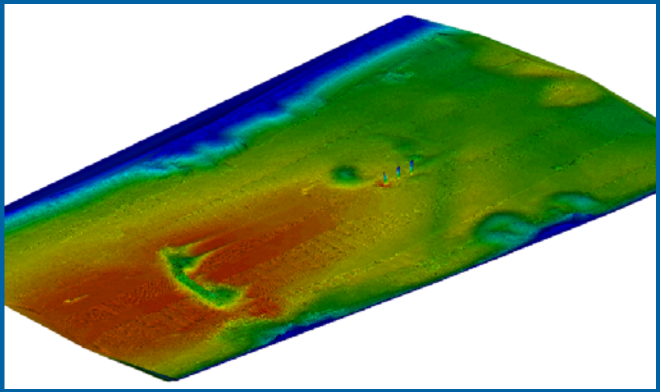
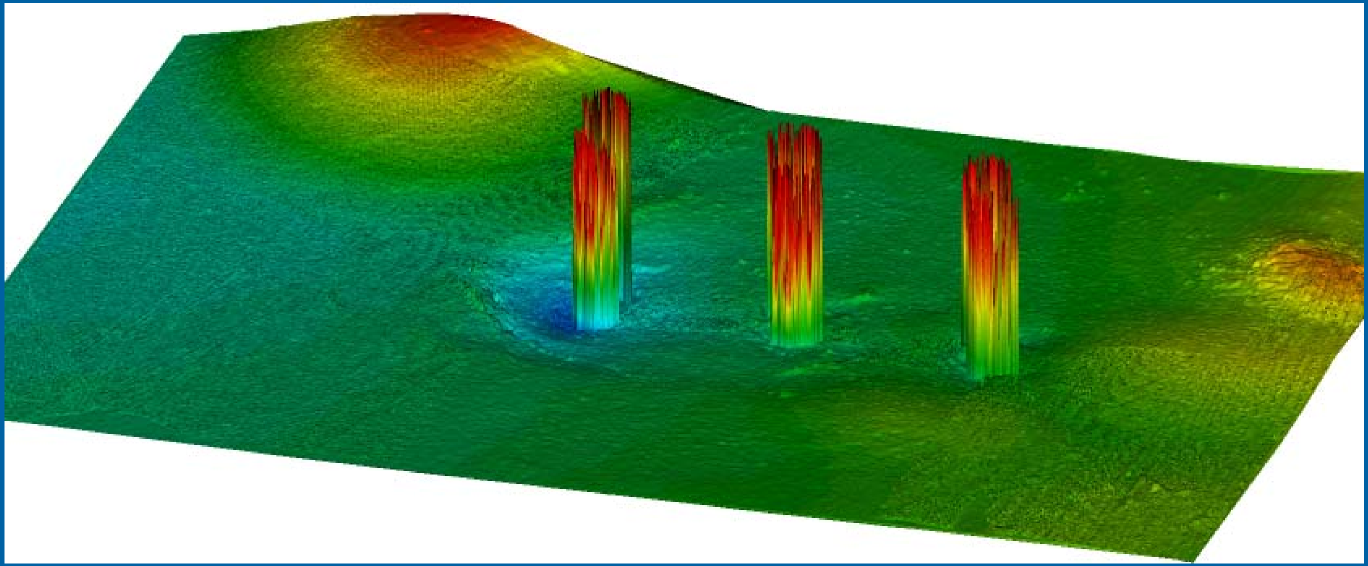
New Technology: Multi-beam echosounders

- Complete bottom coverage
- Expensive
- Steep learning curve
- Depth limitations





Questions?

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- http://mo.water.usgs.gov/

- http://pubs.usgs.gov/sir/2006/5208/