## **RECLANATION** *Managing Water in the West*

Technical Memorandum No. 86-68260-16-01

# Utilization of GIS Software to Develop As-Built Terrains for Hydraulic Modeling

#### Manuals and Standards Project ID: G6187





U.S. Department of the Interior Bureau of Reclamation Technical Service Center Geographic Applications and Analysis Group Denver, CO

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**Bureau of Reclamation** 

Technical Service Center, Denver, CO

Geographic Applications and Analysis Group, 86-68260

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#### **1.0 INTRODUCTION**

The Bureau of Reclamation has established a technique to develop and modify as-built terrains for hydraulic modeling to meet the objectives of the San Joaquin River Restoration Program (SJRRP). Terrains are proprietary continuous elevation models developed by the Environmental Systems Research Institute (ESRI). The model is represented as a multiresolution, triangulated irregular network (TIN)-based surface and is generated using measurements stored as features in geodatabase feature classes. Terrains are very useful for effectively managing, processing, and integrating massive point collections of 3D data that result from collecting high-resolution elevation observations using Lidar, Sonar, and other technologies (Childs, 2011).

This technique is recognized as an improvement over a previous method which involved exporting a GIS elevation surface to contours which were then converted to CAD format for modification. After processing in CAD, the new contours were converted back into a GIS elevation surface that was then used for hydraulic modeling. The existing technique led to loss of data resolution and relied on multiple software platforms and skillsets.

#### **1.1 BACKGROUND**

The SJRRP was established to restore flows to the San Joaquin River from Friant Dam to the confluence of Merced River and revive the Chinook salmon fishery in the river while reducing or avoiding adverse water supply impacts from restoration flows (Johnson, 2016). To accomplish this goal, Reclamation's Technical Service Center (TSC) has been tasked with completing the design of a compact bypass as well as floodplain grading and revegetation over this reach of the river. To support these efforts TSC staff developed a GIS-centric method to modify terrains for testing the hydraulic behavior of these designs. This manual serves to standardize the process resulting in consistent products from all future endeavors.

#### **2.0 PROCESS STEPS**

*Note:* The following process steps prepare the input data to perform a raster based substitution of calculated values that supersede the input elevations within the channel area(s) only.

- 1. Review Channel Cut Alignment(s) [Figure 1]
  - a. Ensure Connectivity with Main Channel
    - i. The polylines should be single features with downstream direction.
  - b. Extend Into Main Channel if Necessary
    - i. If a main channel centerline is available, it may be appropriate to 'snap' channel cut endpoints to the main channel centerline.

- 2. Create Channel Cut Buffers [Figure 2a & 2b]
  - a. Channel Bottom Buffer Width
    - i. Half of Total Bottom Width $^{\dagger}$
  - b. Channel Bank Buffer Width
    - i. Multiply Slope Ratio<sup>†</sup> by 10<sup>‡</sup>
      - 1. Example: 1:5 Ratio = 50
    - ii. Add to Half of Total Bottom Width
  - c. PARAMETERS Side Type: Full, End Type: Flat, Dissolve Type: None
  - d. Explode Multi-Part Features
  - e. Spatial Join ID Field
- 3. Split Channel Cut Buffer(s) by ID Field [Figure 2c]
  - a. Split By Attribute Tool [Add-in]
    - i. Separates Buffers Into Singular Features
  - b. Create Channel Bank and Bottom Geodatabase
- 4. Convert Channel Cut Buffer Polygon(s) to Polylines
  - a. Model Builder Script
    - i. The following script iterates through the geodatabase (Step 3b) to convert polygons to polylines.



- 5. Split Channel Cut Polylines At Endpoints
  - a. Delete Terminus Lines [Figure 2a]
  - b. Merge Unconnected Channel Bank and Bottom Sideline(s) (If Necessary)

<sup>&</sup>lt;sup>†</sup> Information provided by client.

<sup>&</sup>lt;sup>+</sup> Choose appropriate multiplier based on topography. More rugged topography will require a larger multiplier so the resulting channel banks 'daylight' when integrated into the existing terrain.

- 6. Create Channel Cut Station Points [Figure 3a]
  - a. 10 Foot Spacing
  - b. Add Elevation Field (Double)
  - c. Calculate Elevation [Figure 3b]
    - i.  $\Delta$  Elevation = (Upstream Elevation<sup>§</sup> Downstream Elevation<sup>§</sup> / No. of Station Points)
    - ii. (Upstream Elevation (([OBJECTID] 1) \*  $\Delta$  Elevation))
    - iii. Use Six Significant Digits
    - iv. Bank elevations are calculated by adding the slope ratio multiplier (Step 2b) to the upstream and downstream bottom elevation (see i. above).

*Note:* The following steps finalize the raster based substitution of calculated values that supersede the input elevations within the channel area(s).

- 7. Create Channel Cut Terrain(s) [Figure 4]
  - a. Mass Points: Channel Cut Station Points (Step 6)
  - b. Hard Clip: Channel Bank Buffer (Step 2b)
- 8. Convert 'Original' Area of Interest (AOI) Terrain to Raster
  - a. Utilize Terrain as 'Snap Raster' for Step 9
  - b. Verify Raster Cell Size Consistency
- 9. Convert Channel Cut Terrain to Raster(s)
- 10. Run *Cell Statistics* Tool on Rasters (Steps 8 & 9)
  - a. PARAMETERS Overlay Statistic: Minimum
    - i. Using 'Minimum' as the overlay statistic ensures that the channel cuts supersede the elevations from the 'original' AOI.
- 11. Convert Output Raster (Step 10) to Terrain [Figure 5]

<sup>&</sup>lt;sup>§</sup> Information provided by client.

#### 2.1 VISUAL AIDS



Figure 1. Extension of channel cut lines into main river channel.



Figure 2a. Bank and bottom width channel cut buffers.

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Figure 2b. Buffer Tool GUI and Buffer Table with calculated attributes.



Figure 2c. Split By Attribute Tool GUI and Bank Table with ID (i.e. 'Split') field.



Figure 3a. Bank and bottom width channel cut station points.

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Figure 3b. *Station Point Table* with Elevation field calculations.



Figure 4. Channel cut terrains.



Figure 5. Final terrain with channel cuts.

#### **3.0 REFERENCES**

Childs, C. (2011). Terrain Datasets: The Top 10 Reasons to Use Them. ArcUser Spring 2011.

Johnson, T. (Ed.). (2016). San Joaquin River Restoration Program (SJRRP). Retrieved January 4, 2016, from http://www.restoresjr.net.