

# Creating a RAS Terrain for 2D Modeling

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This presentation will discuss the creation of terrain data for hydraulic modeling. The discussion will focus on different data collection methods/sources of data; types of terrain models (TINs v Grids); key considerations in building a terrain model; cell size considerations; and importing terrain model data into HEC-RAS for use in data extraction and mapping.



# Overview



- Projection
- Creating a RAS Terrain Layer
  - Types of Terrain Models
  - Building a Terrain Model
  - Key Feature Considerations
  - Cell Size Considerations
  - Importing Terrain Information to RAS

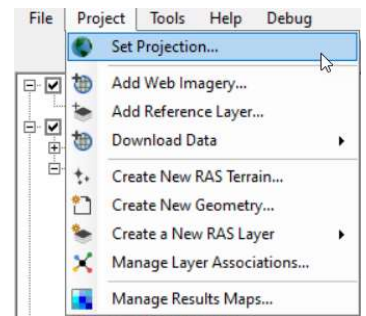


# Overview



- Projection
- Creating a RAS Terrain layer

# Projection



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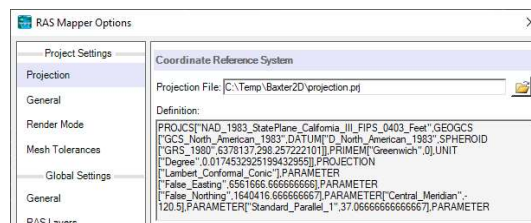




# Projection



- Data used in RAS Mapper must be a common coordinate system.
- Projection will be used to re-project Terrain data that is imported into RAS Mapper.
  - Defined using esri PRJ file.
- Web Imagery will be projected on-the-fly to RAS Mapper coordinate system.



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The Projection (Spatial Reference System) is defined in RAS using an ESRI well-known text PRJ file. Having this defined will allow you to export data to be used with other GIS layers and allow other GIS layers to be displayed with your data. RAS Mapper has the ability to display Web Imagery. If the projection is correctly defined, the web imagery will be projected as a background map. How cool is that! Depending on the projection used for the data the web imagery labels may look great (using local projection) or not so great if you are using a national projection (US Albers) and your data is on the edge of projection limits.



# Projection Files

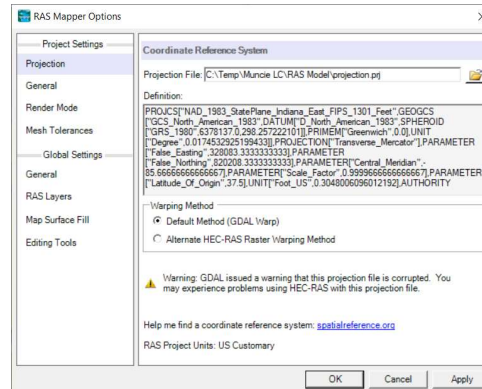
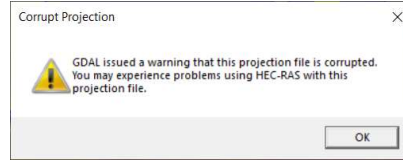


- Not all PRJ files are the same

```

PROJCS["NAD_1983_StatePlane_Pennsylvania_South_FIPS_3702_Feet",
GEOGCS["GCS_North_American_1983",
DATUM["D_North_American_1983",
SPHEROID["GRS_1980",6378137.0,298.257222101]],
PRIMEM["Greenwich",0.0],
UNIT["Degree",0.0174532925199433]],
PROJECTION["Lambert_Conformal_Conic"],
PARAMETER["False_Easting",1968500.0],
PARAMETER["False_Northing",0.0],
PARAMETER["Central_Meridian",-77.75],
PARAMETER["Standard_Parallel_1",39.93333333333333],
PARAMETER["Standard_Parallel_2",40.96666666666667],
PARAMETER["Latitude_Of_Origin",39.33333333333334],
UNIT["Foot_US",0.3048006096012192]]

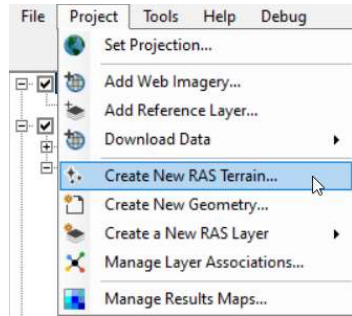
```



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The “old” standard esri projection file is currently supported by HEC-RAS. The newer standard that has the Vertical datum and units information is not supported.

# Terrain

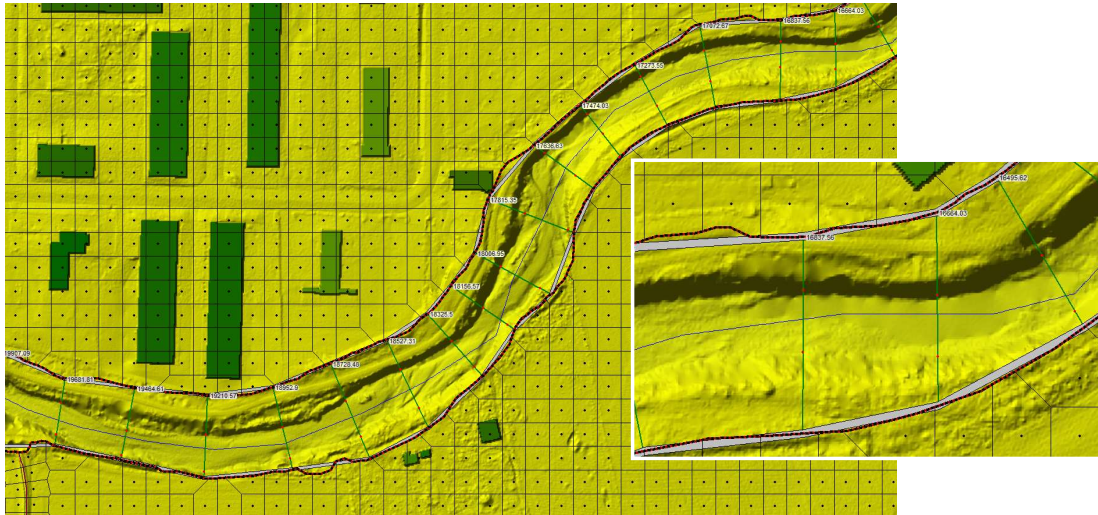


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A good model starts with good terrain ...



A good hydraulic model starts with good representation of the ground surface elevations.

\*Slide courtesy Mark Forest, PE, CFM – HDR

Demonstrates the terrain developed from a combined LiDAR dataset (red LiDAR overbanks, green LiDAR in channel).





## Terrain Cell Size Considerations



- Purpose and scale of model
  - Detailed bridge analysis - piers in terrain
  - Typical riverine model – only bridge opening in terrain
- Small enough to represent the land surface accurately, NOT any smaller
- Terrain model for 2D computations needs to accurately reflect features that direct flow
  - Align 2D cell faces with the controlling features

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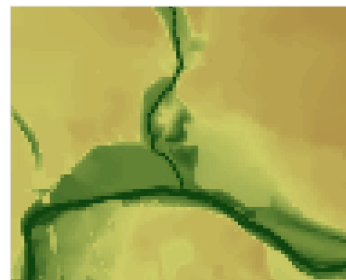
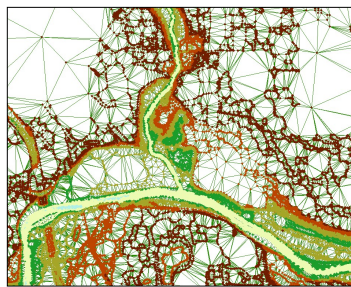
Picking an appropriate grid cell size depends on the needs of the model. For instance, if you are doing detailed bridge analysis you will want the terrain to represent the piers; however, a typical riverine model just need to be detailed enough to represent the bridge opening. You want the grid cell small enough to represent the terrain, but more cells equals longer computation times. You never want your cells smaller than the resolution of the terrain..that's just more data that doesn't add value.

The goal of HEC-RAS to allow the user to define cell faces along linear features that direct flow; however, we currently have limited tools to do that. RAS also has a limitation of only using the underlying grid. This can be problematic in representing linear features.



## Terrain Model Types

- Triangulated Irregular Network (TIN)
- Triangulated points define surface allows for higher density in important areas.
- User-defined triangulation through points and break lines
- Grid
- Single value at regular intervals. Cell size determines surface resolution.
- Fast mathematical computations



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Terrain models are stored as either TINs or Grids. Triangulated Irregular Networks (TINs) are created by triangulating point data. TINs are the best way to represent a surface because they can represent linear features in the terrain using breaklines to enforce edges and elevations. In other words, you can densify information where elevations change rapidly (such as river banks or at levees). All ground surface models start as a TIN.

Grids represent a surface using a single point over a generalized area, typically defined as a grid cell. Grids are efficient at storing information and for mathematical operations; however, they are a generalization of the original terrain surface. The smaller the grid cell size, the more accurate we might be able to make a terrain model, however that results in more data on disk and longer processing times.

In the next slides, we will talk about how a terrain model is constructed.



## Building a Terrain Model Verify and Process Points



- Remove of points that are not necessary/incorrect in representing the ground surface
  - Redundant points (more points = more processing)
  - Bridge deck elevations
- Make sure to add important features
  - Top of roads
  - Top of levees
  - Top of floodwalls
  - Bridge approaches
  - Hydraulic structures
- Replace over-water returns with bathymetric data

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Not only do “bad” points need to be removed, but “vip”s (very important points) need to be added. Points considered for removal include redundant points that don’t improve the surface and removal of man-made features such as bridge decks that would have been collected. For instance, how many points does it take to model a parking lot? Not too many in the middle but maybe a few more along the curb and gutter if we were getting that detailed. Same is true in the floodplain – a lot near the channel, maybe less in the floodplain overbank.

Important points should then be added to properly model linear features such as roads, levees, and floodwalls that may direct the flow of water.

Lastly, the over-water returns must be replace with good bathymetric data!



## Building a Terrain Model Bare Earth Points

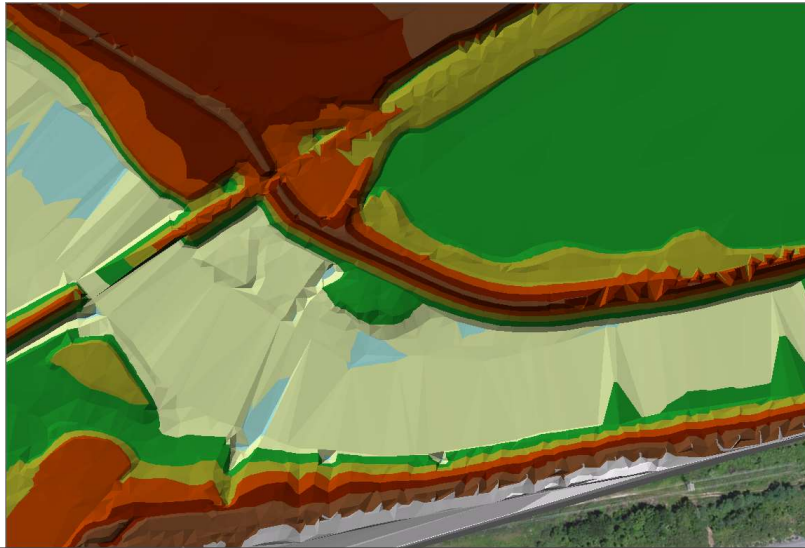


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The slide shows bare earth points where the data has modified to remove the over-water data and extra non-important points.



## Building a Terrain Model Bare Earth Points



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A TIN model is created from those points. As you can see, the resulting TIN is not perfect. We need to add in channel information.



## Building a Terrain Model Bathymetry Points



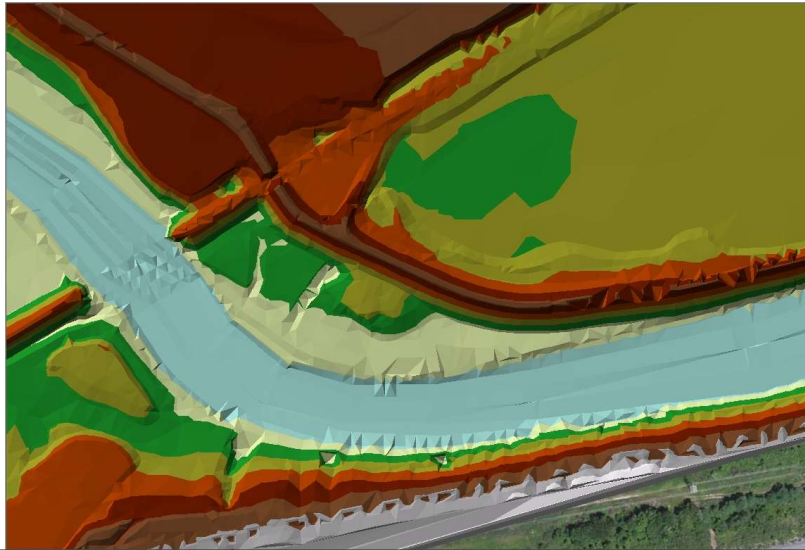
14

Here are channel points that have been generated from under water cross section information and then interpolated along the river.





## Building a Terrain Model Bathymetric Data Added

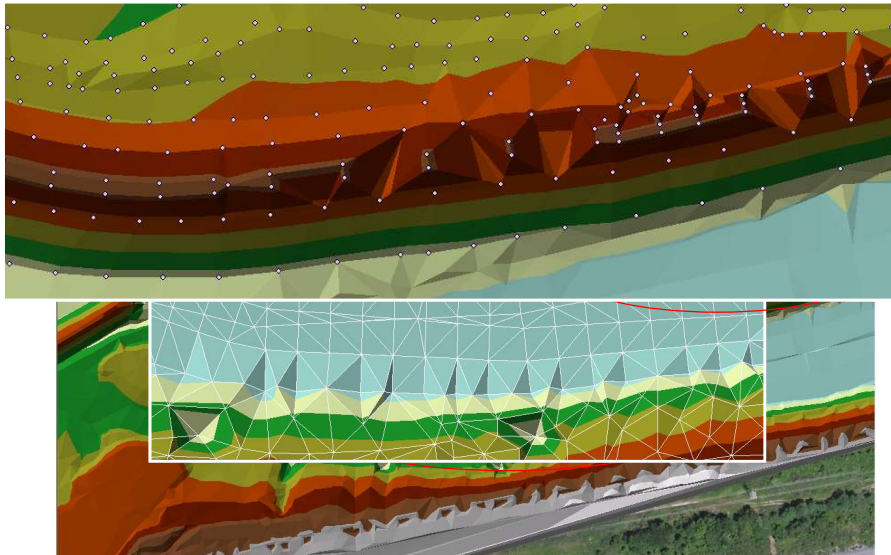


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Adding in the channel data greatly improved the corresponding TIN.  
But as you can see, there are still things that can/should be improved.



## Building a Terrain Model Problems?



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Looking at the TIN, what problems are plainly evident?

1. The triangulation on the south side of the river is suspect. Low points are triangulated with high points in a way that doesn't make for a smooth channel – a channel that most likely doesn't exist in real life!
2. The triangulation on the north side of the river is suspect. There appears to be a levee with a bunch of low spots/cuts through it. Looking at the triangulation shows the issue.

We can fix the triangulation issues using breaklines to enforce elevations and triangle edges.





## Building a Terrain Model Breaklines



- Breaklines are used to enforce triangle edges and elevations. They ensure that interpolation is done “correctly” along linear features.
  - Channel banks
  - Steep drops (drop structures, waterfalls)
  - Roadways
  - Levees
  - Bathymetry points

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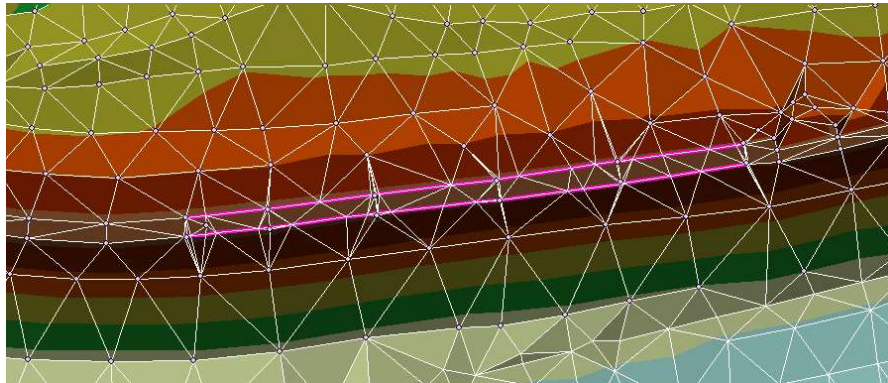
Breaklines are used to enforce triangle edges and elevations. They ensure that interpolation is done “correctly” along linear features. We use them at channel banks, steep drops, roadways, levees, and to connect points in the channel.



## Building a Terrain Model Breaklines



- Breaklines with elevations insert points to enforce elevations and triangle edges



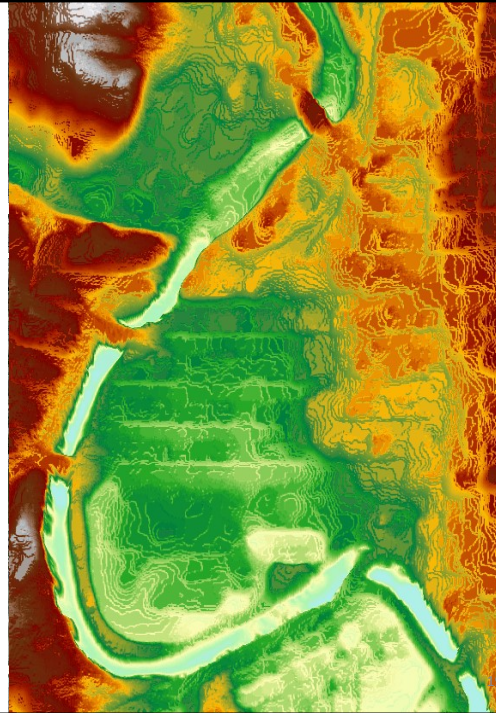
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Here is an example using a single breakline or double breaklines to fix the triangulation along the top of a levee. Not that using 2 breaklines results in a much more realistic representation of the levee feature.



## Bridges

- Removal of bridges from terrain data is important for 2D modeling.
- High ground directs flow – determined directly from ground surface model.
- 1D modeling place cross sections at appropriate locations as work around.



Representing bridges in a terrain model must be done properly for 2D modeling. In 1D modeling, you can just cut cross sections at the bridge embankment and the geometry will be correct, only the mapping will be wrong. In 2D modeling the bridges must be removed, otherwise you create dams in the river.



## Terrain Cell Size Considerations



- Purpose – scale of model
  - Detailed bridge analysis requires piers be represented
  - Riverine model requires flow opening is represented
- Small enough to represent the land surface accurately, NOT any smaller
- Terrain model needs to accurately reflect linear features that direct flow. HEC-RAS uses a 2D computational grid as the underlying representation of terrain. 2D cell faces should be aligned with linear feature in the terrain.

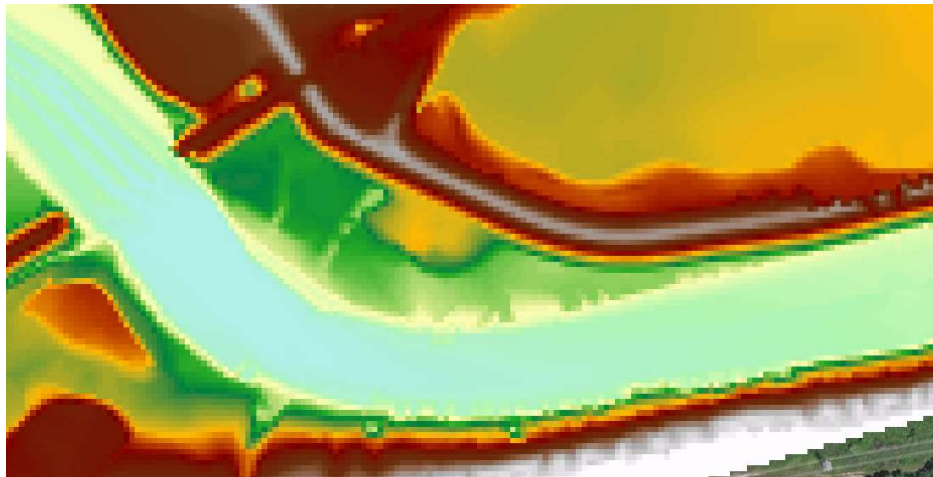
20

Picking an appropriate grid cell size depends on the needs of the model. For instance, if you are doing detailed bridge analysis you will want the terrain to represent the piers; however, a typical riverine model just need to be detailed enough to represent the bridge opening. You want the grid cell small enough to represent the terrain, but more cells equals longer computation times. You never want your cells smaller than the resolution of the terrain..that's just more data that doesn't add value.

The goal of HEC-RAS to allow the user to define cell faces along linear features that direct flow; however, we currently have limited tools to do that. RAS also has a limitation of only using the underlying grid. This can be problematic in representing linear features.



## Raster Cell Size

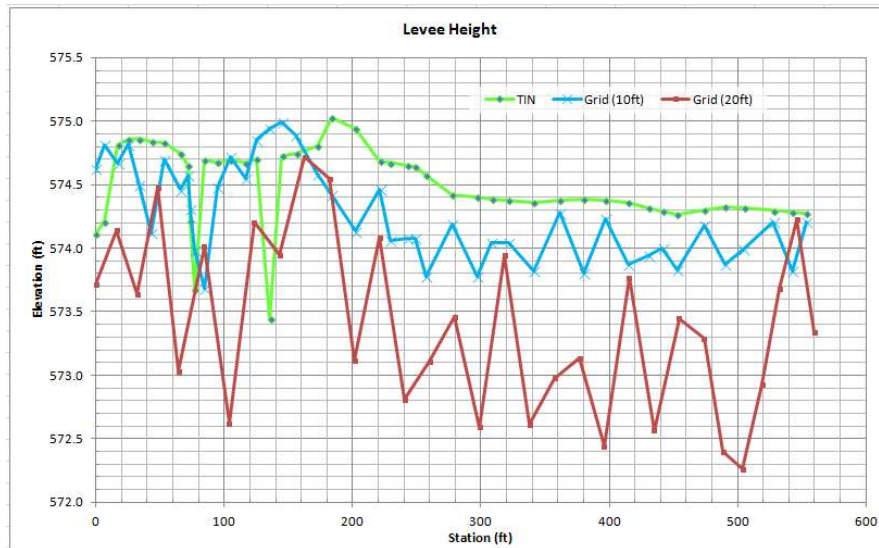


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This slide shows various resolutions of grid cells used to represent the ground surface. What resolution allows for definition of the levee? 100, 50, 20, 10 ft?



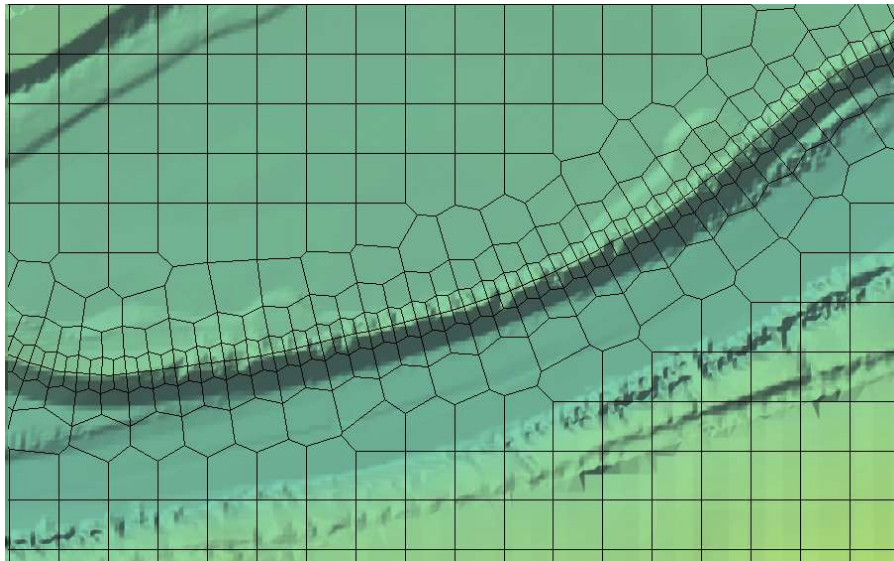
## Raster Cell Size



If we take a profile line along the top of levee we can see the affect of the terrain model on the resulting data. The green line is the data taken from the TIN, the blue line from a grid with 10ft spacing, and the red line a 20ft grid. If we use the levee line from the 20ft spacing the levee will be overtopped 2ft lower!



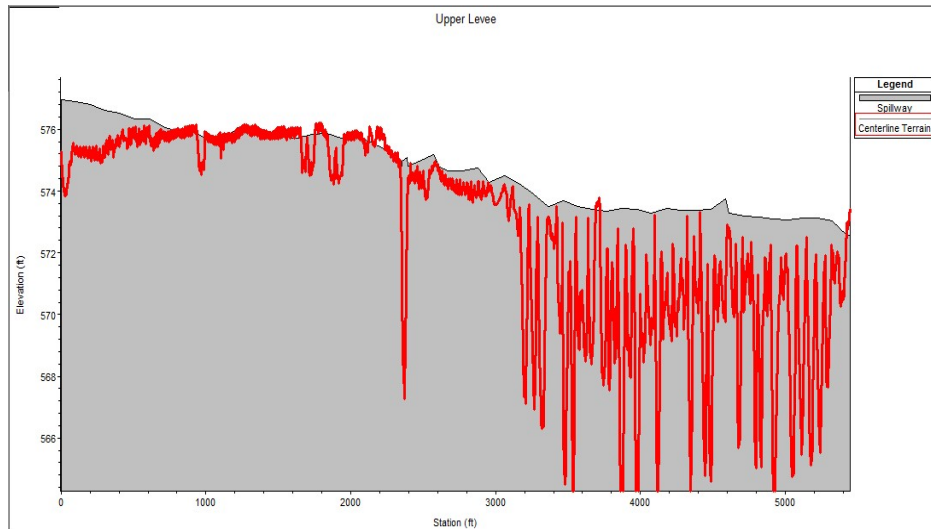
# HEC-RAS Terrain Fixes



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# Hydraulic Structure Elevations



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## Terrain Model Development Summary



- Terrain models are developed as TINs
- Model is typically exported to a Grid for visualization and analysis
  - TINs are more difficult to render
  - TINs are more expensive to store
  - Calculations with TINs more difficult than with rasters
- Grid-cell size determines the effective accuracy of the resulting terrain model
  - How are you going to represent a levee in a raster with a 20ft grid cell?

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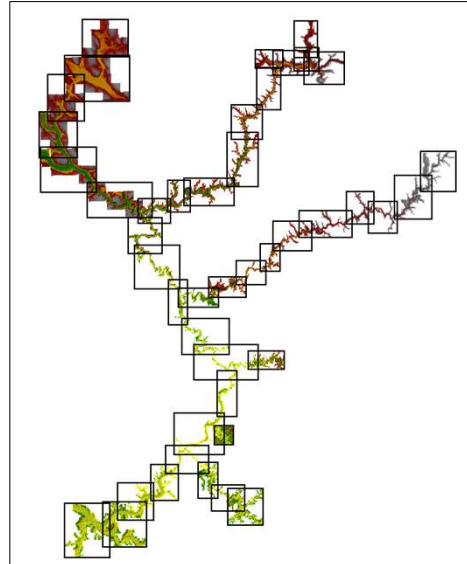
As previously discussed, terrain models are created as TINs and then typically utilized at grids for analysis because they are easier computationally to visualize and process. However, the grid cell size is going to affect the what we can represent in the terrain.

Terrain modifications provide the capability to represent linear features in the terrain in addition to the grid.



## Terrain in RAS Mapper

- Uses GeoTIFF format
  - Tiled data for more efficient storage
  - Compressed data for efficient storage
  - Pyramided data for fast visualization
    - Allows for on-the-fly inundation mapping
- One Layer for Multiple Terrain Models
- No file size limitations – BigTIFF supported



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The file format that HEC-RAS has adopted for raster data is the GeoTiff file format. This file format allows for efficient data storage and some benefits that assist in data visualization.

1. The data is compressed for smaller file size. Smaller file size means faster read/write times. (For example 46 tiles of 13GB compresses to 2.3GB)
2. Pyramids allow for fast visualization based on a particular zoom level. For instance, if you are zoomed out, there is no need to render the entire dataset, just a resample version that matches the number of pixels on your screen. Because RAS is only plotting the number of cell values corresponding to the number of pixels on the screen, RAS can use the pyramiding to do on-the-fly map generation. No need to store depth grids – just generate what the user wants.

RAS manages multiple terrain model files as one 1 layer within RAS (we'll talk about that in the coming slides).

No file size limitations! – the library used for reading GeoTiffs has been modified to read BigTIFF.



## Terrain in RAS Mapper



- Various formats are supported
  - Binary Floating Point Raster (FLT)
  - Esri Arc/Info Grid format
  - GeoTIFF (still rounds and compresses)
  - Others (e.g. USGS DEM, etc)
- Imported data is rounded to based on precision selected
  - Default is 1/32 (~0.03 ft) (1/128 for metric)
- Recommended that a projection is defined for the RAS Mapper project first.

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RAS support the import of various file formats into the GeoTIFF format. Common GIS formats that are supported are the FLT, esri Grid, and GeoTIFF, but there tons of other formats. Refer to [http://www.gdal.org/formats\\_list.html](http://www.gdal.org/formats_list.html) for a full list (there are like 100 of them).

Imported data is also rounded. Rather than keeping data stored out to the 8<sup>th</sup> decimal place, the data will be rounded. The default is to round the data to 1/32 (or ~0.03ft). We have found that round algorithms using Base2 compression is more successful than Base10, so that is the default. We also allow the user to not round and keep the data as is, or use a Base10 compression.

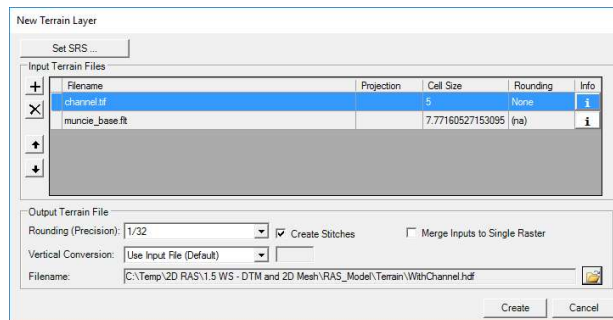
Because you are using a Terrain model for data extraction and mapping, it is important that the data has a defined projection and that it is set in the RAS Mapper interface!



## Terrain Importer



- Add files – allows user to select rasters for import
- Order raster files based on **Priority** on what cell value should be used if there is overlap by the terrain models.
  - Highest Priority to the top



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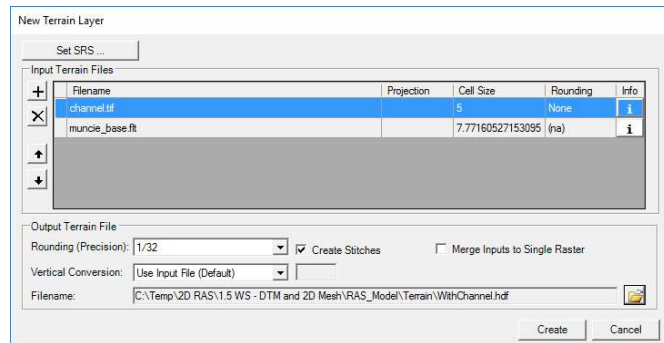
Once a projection is defined, then you can Add a New Terrain. The Terrain will be created from input terrain models. This is how it works.

1. Add File of interest
2. You specify the Priority for using the terrain files (highest is most important).



## Terrain Importer

- Rounding – Precision which data is stored
- Terrain Filename and Folder
  - name.tilename.tif file for each imported terrain tile
  - name.hdf file contains “stitch” information for data gaps
  - name.vrt file contains statistics info and color ramp info



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Once a projection is defined, then you can Add a New Terrain. The Terrain will be created from input terrain models. This is how it works.

1. You provide the Rounding Precision and as the GeoTIFF is built the data is rounded, compressed, and tiled.
2. You decide on the Terrain Filename to create a GeoTIFF of each of the input files. An HDF file will be created. This is the file that is loaded into RAS. It will have a pointer to the TIF file – the actual elevation data.



# Terrain Importer



- Data is translated, projected, rounded for all data
- Data is pyramided (overlays) and compressed
- TIN stitches created for overlapping regions
- Terrain.hdf is the single layer loaded to RAS Mapper

```
Compute Window - Creating Terrain Terrain
-----
Importing 1 of 2: BEC_28ft.fit
Step 1 of 4: Translating to Geotiff with CRS... 1
Step 2 of 4: Rounding and/or Generating Statistics... 7
Step 3 of 4: Generating Histogram... 2
Step 4 of 4: Adding Overlays... 2
BEC_28ft.fit Import Complete. 34
-----
Importing 2 of 2: BEC_08ft.fit
Step 1 of 4: Translating to Geotiff and reprojecting... 26
Step 2 of 4: Rounding and/or Generating Statistics... 105
Step 3 of 4: Generating Histogram... 11
Step 4 of 4: Adding Overlays... 13
BEC_08ft.fit Import Complete. 156
-----
Final Processing: Terrain.hdf
Step 1 of 3: Creating Terrain.vrt... 0
Step 2 of 3: Creating Terrain.hdf... 1:17
Step 3 of 3: Creating Stitch-ras for merging rasters... 6
Terrain Complete 3:34
-----
Close
```

30

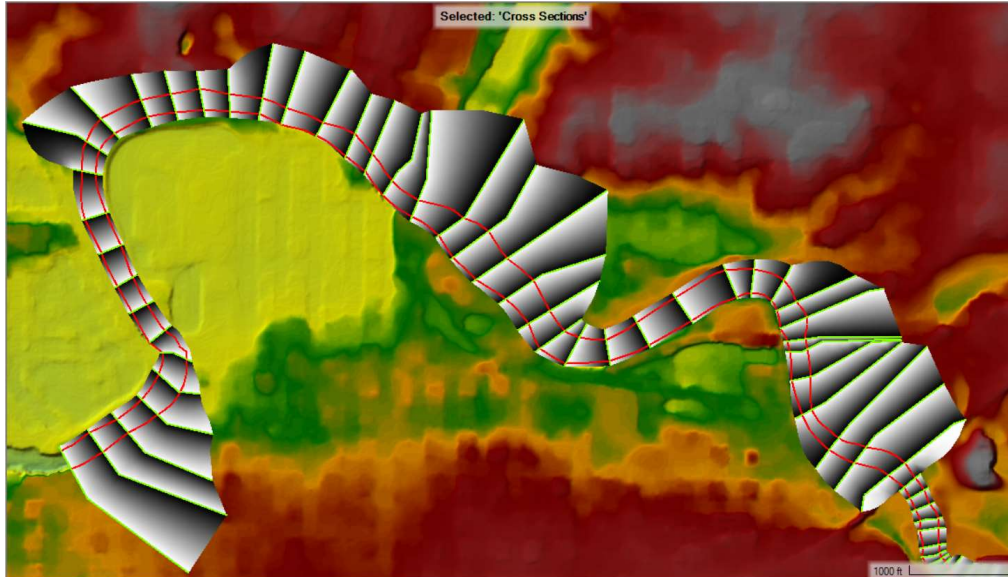
Once a projection is defined, then you can Add a New Terrain. The Terrain will be created from input terrain models. This is how it works.

1. You decide on the Name and location to store the data and the name is used to create a GeoTIFF of each of the input files
2. You specify the Priority for using the terrain files (highest is most important).
3. You provide the Rounding Precision and as the GeoTIFF is built the data is rounded, compressed, and tiled.
4. The data is projected (if necessary)
5. A "Terrain.hdf" file is created that manages the data as one layer. Within Terrain.hdf file there is also information which includes triangulation of the data across boundaries if multiple terrain models or holes in the data exist.

An output dialog provides the status of the GeoTIFF import process.



## Improving Channel Data – From XS



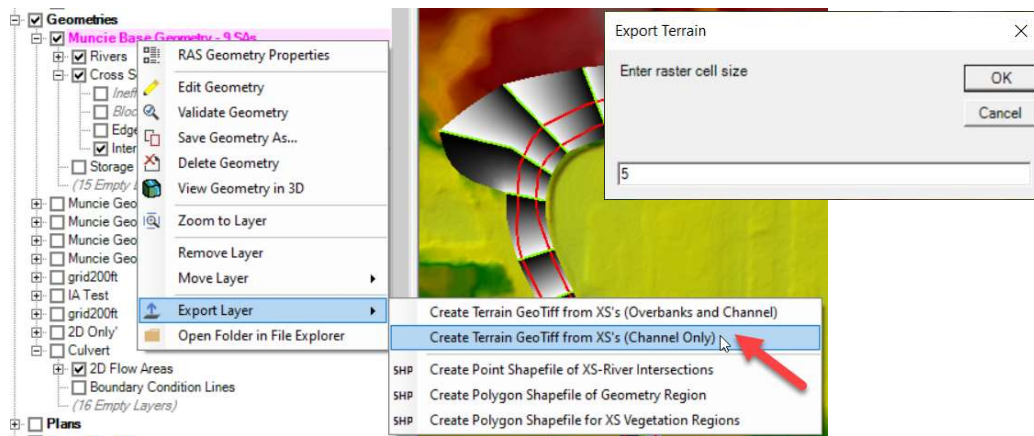
31

Sometimes you don't have channel information in the terrain model. And sometimes you have cross sections that have channel information for that area. When this serendipitous occasion occurs, you can take advantage of using RAS Mapper to add the data to your terrain model.

Of course there are some limitations. RAS will triangulate the cross sections using the Edge Lines and Bank Station Lines. The bank lines might not be exactly where you'd like them, so create a copy of your geometry and move the banks down to the low-flow portion of the channel (or "top of water/water edge").



# Export Channel Surface to GeoTiff



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Next, if you right-click on the Geometry layer, you can create a Terrain raster of the either the main Channel or the all of the cross sections. For this example, we are doing just the main channel. Once selected, you then can specify the grid cell size to create the raster. A GeoTIFF will be created for just the channel information.

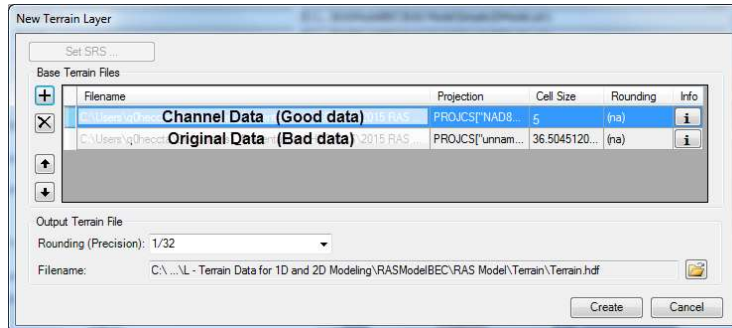




## Adding Channel Data



- New Terrain
- Priority – Channel data highest



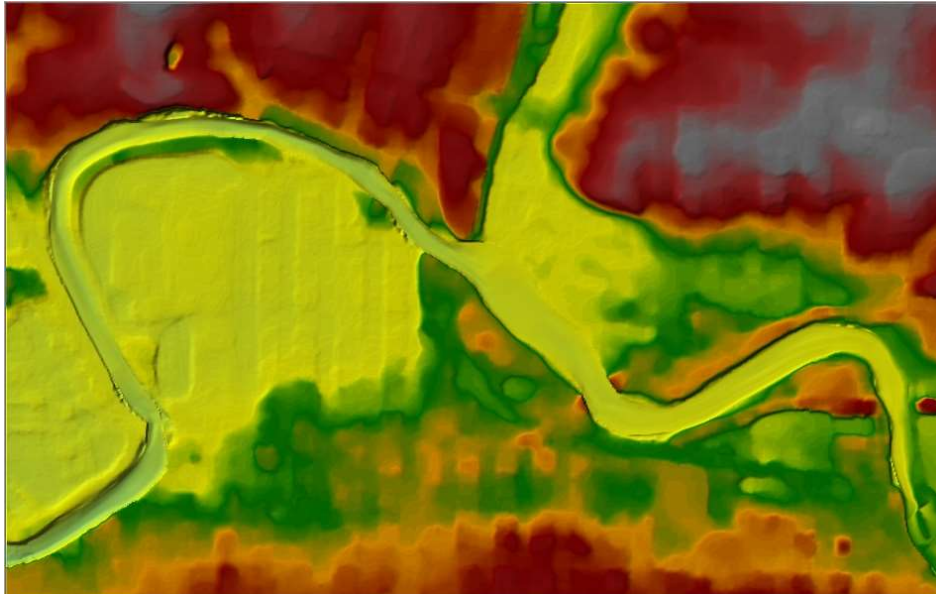
33

To add the Channel GeoTIFF, use the option to Create a New Terrain. In the new Terrain Layer add in all Terrain Model files and specify the Channel GeoTiff as having the Top Priority. Bam! You now have a Terrain Layer with channel data.

Channel data is important if you plan to mode the channel using 2D Cells or if you want the mapping to be correct.



## Terrain with Channel

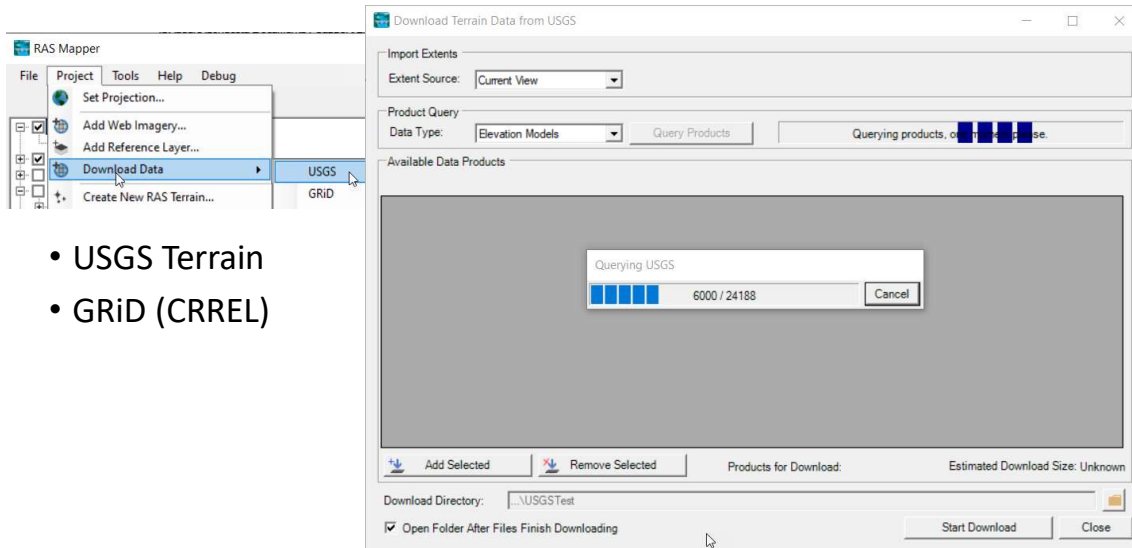


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Here is an example of a terrain layer with bridge information in the terrain and a picture of the same terrain but with the cross sections used to create a channel raster and then add into the terrain layer.



# Terrain Data Download



RAS Mapper has the capability to download data from both the USGS 3DEP web service and the Geospatial Repository and Data Management System (GRiD) (which is hosted by CRREL and NGA). This allows you to get data without going to another website or use a GIS to process the Terrain data.

The USGS 3DEP (<https://www.usgs.gov/3d-elevation-program>) DEMs is open access. The GRiD (<https://grid.nga.mil/grid/>) data requires a GEOAxis account and is attempting to publish the best elevation data available (which may be District surveys, etc).

The tool is intended to get HEC-RAS modelers up and running with a coarse model that can be improved as better data becomes available (such as bathymetric data). I think this will be extremely beneficial in emergency situations where models do not exist and something needs to be put together quickly.

So, to use the tool, the user queries the one of the databases.



# Terrain Data Download

The screenshot displays the RAS Mapper software interface. On the left, the 'Map Layers' panel shows 'USGS Products Available' and 'USGS Products To Download'. The central map view shows a river network overlaid on a grid of terrain data extents. On the right, the 'Download Terrain Data from USGS' dialog box is open, showing a table of data products. A red circle highlights the '1m' extent filter option. The table lists 10 data products with columns for ID, Extent, Description, Date, File Size, and Web link.

ID	Extent	Description	Date	File Size	Web
1	1m	USGS one meter x49,378 CA SoCal Wildfires B1 2018	2020-03-30	429 MB	<a href="#">Link</a>
2	1m	USGS one meter x43,384 CA SoCal Wildfires B2 2018	2020-03-30	5 MB	<a href="#">Link</a>
3	1m	USGS one meter x43,378 CA LosAngeles 2016	2020-03-30	Unknown	<a href="#">Link</a>
4	1m	USGS one meter x45,377 CA SoCal Wildfires B1 2018	2020-03-30	423 MB	<a href="#">Link</a>
5	1m	USGS one meter x40,375 CA SoCal Wildfires B1 2018	2020-03-30	311 MB	<a href="#">Link</a>
6	1m	USGS one meter x47,378 CA SoCal Wildfires TL 2018	2020-03-30	18 MB	<a href="#">Link</a>
7	1m	USGS one meter x48,378 CA SoCal Wildfires B1 2018	2020-03-30	387 MB	<a href="#">Link</a>
8	1m	USGS one meter x46,380 CA SoCal Wildfires B1 2018	2020-03-30	145 MB	<a href="#">Link</a>
9	1m	USGS one meter x49,378 CA SoCal Wildfires B1 2018	2020-03-30	474 MB	<a href="#">Link</a>
10	1m	USGS one meter x40,378 CA SE Fault Zone 2017	2020-03-30	12 MB	<a href="#">Link</a>

Once the database has been queried, a list of data availability will be returned. RAS Mapper will allow you to visual the extents of data availability. To assist in weeding through the data, we have provided a filtering mechanism.

You then can select data for download using the list or by interacting with RAS Mapper – 2 new layers are added to show you what you can select from and what you already have added to the Download list.



# Terrain Data Download



The screenshot shows the RAS Mapper interface with a map of a watershed. A dialog box titled "Download Terrain Data from USGS" is open, displaying a table of available data products. The table has columns for CellSize, Description, Date, FileSize, and Web. A pink arrow points from the "Download" button in the dialog box to the "Download" button in the "Download Terrain Data from USGS" dialog box.

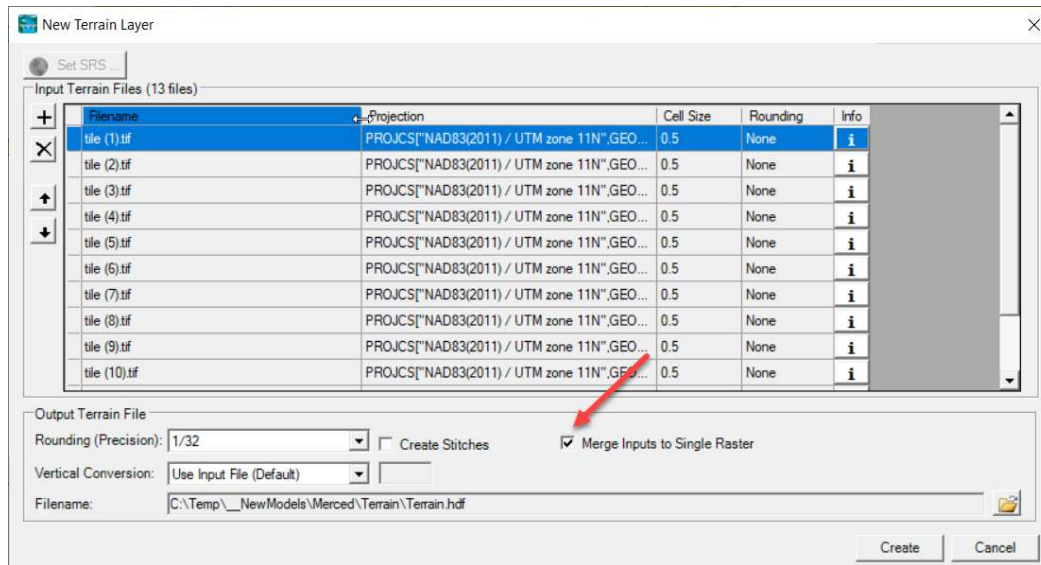
CellSize	Description	Date	FileSize	Web
1	USGS one meter x493770 CA SoCal Wildfires B1 2018	2020-03-30	429 MB	Link
2	USGS one meter x493784 CA SoCal Wildfires B2 2018	2020-03-30	5 MB	Link
3	USGS one meter x493770 CA LosAngeles 2016	2020-03-30	Unknown	Link
4	USGS one meter x493777 CA SoCal Wildfires B1 2018	2020-03-30	423 MB	Link
5	USGS one meter x493775 CA SoCal Wildfires B1 2018	2020-03-30	311 MB	Link
6	USGS one meter x493770 CA SoCal Wildfires T1 2018	2020-03-30	19 MB	Link
7	USGS one meter x493770 CA SoCal Wildfires B1 2018	2020-03-30	387 MB	Link
8	USGS one meter x493780 CA SoCal Wildfires B1 2018	2020-03-30	145 MB	Link
9	USGS one meter x493770 CA SoCal Wildfires B1 2018	2020-03-30	474 MB	Link
10	USGS one meter x493770 CA SE Fault Zone 2017	2020-03-30	12 MB	Link

Once you have selected the data of interest, you click the Download button and data is downloaded asynchronously.

Once downloaded, you Create a Terrain model, choosing the terrain files you downloaded. RAS Mapper will reproject the data to the defined coordinate system during the Terrain Layer generation process.



# Terrain Build



If using the USGS Terrain download tool, use the Merge Inputs option to mosaic the terrain tiles.

Questions?



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