Geoscience Australia's Semi-automated Morphological Mapping Tools for Seabed Characterisation (GA-SaMMT v2.0)

Tutorials and User Guide

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Contents

1. Background

Seabed characterisation requires the measurement, description and classification of physical features on the seabed. A key first step in this process is the identification of morphological forms, as derived from bathymetric data. To facilitate efficient, consistent and objective morphological mapping, Geoscience Australia has developed several semi-automated ArcGIS toolboxes (GA-SaMMT, Geoscience Australia's Semi-automated Morphological Mapping Tools) that:

- generate polygons from bathymetry surfaces that represent 'bathymetric high' and 'bathymetric low' seabed morphological features;
- calculate metrics/attributes to describe the characteristics of each feature polygon; and
- classify individual polygons into one of the bathymetric high or low seabed morphology features.

The toolboxes adopt the suite of terms as presented in the glossary of seabed morphology features defined by Dove et al. (2020).

Dove, D., Nanson, R., Bjarnadóttir, L., Guinan, J., Gafeira, J., Post, A., Dolan, M.; Stewart, H.; Arosio, R, Scott, G. (October, 2020). A two-part seabed geomorphology classification scheme (v.2); Part 1: morphology features glossary. Zenodo. http://doi.org/10.5281/zenodo.4075248

These semi-automated tools have been applied to many study areas with real world applications. Some of the mapping results and detailed descriptions of these tools are published in the following article which should be used as the key reference to the GA-SaMMT.

Huang, Z., Nanson, R., McNeil, M., Wenderlich, M., Gafeira, J., Post, A, Nichol, S., 2023. Rule-based semi-automated tools for mapping seabed morphology from bathymetry data, Frontiers in Marine Science, 10, 1236788.

This document provides a brief user guide and step-by-step tutorials for the use of the tool kit, including worked examples. Note that these tutorials assume that the user is experienced with ArcGIS Desktop and ArcGIS Pro. Otherwise, the user should consult manuals and user-guides of these ArcGIS software for further guidance. Users with some Python programming skills and experience would also be benefited from the Python scripting capabilities offered by the GA-SaMMT. Some examples of using Python scripting to run the GA-SaMMT are provided in the Appendix.

2. System and Data Requirements

These semi-automated morphological mapping tools are developed as ArcGIS Python tools using Python 3+. As a result, the tools can only be directly used in ArcGIS Pro. In addition, please note that the tools only accept raster and vector data stored in a File Geodatabase. Therefore if the input bathymetry grid is not already in a File Geodatabase, the users need to create a File Geodatabase and import the bathymetry grid into the File Geodatabase. The subsequent output vector and raster data should also be stored in a File Geodatabase. Also note that all the input raster and vector data must have projected coordinate system.

The semi-automated morphological tools and sample data are in the GA-SaMMT_v2p0 folder. Please use this link https://dx.doi.org/10.26186/146832 to download the sample data if you have not yet done so. The Tools sub-folder contains seven Python toolboxes:

- BathymetricHigh.pyt: Mapping Bathymetric High features
- BathymetricLow.pyt: Mapping Bathymetric Low features
- AddAttributes.pyt: Generate attributes for Bathymetric High (Low) features
- AddAttributesFast.pyt: Generate attributes for Bathymetric High (Low) features with multiprocessing capabilities
- ClassificationFeature.pyt: Classify Bathymetric High (Low) features
- Accessory_Tools.pyt: Accessory Tools
- Surface.pyt: Mapping three-class morphological surface

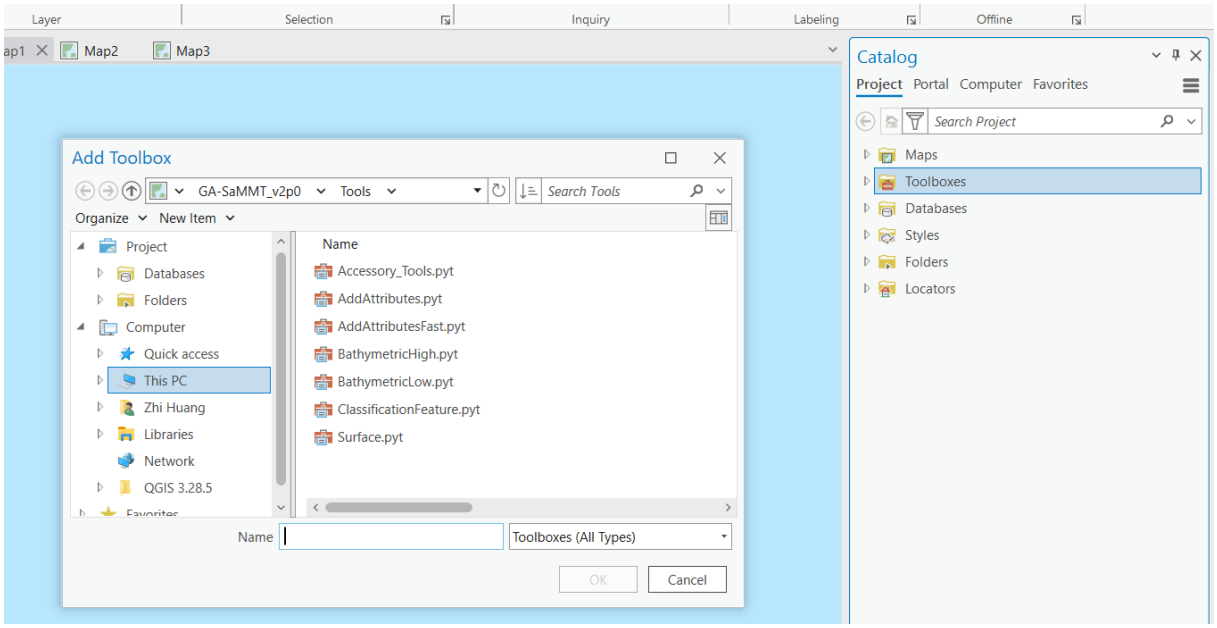
The sample data are contained in three File Geodatabase:

- Gifford.gdb
- Oceanic_Shoals.gdb
- Points_Cloates.gdb

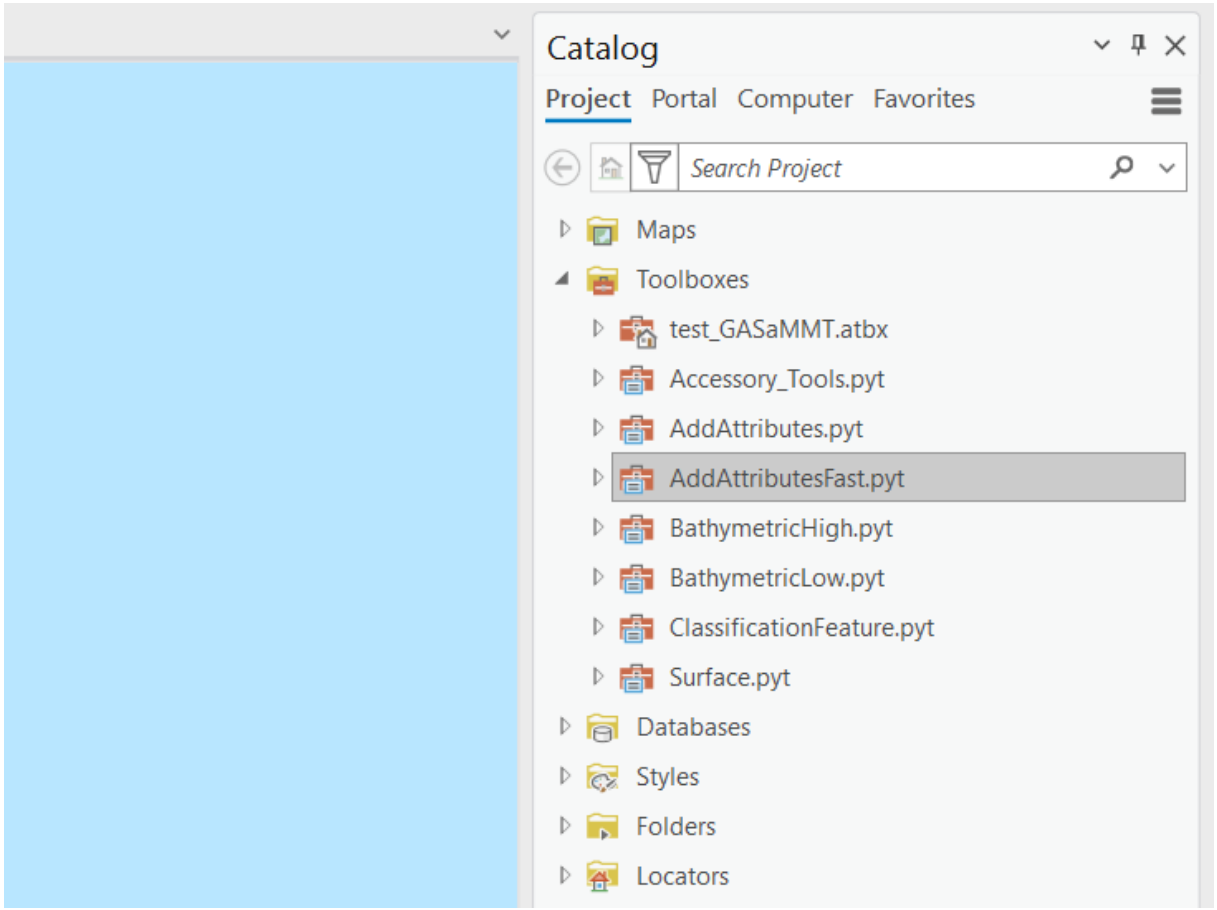
These current version (v2.0) of the semi-automated morphological mapping tools are tested in ArcGIS Pro 2.6.4, ArcGIS Pro 2.9.2, ArcGIS Pro 3.0.2 and ArcGIS Pro 3.2.2. Earlier versions of ArcGIS Pro are likely to generate errors. Please use ArcGIS Pro 2.6.4 and higher versions for these tutorials. The tools also require Advanced ArcGIS Pro license and Spatial Analyst extension.

3. Add Tools and Data

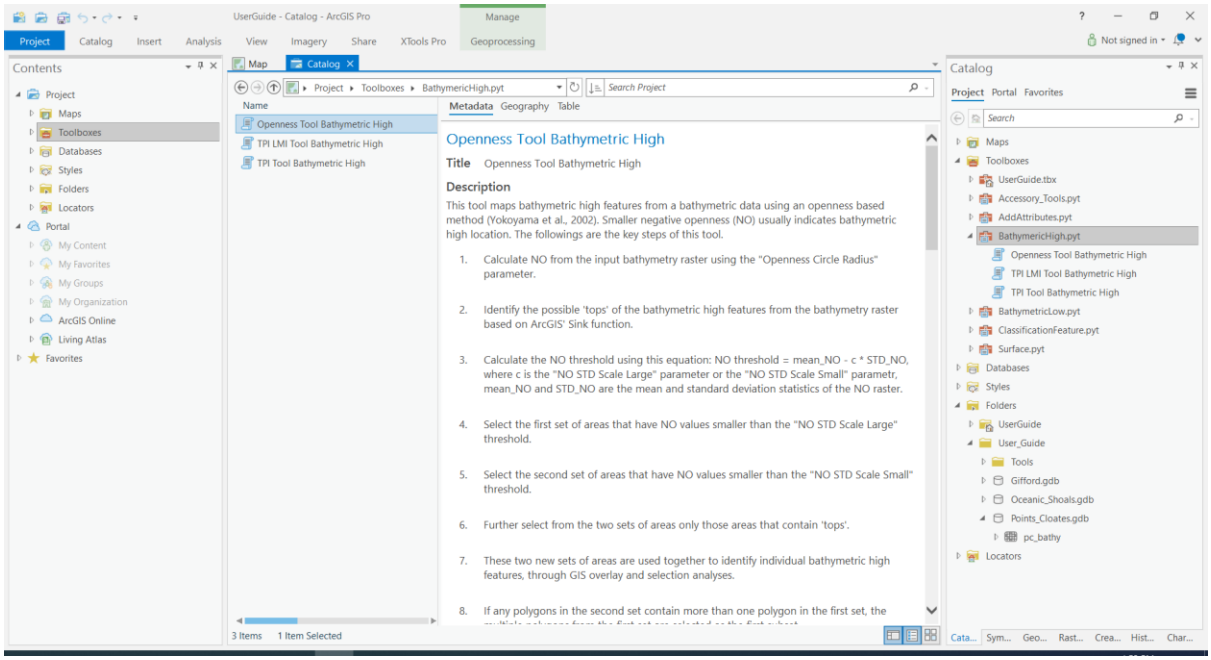
1. Open an existing or create a new project in ArcGIS Pro
2. Under the Catalog Pane, Right-Click Toolboxes, Click Add Toolbox



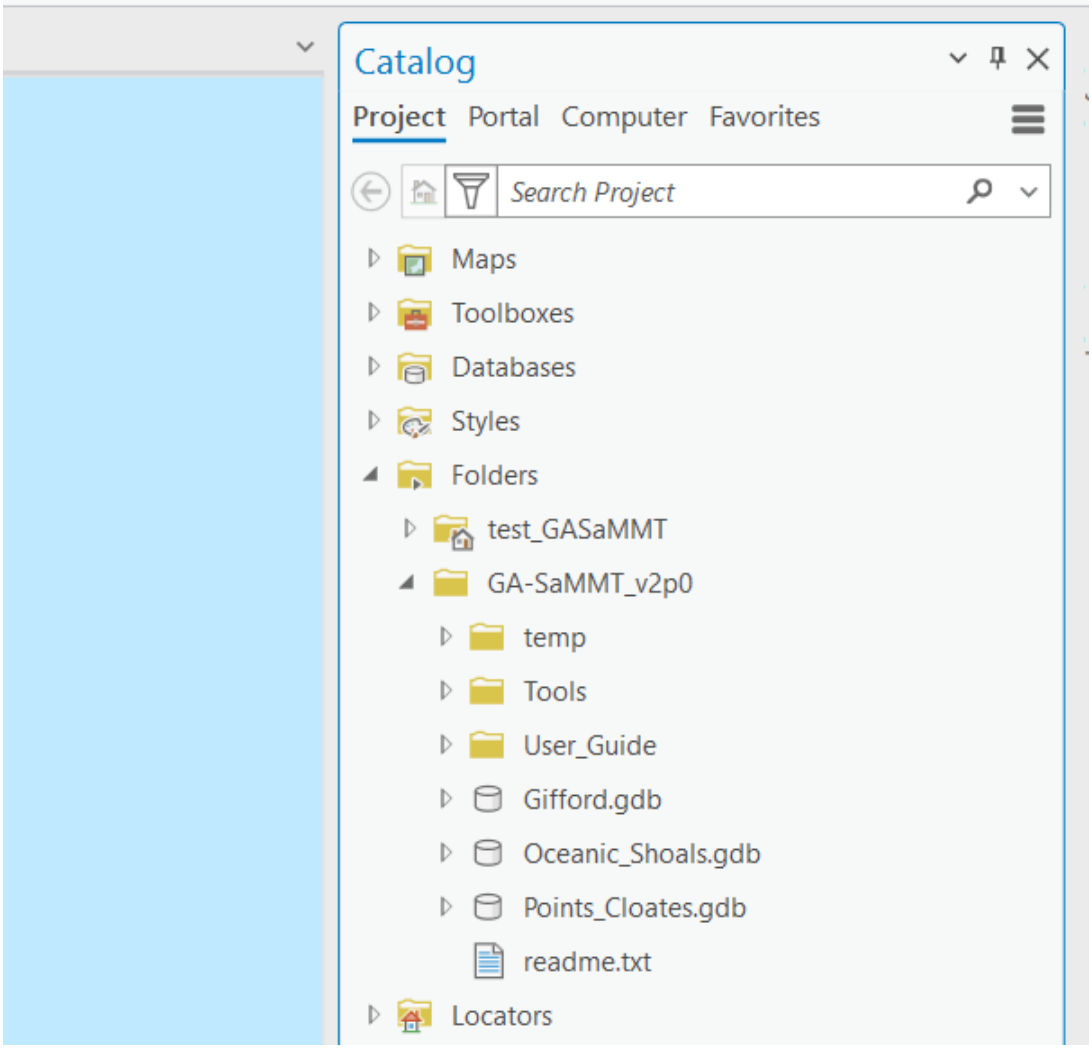
3. Navigate to …\GA-SaMMT_v2p0\Tools folder, Add all seven Python toolboxes



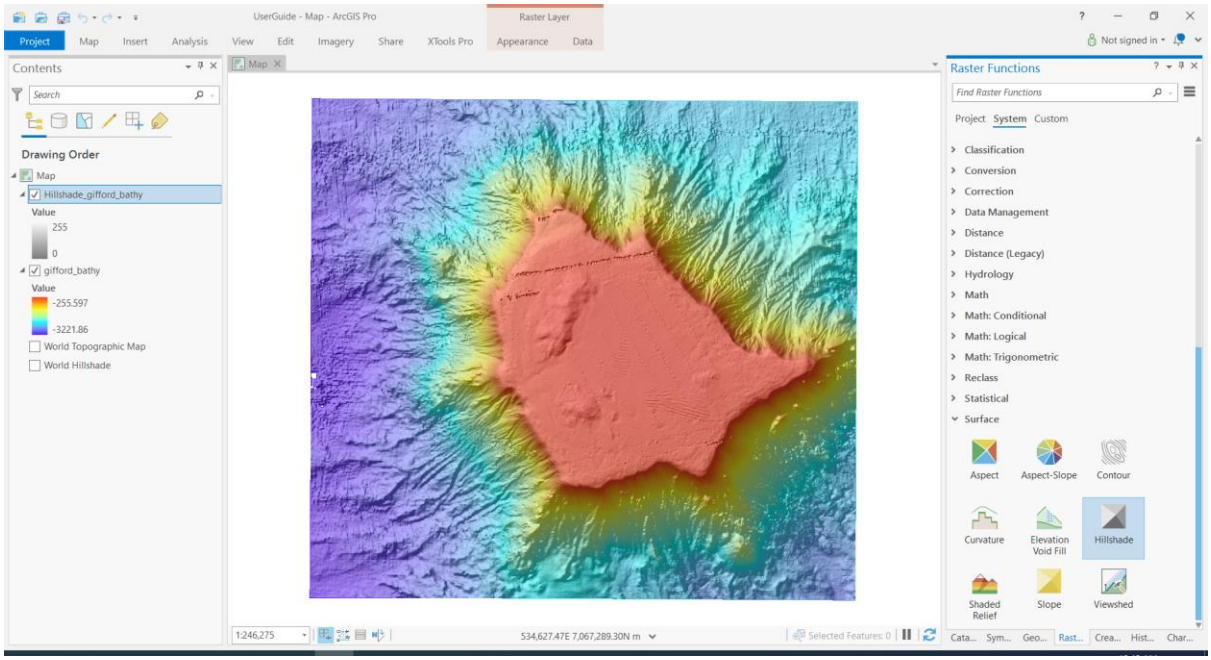
4. Right-Click the individual tools, Click View Metadata menu to examine the metadata of these tools. Note that these metadata provide detailed descriptions, graphic illustrations, usages and Python code examples of individual tools.



5. Go to Catalog Pane, Right-Click Folders, Click Add Folder Connection, Navigate and Add the GA-SaMMT_v2p0 folder, the three File Geodatabases appear under the folder.



6. Open the Gifford.gdb and add the bathymetry grid named gifford_bathy to the map, change the displaying symbology if necessary, generate a hill-shade layer using Raster Functions -> Surface -> HillShade (you can change the Z-factor for vertical exaggeration), change the hill-shade layer to 50% transparency, explore the bathymetry data.



7. Explore the other two bathymetry grids under the Oceanic_Shoals.gdb and the Point_Cloates.gdb, respectively. Note that you may need to create new maps for exploring these bathymetry grids.

4. Use Bathymetric High tools

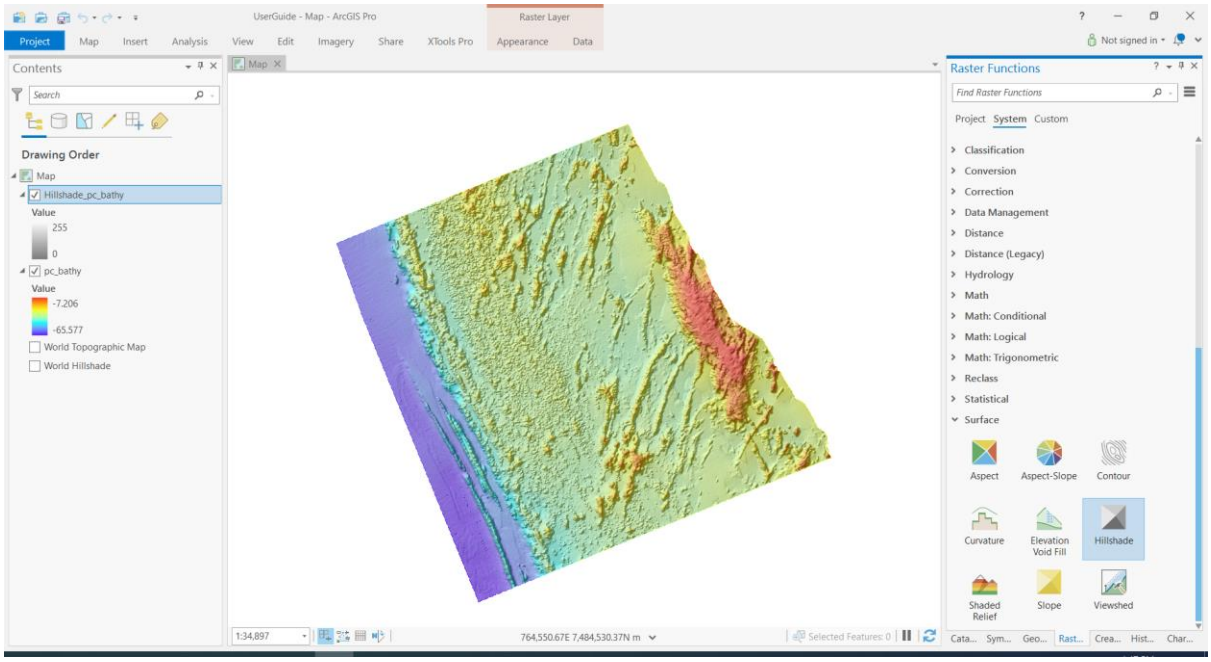
There are three tools under the BathymetricHigh toolbox. Please see detailed metadata of each tool.

1. TPI Tool Bathymetric High: This tool maps bathymetric high features from a bathymetric data using a Topographic Position Index (TPI) based method.
2. TPI LMI Tool Bathymetric High: This tool maps bathymetric high features from a bathymetric data using a combination of Topographic Position Index (TPI) and Local Moran's I (LMI) method.
3. Openness Tool Bathymetric High: This tool maps bathymetric high features from a bathymetric data using an openness based method.

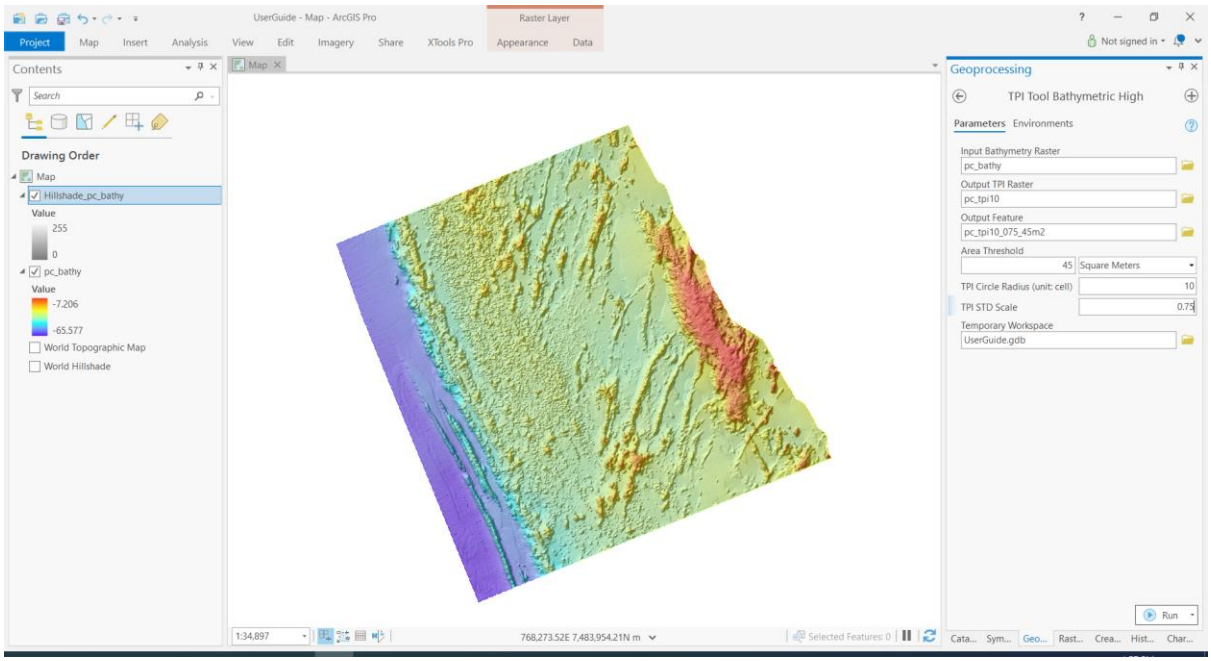
All of these three BathymetricHigh tools are able to map bathymetric high features. However, they are based on different methodologies and thus could be suitable for different applications. Please familiar yourself with the metadata of these tools before attempting to use them. When applying to real-world applications, the users are advised to evaluate which tool(s) are the most suitable for their applications.

4.1. TPI Tool Bathymetric High

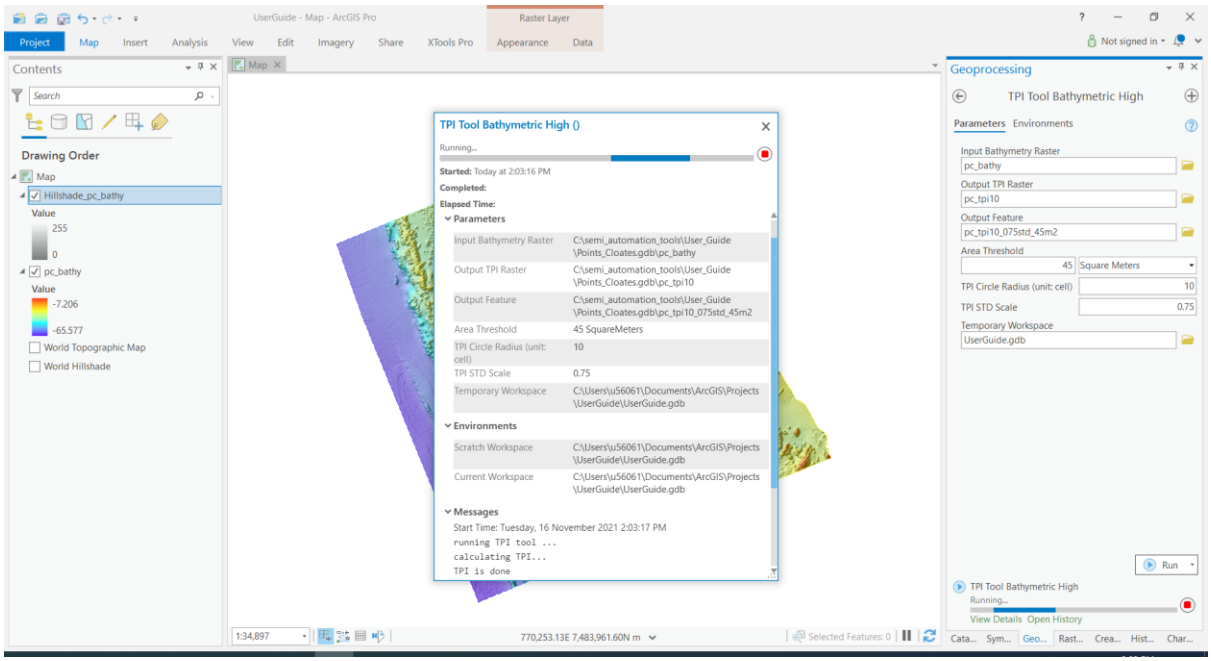
1. If not already loaded, add the pc_bathy bathymetry grid from the Points_Cloates.gdb into the map. Explore the bathymetry data which contains many bathymetric high features.



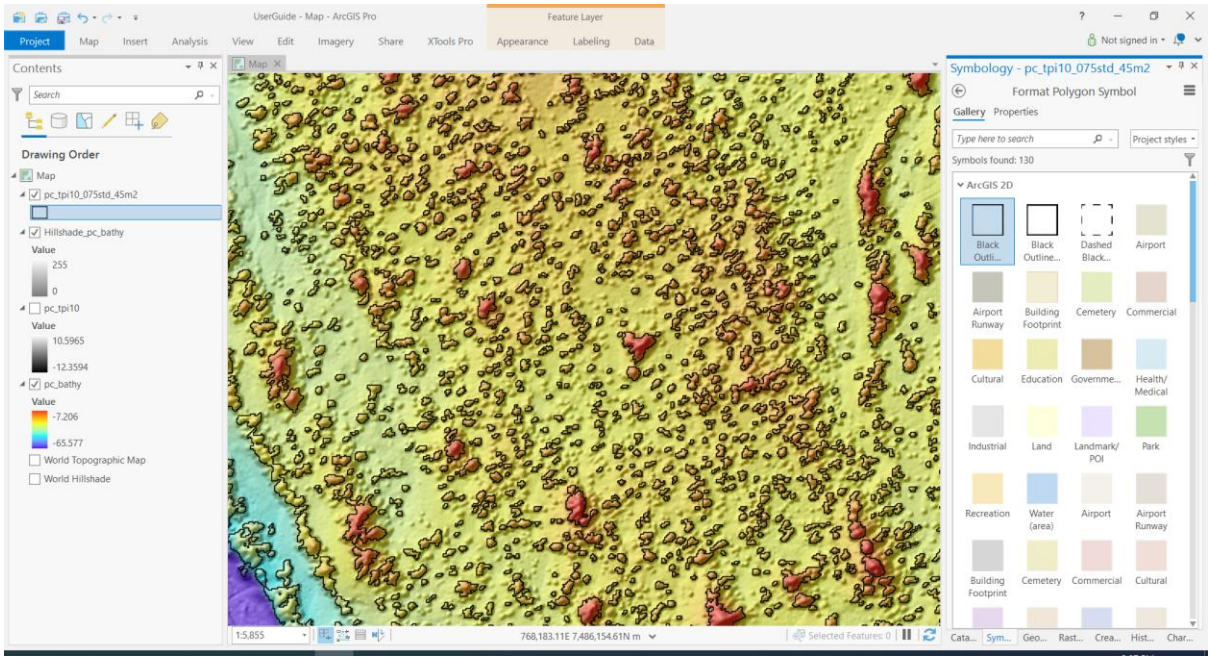
2. Select the TPI Tool Bathymetric High tool, Double-Click to open the tool in Geoprocessing tab. For the Input Bathymetry Raster, select the pc_bathy grid from the drop-down list or navigate to the Points_Cloates.gdb and select the pc_bathy grid. For the Output TPI Raster, navigate to the Points_Cloates.gdb and enter a name like “pc_tpi10”. For the Output Feature, navigate to the Points_Cloates.gdb and enter a name like “pc_tpi10_075std_45m2”. For the Area Threshold, enter 45 Square Meters. For the TPI Circle Radius, enter 10. For the TPI STD Scale, enter 0.75. For the Temporary Workspace, nominate a File Geodatabase that is different from the input/output workspace(s).



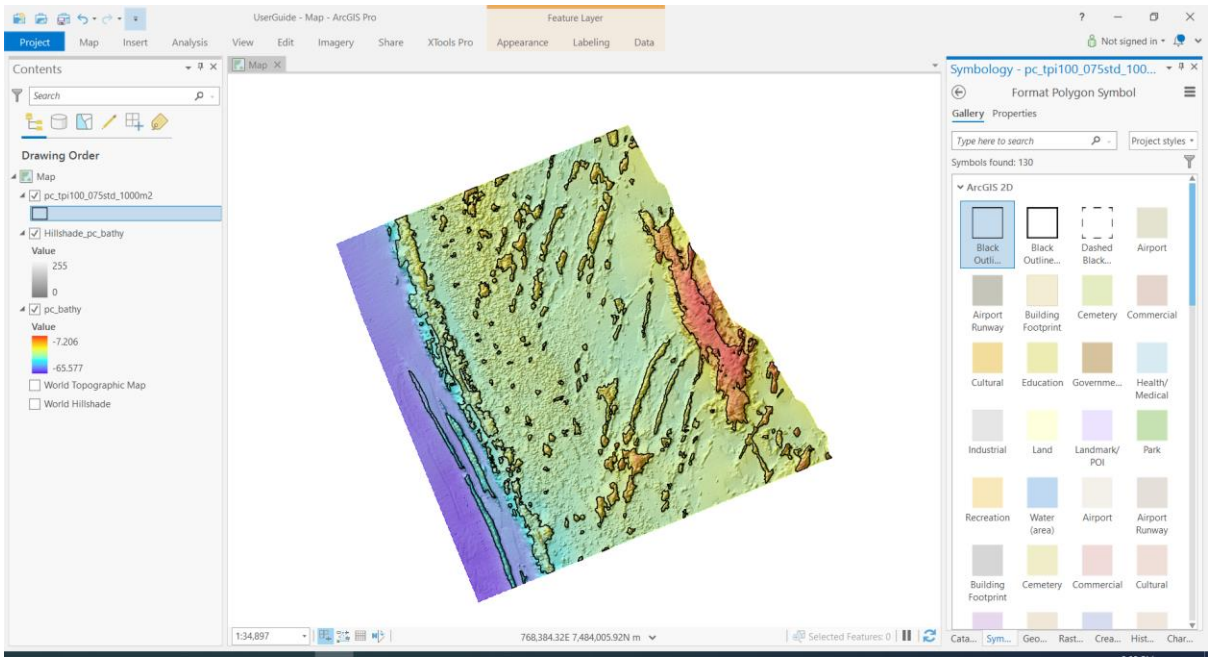
3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



4. After the geoprocessing is completed, the pc_tpi10 TPI grid and the pc_tpi10_075std_45m2 output bathymetric high features have been generated and added to the current map. Explore the output TPI grid and the bathymetric high features which map a large number of fine-scale bathymetric high features including hummocks and ridges.



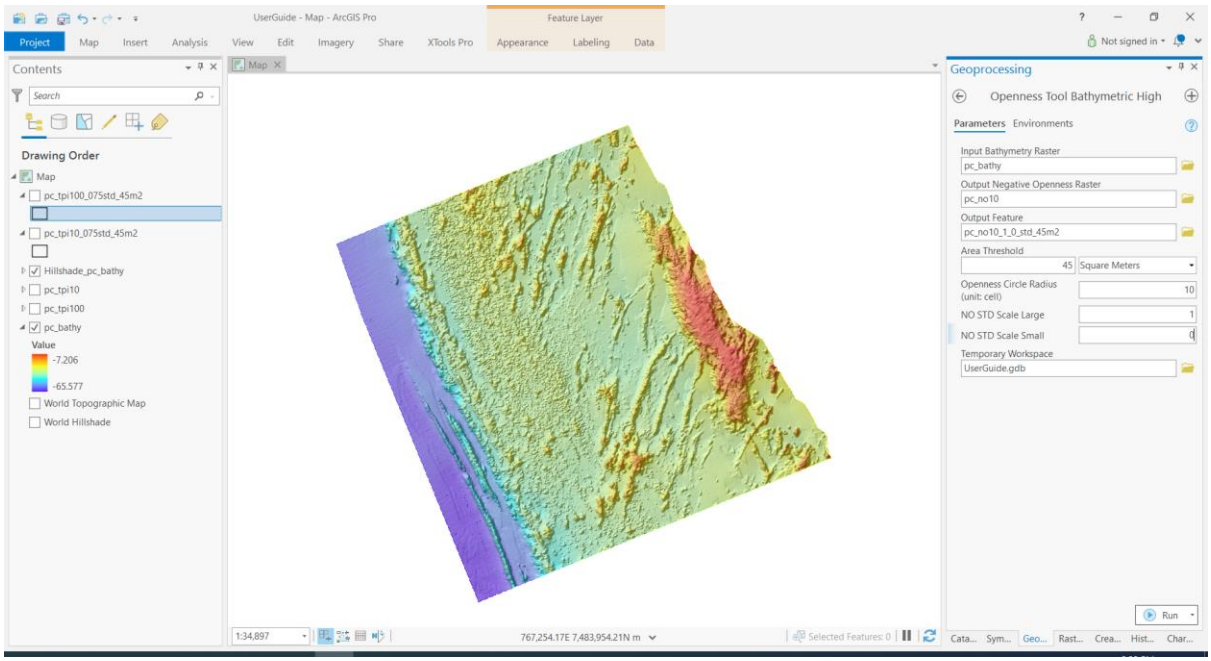
5. Now change the Area Threshold to 1000 m^2 and the TPI radius to 100, and re-run the tool. Remember to change the names of the ouput TPI grid and the bathymetric high features (e.g., pc_tpi100 and pc_tpi100_075std_1000m2, respectively) accordingly.
6. Explore the new outputs. This time, you have mapped broader-scale bathymetric high features.



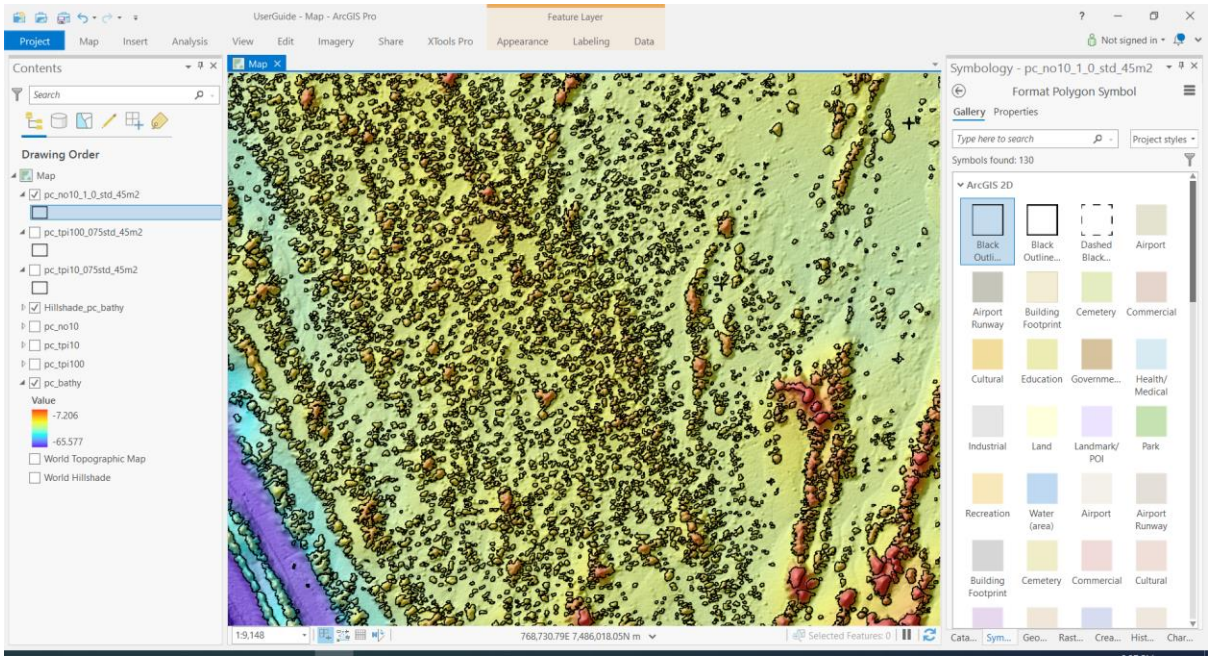
7. Additional Tasks
    a. Explore other values for the input parameters: TPI Radius, TPI STD scale, Area Threshold, etc.
    b. Try different GIS tools in ArcGIS toolboxes to combine the fine-scale and broad-scale bathymetric high features into one single output of bathymetric high features.

4.2. Openness Tool Bathymetric High

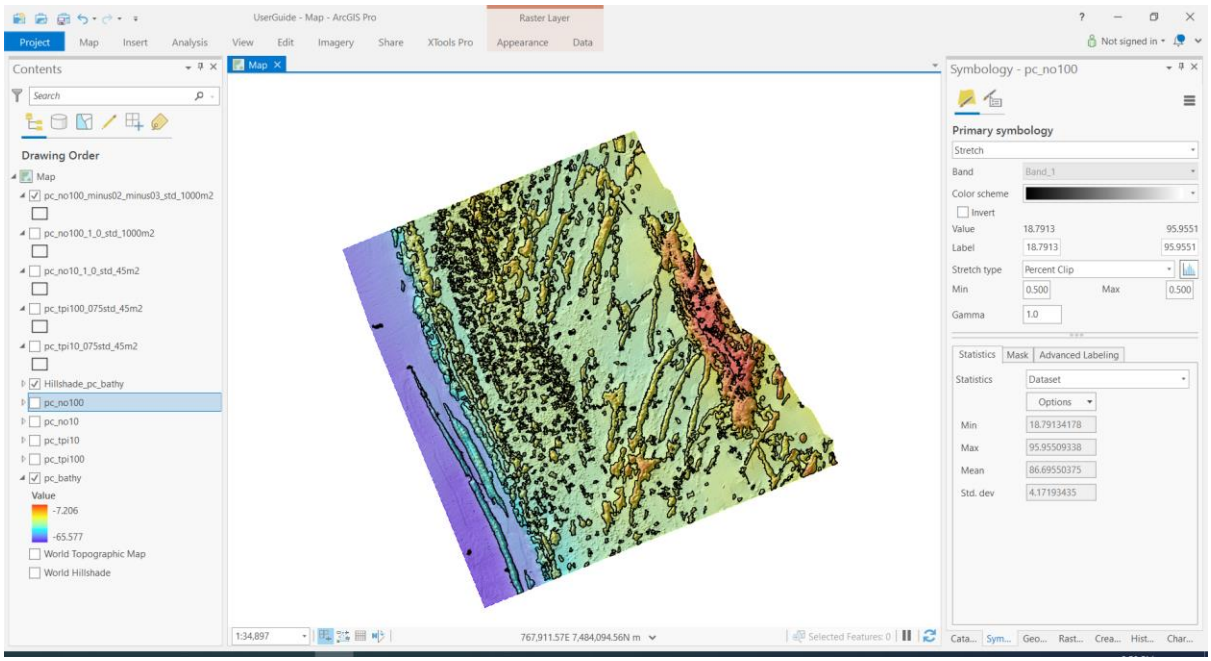
1. If not already loaded, add the pc_bathy bathymetry grid from the Points_Cloates.gdb into the map. Explore the bathymetry data which contains many bathymetric high features.
2. Select the Openness Tool Bathymetric High tool, Double-Click to open the tool in the Geoprocessing tab. For the Input Bathymetry Raster, select the pc_bathy grid from the drop-down list or navigate to the Points_Cloates.gdb and select the pc_bathy grid. For the Output Negative Openness Raster, navigate to the Points_Cloates.gdb and enter a name like “pc_no10”. For the Output Feature, navigate to the Points_Cloates.gdb and enter a name like “pc_no10_1_0_std_45m2”. For the Area Threshold, enter 45 Square Meters. For the Openness Circle Radius, enter 10. For the NO STD Scale Large, enter 1. For the NO STD Scale Small, enter 0. For the Temporary Workspace, nominate a File Geodatabase that is different from the input/output workspace(s).



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.
4. After the geoprocessing is completed, the pc_no10 Negative Openness grid and the pc_no10_1_0_std_45m2 output bathymetric high features have been generated and added to the current map. Explore the output NO grid and the bathymetric high features which map a large number of fine-scale bathymetric high features including hummocks and ridges.



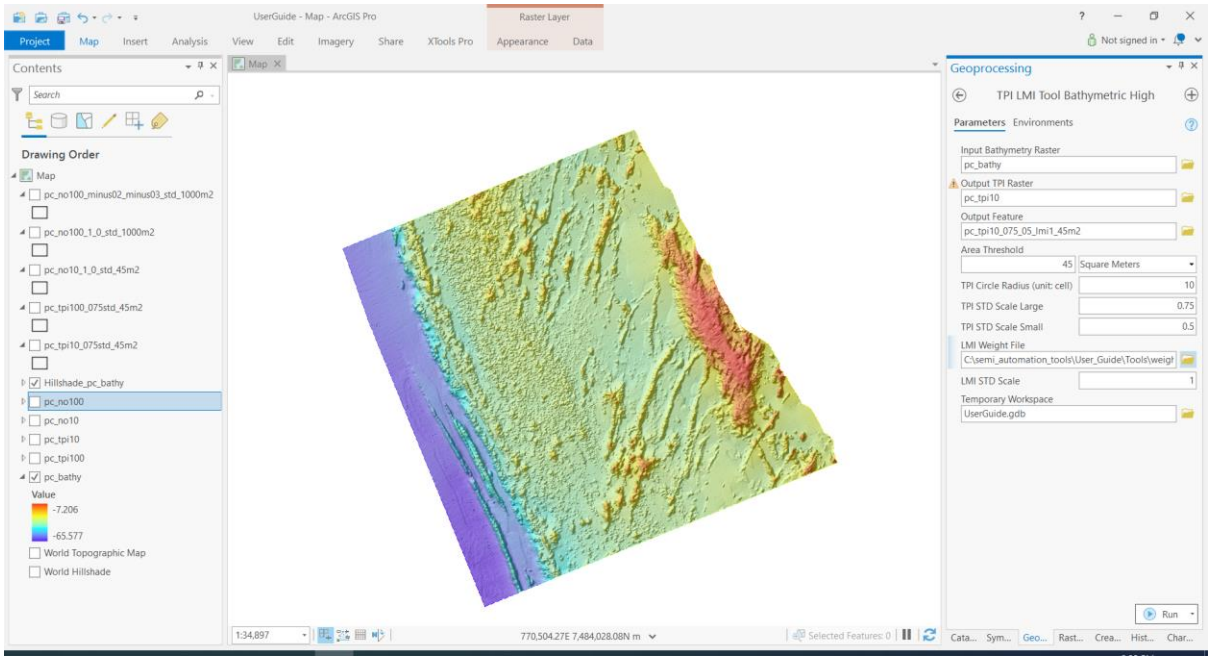
5. Now change the Area Threshold to 1000 m^2, the NO radius to 100, the NO STD Scale Large to -0.2 and the NO STD Scale Small to -0.3, and re-run the tool. Remember to change the names of the output NO grid and the bathymetric high features accordingly.
6. Explore the new outputs. This time, you have mapped broader-scale bathymetric high features.



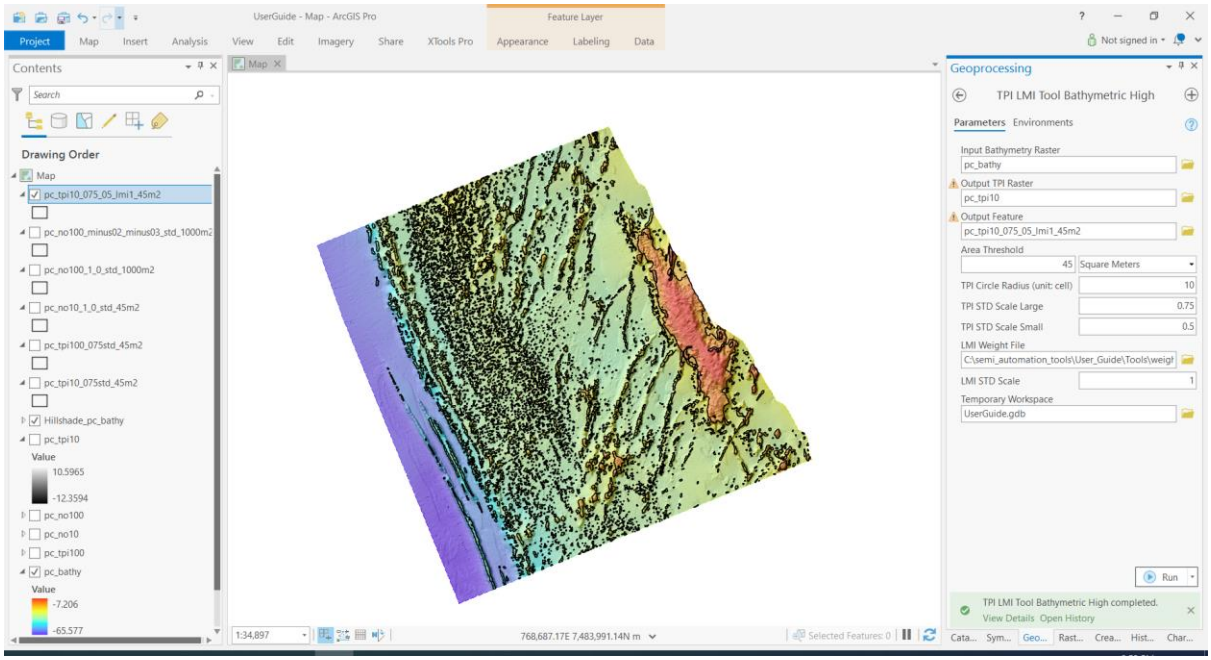
7. Additional Tasks
    a. Explore other values for the input parameters: NO Radius, NO STD scales, Area Threshold, etc.
    b. Try different GIS tools in ArcGIS toolboxes to combine the fine-scale and broad-scale bathymetric high features into one single output of bathymetric high features.

4.3. TPI LMI Tool Bathymetric High

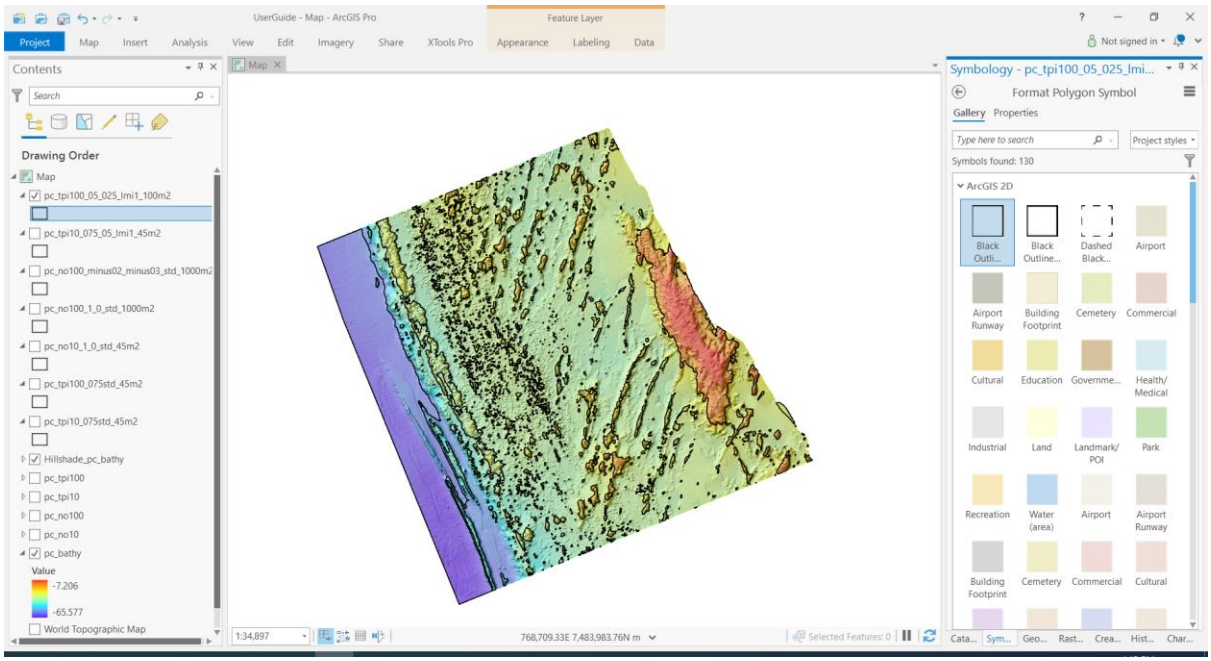
1. If not already loaded, add the pc_bathy bathymetry grid from the Points_Cloates.gdb into the map. Explore the bathymetry data which contains many bathymetric high features.
2. Select the TPI LMI Tool Bathymetric High tool, Double-Click to open the tool in the Geoprocessing tab. For the Input Bathymetry Raster, select the pc_bathy grid from the drop-down list or navigate to the Points_Cloates.gdb and select the pc_bathy grid. For the Output TPI Raster, navigate to the Points_Cloates.gdb and enter a name like “pc_tpi10”. For the Output Feature, navigate to the Points_Cloates.gdb and enter a name like “pc_tpi10_075_05_lmi1_45m2”. For the Area Threshold, enter 45 Square Meters. For the TPI Circle Radius, enter 10. For the TPI STD Scale Large, enter 0.75. For the TPI STD Scale Small, enter 0.5. For the LMI Weight File, navigate to GA-SaMMT_v2p0\Tools\weight_3.txt. For the LMI STD Scale, enter 1.0. For the Temporary Workspace, nominate a File Geodatabase that is different from the input/output workspace(s).



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.
4. After the geoprocessing is completed, the pc_tpi10 TPI grid and the pc_tpi10_075_05_lmi1_45m2 output bathymetric high features have been generated and added to the current map. Explore the output TPI grid and the bathymetric high features which map a large number of fine-scale bathymetric high features including hummocks and ridges.



5. Now change the Area Threshold to 1000 m^2, the TPI radius to 100 and, the TPI STD Scale Large to 0.5, and the TPI STD Scale Small to 0.25, and re-run the tool. Remember to change the names of the output TPI grid and the bathymetric high features accordingly.
6. Explore the new outputs. This time, you have mapped broader-scale bathymetric high features.



7. Additional Tasks
    a. Explore other values for the input parameters: TPI Radius, TPI STD scales, LMI STD scale, Area Threshold, etc.
    b. Try different GIS tools in ArcGIS toolboxes to combine the fine-scale and broad-scale bathymetric high features into one single output of bathymetric high features.

5. Use Bathymetric Low tools

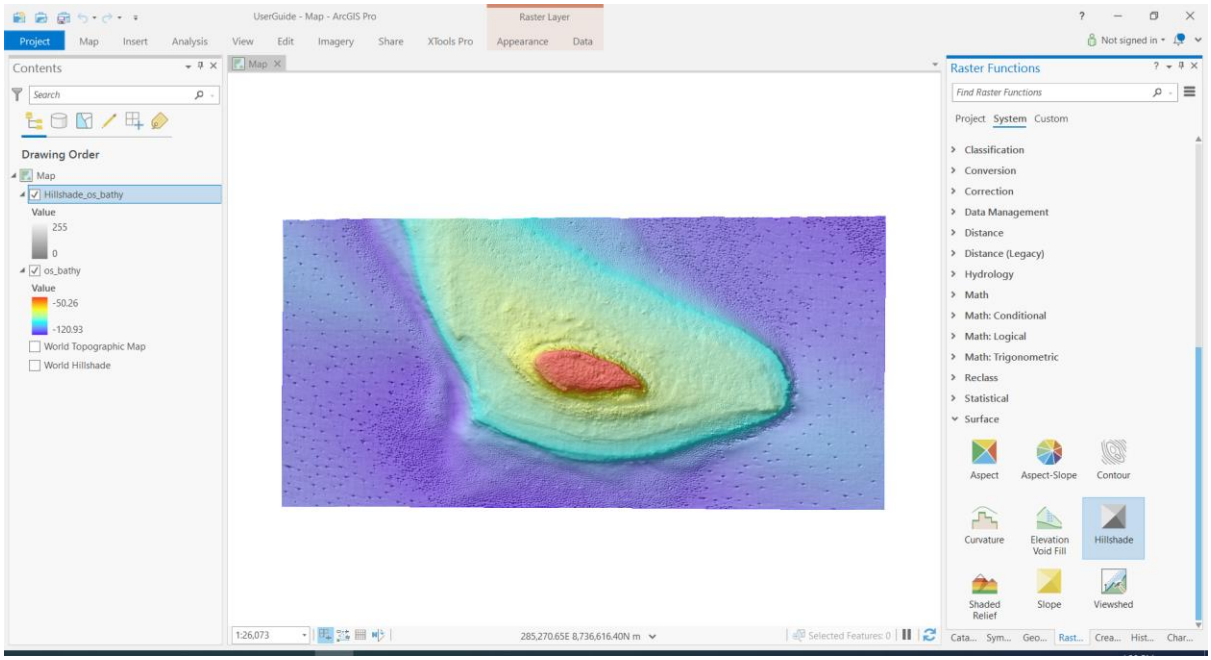
There are three tools in the BathymetricLow toolbox. Please see detailed metadata of each tool.

1. TPI Tool Bathymetric Low: This tool maps bathymetric low features from a bathymetric data using a Topographic Position Index (TPI) based method.
2. TPI CI Tool Bathymetric Low: This tool maps bathymetric low features from a bathymetric data using a combination of Topographic Position Index (TPI) and Convergence Index (CI) method.
3. Openness Tool Bathymetric Low: This tool maps bathymetric low features from a bathymetric data using an openness based method.

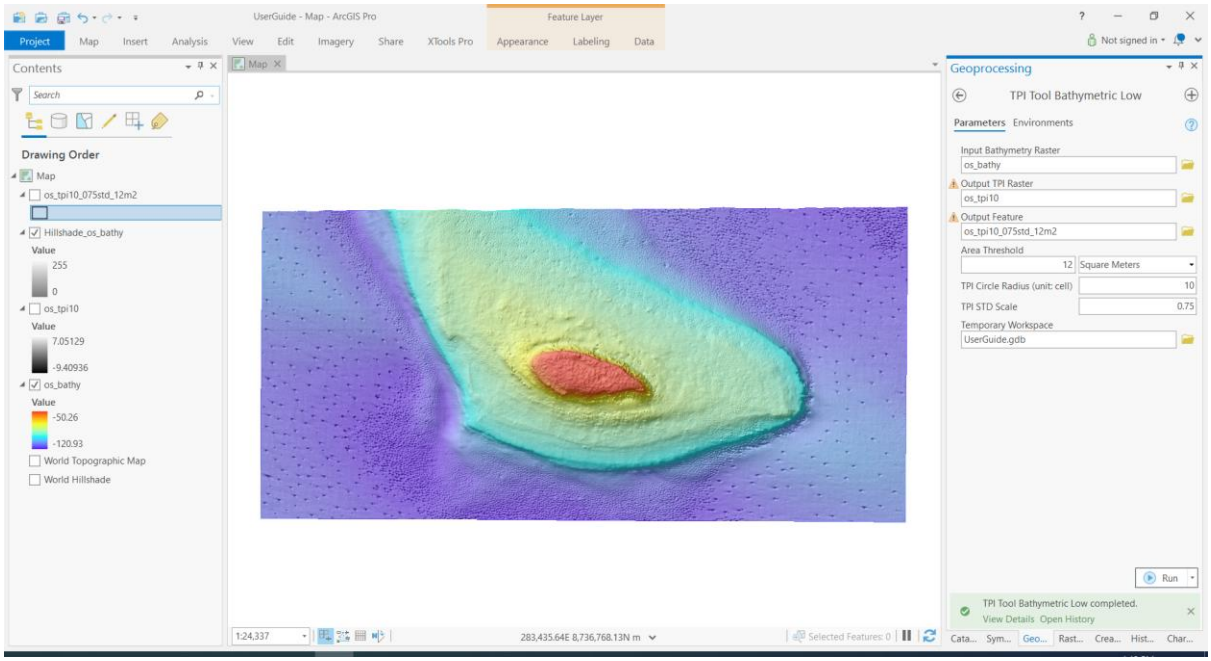
All of these three BathymetricLow tools are able to map bathymetric low features. However, they are based on different methodologies and thus could be suitable for different applications. Please familiar yourself with the metadata of these tools before attempting to use them. When applying to real-world applications, the users are advised to evaluate which tool(s) are the most suitable for their applications.

5.1. TPI Tool Bathymetric Low

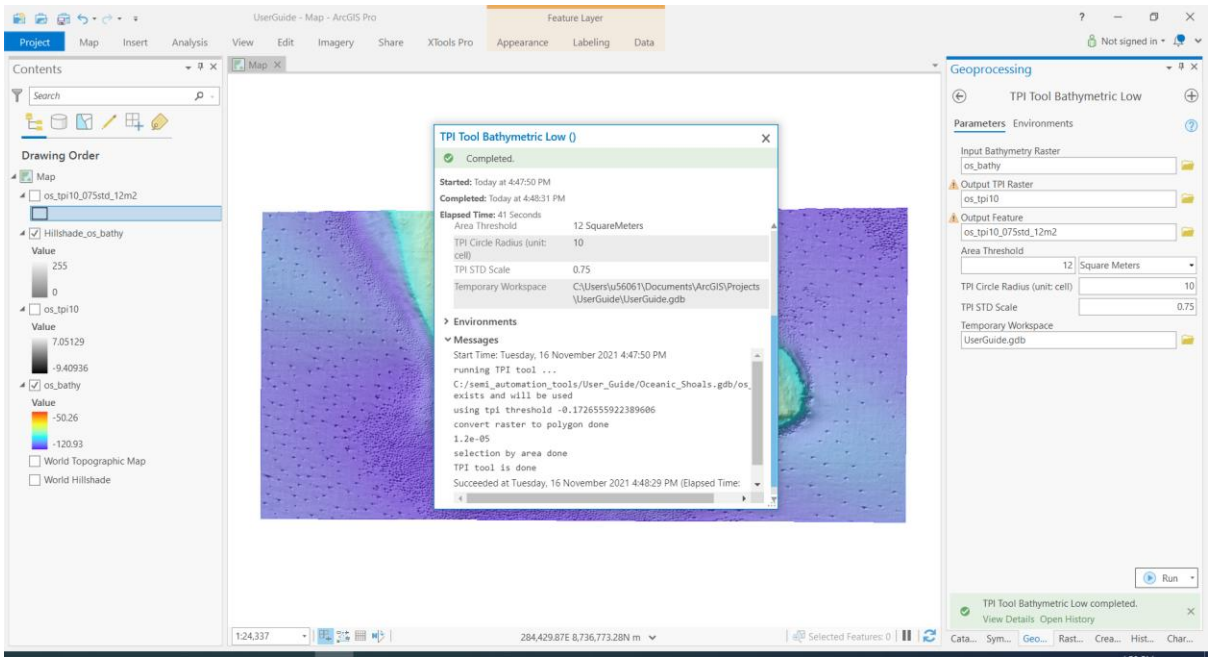
1. Create a new map (e.g., using Insert New Map menu), add the os_bathy bathymetry grid from the Oceanic_Shoals.gdb into the map. Explore the bathymetry data which contains a large number of pockmarks as bathymetric low features.



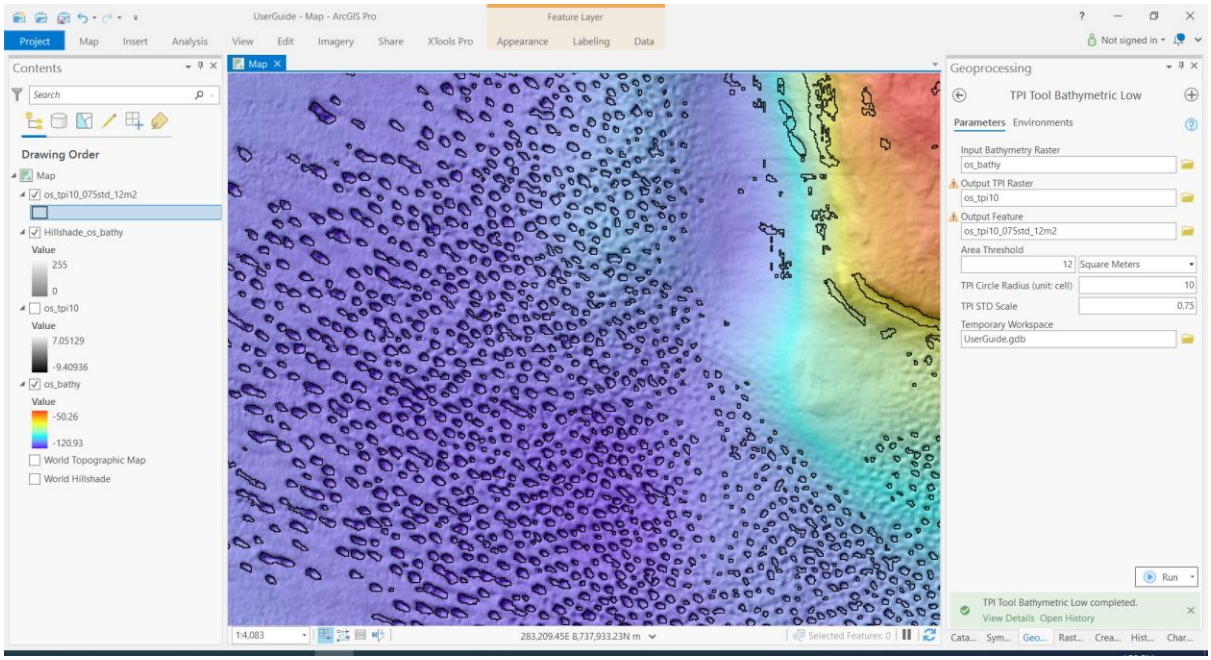
2. Select the TPI Tool Bathymetric Low tool, Double-Click to open the tool in the Geoprocessing tab. For the Input Bathymetry Raster, select the os_bathy grid from the drop-down list or navigate to the Oceanic_Shoals.gdb and select the os_bathy grid. For the Output TPI Raster, navigate to the Oceanic_Shoals.gdb and enter a name like “os_tpi10”. For the Output Feature, navigate to the Oceanic_Shoals.gdb and enter a name like “os_tpi10_075std_12m2”. For the Area Threshold, enter 12 Square Meters. For the TPI Circle Radius, enter 10. For the TPI STD Scale, enter 0.75. For the Temporary Workspace, nominate a File Geodatabase that is different from the input/output workspace(s).



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



4. After the geoprocessing is completed, the os_tpi10 TPI grid and the os_tpi10_075std_12m2 output bathymetric high features have been generated and added to the current map. Explore the output TPI grid and the bathymetric low features which map a large number of pockmarks.

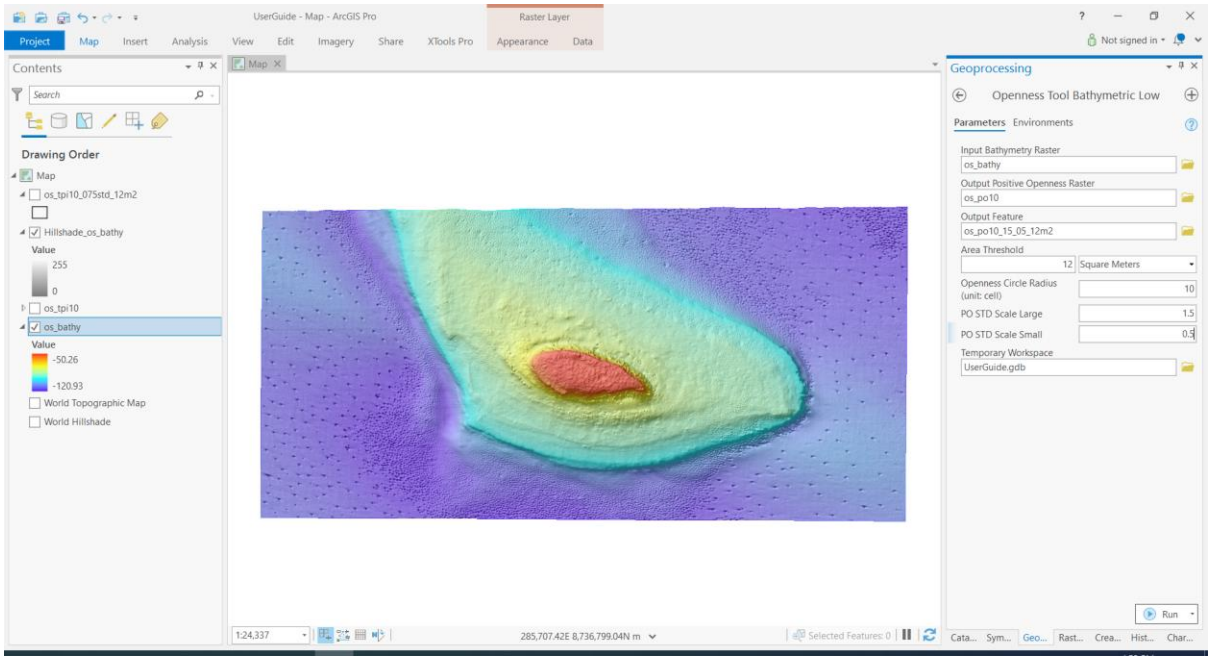


5. Explore other values for the input parameters: TPI Radius, TPI STD scale, Area Threshold, etc.

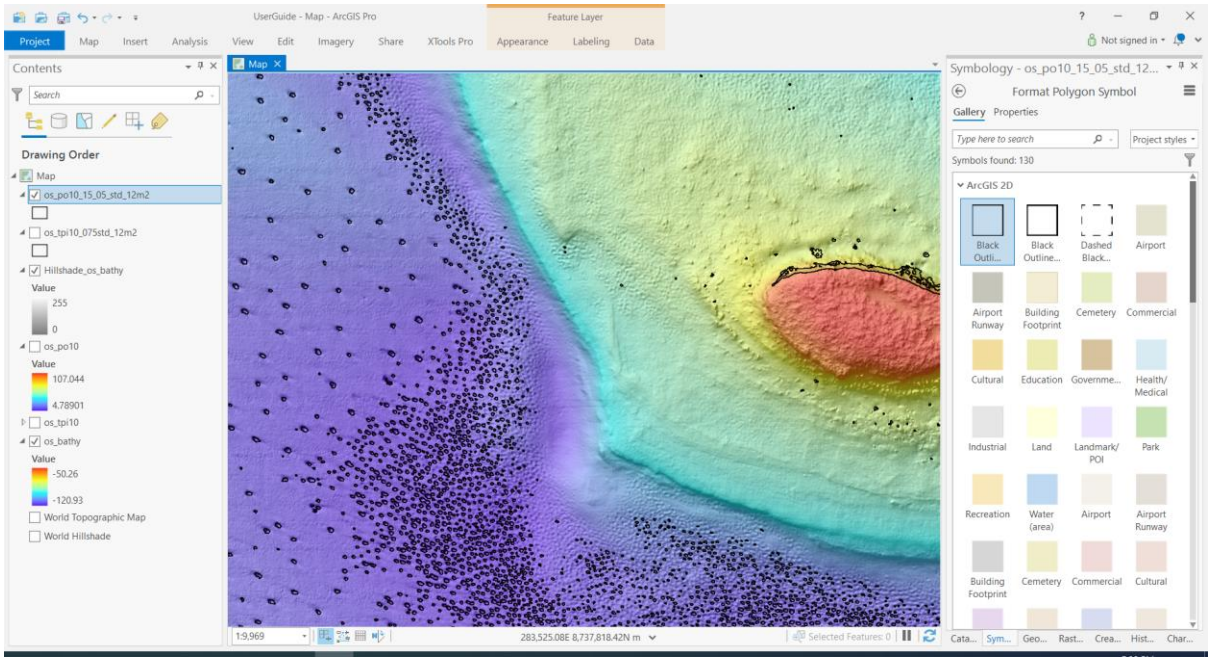
5.2. Openness Tool Bathymetric Low

1. If not already loaded, add the os_bathy bathymetry grid from the Oceanic_Shoals.gdb into the map. Explore the bathymetry data which contains a large number of pockmarks as bathymetric low features.
2. Select the Openness Tool Bathymetric Low tool, Double-Click to open the tool in the Geoprocessing tab. For the Input Bathymetry Raster, select the os_bathy grid from the drop-down list or navigate to the Oceanic_Shoals.gdb and select the os_bathy grid. For the Output

Positive Openness Raster, navigate to the Oceanic_Shoals.gdb and enter a name like “os_po10”. For the Output Feature, navigate to the Oceanic_Shoals.gdb and enter a name like “os_po10_15_05_std_12m2”. For the Area Threshold, enter 12 Square Meters. For the Openness Circle Radius, enter 10. For the PO STD Scale Large, enter 1.5. For the PO STD Scale Small, enter 0.5. For the Temporary Workspace, nominate a File Geodatabase that is different from the input/output workspace(s).



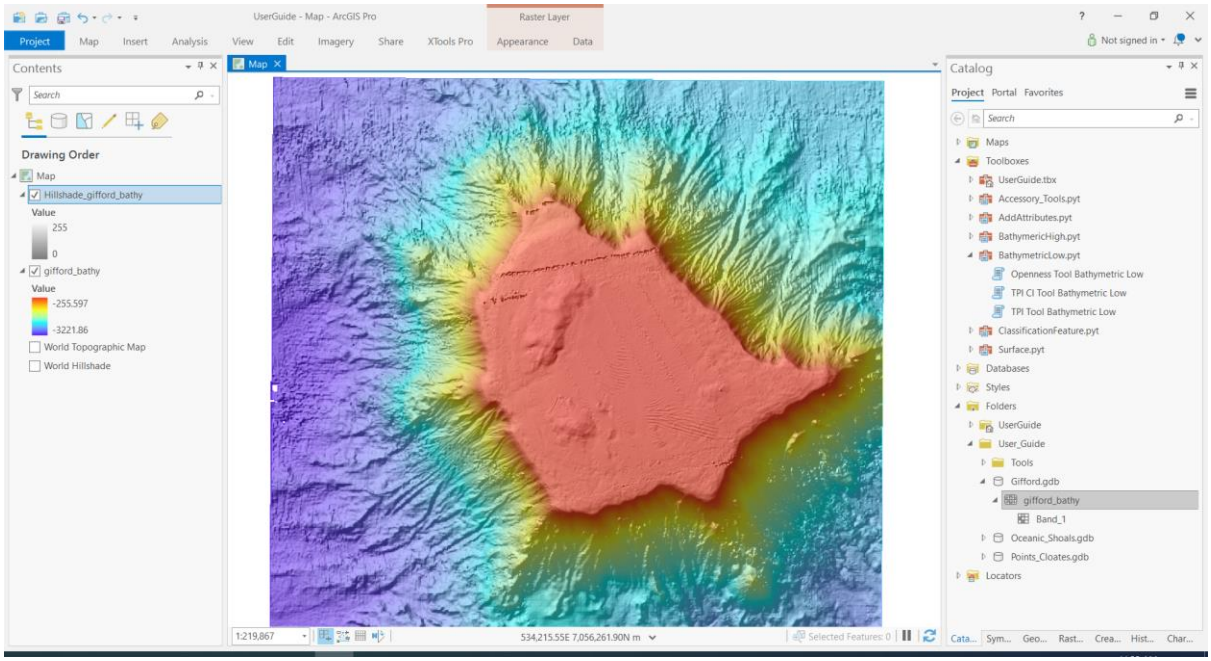
3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.
4. After the geoprocessing is completed, the os_po10 Positive Openness grid and the os_po10_15_05_std_12m2 output bathymetric high features have been generated and added to the current map. Explore the output PO grid and the bathymetric low features which map a large number of pockmarks.



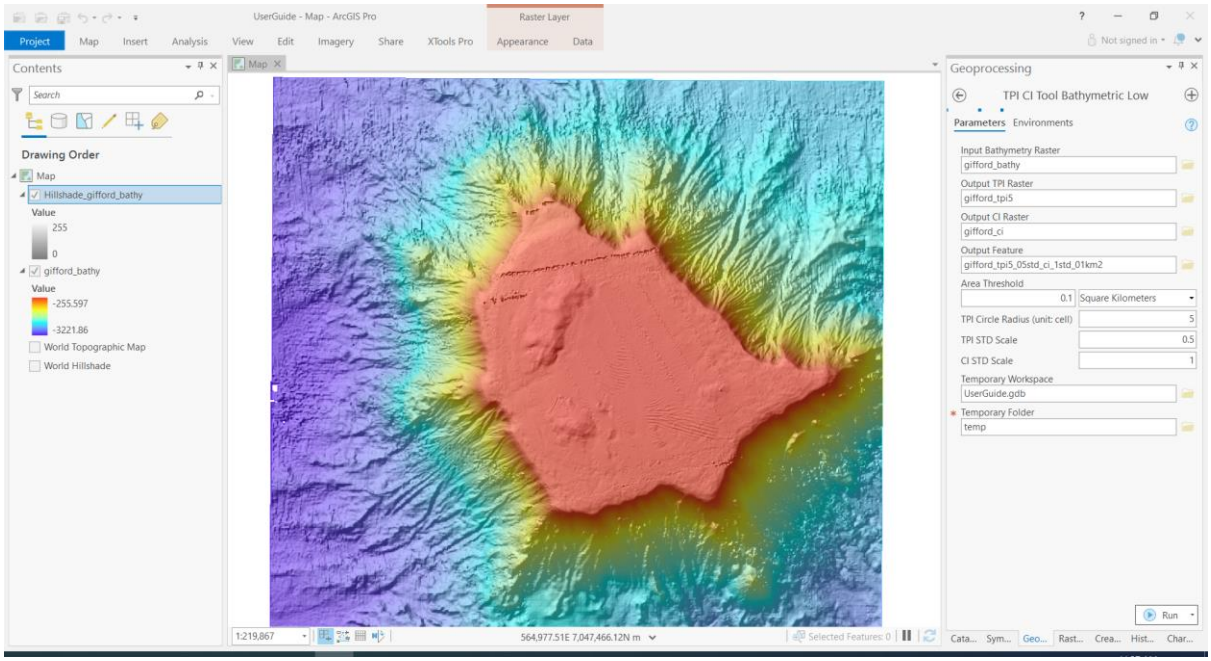
5. Explore other values for the input parameters: Openness Radius, PO STD scales, Area Threshold, etc.

5.3. TPI CI Tool Bathymetric Low

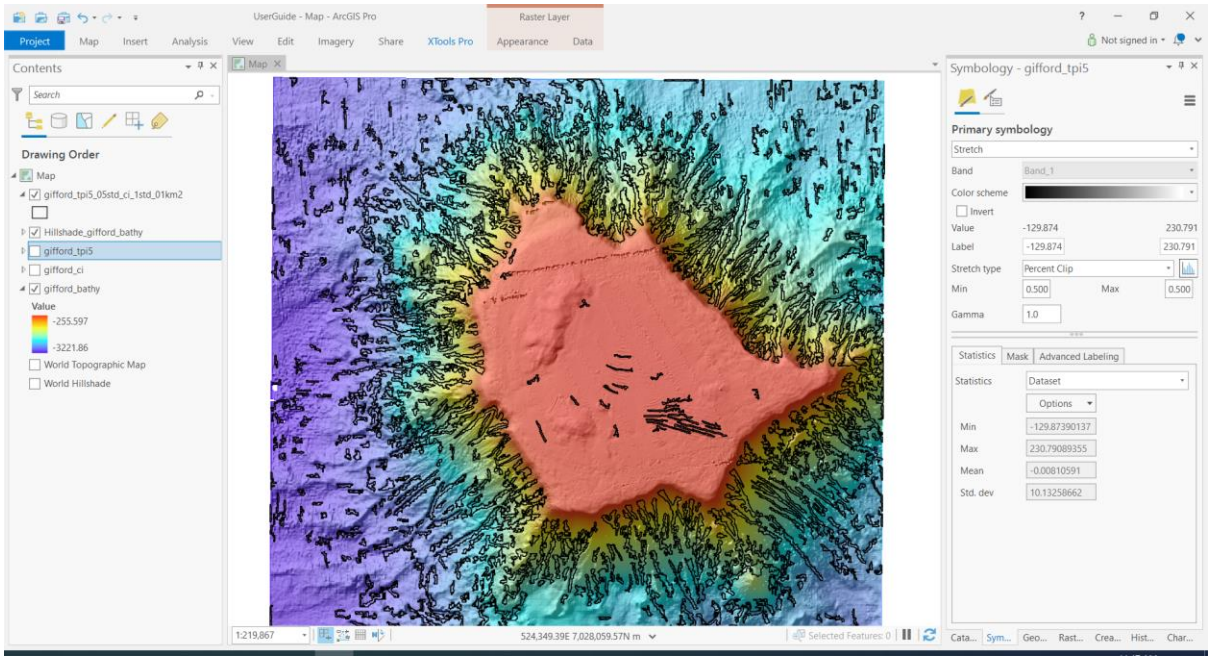
1. Create a new map (e.g., using Insert New Map menu), add the gifford_bathy bathymetry grid from the Gifford.gdb into the map. Explore the bathymetry data which contains bathymetric low features on the flank of the seamount.



2. Select the TPI CI Tool Bathymetric Low tool, Double-Click to open the tool in the Geoprocessing tab. For the Input Bathymetry Raster, select the gifford_bathy grid from the drop-down list or navigate to the Gifford.gdb and select the gifford_bathy grid. For the Output TPI Raster, navigate to the Gifford.gdb and enter a name like “gifford_tpi5”. For the Output CI Raster, navigate to the Gifford.gdb and enter a name like “gifford_ci”. For the Output Feature, navigate to the Gifford.gdb and enter a name like “gifford_tpi5_05std_ci_1std_01km2”. For the Area Threshold, enter 0.1 Square Kilometers. For the TPI Circle Radius, enter 5. For the TPI STD Scale, enter 0.5. For the CI STD Scale, enter 1.0. For the Temporary Workspace, nominate a File Geodatabase that is different from the input/output workspace(s). For the Temporary Folder, nominate a folder.



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.
4. After the geoprocessing is completed, the gifford_tpi5 TPI grid, the gifford_ci grid and the gifford_tpi5_05std_ci_1std_01km2 output bathymetric low features have been generated and added to the current map. Explore the output grids and the bathymetric low features.



5. Explore other values for the input parameters: TPI Radius, TPI STD scale, CI STD scale, Area Threshold, etc.

6. Use Add Attributes tools

The AddAttributes toolbox contains the following six tools. Please see detailed metadata of each tool.

1. Add Shape Attributes High Tool: This tool generates shape attributes for each bathymetric high feature.
2. Add Shape Attributes Low Tool: This tool generates shape attributes for each bathymetric low feature.
3. Add Topographic Attributes High Tool: This tool generates topographic attributes for each bathymetric high feature.
4. Add Topographic Attributes Low Tool: This tool generates topographic attributes for each bathymetric low feature.
5. Add Profile Attributes High Tool: This tool generates profile attributes for each bathymetric high feature.
6. Add Profile Attributes Low Tool: This tool generates profile attributes for each bathymetric low feature.

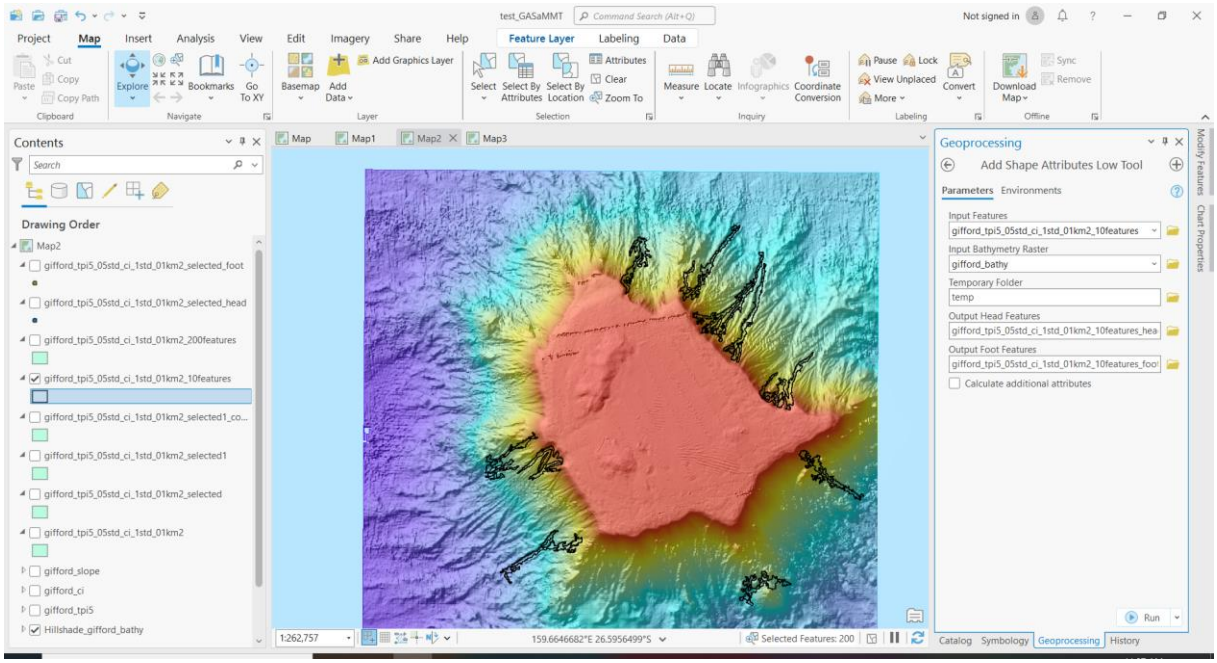
For both bathymetric high and bathymetric low features, there are three groups of attributes to be calculated: Shape, Topographic and Profile, using three individual tools. These three groups of attributes need to be calculated in the order of Shape, Topographic and Profile attributes due to the inter-dependency.

This user guide illustrates the usage of these *add attributes* tools using two examples. The first example is to generate the attributes for a subset of the output bathymetric low features: gifford_tpi5_05std_ci_1std_01km2. The other example is to generate the attributes for a subset of the output bathymetric high features: pc_tpi10_075std_45m2.

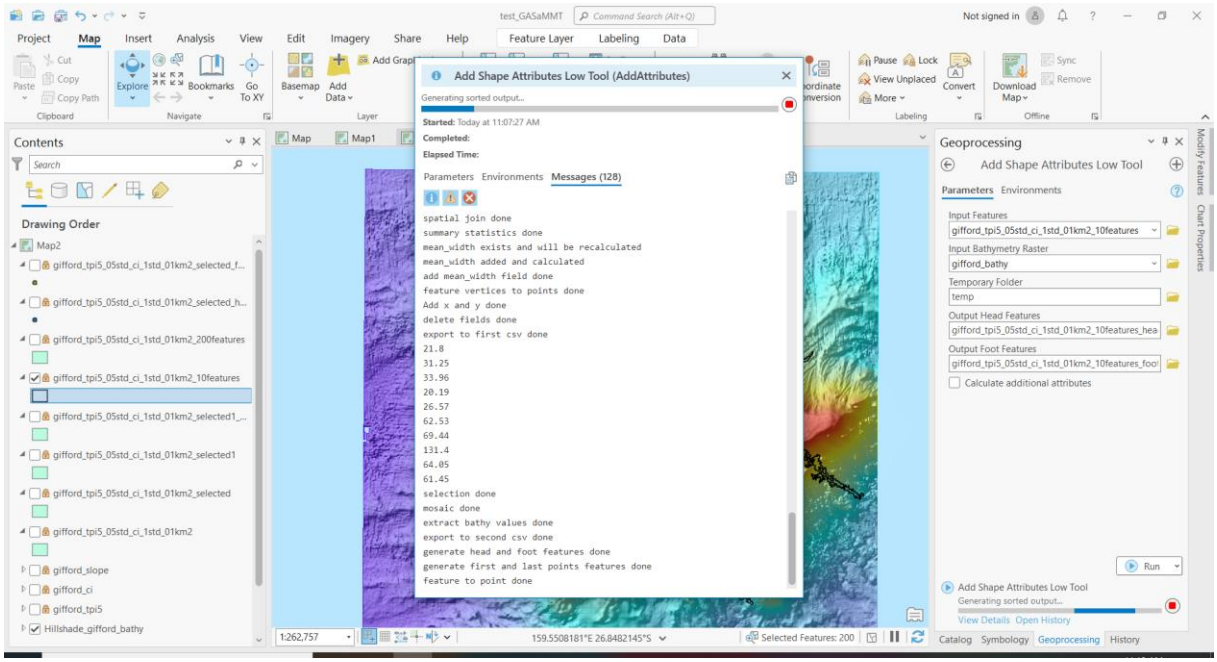
6.1. Add Shape Attributes Low Tool

The Add Shape Attributes Low Tool is time-consuming. For the purpose of simplification, we just calculate the attributes for the largest 10 features (polygons).

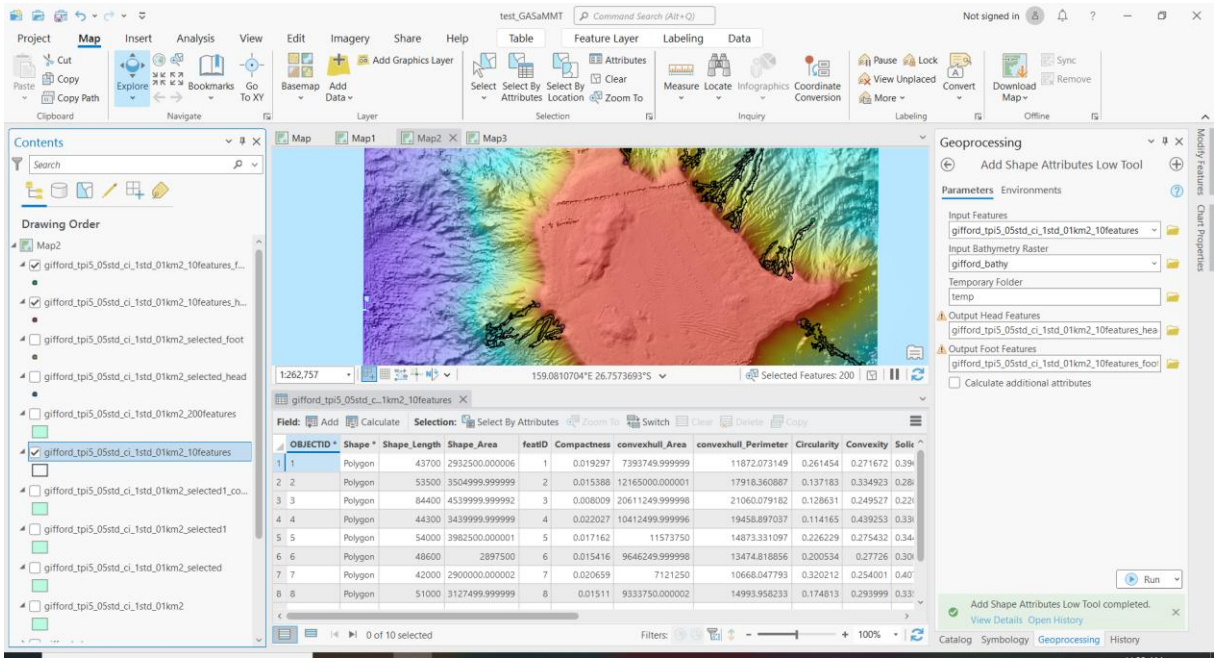
1. Select the largest 10 features (polygons) from gifford_tpi5_05std_ci_1std_01km2 and export the selected features as a new feature class: gifford_tpi5_05std_ci_1std_01km2_10features.
2. Select the Add Shape Attributes Low Tool from the AddAttributes toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select gifford_tpi5_05std_ci_1std_01km2_10features from the drop-down list or navigate to the Gifford.gdb and add gifford_tpi5_05std_ci_1std_01km2_10features. For the Input Bathymetry Raster, select gifford_bathy from the drop-down list or navigate to the Gifford.gdb and add gifford_bathy. For the Temporary Folder, nominate a folder (e.g., C:\GA-SaMMT_v2p0\temp). For the Output Head Features, navigate to the Gifford.gdb, enter a name like "gifford_tpi5_05std_ci_1std_01km2_10features_head". For the Output Foot Features, navigate to the Gifford.gdb, enter a name like "gifford_tpi5_05std_ci_1std_01km2_10features_foot". For the Calculate additional attributes, leave it unchecked.



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



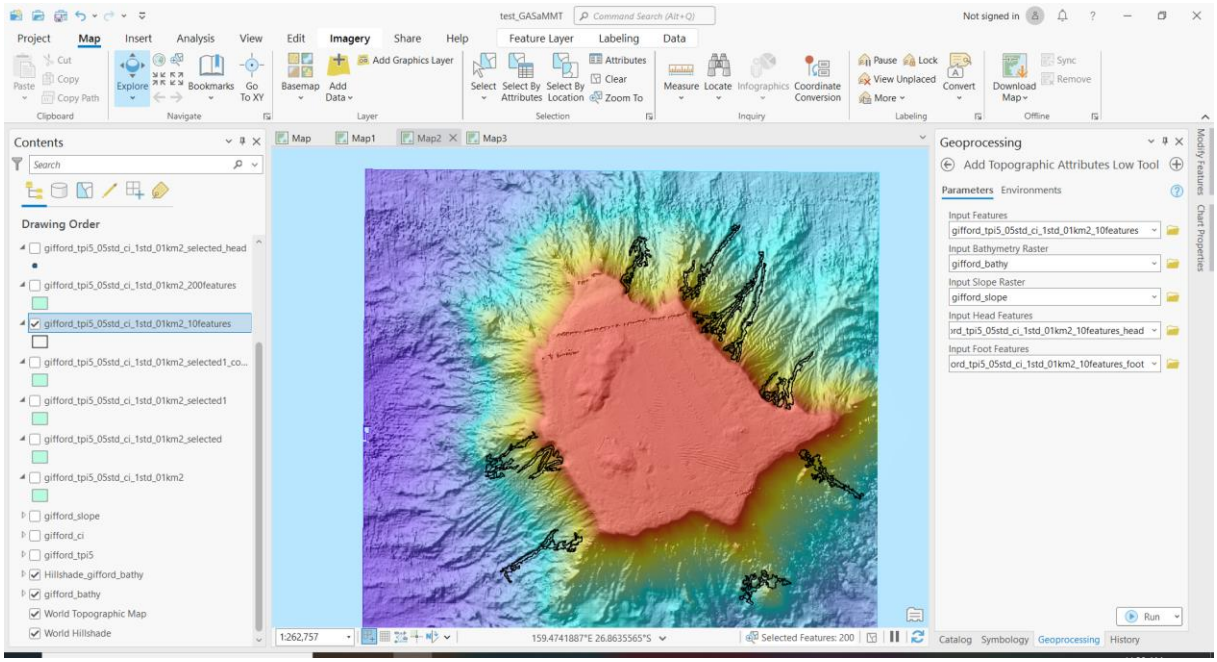
4. After the geoprocessing is completed, check that the shape attributes have been generated.



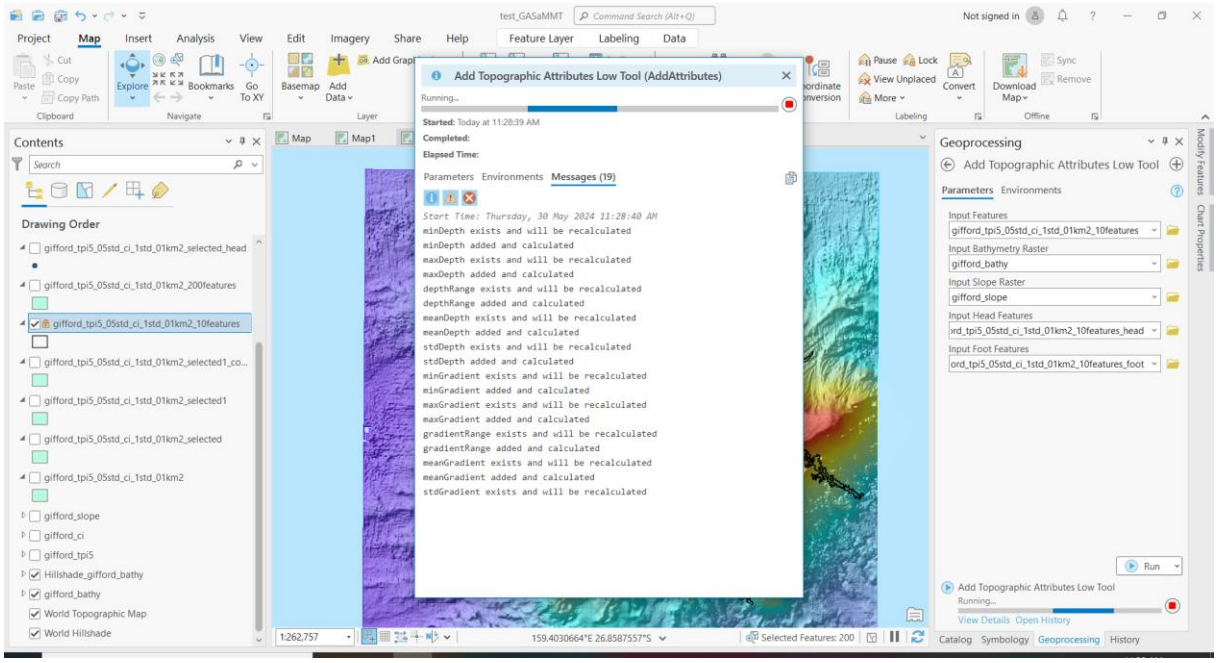
5. Explore the shape attributes of the bathymetric low features if you wish. Otherwise, continue next step.
6. Additional task (in your spare time):
    a. Select 200 features from gifford_tpi5_05std_ci_1std_01km2 and export the selected features as a new feature class: gifford_tpi5_05std_ci_1std_01km2_200features.
    b. Run Add Shape Attributes Low tool using gifford_tpi5_05std_ci_1std_01km2_200features as the Input Features, changing the names of the head and foot features accordingly, and check the Calculate additional attributes option.
    c. Record the time required to complete the tool (4h55m30s in my laptop).

6.2. Add Topographic Attributes Low Tool

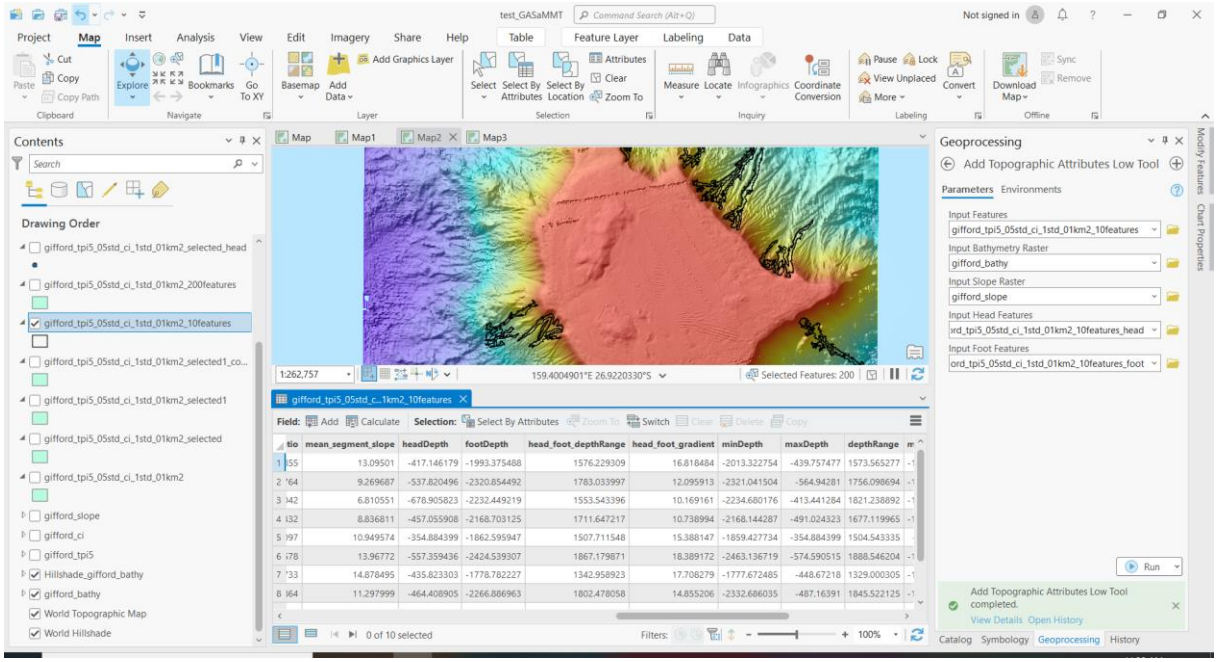
1. The Add Topographic Attributes Low Tool requires slope gradient grid as input. First, generate the slope grid from the gifford_bathy.
2. Select the Add Topographic Attributes Low Tool from the AddAttributes toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select gifford_tpi5_05std_ci_1std_01km2_10features from the drop-down list or navigate to the Gifford.gdb and add gifford_tpi5_05std_ci_1std_01km2_10features. For the Input Bathymetry Raster, select gifford_bathy from the drop-down list or navigate to the Gifford.gdb and add gifford_bathy. For the Input Slope Raster, select the slope grid generated in the previous step from the drop-down list or navigate and add the slope grid. For the Input Head Features, select the head features generated in the Add Shape Attributes Low Tool or navigate to the Gifford.gdb and select the head features. For the Input Foot Features, select the foot features generated in the Add Shape Attributes Low Tool or navigate to the Gifford.gdb and select the foot features.



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



4. After the geoprocessing is completed, check that the topographic attributes have been generated.

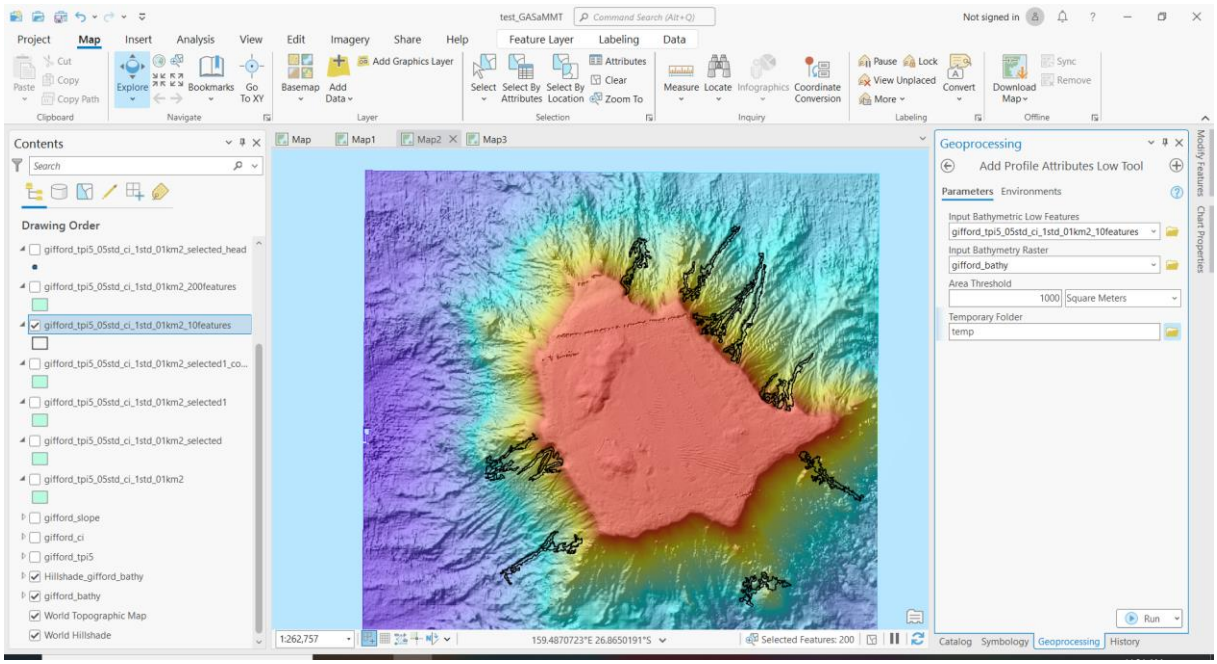


5. Explore the topographic attributes of the bathymetric low features if you wish. Otherwise, continue next step.

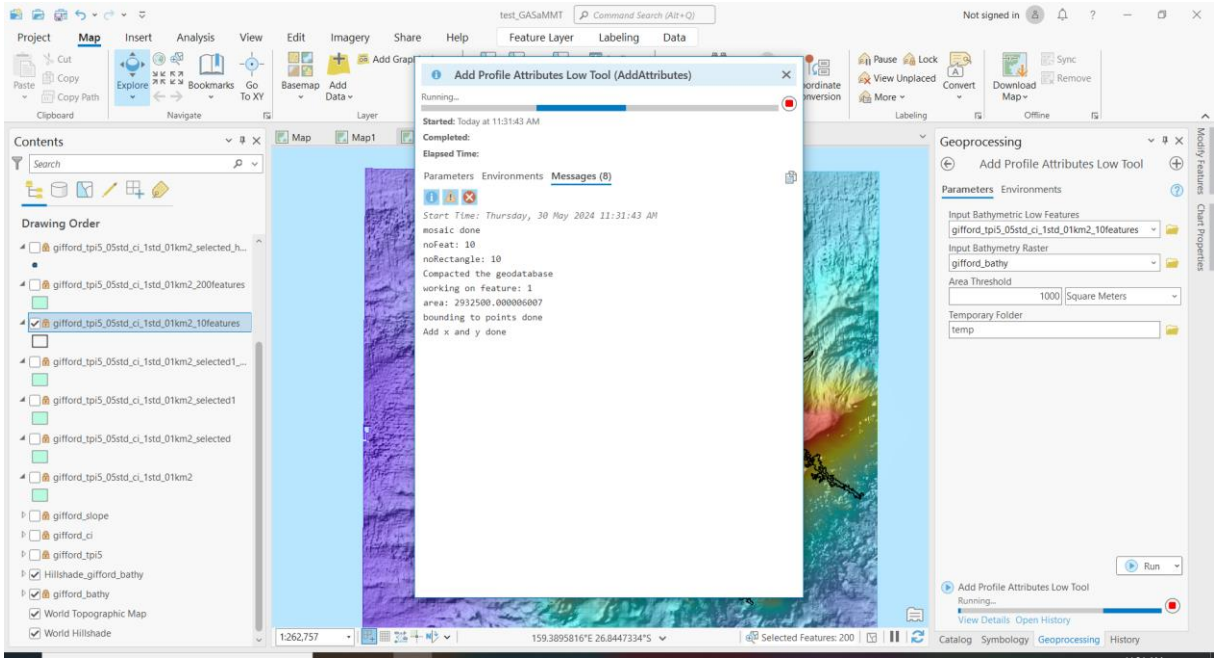
6.3. Add Profile Attributes Low Tool

1. Select the Add Profile Attributes Low Tool from the AddAttributes toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select gifford_tpi5_05std_ci_1std_01km2_10features from the drop-down list or navigate to the Gifford.gdb and add gifford_tpi5_05std_ci_1std_01km2_10features. For the Input Bathymetry Raster, select gifford_bathy from the drop-down list or navigate to the Gifford.gdb and add

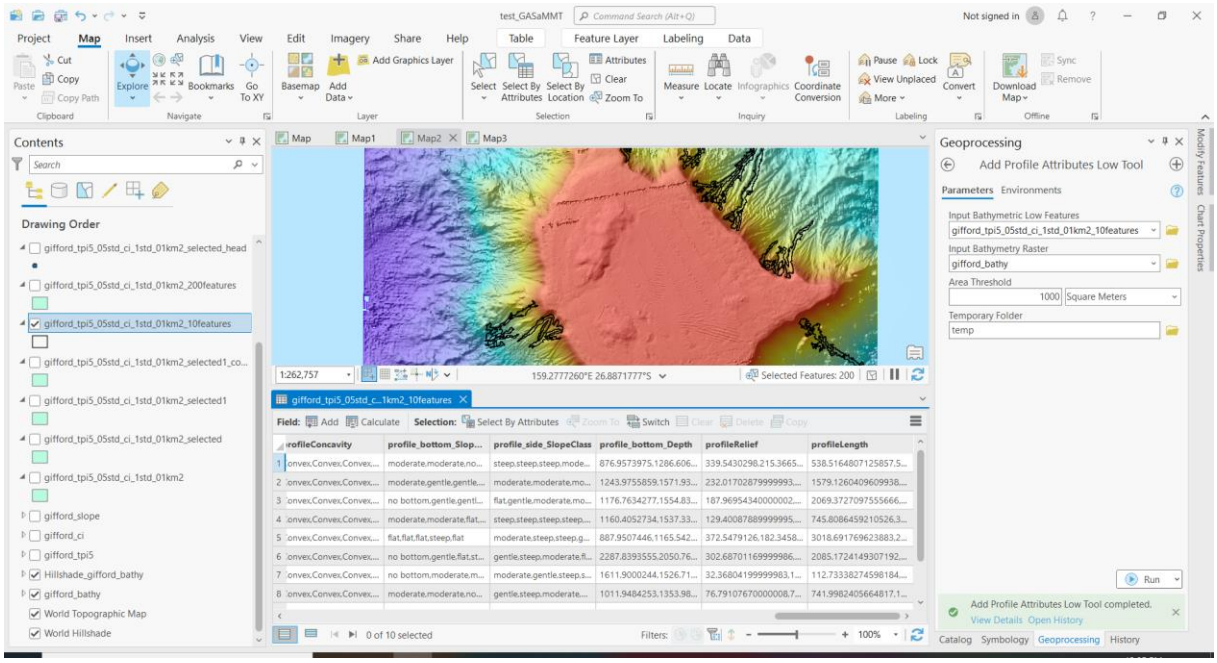
gifford_bathy. For the Area Threshold, enter 1000 Square Meters. For the Temporary Folder, nominate a folder.



2. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



3. After the geoprocessing is completed, check that the profile attributes have been generated.

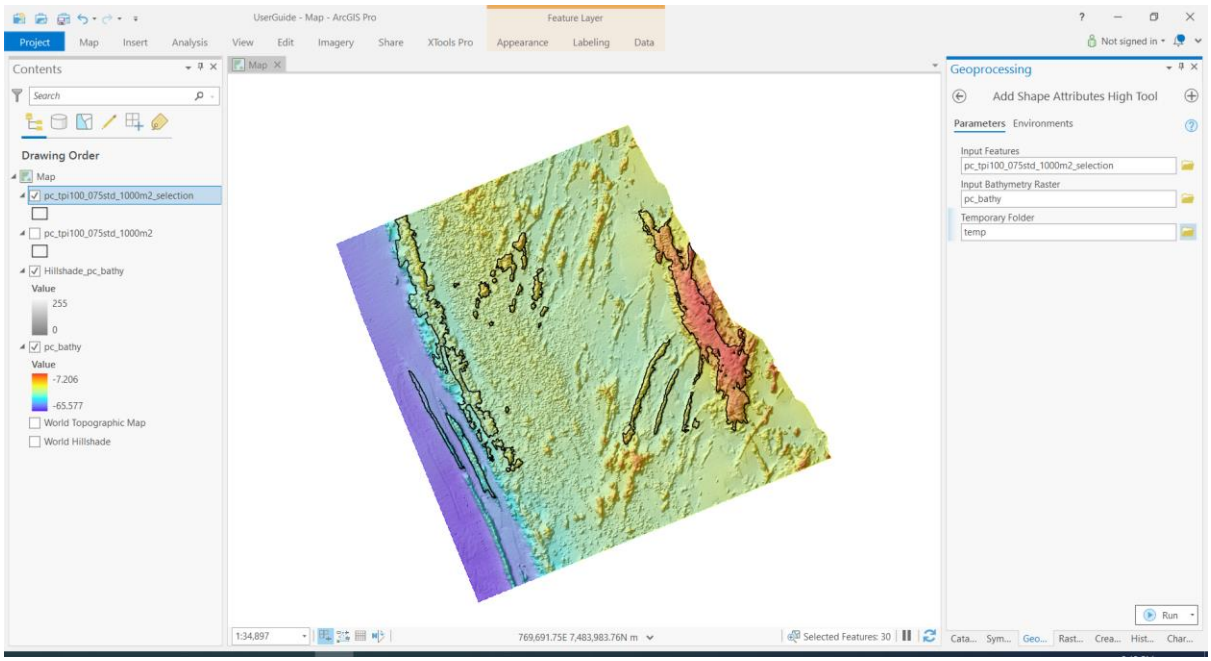


4. Explore the profile attributes of the bathymetric low features if you wish.
5. Additional task (in your spare time):
    a. Run Add Profile Attributes Low tool using gifford_tpi5_05std_ci_1std_01km2_200features as the Input Bathymetric Low Features, and other parameters same as above.
    b. Record the time required to complete the tool (9h35m49s in my laptop).

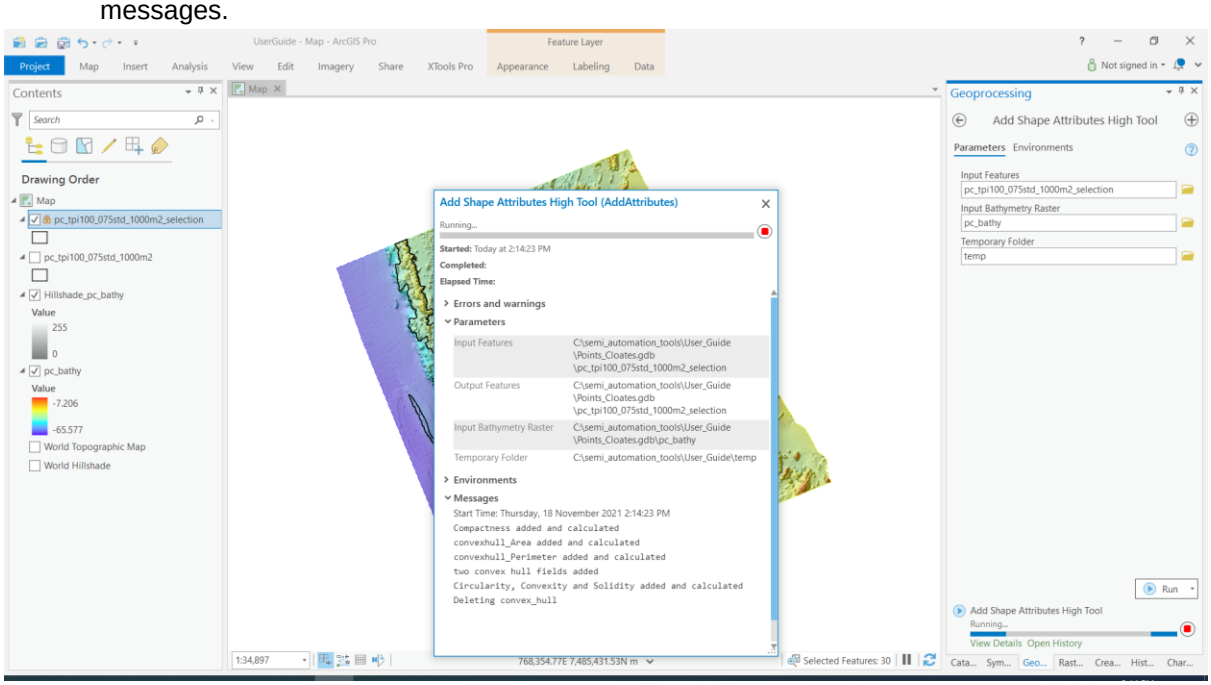
6.4. Add Shape Attributes High Tool

The Add Shape Attributes High Tool is time-consuming. For the purpose of simplification, we just randomly select a number of large and small bathymetric features and calculate the attributes for these features.

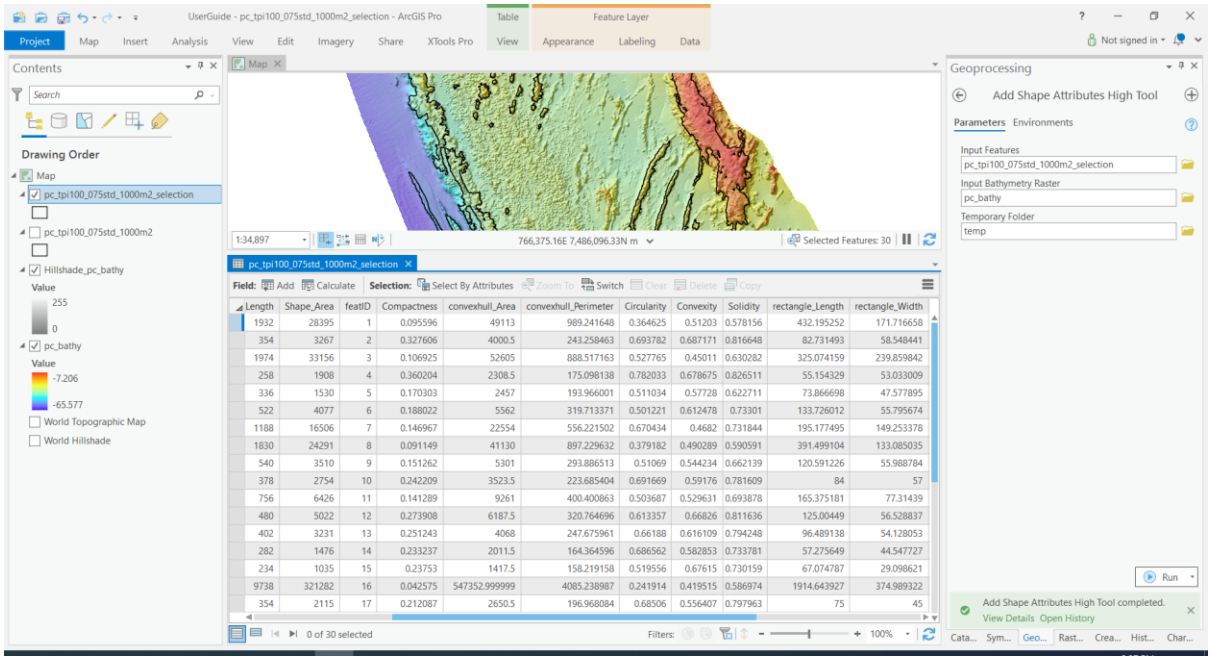
1. If not already open, create a new map and add pc_bathy from the Points_Cloates.gdb to the map, create a hill-shade layer.
2. Add pc_tpi100_075std_1000m2 bathymetric high features from the Points_Cloates.gdb to the map.
3. Randomly select a number of features and export the selection to a new feature class: pc_tpi100_075std_1000m2_selection.
4. Select the Add Shape Attributes High Tool from the AddAttributes toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select pc_tpi100_075std_1000m2_selection from the drop-down list or navigate to the Points_Cloates.gdb and add pc_tpi100_075std_1000m2_selection. For the Input Bathymetry Raster, select pc_bathy from the drop-down list or navigate to the Points_Cloates.gdb and add pc_bathy. For the Temporary Folder, nominate a folder.



5. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



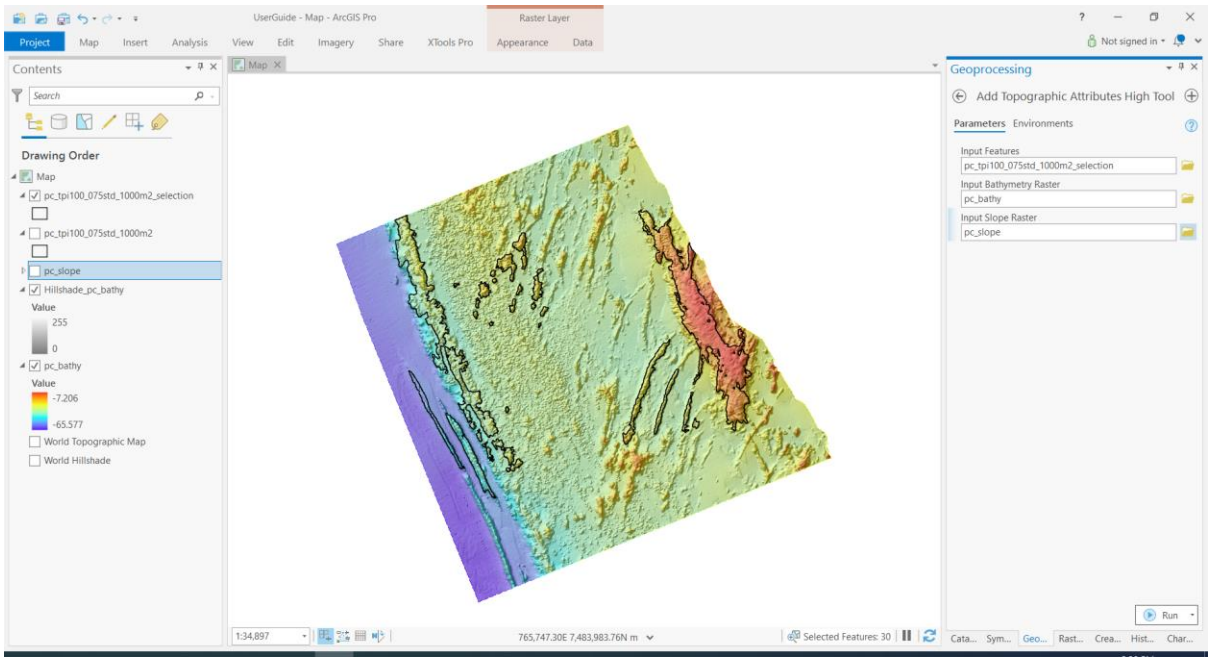
6. After the geoprocessing is completed, check that the shape attributes have been generated.



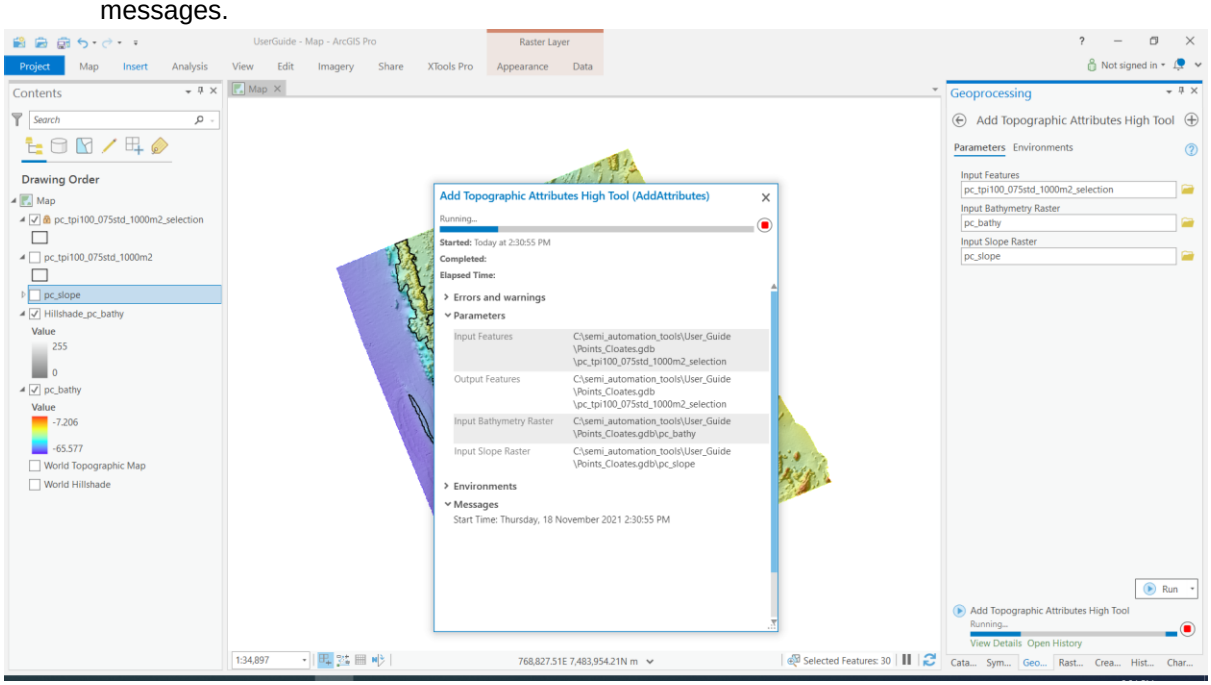
7. Explore the shape attributes of the bathymetric high features if you wish. Otherwise, continue next step.
8. Additional task (in your spare time):
    a. Select 200 features from pc_tpi10_075std_45m2 and export the selected features as a new feature class: pc_tpi10_075std_45m2_200features.
    b. Run Add Shape Attributes High tool using pc_tpi10_075std_45m2_200features as the Input Features.
    c. Record the time required to complete the tool (52m40s in my laptop).

6.5. Add Topographic Attributes High Tool

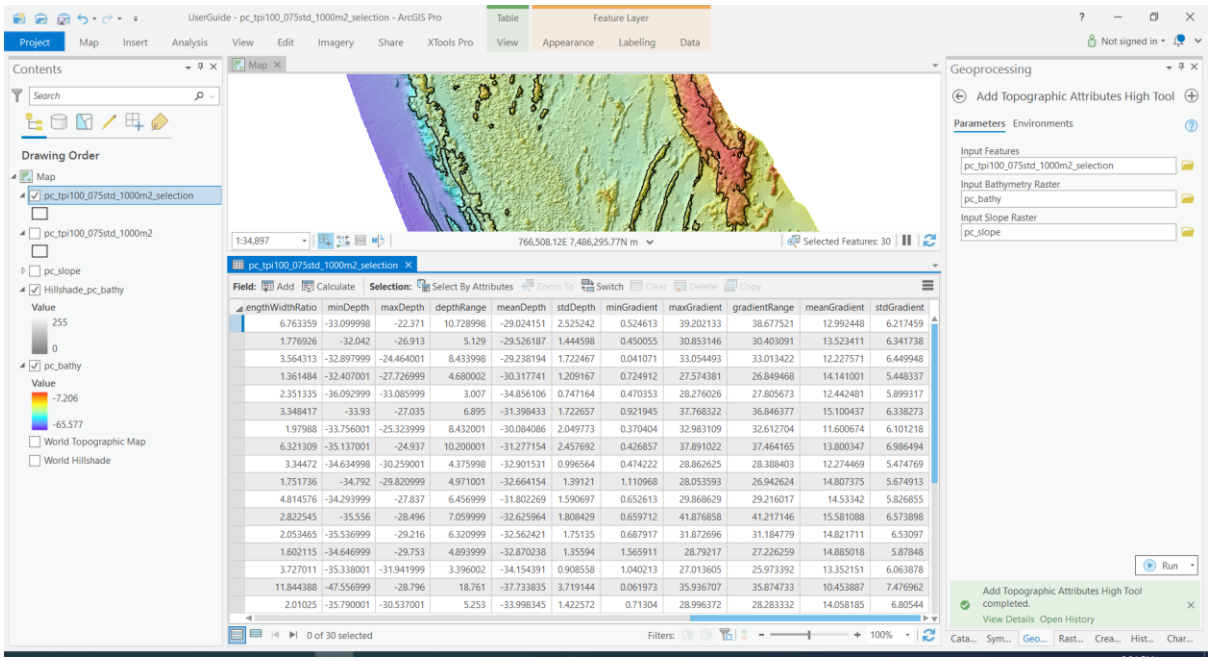
1. The Add Topographic Attributes High Tool requires slope gradient grid as input. First, generate the slope grid from pc_bathy.
2. Select the Add Topographic Attributes High Tool from the AddAttributes toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select pc_tpi100_075std_1000m2_selection from the drop-down list or navigate to the Points_Cloates.gdb and add pc_tpi100_075std_1000m2_selection. For the Input Bathymetry Raster, select pc_bathy from the drop-down list or navigate to the Points_Cloates.gdb and add pc_bathy. For the Input Slope Raster, select the slope grid generated in the previous step from the drop-down list or navigate and add the slope grid.



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



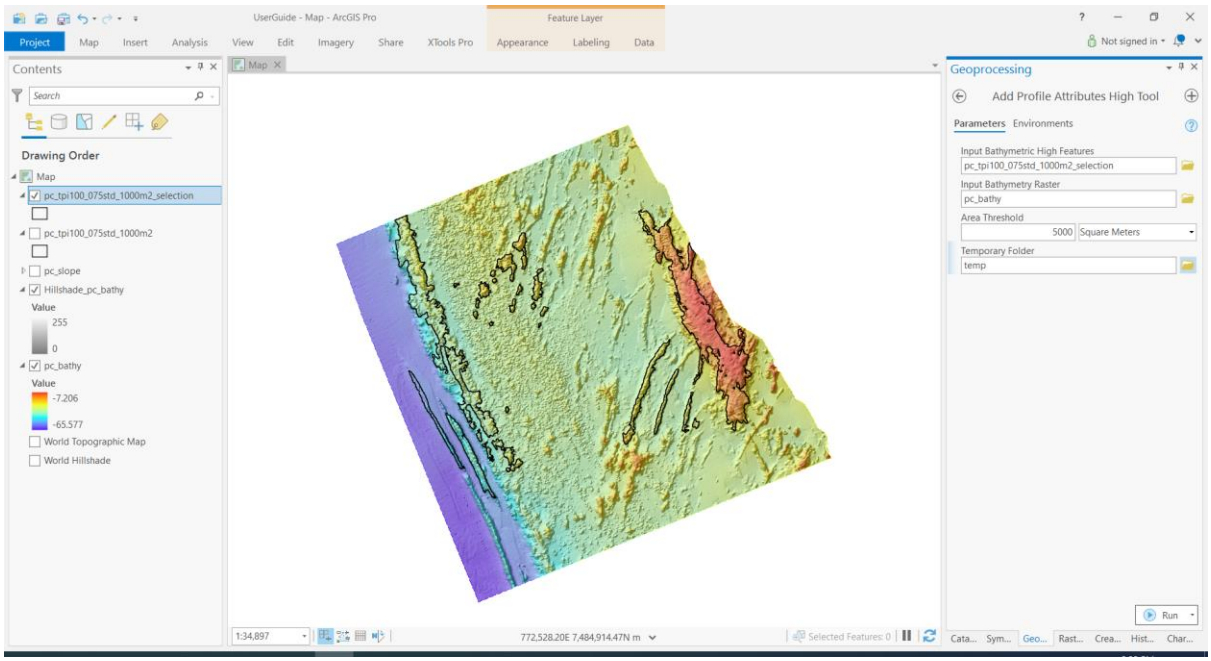
4. After the geoprocessing is completed, check that the topographic attributes have been generated.



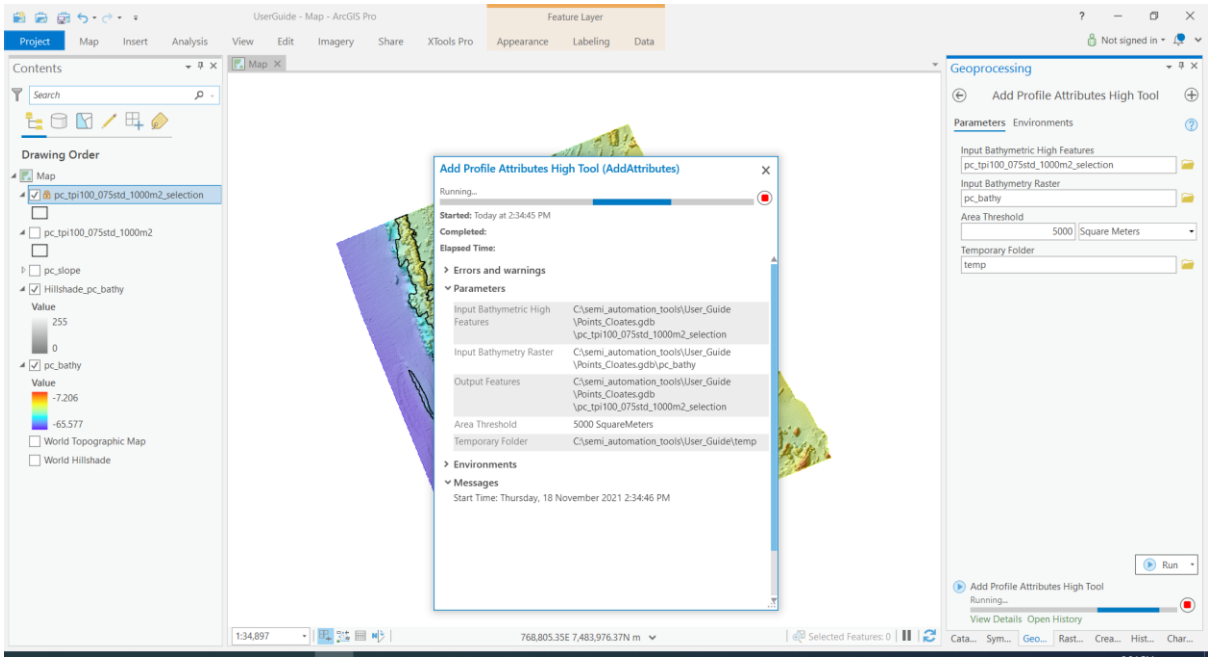
5. Explore the topographic attributes of the bathymetric high features if you wish. Otherwise, continue next step.

6.6. Add Profile Attributes High Tool

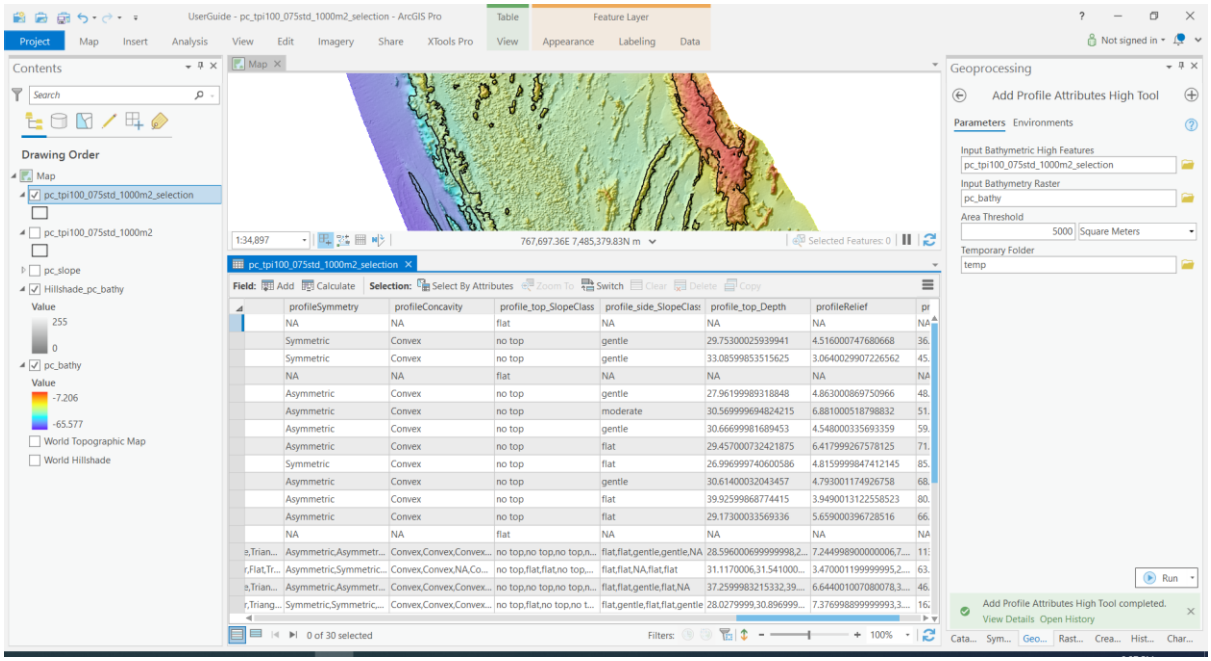
1. Select the Add Profile Attributes High Tool from the AddAttributes toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select pc_tpi100_075std_1000m2_selection from the drop-down list or navigate to the Points_Cloates.gdb and add pc_tpi100_075std_1000m2_selection. For the Input Bathymetry Raster, select pc_bathy from the drop-down list or navigate to the Points_Cloates.gdb and add pc_bathy. For the Area Threshold, enter 5000 Square Meters. For the Temporary Folder, nominate a folder.



2. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



3. After the geoprocessing is completed, check that the profile attributes have been generated.



4. Explore the profile attributes of the bathymetric high features if you wish.
5. Additional task (in your spare time):
    a. Run Add Profile Attributes High tool using pc_tpi10_075std_45m2_200features as the Input Features.
    b. Record the time required to complete the tool (8h12m17s in my laptop).

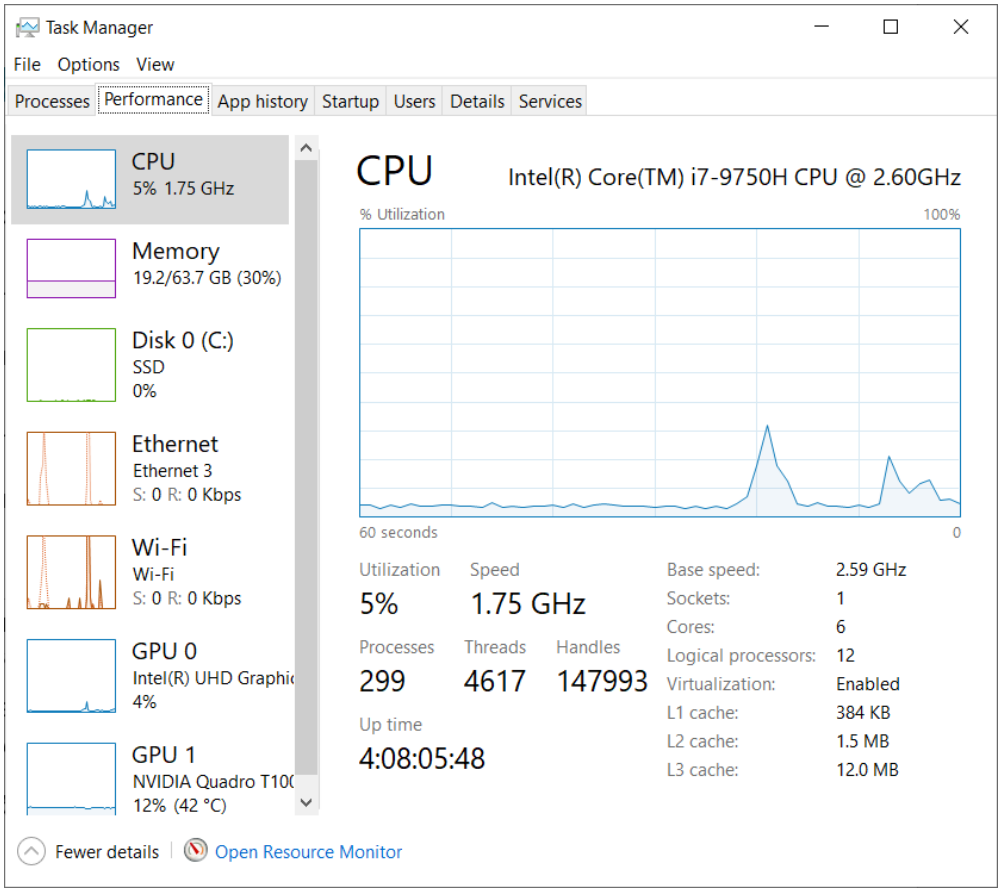
7. Use Add Attributes Fast tools

The AddAttributesFast toolbox contains the following four tools. Please see detailed metadata of each tool.

1. Add Shape Attributes High Tool Fast: This tool generates shape attributes for each bathymetric high feature using multiprocessing capability.
2. Add Shape Attributes Low Tool Fast: This tool generates shape attributes for each bathymetric low feature using multiprocessing capability.
3. Add Profile Attributes High Tool Fast: This tool generates profile attributes for each bathymetric high feature using multiprocessing capability.
4. Add Profile Attributes Low Tool Fast: This tool generates profile attributes for each bathymetric low feature using multiprocessing capability.

To calculate topographic attributes for bathymetric high and low features, the multiprocessing capability is not needed. The two add topographic attributes tools in the AddAttributes toolbox are fast and should be used.

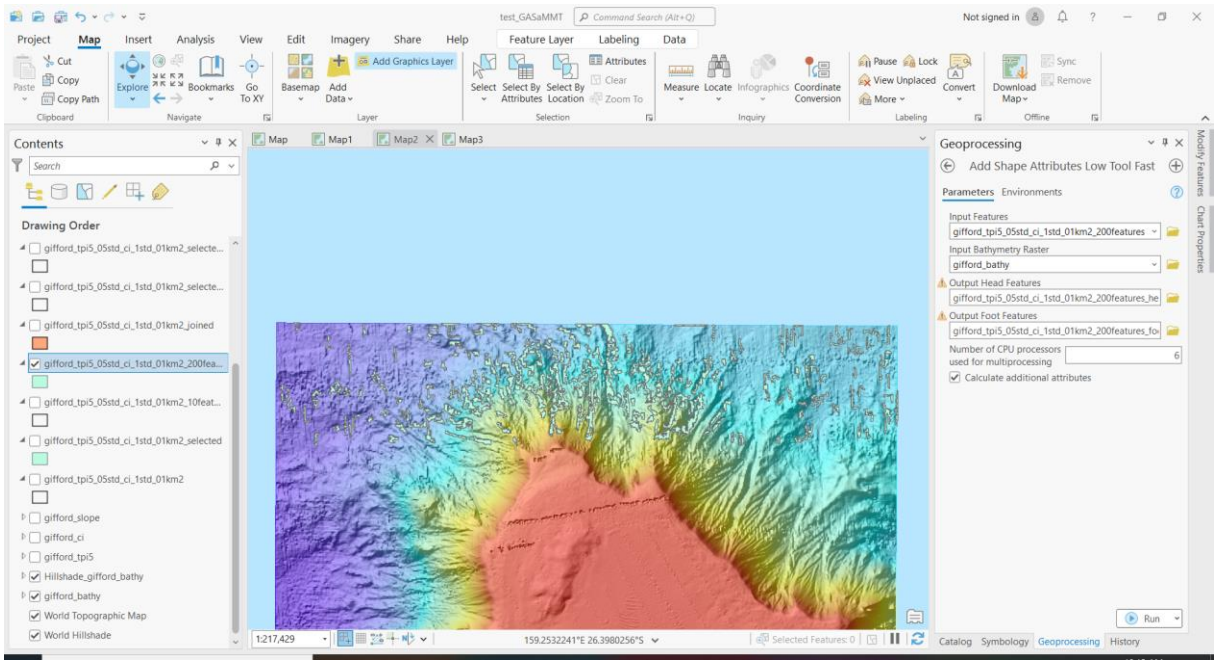
This user guide illustrates the usage of these *add attributes fast* tools using two examples. The first example is the bathymetric low features: gifford_tpi5_05std_ci_1std_01km2_200features. The other example is the bathymetric high features: pc_tpi10_075std_45m2_200features. To check how many processes you can potentially run in your windows PC or laptop, open the Task Manager and go to the Performance tab.



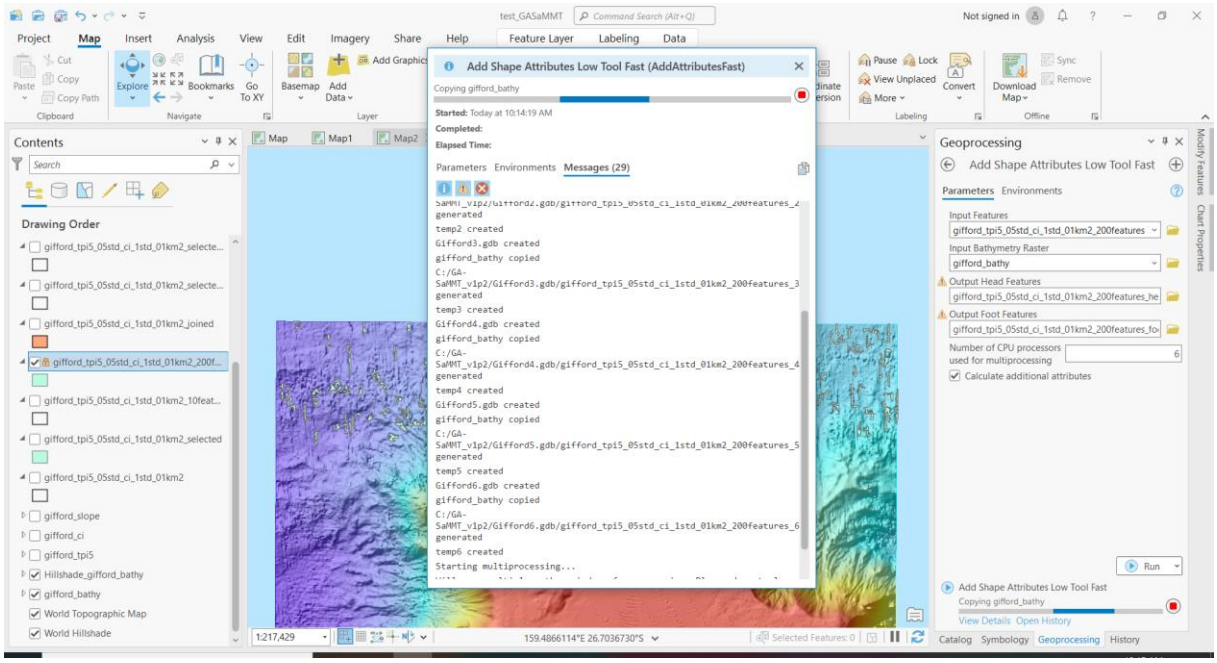
For my laptop, I have 12 Logical processors and thus can run maximum 12 co-current processes at any one time. However, in reality, running 12 co-current processes often does not result in optimal performance due to the overhead incurred in switching between processors. Before running the above multiprocessing tools for a large dataset, the users are advised to conduct an experiment with a small subset to find the optimal number of CPU processors for the task. The rule of thumb is using half of the total number of the logical processors (e.g., 6 in my case).

7.1. Add Shape Attributes Low Tool Fast

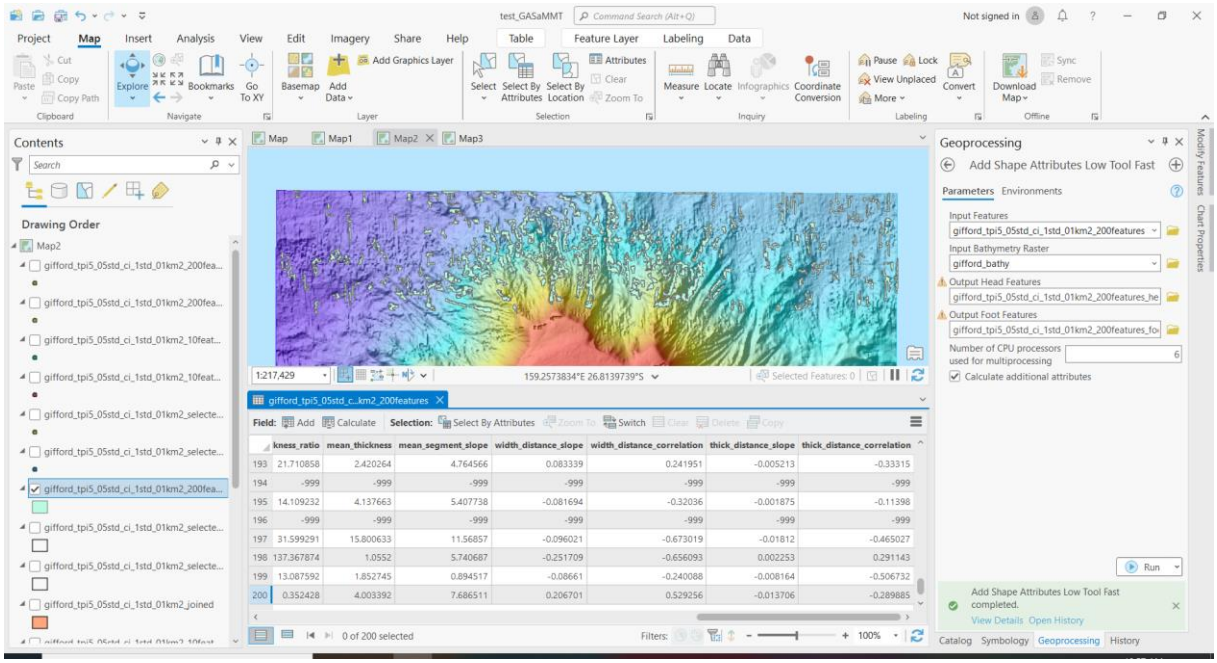
1. Select the Add Shape Attributes Low Tool Fast Tool from the AddAttributesFast toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select gifford_tpi5_05std_ci_1std_01km2_200features from the drop-down list or navigate to the Gifford.gdb and add gifford_tpi5_05std_ci_1std_01km2_200features. For the Input Bathymetry Raster, select gifford_bathy from the drop-down list or navigate to the Gifford.gdb and add gifford_bathy. For the Output Head Features, navigate to the Gifford.gdb, enter a name like "gifford_tpi5_05std_ci_1std_01km2_200features_head". For the Output Foot Features, navigate to the Gifford.gdb, enter a name like "gifford_tpi5_05std_ci_1std_01km2_200features_foot". For the Number of CPU processors used for multiprocessing, enter 6. For the Calculate additional attributes, check the option box.



2. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages. Note that during the running process, six Python windows will open, each uses one CPU processor to process a subset of the input features.

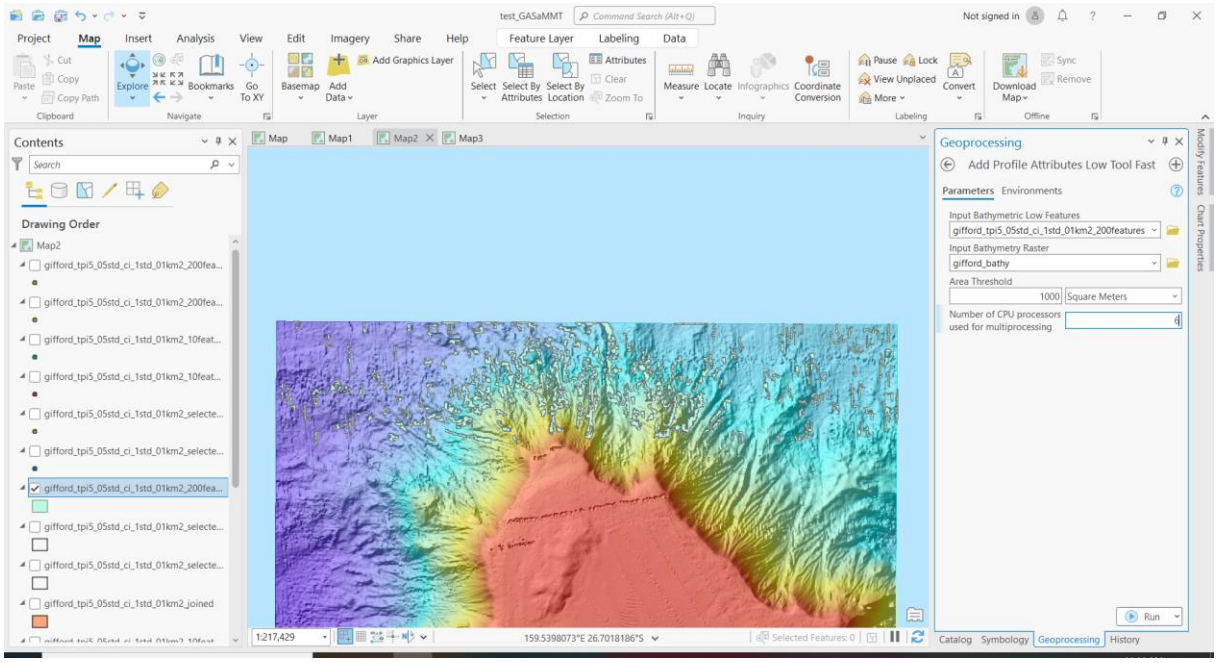


3. Record the time taken to complete the tool (41m54s in my laptop). This time is seven times faster than the time used for the Add Shape Attributes Low Tool (4h55m30s in my laptop) recorded in the additional tasks of section 6.1.
4. After the geoprocessing is completed, check that the shape attributes have been generated.

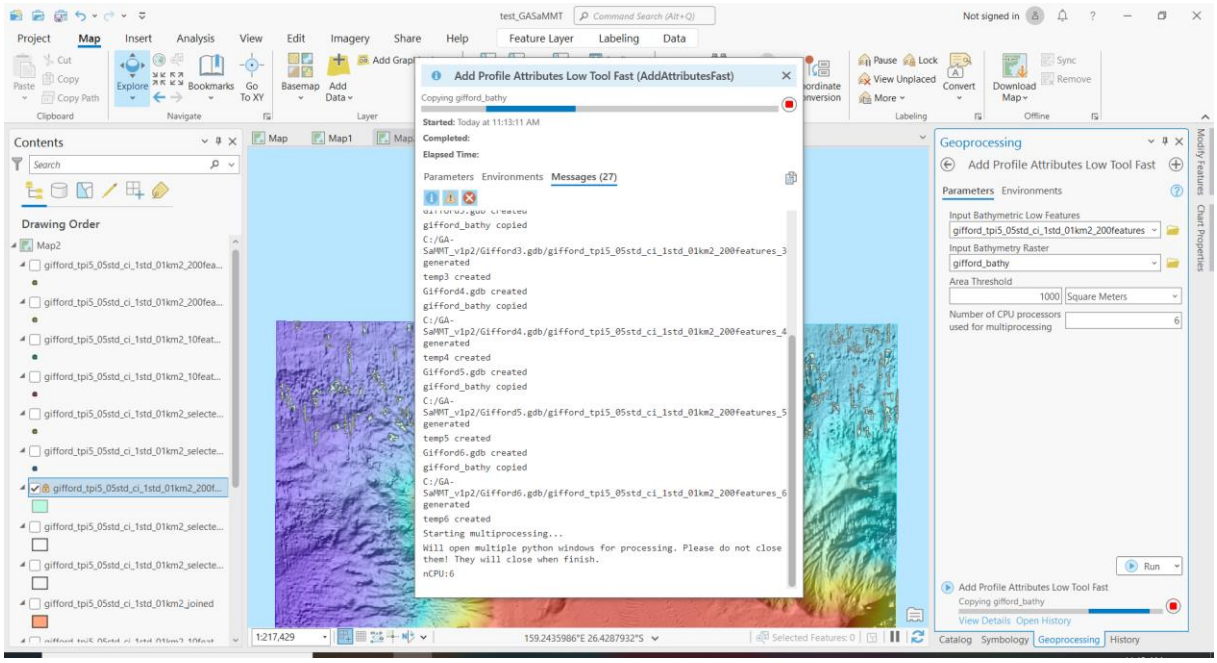


7.2. Add Profile Attributes Low Tool Fast

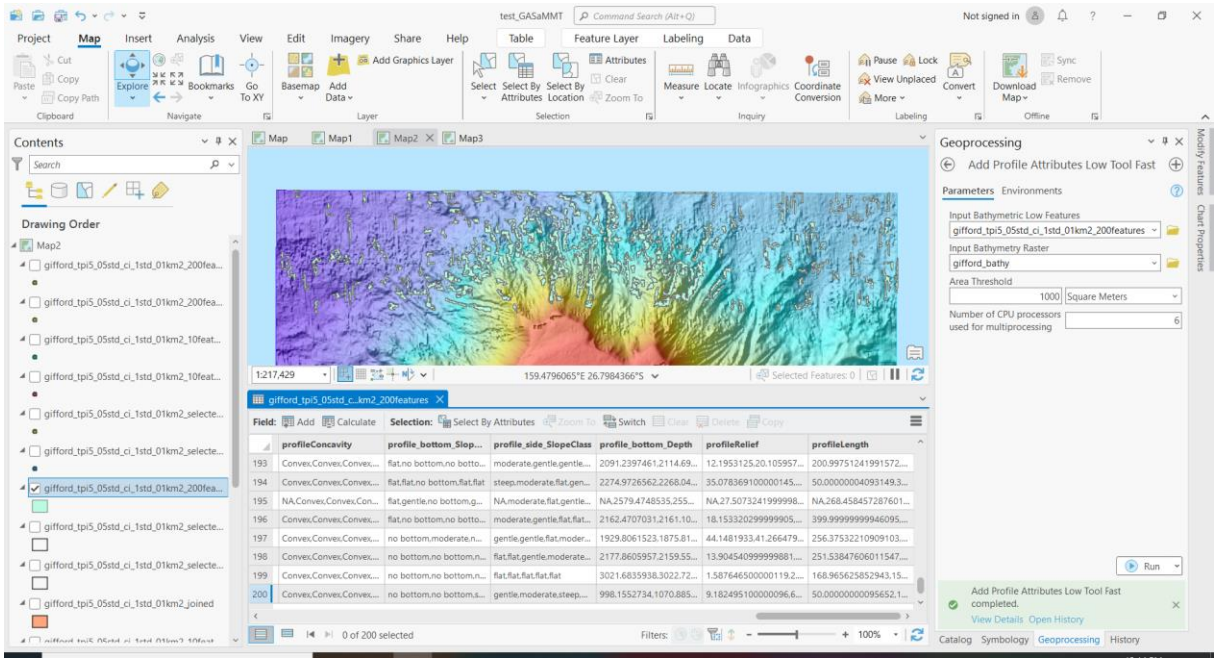
1. Select the Add Profile Attributes Low Tool Fast from the AddAttributesFast toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select gifford_tpi5_05std_ci_1std_01km2_200features from the drop-down list or navigate to the Gifford.gdb and add gifford_tpi5_05std_ci_1std_01km2_200features. For the Input Bathymetry Raster, select gifford_bathy from the drop-down list or navigate to the Gifford.gdb and add gifford_bathy. For the Area Threshold, enter 1000 Square Meters. For the Number of CPU processors used for multiprocessing, enter 6.



2. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages. Note that during the running process, six Python windows will open, each uses one CPU processor to process a subset of the input features.

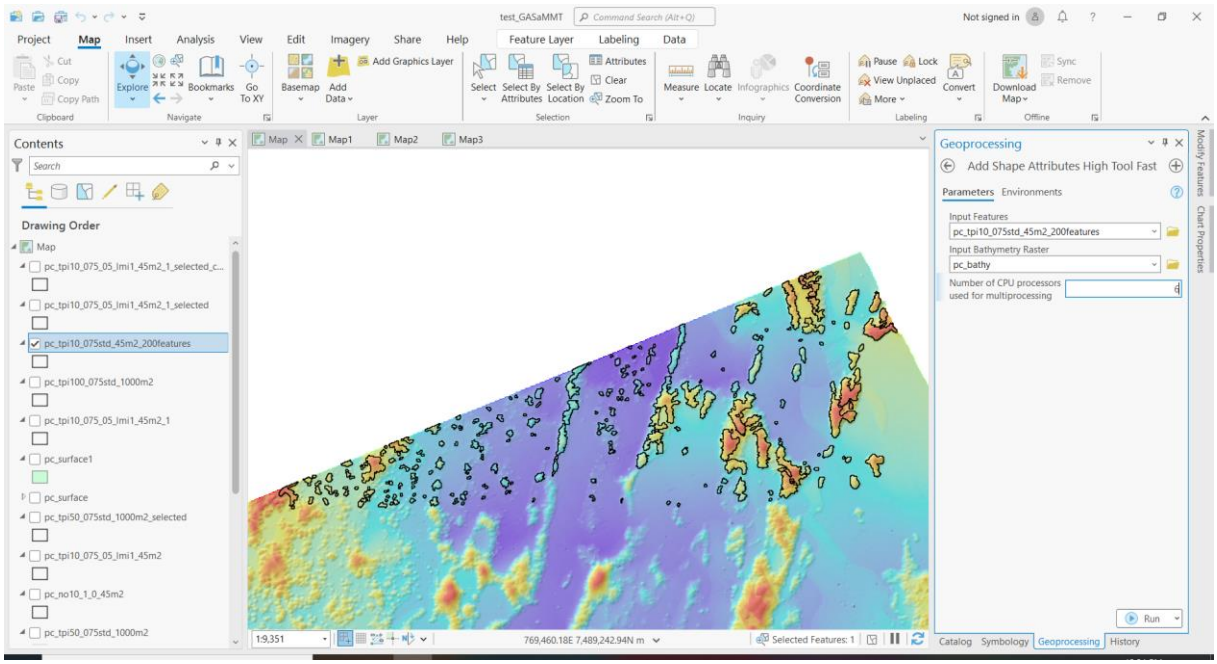


3. Record the time taken to complete the tool (59m49s in my laptop). This time is nine times faster than the time used for the Add Profile Attributes Low Tool (9h35m49s in my laptop) recorded in the additional tasks of section 6.3.
4. After the geoprocessing is completed, check that the profile attributes have been generated.

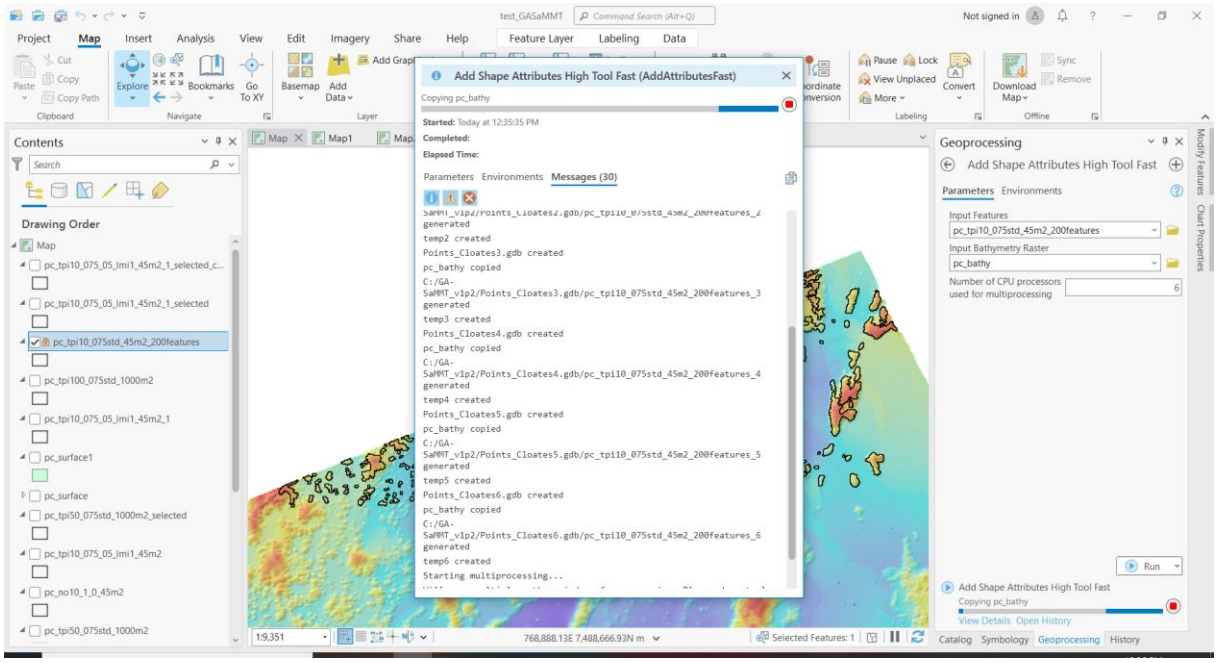


7.3. Add Shape Attributes High Tool Fast

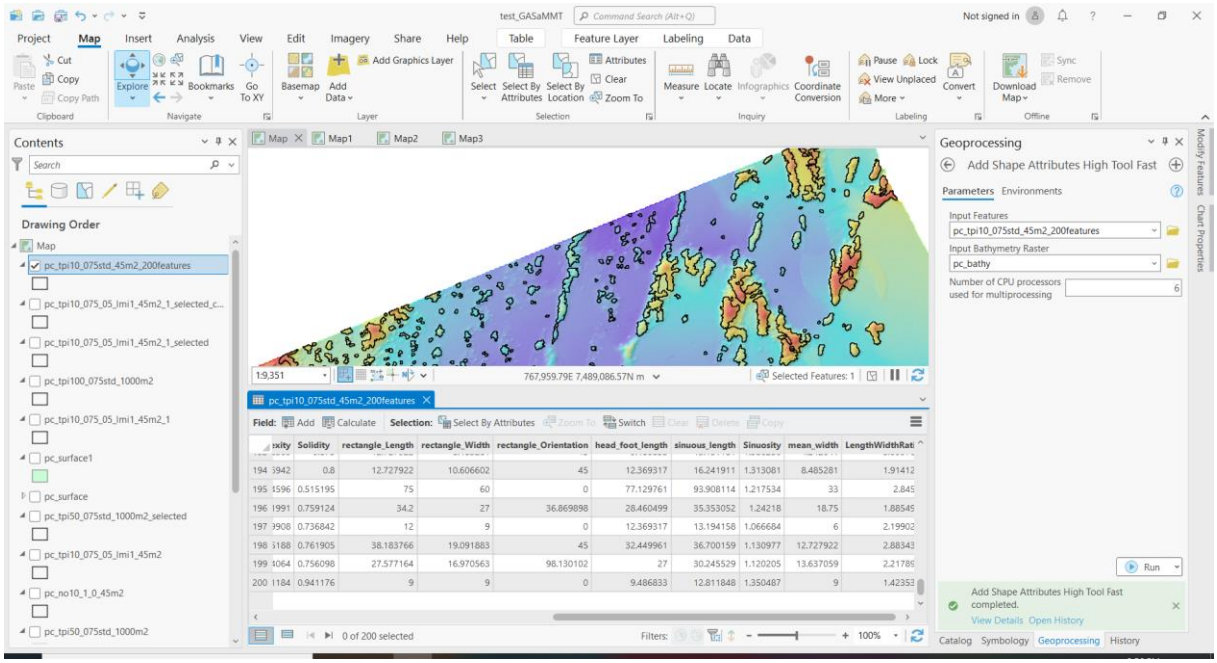
1. Select the Add Shape Attributes High Tool Fast Tool from the AddAttributesFast toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select pc_tpi10_075std_45m2_200features from the drop-down list or navigate to the Points_Cloates.gdb and add pc_tpi10_075std_45m2_200features. For the Input Bathymetry Raster, select pc_bathy from the drop-down list or navigate to the Points_Cloates.gdb and add pc_bathy. For the Number of CPU processors used for multiprocessing, enter 6.



2. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages. Note that during the running process, six Python windows will open, each uses one CPU processor to process a subset of the input features.

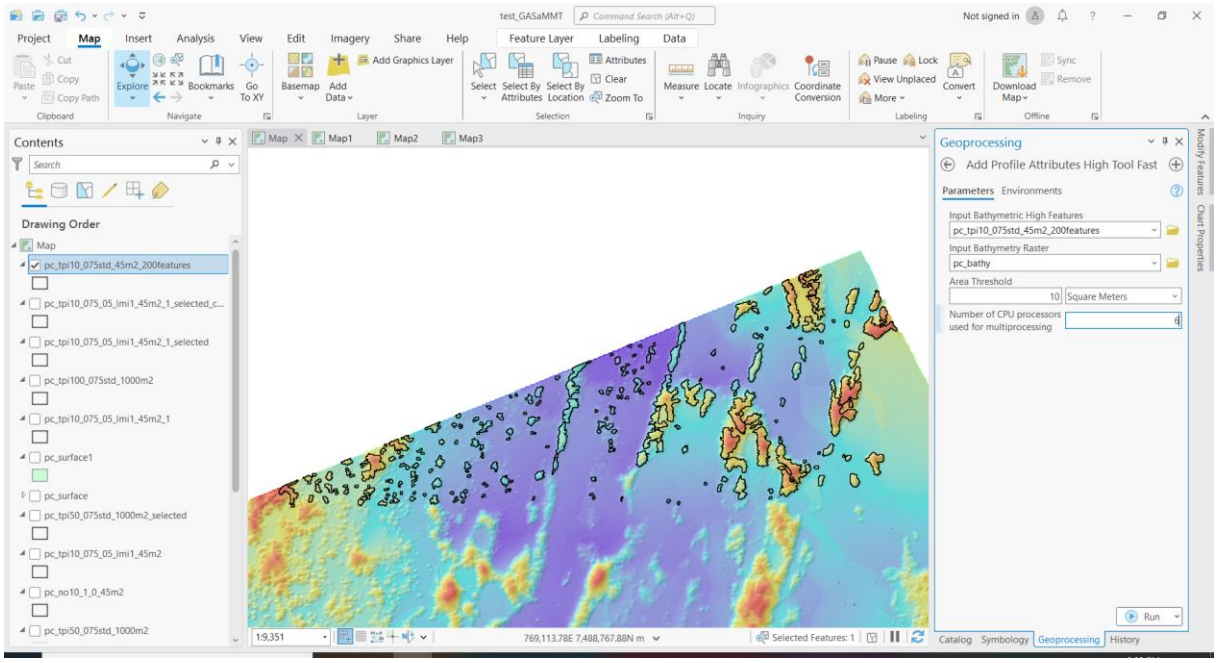


3. Record the time taken to complete the tool (8m54s in my laptop). This time is six times faster than the time used for the Add Shape Attributes High Tool (52m40s in my laptop) recorded in the additional tasks of section 6.4.
4. After the geoprocessing is completed, check that the shape attributes have been generated.

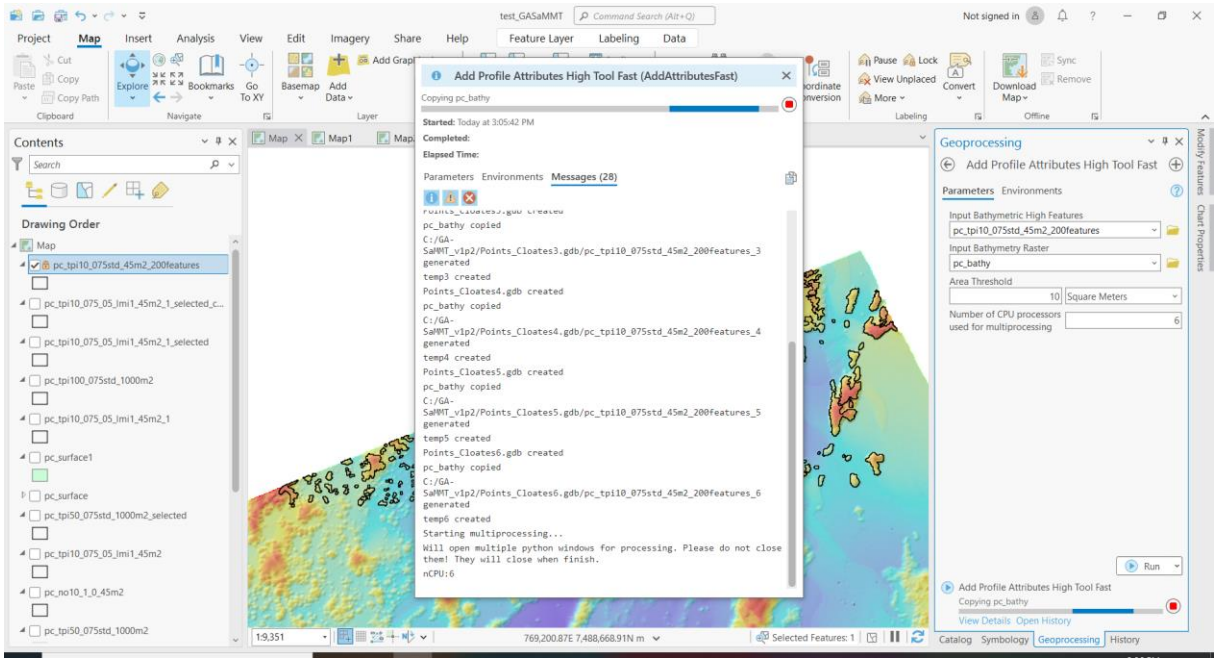


7.4. Add Profile Attributes High Tool Fast

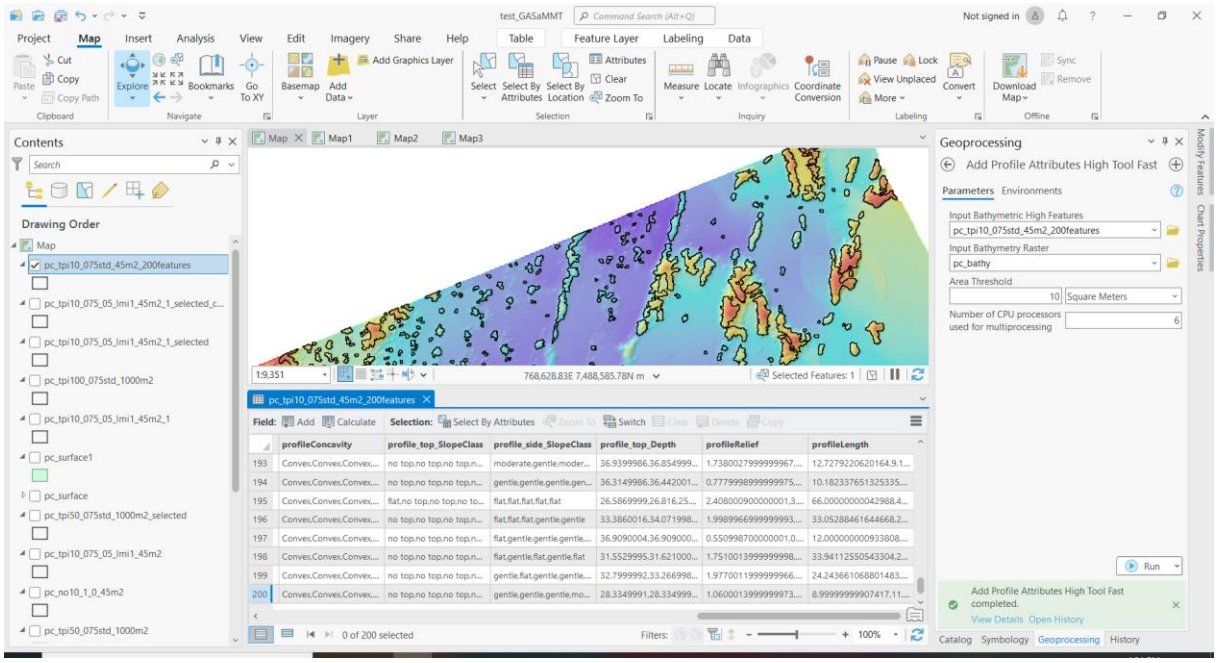
1. Select the Add Profile Attributes Low Tool Fast tool from the AddAttributesFast toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Features, select pc_tpi10_075std_45m2_200features from the drop-down list or navigate to the Points_Cloates.gdb and add pc_tpi10_075std_45m2_200features. For the Input Bathymetry Raster, select pc_bathy from the drop-down list or navigate to the Points_Cloates.gdb and add pc_bathy. For the Area Threshold, enter 10 Square Meters. For the Number of CPU processors used for multiprocessing, enter 6.



2. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages. Note that during the running process, six Python windows will open, each uses one CPU processor to process a subset of the input features.



3. Record the time taken to complete the tool (55m39s in my laptop). This time is nearly nine times faster than the time used for the Add Profile Attributes High tool (8h12m17s in my laptop) recorded in the additional tasks of section 6.6.
4. After the geoprocessing is completed, check that the profile attributes have been generated.



8. Use Classification Feature tools

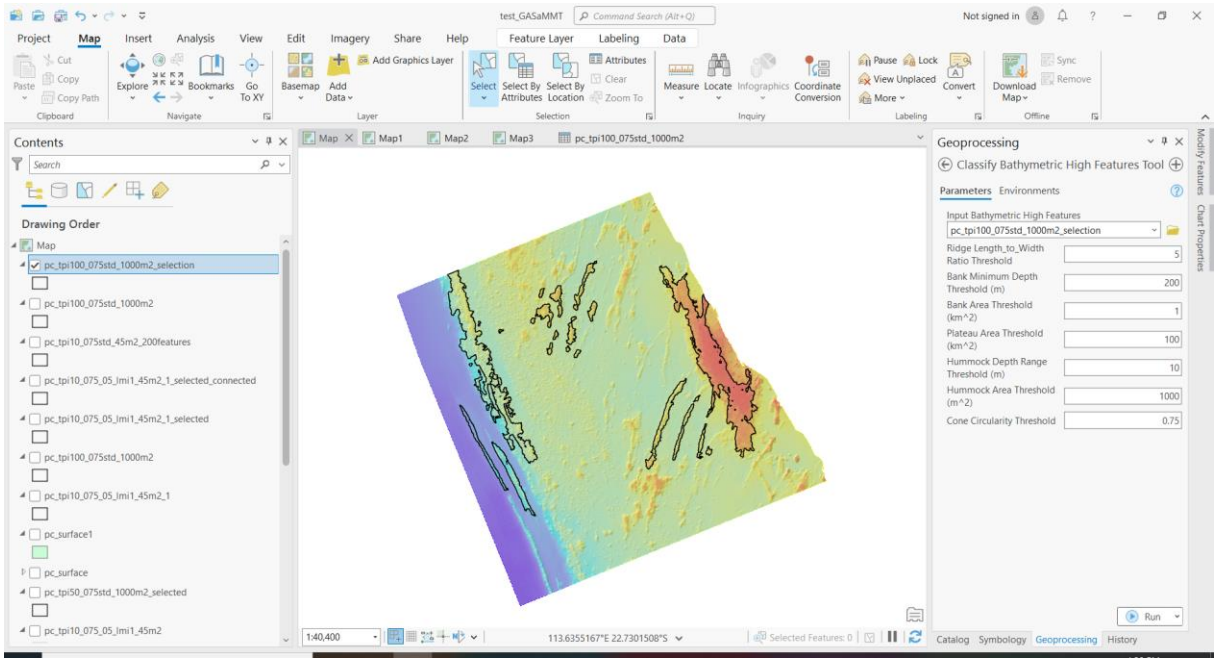
The ClassificationFeature toolbox contains two tools. Please see detailed metadata of these tools.

- Classify Bathymetric High Features: This tool classifies each bathymetric high feature into one of several feature types.
- Classify Bathymetric Low Features: This tool classifies each bathymetric low feature into one of several feature types.

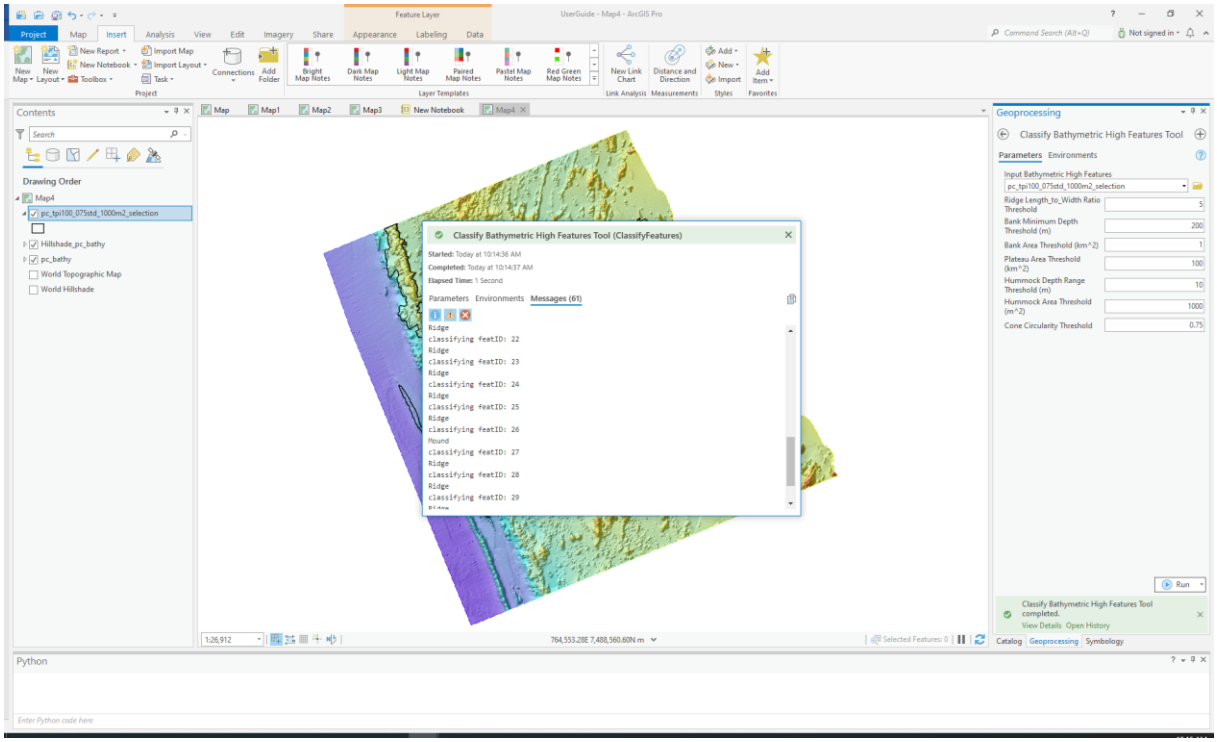
8.1. Classify Bathymetric High Features Tool

This tool classifies each bathymetric high feature into one morphological feature type based on the attributes calculated from the AddAttributes or the AddAttributesFast toolbox.

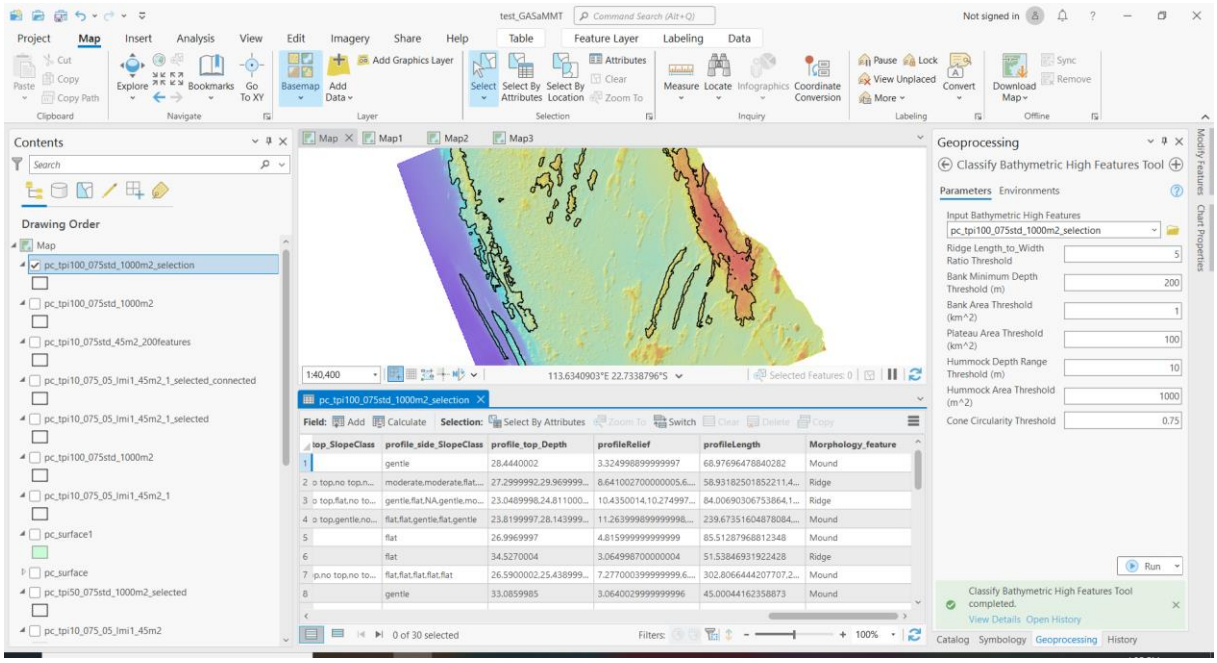
1. If not already loaded, create a new map and open pc_tpi100_075std_1000m2_selection bathymetric high features and associated data from the Points_Cloates.gdb in the map.
2. Select the Classify Bathymetric High Features Tool from the ClassificationFeature toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Bathymetric High Features, select pc_tpi100_075std_1000m2_selection from the drop-down list or navigate to the Points_Cloates.gdb and select pc_tpi100_075std_1000m2_selection. For all other parameters, keep the default values.



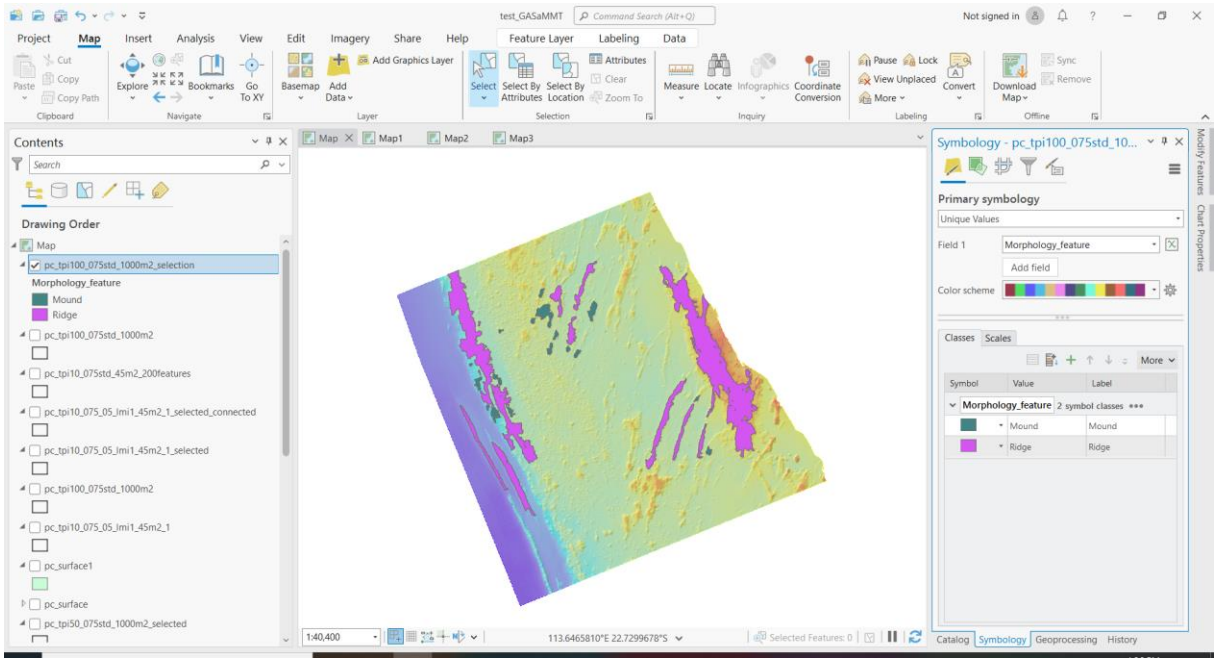
3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



4. After the geoprocessing is completed, check that the Morphology_feature attribute has been generated. This attribute lists the morphological feature type resulted from the classification.



5. To display the classification results, change the symbology as Unique Values, select Morphology_feature field, select an appropriate colour scheme, and apply the new symbology. The individual morphological feature types are now displayed as distinctive colours.

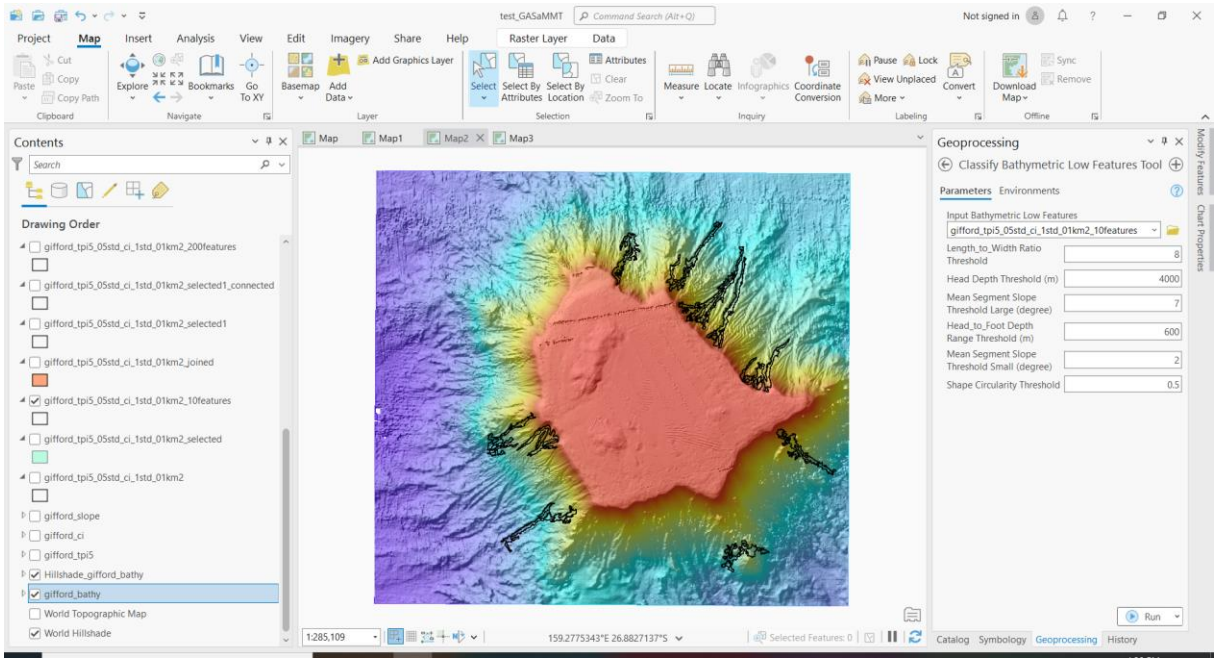


8.2. Classify Bathymetric Low Features Tool

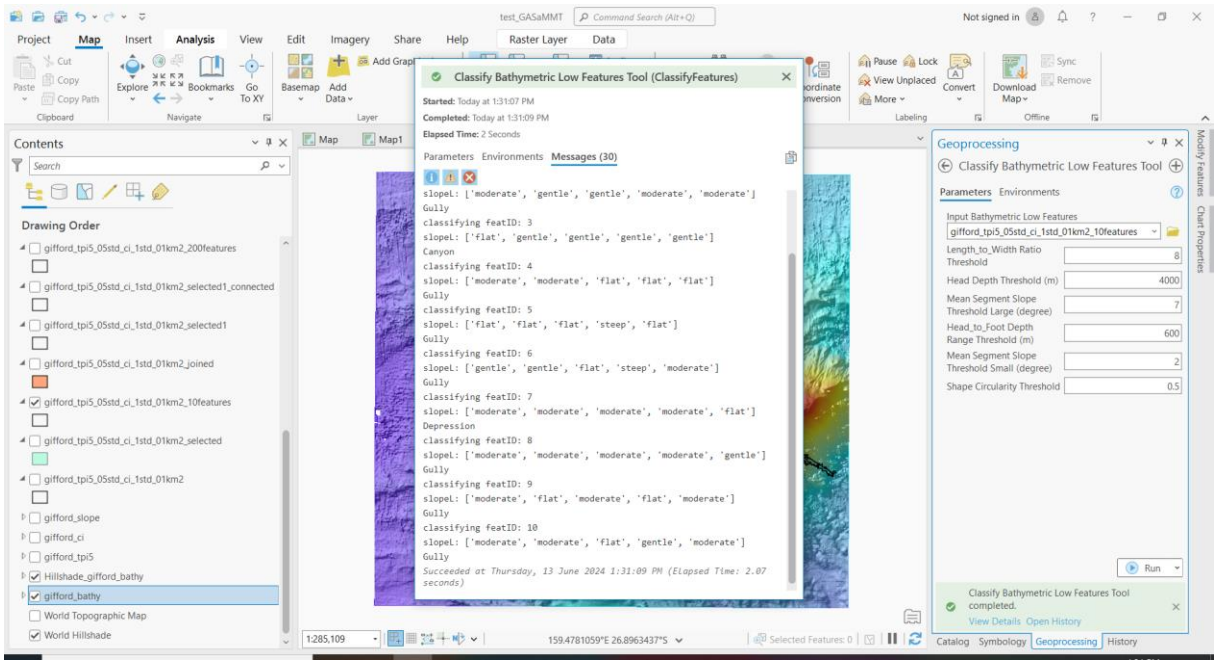
This tool classifies each bathymetric low feature into one morphological feature type based on the attributes calculated from the Add Attributes tools.

1. If not already loaded, create a new map and open gifford_tpi5_05std_ci_1std_01km2_10features bathymetric low features and associated data from the Gifford.gdb in the map.

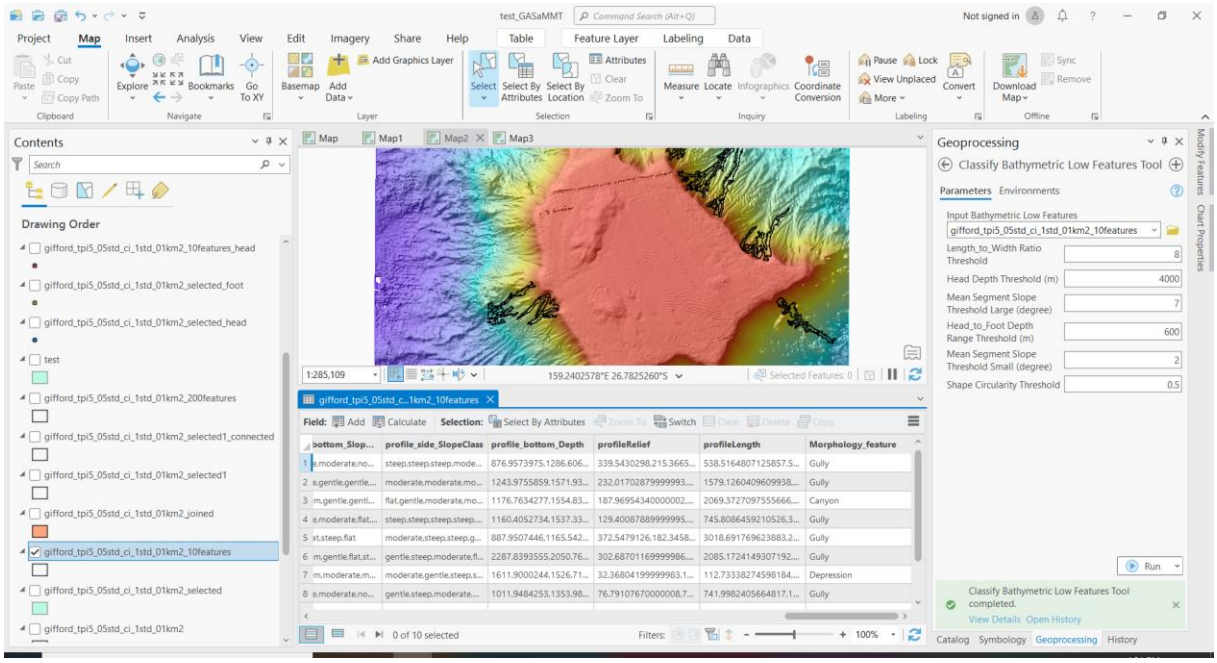
2. Select the Classify Bathymetric Low Features Tool from the ClassificationFeature toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Bathymetric Low Features, select gifford_tpi5_05std_ci_1std_01km2_10features from the drop-down list or navigate to the Gifford.gdb and select gifford_tpi5_05std_ci_1std_01km2_10features. For all other parameters, keep the default values.



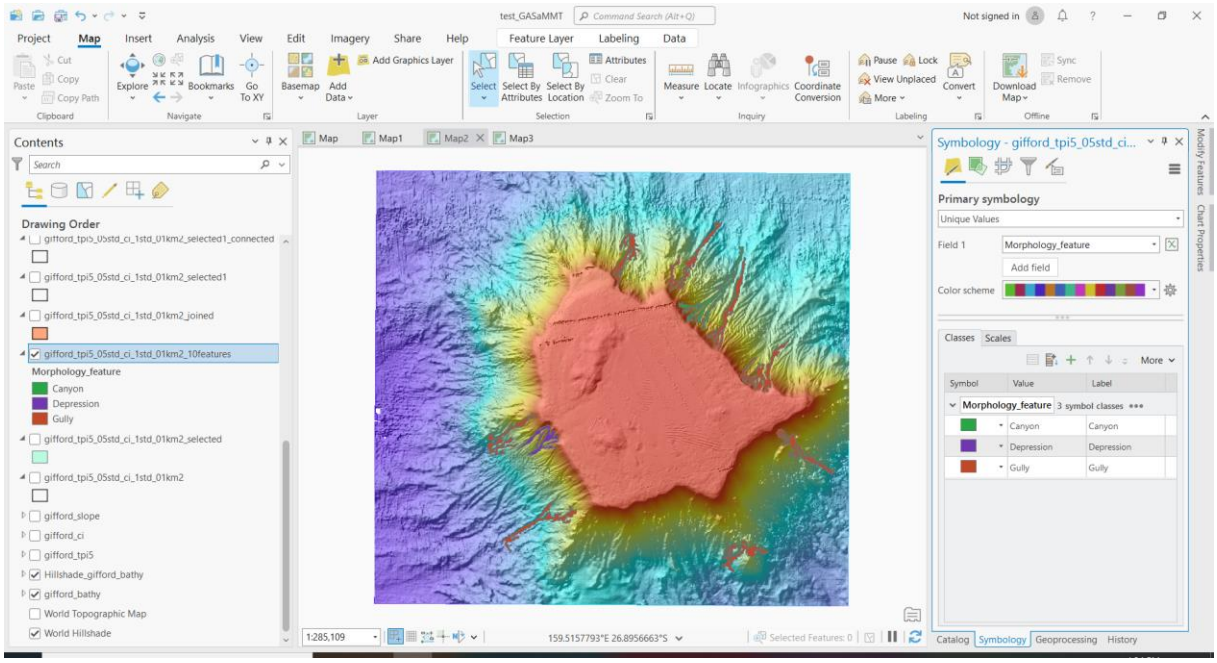
3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



4. After the geoprocessing is completed, check that the Morphology_feature attribute has been generated. This attribute lists the morphological feature type resulted from the classification.



5. To display the classification results, change the symbology as Unique Values, select Morphology_feature field, select an appropriate colour scheme, and apply the new symbology. The individual morphological feature types are now displayed as distinctive colours.



9. Use Accessory Tools

The Accessory_Tools toolbox currently contains four tools. Please see the detailed metadata from each tool.

- Merge Connected Features Tool: This tool merges polygon features that are connected through shared points or borders.

- Connect Nearby Linear Features Tool: This tool connects nearby linear bathymetric high or low features.
- Connect Nearby Linear HF Features Tool: This tool connects nearby linear bathymetric low features through their feet and heads.
- Update Feature Boundary Tool: This tool merges overlapped features and update the feature boundary.

Two or multiple polygons that are connected through a shared point may be considered as a single feature. The Merge Connected Features Tool is used to merge (or dissolve) these connected polygons into larger polygons.

A linear bathymetric high or low feature such as ridge, canyon, channel, valley and gully is sometimes broken into multiple smaller and disconnected features due to several possible reasons:

- deficiency in the bathymetric data,
- deficiency in the mapping method, and
- natural local processes such as erosion and disposition.

Ideally, these disconnected features should be merged to form a single integrated linear feature to facilitate the subsequent attribute generation and classification. However, the users are advised to make their own judgement on whether to apply one of these feature connection/merge accessory tools before the subsequent attribute generation and classification steps.

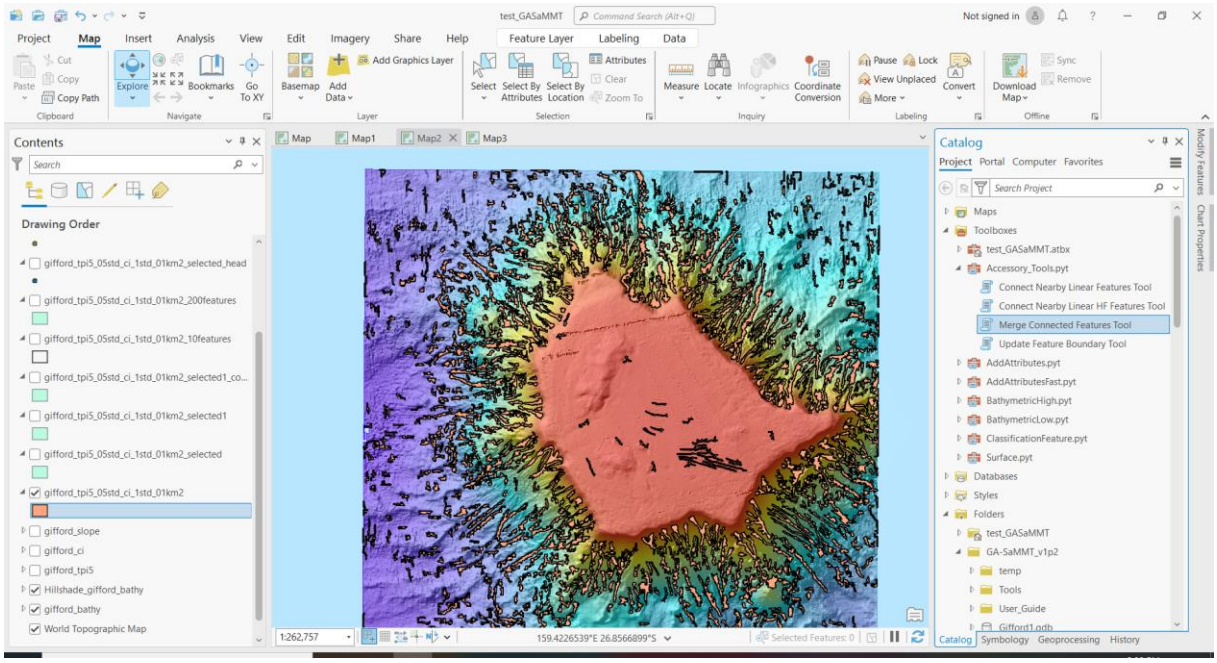
The Connect Nearby Linear Features Tool and the Connect Nearby Linear HF Features Tool are used to connect (or merge) two or multiple bathymetric high or low features that satisfying the following conditions:

- the distance between two nearby features is less than a user-defined threshold, and
- the two nearby features align in orientation with the intersecting angle less than a user-defined threshold.

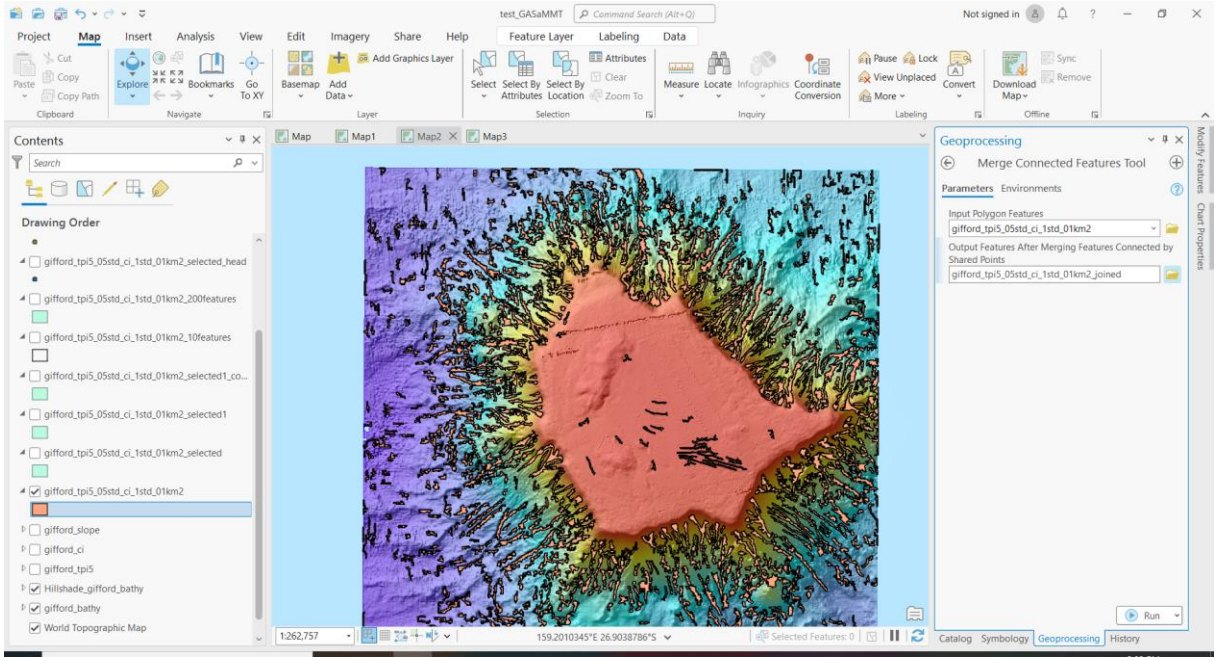
In addition, sometimes, there is need to use one mapping output to update the boundaries of another mapping output. In this case, the Update Feature Boundary Tool, which is cleaner than ArcGIS Update tool, can be used.

9.1. Merge Connected Features Tool

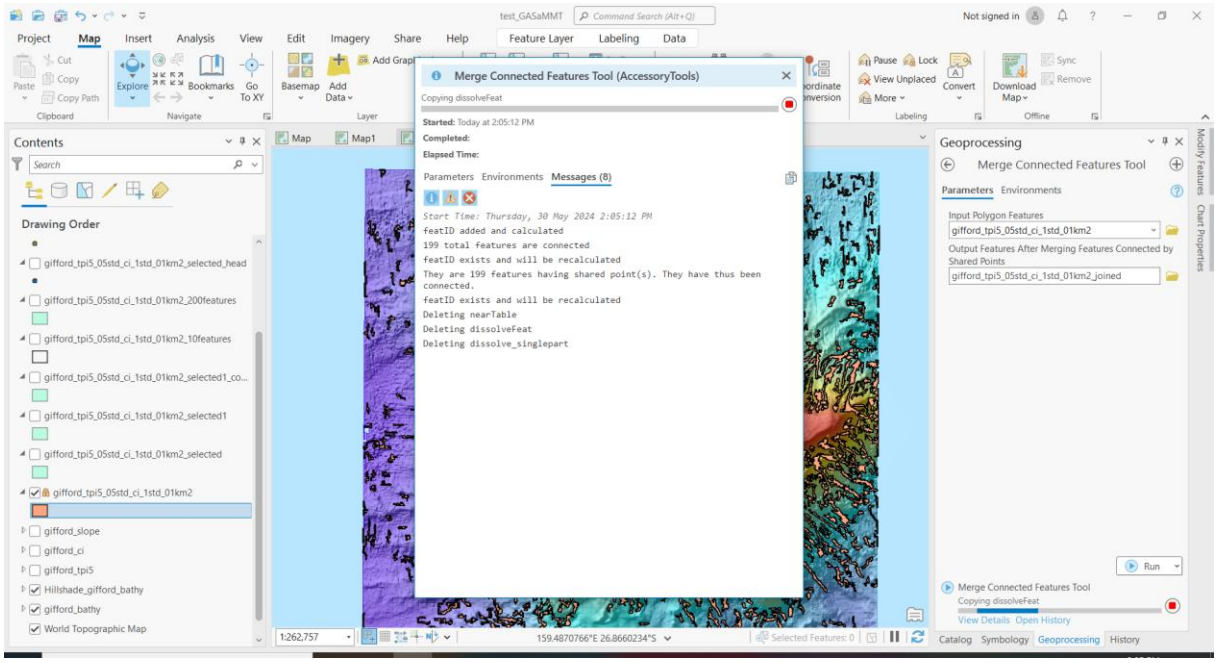
1. If not already loaded, create a new map and add gifford_tpi5_05std_ci_1std_01km2 bathymetric low features and associated data from the Gifford.gdb in the map.



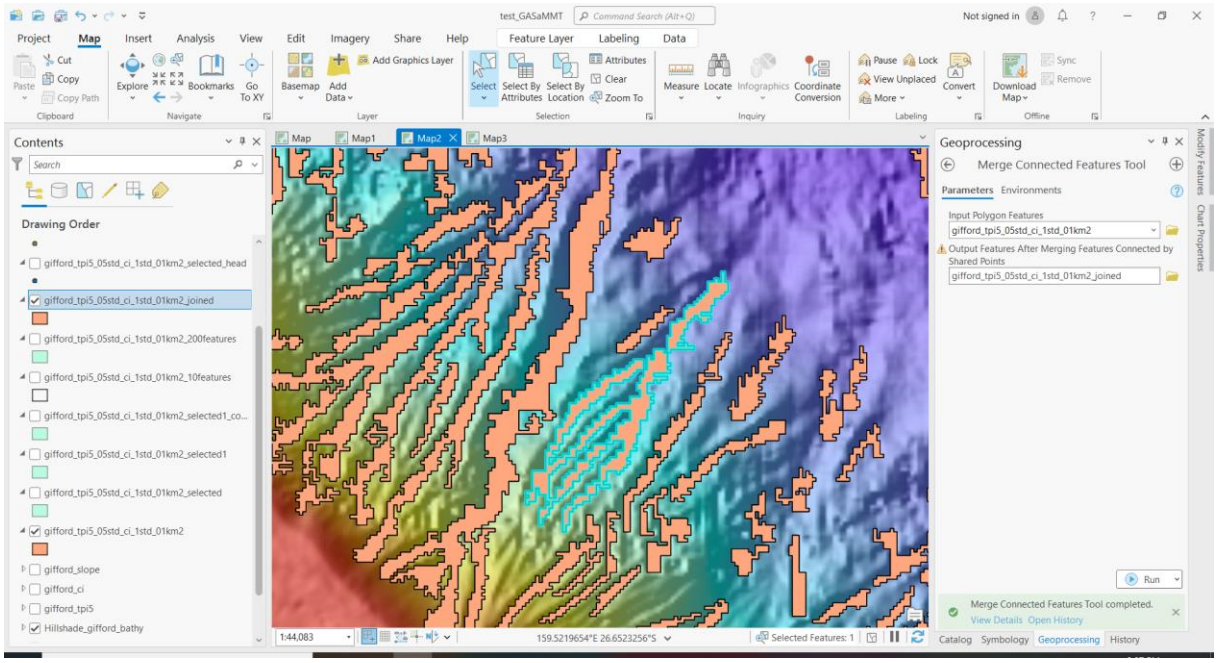
2. Select the Merge Connected Features Tool from the Accessory_Tools toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Polygon Features, select gifford_tpi5_05std_ci_1std_01km2 from the drop-down list or navigate to the Gifford.gdb and select gifford_tpi5_05std_ci_1std_01km2. For the Output Features After Merging Only Features Connected by Shared Point, navigate to the Gifford.gdb and enter a name like "gifford_tpi5_05std_ci_1std_01km2_joined".



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages. From the messages, we know that there are 199 features spatially connected by shared points.

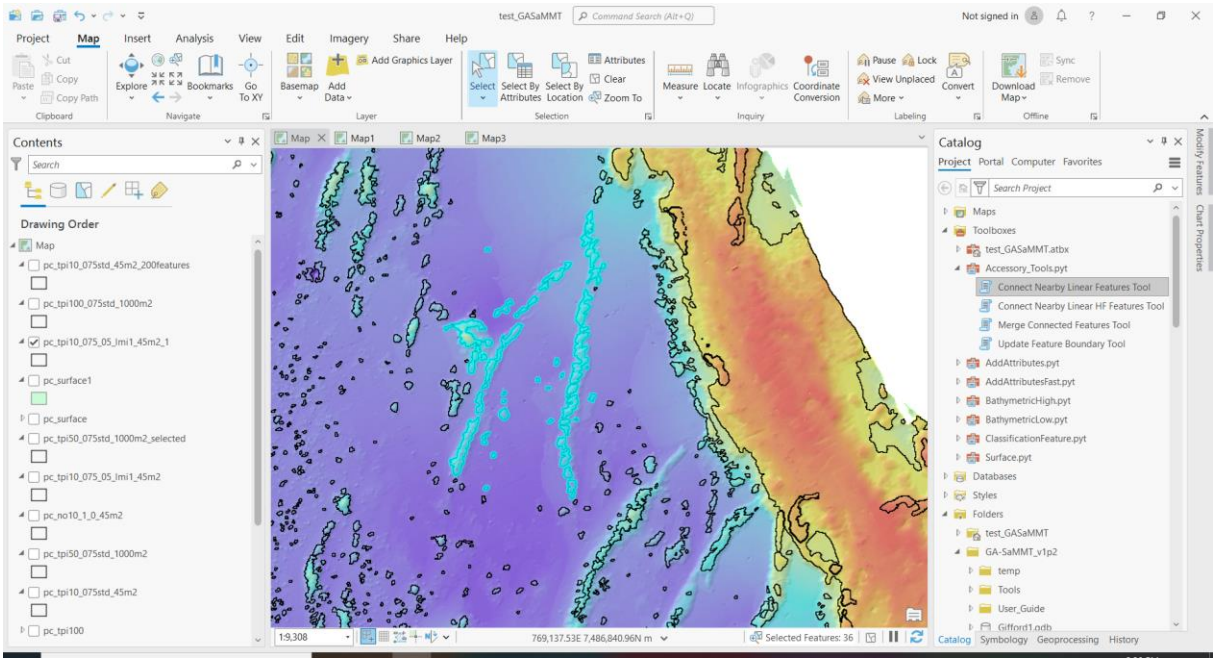


4. Examine the output features after merging the connected features. For example, the highlighted feature shown below is the result of merging two features connecting through a point.

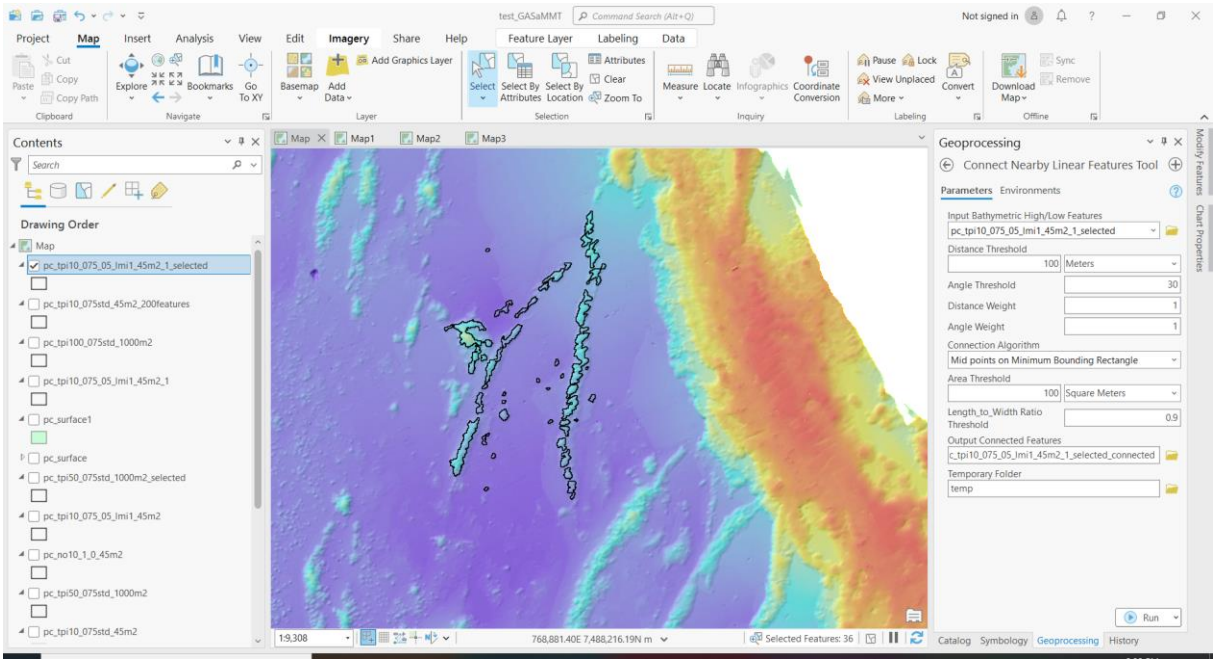


9.2. Connect Nearby Linear Features Tool

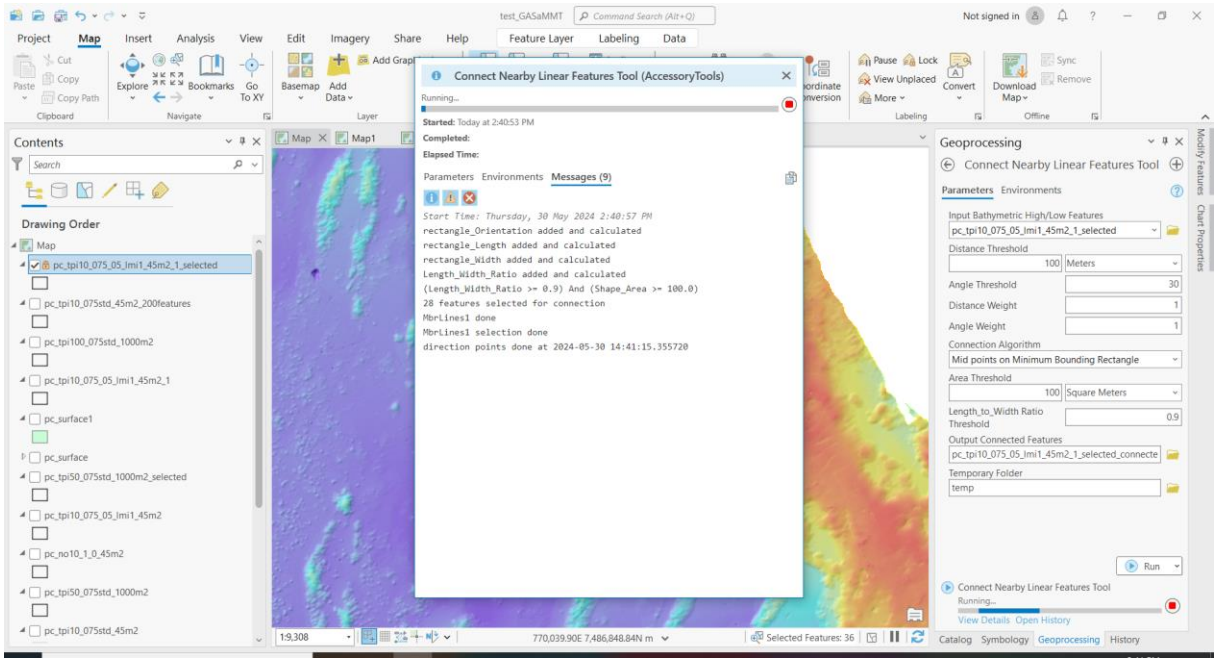
1. If not already loaded, create a new map and add pc_tpi10_075_05_lmi1_45m2_1 bathymetric high features and associated data from the Points_Cloates.gdb to the map.
2. Select a number of linear ridge features and export them as pc_tpi10_075_05_lmi1_45m2_1_selected.



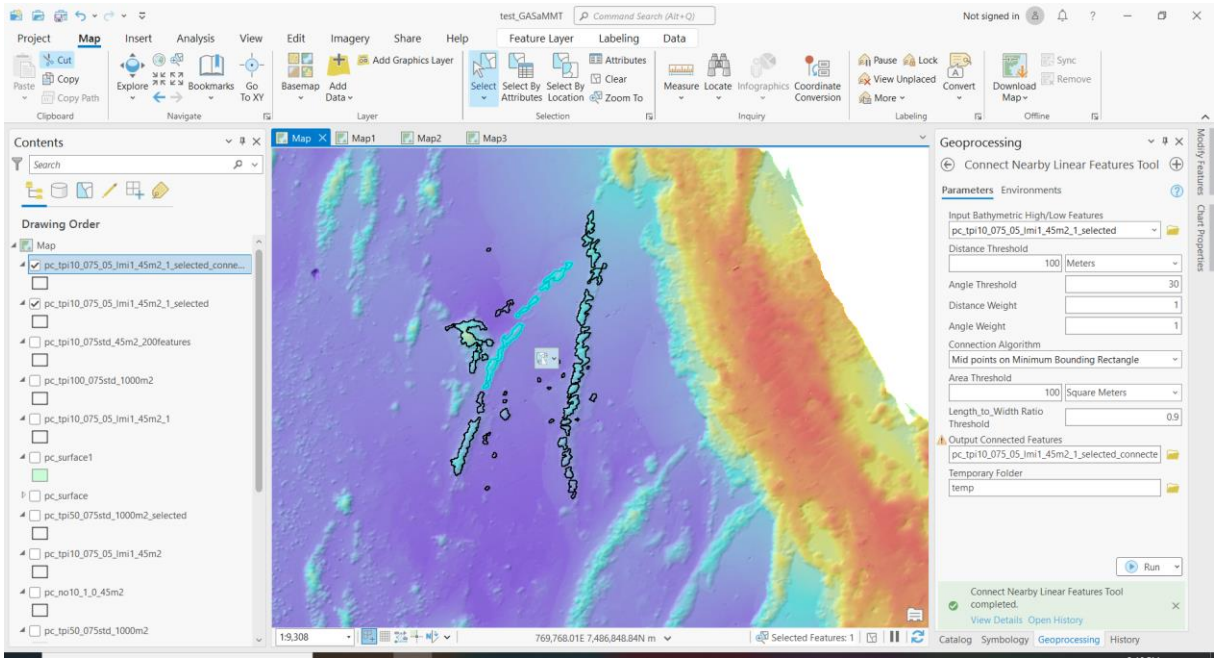
3. Select the Connect Nearby Linear Features Tool from the Accessory Tools toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Bathymetric High/Low Features, select pc_tpi10_075_05_lmi1_45m2_1_selected from the drop-down list or navigate to the Points_Cloates.gdb and select pc_tpi10_075_05_lmi1_45m2_1_selected. Enter 100 meters as the Distance Threshold. Enter 30 as the Angle Threshold. Enter 1 for both the Distance Weight and the Angle Weight. For the Connection Algorithm, select “Mid points on Minimum Bounding Rectangle” from the drop-down list. For the Area Threshold, enter 100 Square Meters. For the Length_to_Width Ratio, enter 0.9. For the Output Connected Features, navigate to the Points_Cloates.gdb and enter a name like “pc_tpi10_075_05_lmi1_45m2_1_selected _connected”. For the Temporary Folder, nominate a folder.



4. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.

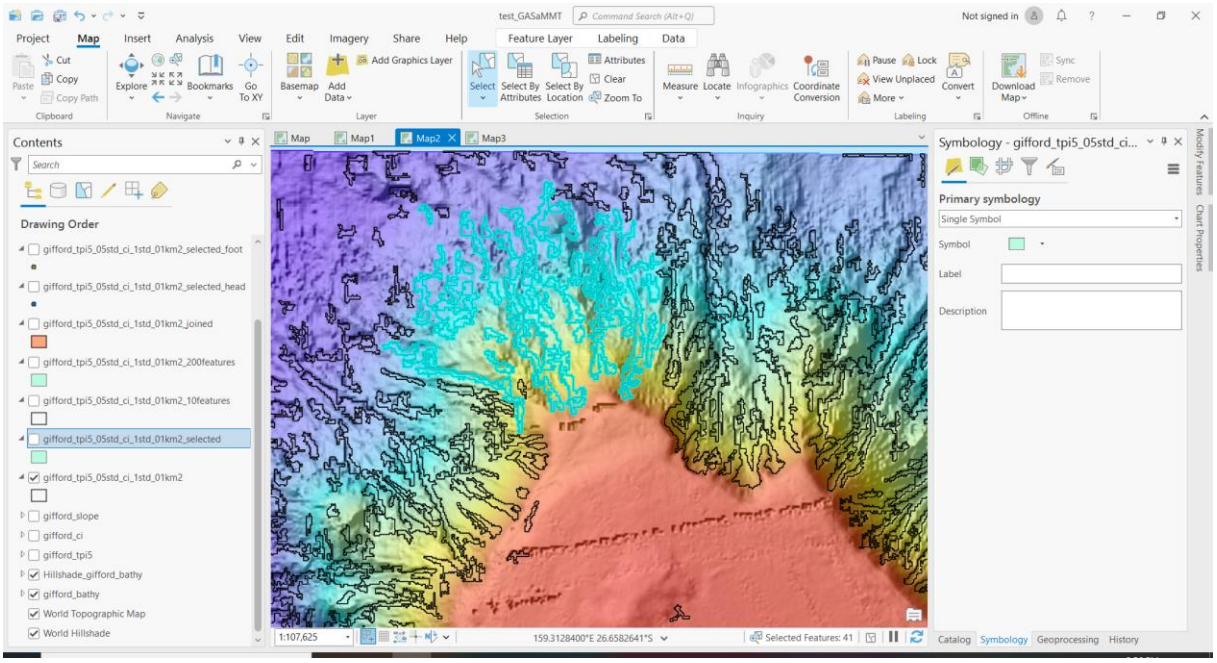


5. Examine the output features after connecting the linear nearby features. For example, the highlighted feature shown below is the result of merging three features that are spatially separated but satisfying the connecting criteria.

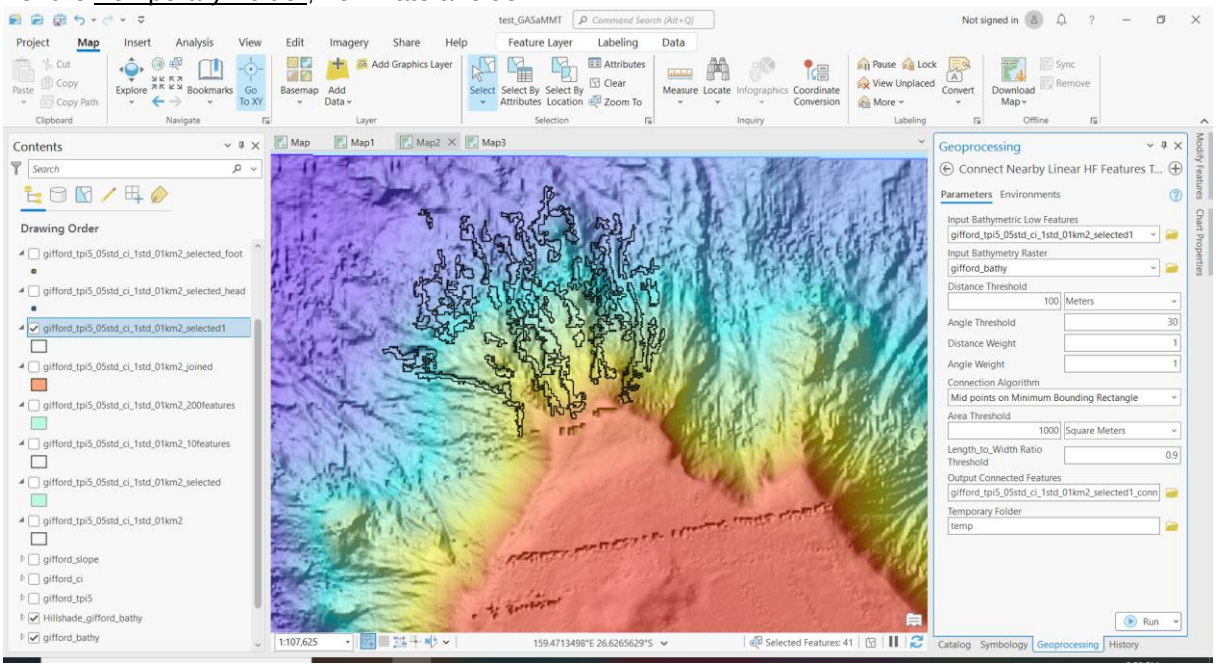


9.3. Connect Nearby Linear HF Features Tool

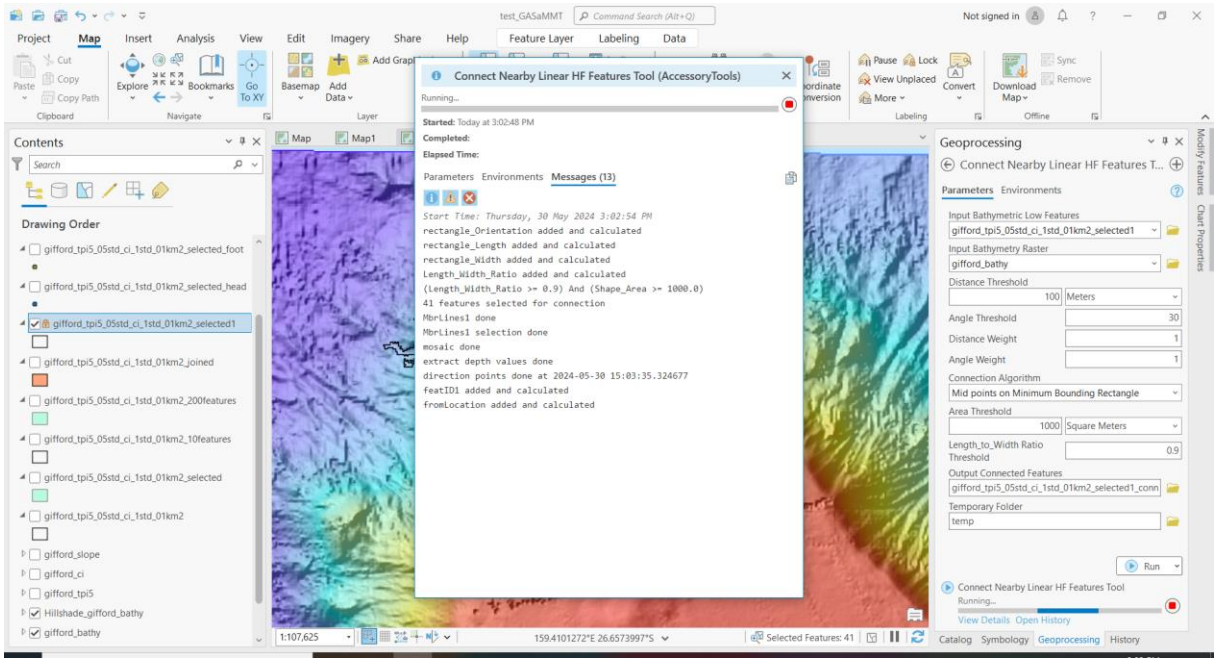
1. If not already loaded, create a new map and add gifford_tpi5_05std_ci_1std_01km2 bathymetric low features and associated data from the Gifford.gdb to the map.
2. Select a number of linear features and export them as gifford_tpi5_05std_ci_1std_01km2_selected1.



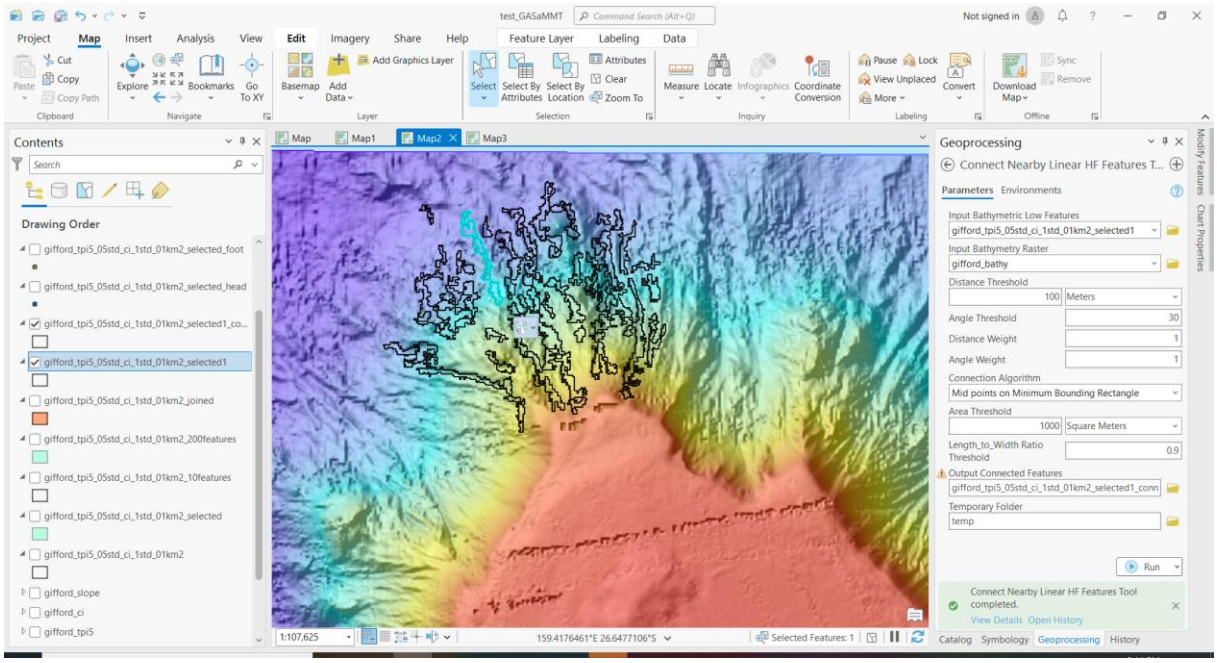
3. Select the Connect Nearby Linear HF Features Tool from the Accessory Tools toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Bathymetric Low Features, select gifford_tpi5_05std_ci_1std_01km2_selected1 from the drop-down list or navigate to the Gifford.gdb and select gifford_tpi5_05std_ci_1std_01km2_selected1. For the Input Bathymetry Raster, select from the drop-down list or navigate to gifford_bathy. Enter 100 meters as the Distance Threshold. Enter 30 as the Angle Threshold. Enter 1 for both the Distance Weight and the Angle Weight. For the Connection Algorithm, select “Mid points on Minimum Bounding Rectangle” from the drop-down list. For the Area Threshold, enter 1000 Square Meters. For the Length_to_Width Ratio, enter 0.9. For the Output Connected Features, navigate to the Gifford.gdb and enter a name like “gifford_tpi5_05std_ci_1std_01km2_selected1 _connected”. For the Temporary Folder, nominate a folder.



4. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.

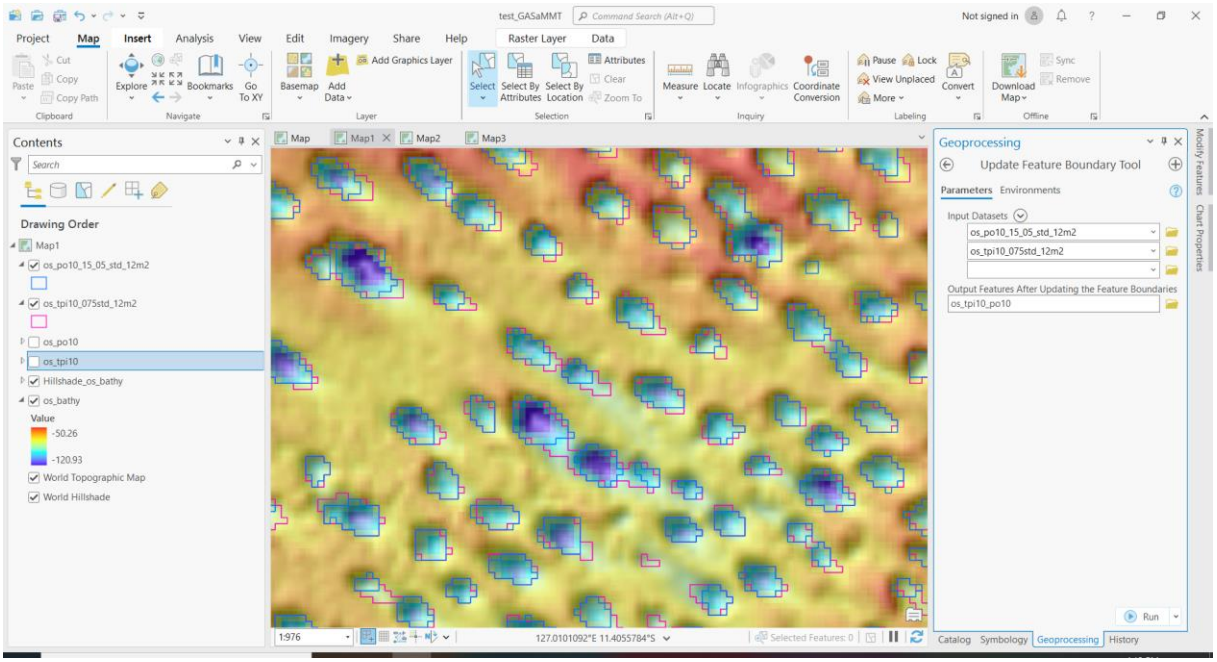


5. Examine the output features after connecting the linear nearby features. For example, the highlighted feature shown below is the result of merging two features that are spatially separated but satisfying the connecting criteria.

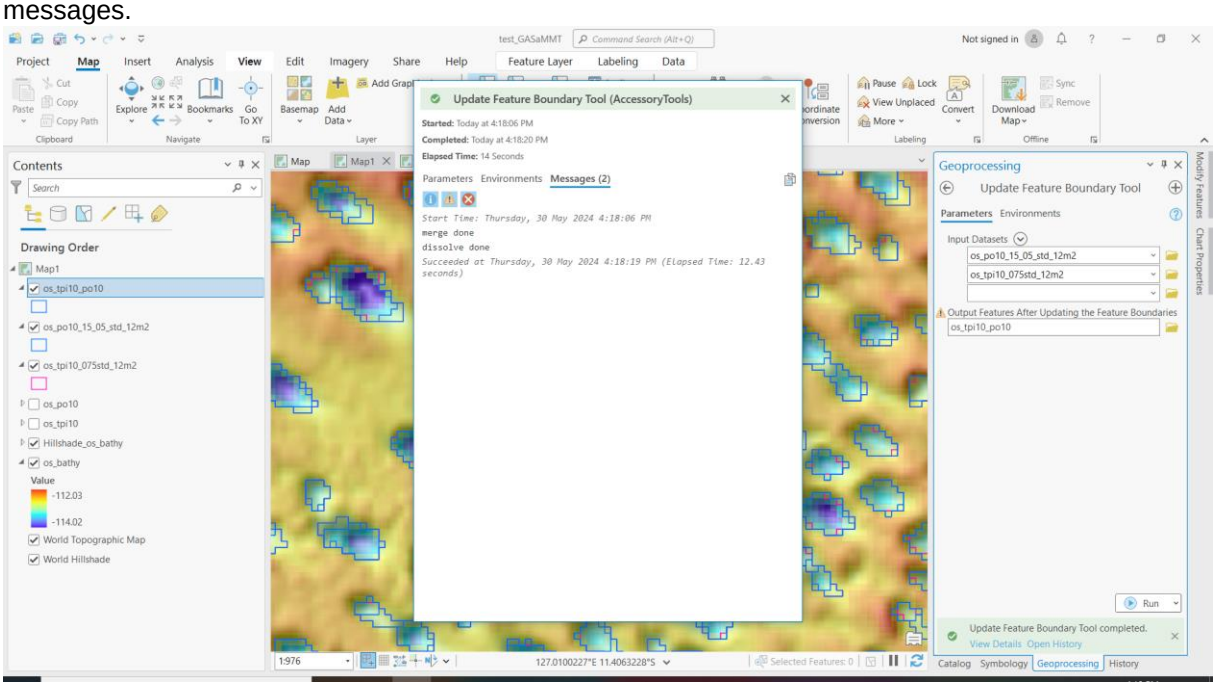


9.4. Update Feature Boundary Tool

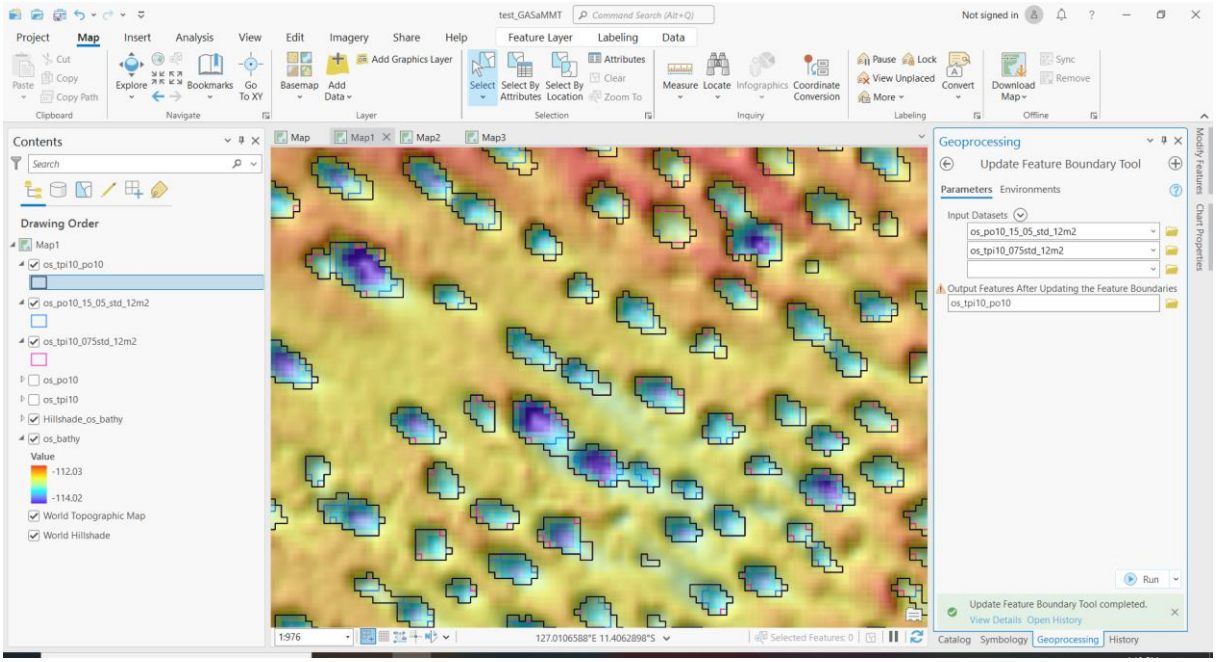
1. If not already loaded, create a new map and add os_tpi10_075std_12m2 and os_po10_15_05_std_12m2 bathymetric low features and associated data from the Oceanic_Shoals.gdb to the map.
2. Select the Update Feature Boundary Tool from the Accessory Tools toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Datasets, select both os_tpi10_075std_12m2 and os_po10_15_05_std_12m2 from the drop-down lists. For the Output Features After Updating the Feature Boundaries, navigate to the Oceanic_Shoals.gdb and enter a name like “os_tpi10_po10”.



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.



4. Check that the boundaries of individual output features are indeed the results of the merging the two input features.



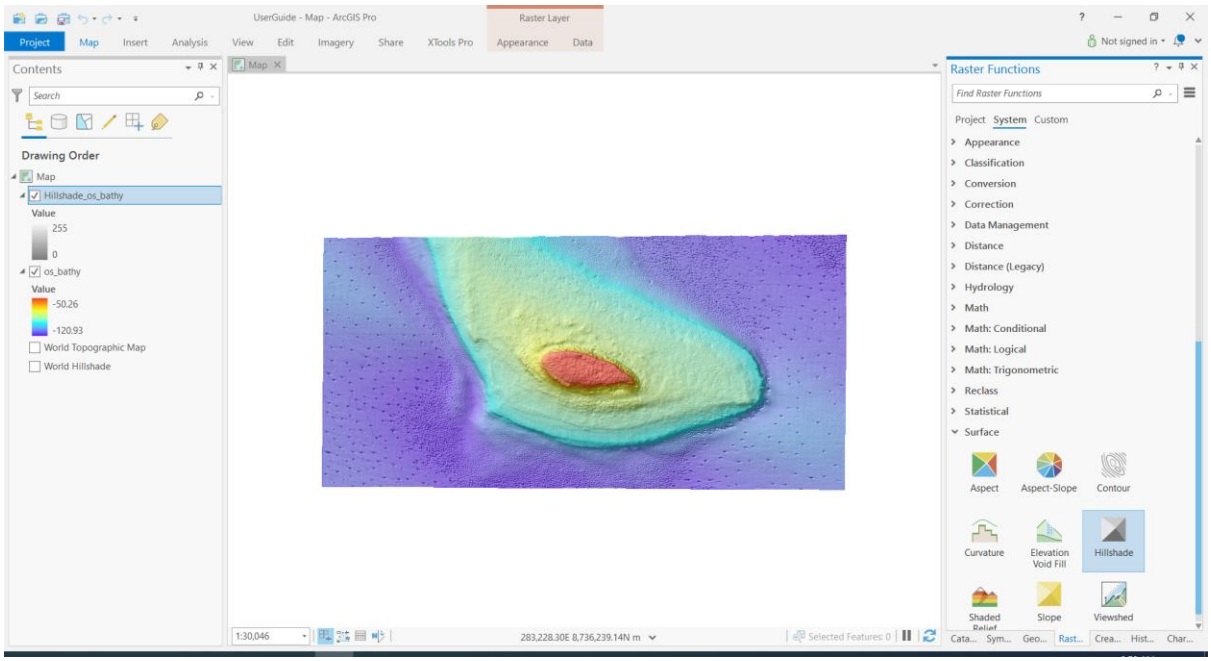
10. Use Surface Tools

The Surface toolbox contains two tools. Please see detailed metadata of each tool.

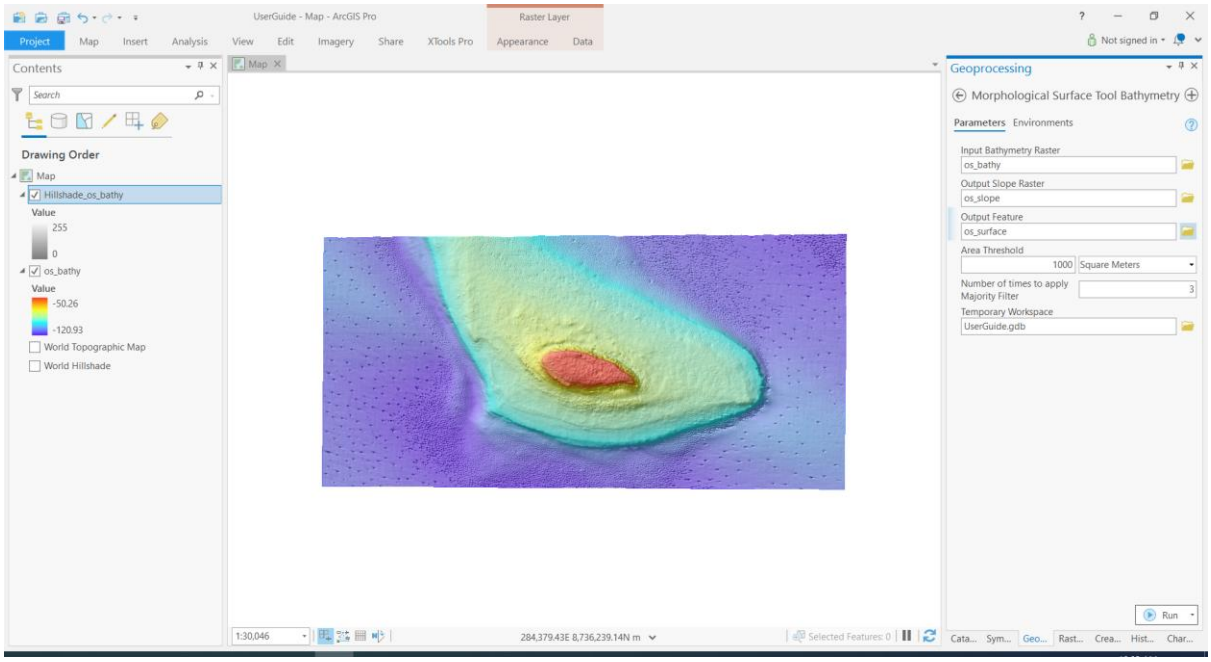
- Morphological Surface Tool Bathymetry: This tool classifies an area into three "surface" categories: Plane, Slope and Escarpment from a bathymetric data.
- Morphological Surface Tool Slope: This tool classifies an area into three "surface" categories: Plane, Slope and Escarpment from a slope gradient grid.

10.1. Morphological Surface Tool Bathymetry

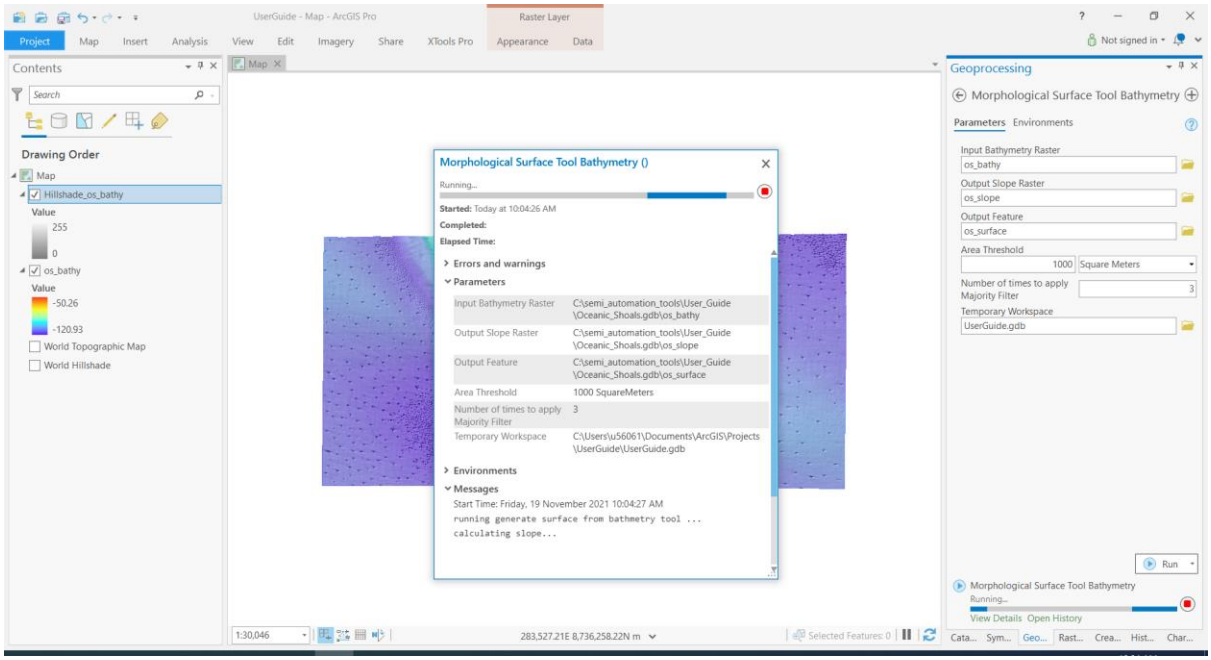
1. If not already loaded, create a new map and open os_bathy grid from the Oceanic_Shoals.gdb in the map.



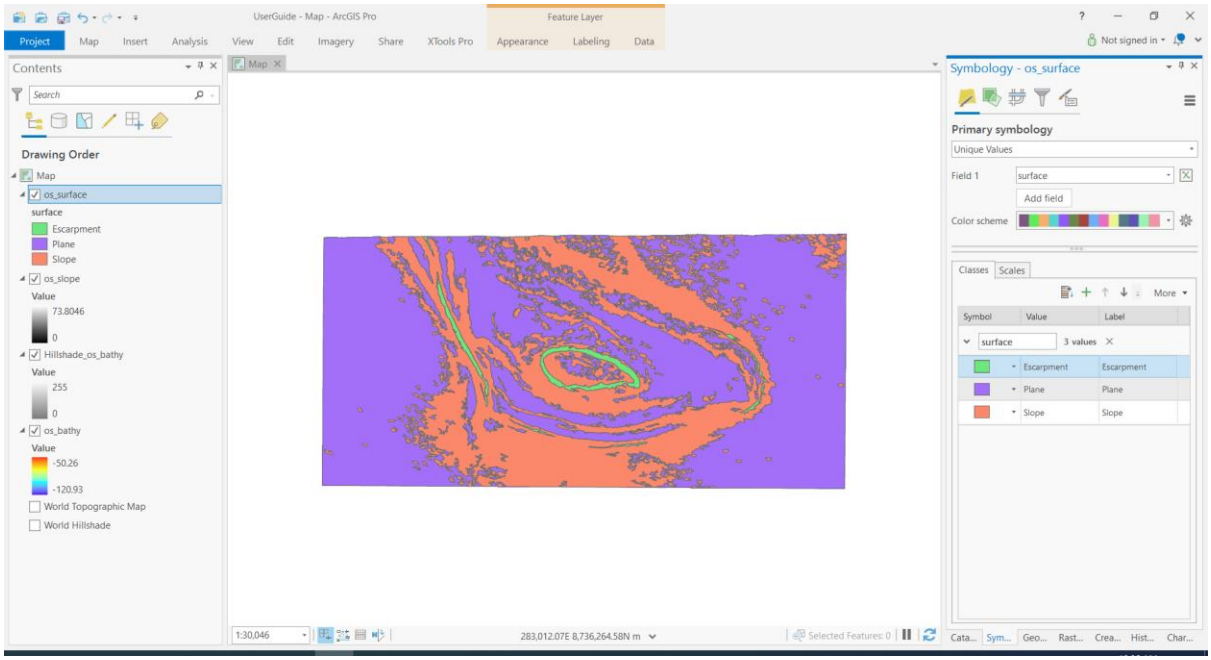
2. Select the Morphological Surface Tool Bathymetry from the Surface toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Bathymetry Raster, select os_bathy from the drop-down list or navigate to the Oceanic_Shoals.gdb and select os_bathy grid. For the Output Slope Raster, navigate to the Oceanic_Shoals.gdb and enter a name like “os_slope”. For the Output Feature, navigate to the Oceanic_Shoals.gdb and enter a name like “os_surface”. For the Area Threshold, enter 1000 Square Meters. For the Number of times to apply Majority Filter, keep the default value. For the Temporary Workspace, nominate a File Geodatabase that is different from the input/output workspace(s).



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.

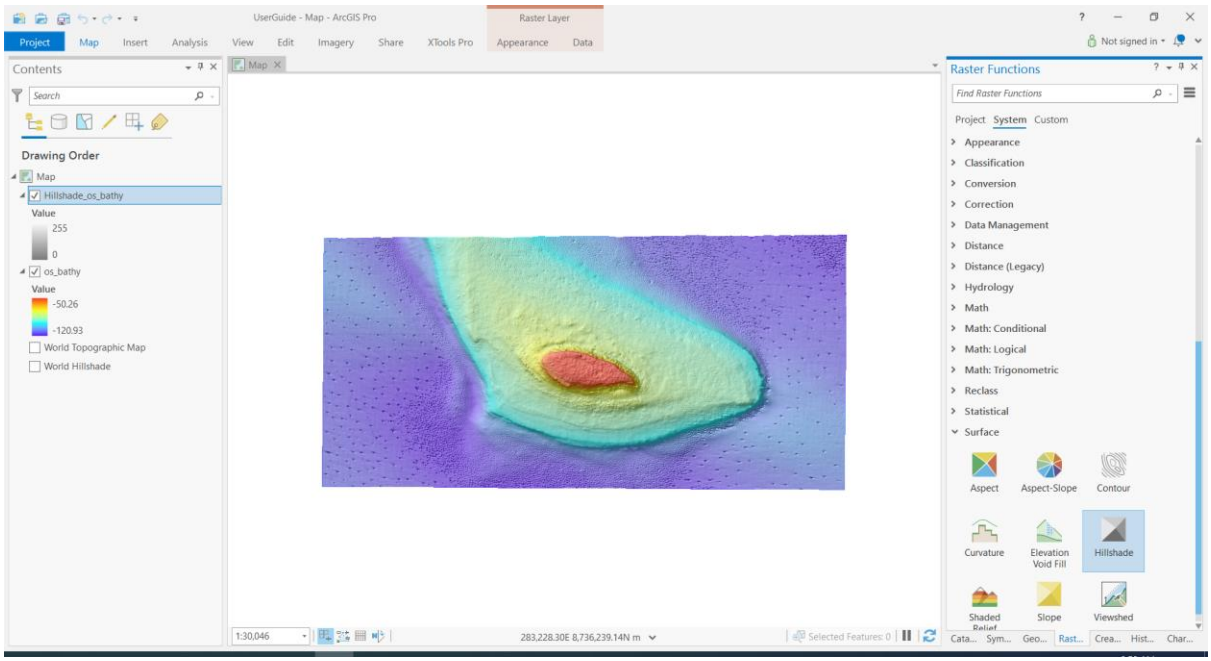


4. Examine the output surface features after the geoprocessing is completed. Symbolise the output features to display the three surface classes as distinct colors.

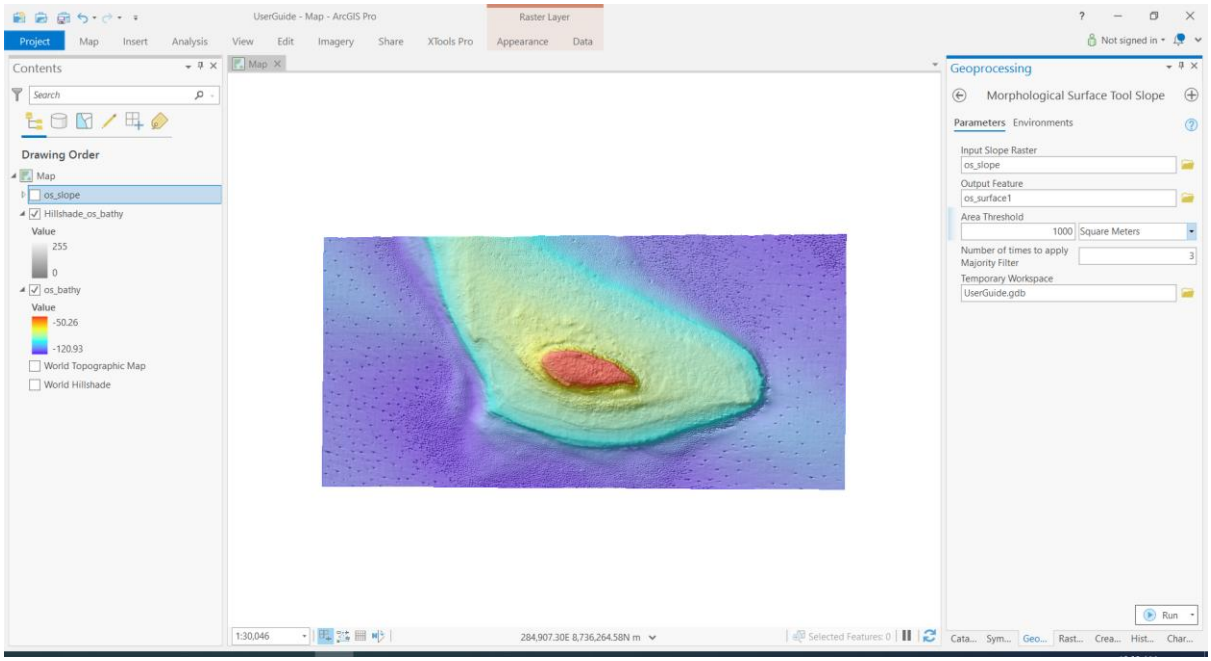


10.2. Morphological Surface Tool Slope

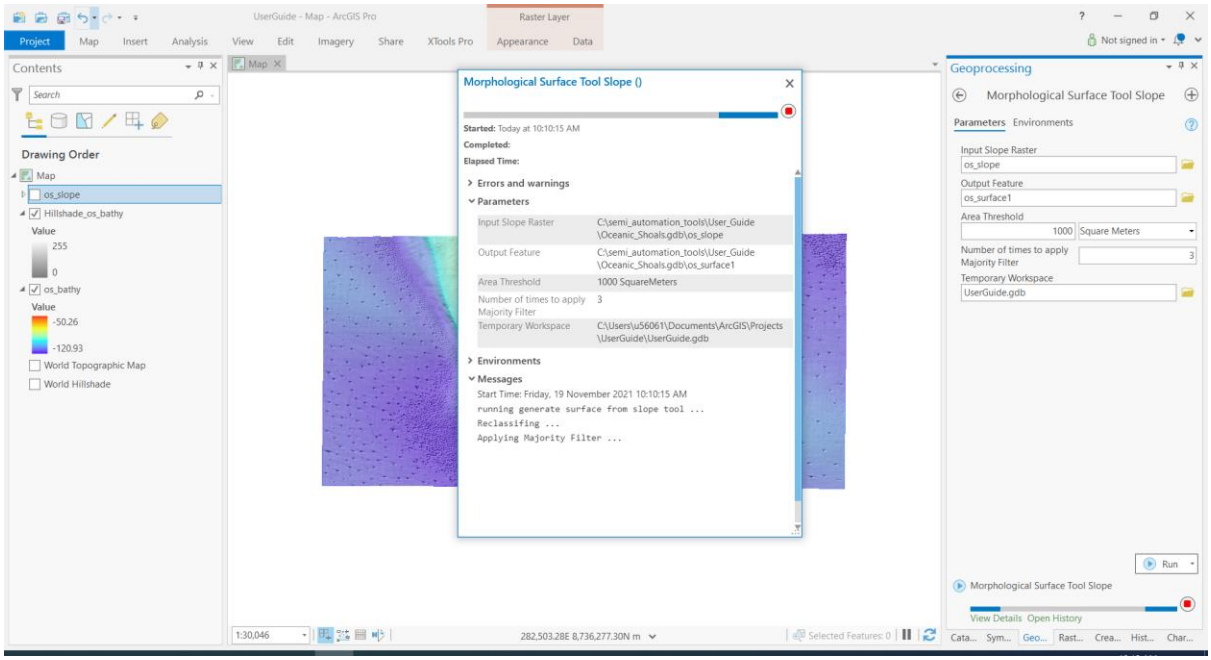
1. If not already loaded, create a new map and open os_bathy grid from the Oceanic_Shoals.gdb in the map.



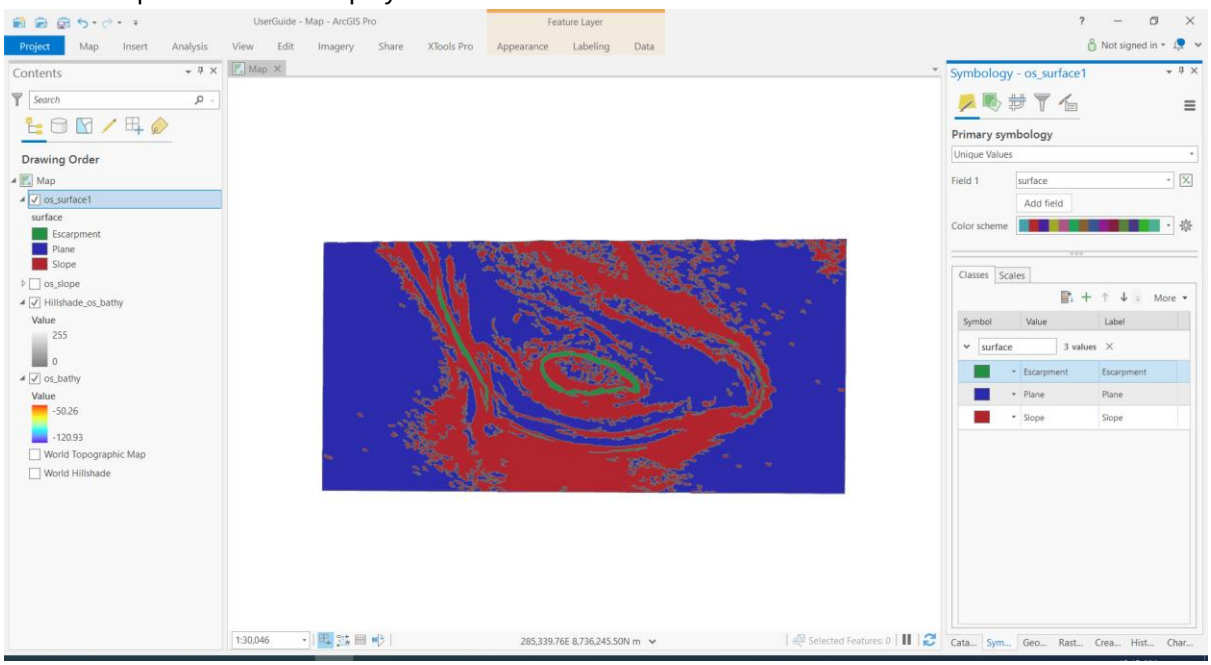
2. Select the Morphological Surface Tool Slope from the Surface toolbox. Double-Click to open it on the Geoprocessing tab. For the Input Slope Raster, select os_slope grid from the drop-down list or navigate to the Oceanic_Shoals.gdb and select os_slope grid. For the Output Feature, navigate to the Oceanic_Shoals.gdb and enter a name like “os_surface1”. For the Area Threshold, enter 1000 Square Meters. For the Number of times to apply Majority Filter, keep the default value. For the Temporary Workspace, nominate a File Geodatabase that is different from the input/output workspace(s).



3. Click the Run button to start the tool. Open the View Details tab to display the geoprocessing messages.

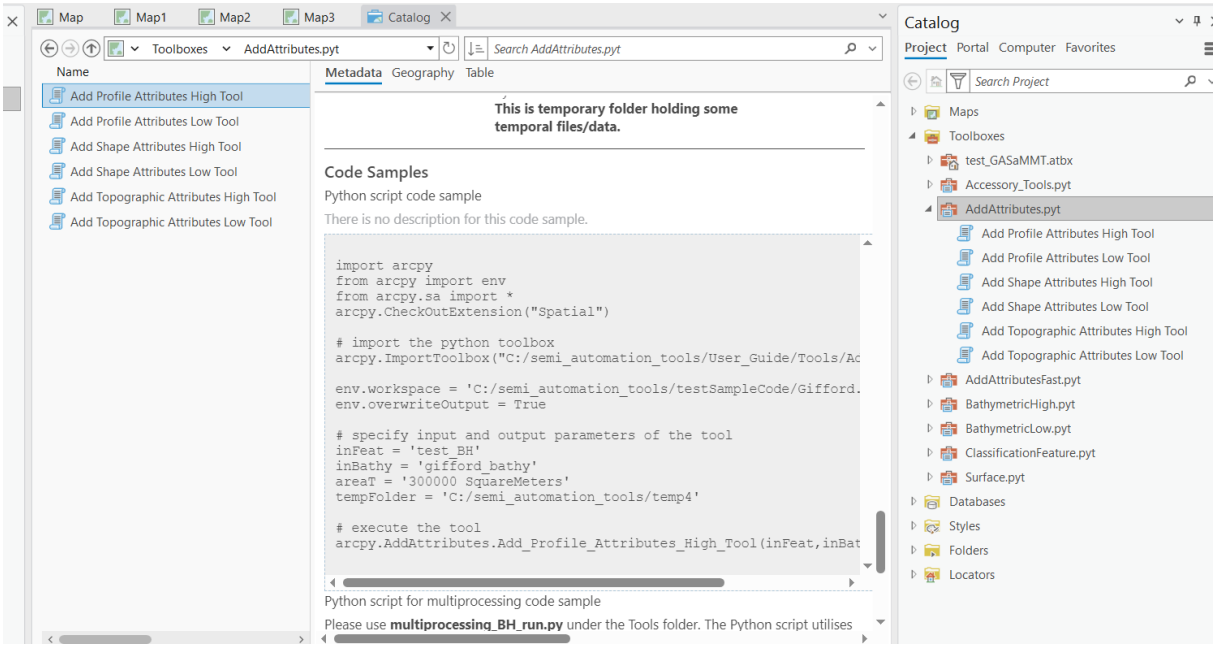


4. Examine the output surface features after the geoprocessing is completed. Symbolise the output features to display the three surface classes as distinct colors.



Appendix

Most of individual tools in GA-SaMMT can be called from within a Python script or a Python command line window, just like any geoprocessing tools in standard ArcGIS toolboxes. To see the code sample of a tool, Right-Click the tool, Click View Metadata menu and scroll down to the Code Samples section.



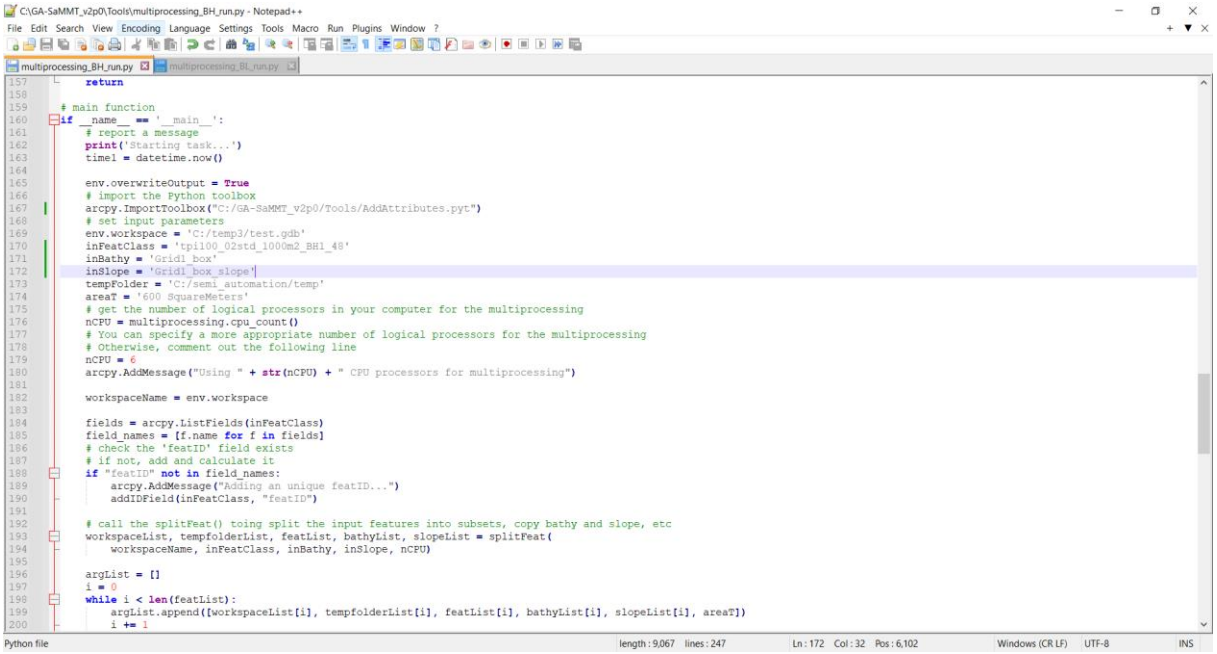
Users can copy and paste the code sample into a Python script, make some necessary changes (e.g., the input and output parameters, and the locations of toolbox and workspace), and execute the script. The code samples of several tools can also be combined into a Python script for batch processing.

The four add attributes tools in the AddAttributesFast toolbox can not be called from a Python script or a Python command line window. To be able to utilise the multiprocessing (hence the high performing) capabilities for the batch processing of the add attributes tools, we have included two Python scripts under the \GA-SaMMT_v2p0\Tools folder. The multiprocessing_BH_run.py and the multiprocessing_BL_run.py are used to calculate all three groups of attributes for the bathymetric high and low features, respectively. Note that these two Python scripts are actually calling the AddAttributes toolbox instead of the AddAttributesFast toolbox. The followings are the steps for running the multiprocessing_BH_run.py. The same steps are used for running the multiprocessing_BL_run.py.

1. Open the multiprocessing_BH_run.py on a Python or a text editor.

2. Make necessary changes to the locations of the toolbox and workspace, and the input and output parameters, under the main function section. You also need to change the location of the toolbox under the add_shape_attributes_high_function(arg), add_topographic_attributes_high_function(arg) and add_profile_attributes_high_function(arg)

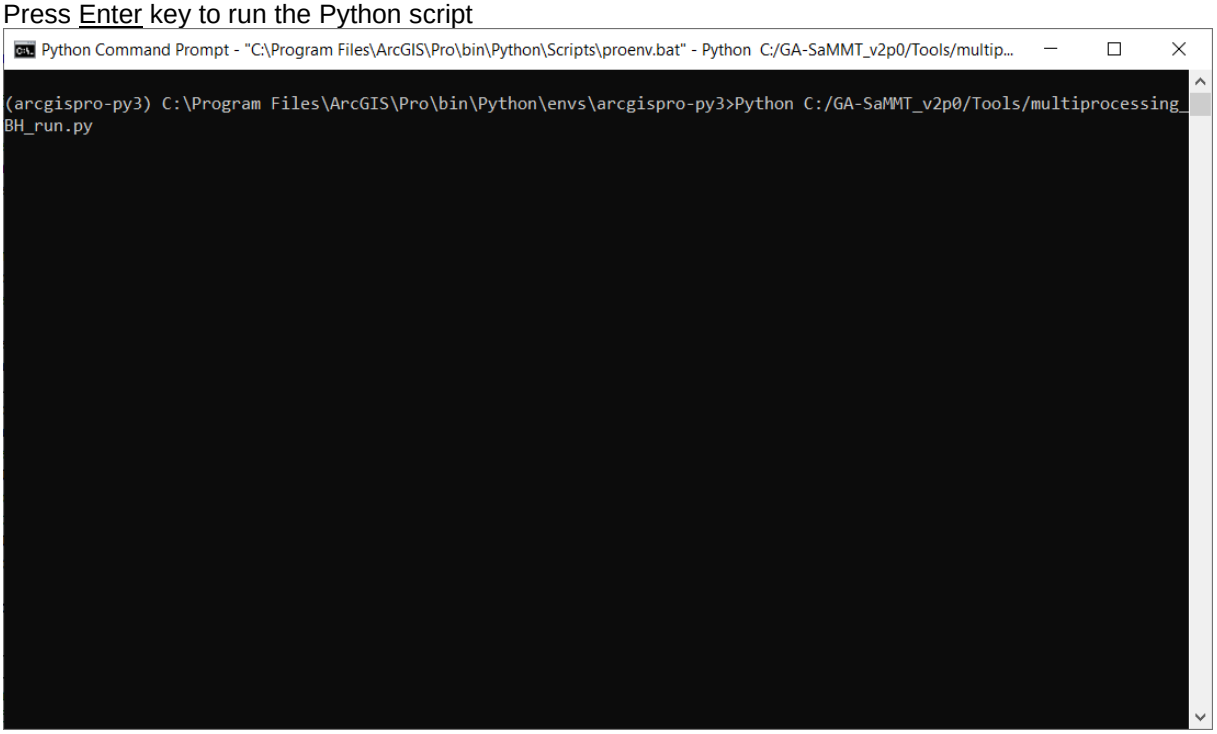
functions.



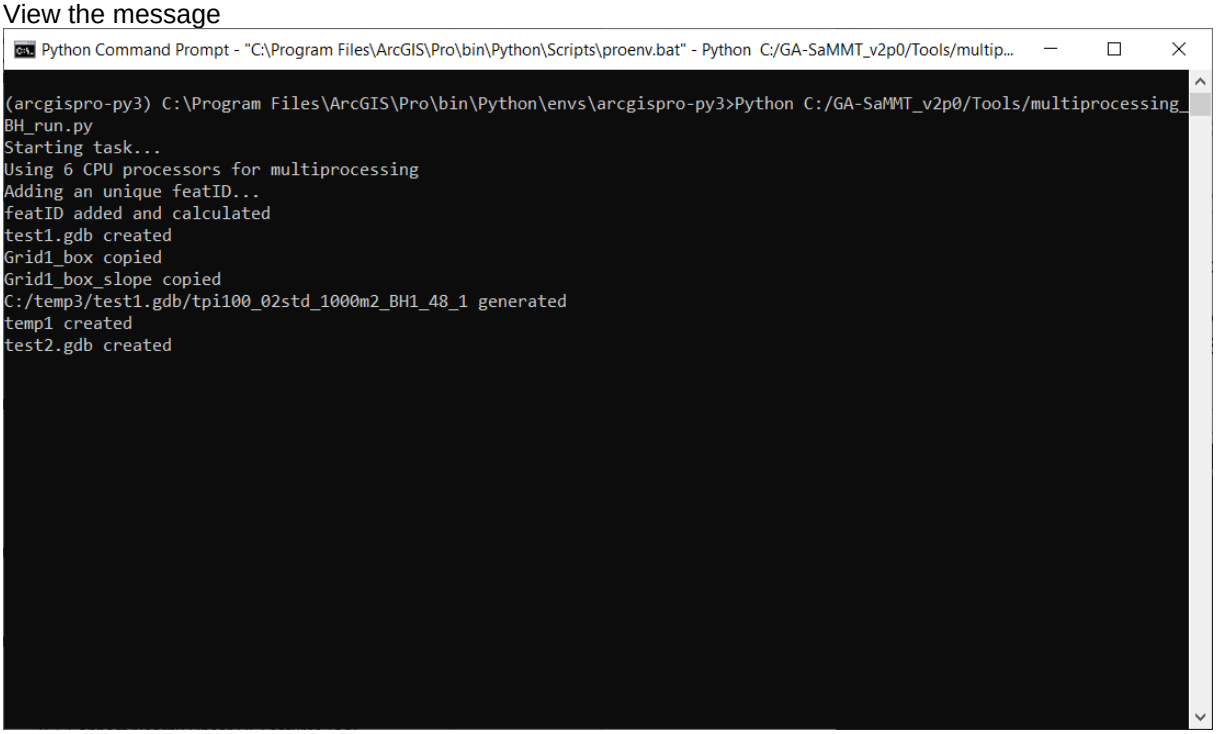
3. Open a Python Command Prompt window from under the ArcGIS software suite.

4. Type in the following command line: Python C:/GA-SaMMT_v2p0/Tools/multiprocessing_BH_run.py

5. Press Enter key to run the Python script



6. View the message



7. After the script is completed, check that all three groups of attributes have been added to the input features.