

Benthic Terrain Modeler

Introduction

Introduction to Benthic Terrain Modeling

Exercise A

Setting up your workspace: Installing the BTM and activating the Spatial Analyst Extension

Exercise B

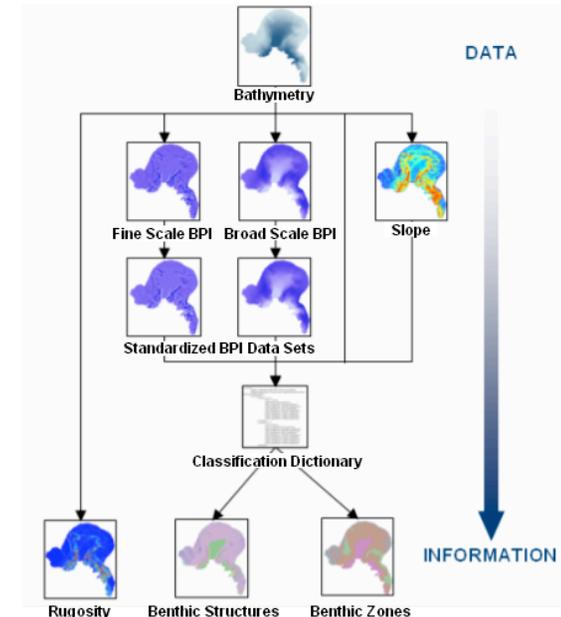
Calculating Bathymetric Position Index, Applying a Classification Dictionary and Calculating Rugosity



Introduction

This exercise will introduce you to the **Benthic Terrain Modeler**, a collection of ESRI® ArcGIS®-based tools that coastal and marine resource managers can use in concert with bathymetric data sets, in order to examine and classify the benthic environment.

The BTM toolbar contains a set of tools that allow users to create grids of slope, bathymetric position index and rugosity from an input data set. An integrated XML-based terrain classification dictionary gives users the freedom to create their own classifications and define the relationships that characterize them. A unique feature of the tool is its wizard-like functionality that steps users through the processes involved in benthic terrain characterization, and provides access to information on key concepts along the way.



Skills Learned

- Creating a Bathymetric Position Index (BPI) Grid
- Loading a Classification Dictionary
- Creating a Rugosity Grid

Tools and Technology

ArcGIS Components

- ArcMap

ArcGIS Extension

- Spatial Analyst
- Benthic Terrain Modeler

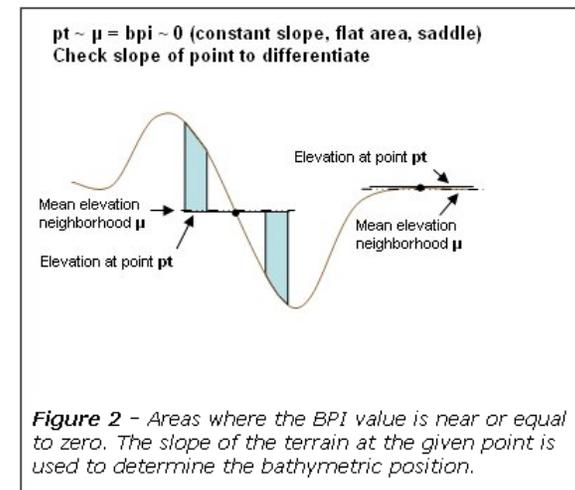
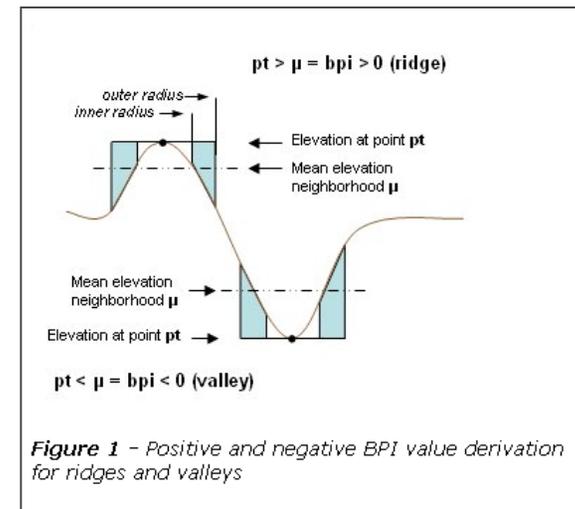


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Bathymetric Position Index (BPI)

The concept of bathymetric position is central to the benthic terrain classification process that is utilized by the BTM. Bathymetric Position Index (BPI) is a measure of where a referenced location is relative to the locations surrounding it. BPI is derived from an input bathymetric data set and itself is a modification of the topographic position index (TPI) algorithm that is used in the terrestrial environment. The application of TPI to develop terrain classifications was explored and developed by Andrew Weiss during his study of terrestrial watersheds in Central Oregon (Weiss 2001). These applications can be carried into the benthic environment through BPI.

Bathymetric Position Index (BPI) data sets are created through a neighborhood analysis function. Positive cell values within a BPI data set denote features and regions that are higher than the surrounding area. Therefore, areas of positive values generally characterize ridges and other associated features within the benthic terrain. Likewise, negative cell values within a BPI data set denote features and regions that are lower than the surrounding area. Areas of negative cell values generally characterize valleys and other associated features within a bathymetric data set (Figure 1). BPI values near zero are either flat areas (where the slope is near zero) or areas of constant slope (where the slope of the point is significantly greater than zero) (Figure 2) (Weiss 2001).



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Bathymetric Position Index (BPI)

BPI data sets are created from an input bathymetric data set by applying an algorithm that utilizes a focal or neighborhood function. Neighborhood functions produce an output raster in which the output cell value at each location is a function of the input cell value and the values of the cells in a specified "neighborhood" surrounding that location (Figure 3).

The BTM Tool utilizes the Raster Map Algebra Operation object, available through the ArcGIS Spatial Analyst extension, to apply the following algorithm and create an output BPI data set:

$$BPI<scalefactor> = int((bathy - focalmean(bathy,annulus,irad,orad)) + .5)$$

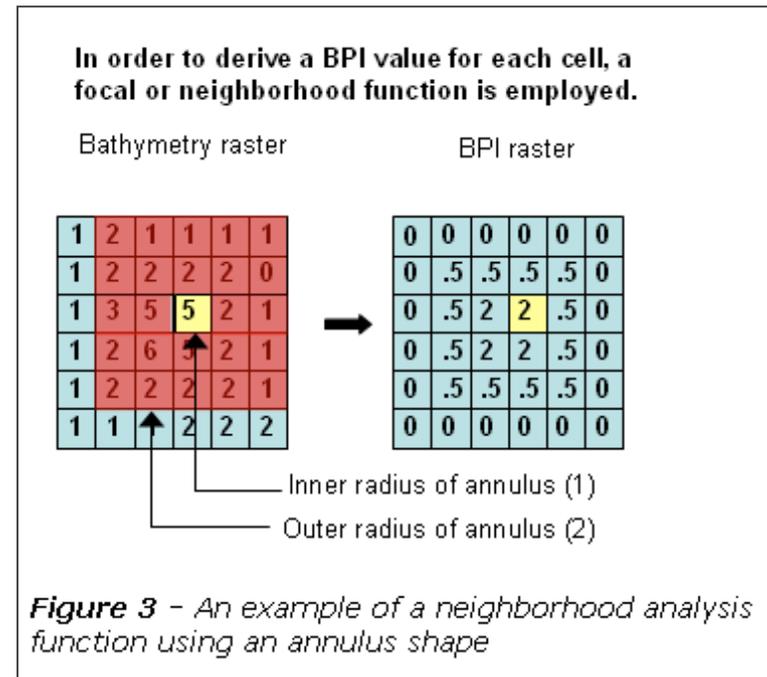
scalefactor = outer radius in map units * input bathymetric data set resolution(cell size)

bathy = input bathymetric data set

irad = inner radius of annulus-shaped analysis neighborhood in cells

orad = outer radius of annulus-shaped analysis neighborhood in cells

Bathymetric position is an inherently scale-dependent phenomenon (Weiss 2001). Two different BPI datasets, with different scale factors, are created during the benthic terrain classification process. Fine scale BPI data sets have smaller analysis neighborhoods, and thus a smaller scale factor. Fine scale BPI data sets are useful for identifying smaller benthic terrain features. Broad scale BPI data sets have larger analysis neighborhoods, and thus a larger scale factor. These data sets are useful in identifying larger benthic terrain regions or areas.



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Standardizing BPI Grids

Once BPI data sets have been created at both fine and broad scales, the next step in the benthic terrain classification process is to standardize the values of these raster data sets.

Bathymetric data tends to be spatially autocorrelated (i.e. locations that are closer together are more related than locations that are farther apart) (Weiss 2001). Therefore, the range of BPI values increases with scale. For example, broad (small) scale BPI data sets would have smaller BPI values because a larger analysis neighborhood is used. This would have the effect of averaging out small variations in the terrain. Fine (large) scale BPI data sets would have larger BPI values because of the smaller neighborhood that is used. This smaller analysis neighborhood would result in the detection of smaller, localized variations in the terrain.

Standardization of the raw BPI values allows for the classification of BPI data sets at almost any scale (Weiss 2001). This step also allows easier parameter entry during the classification dictionary editor creation process. Once again, the BTM utilizes the Raster Map Algebra Operation object available through the ArcGIS Spatial Analyst extension to create the standardized output data set. The following algorithm is used:

$$BPI<scalefactor>_std = int((((BPI<scalefactor> - mean) / std dev) * 100) + 0.05)$$

scalefactor = outer radius in map units * input bathymetric data set resolution(cell size)

mean = mean cell value across BPI data set

std dev= standard deviation of cell values across BPI data set

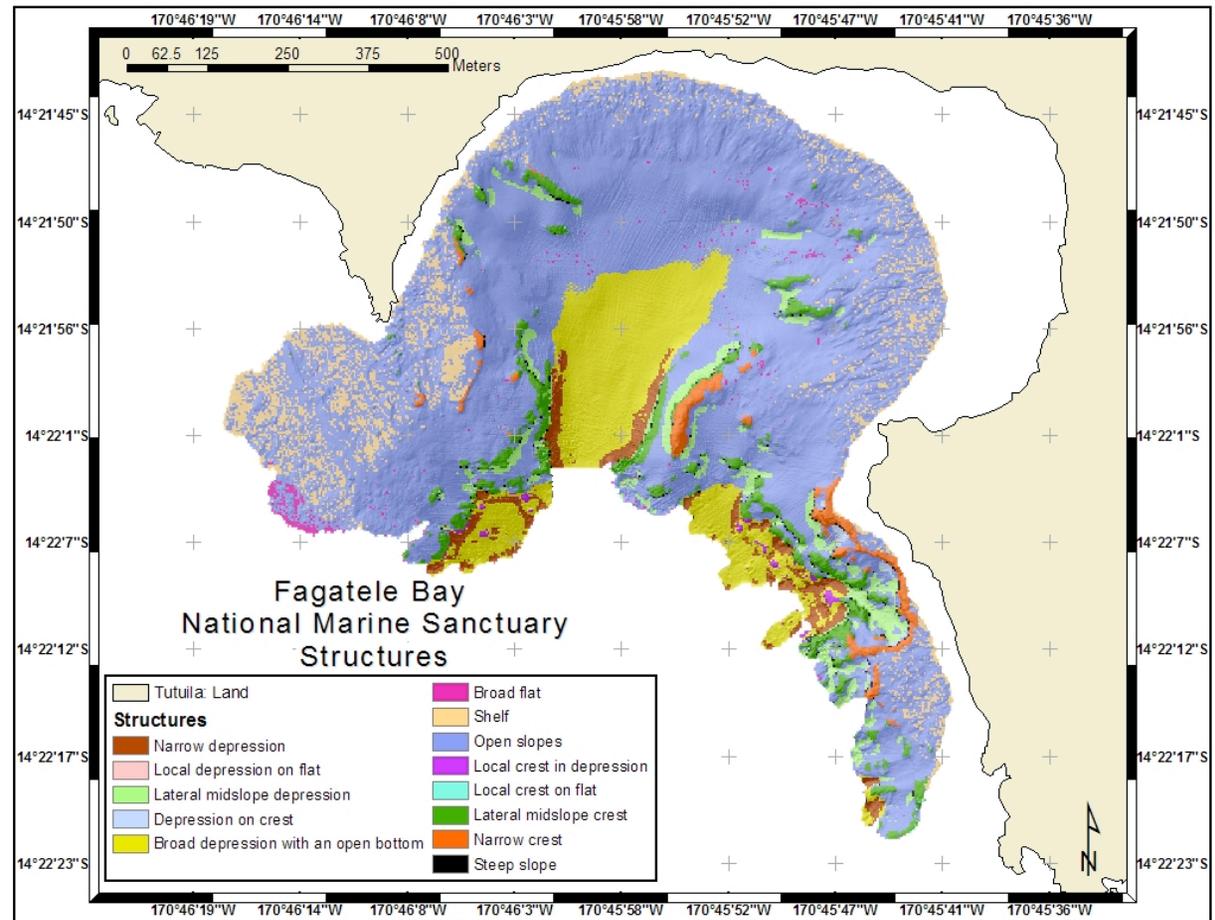


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Examples of benthic terrain modeling

The BTM tool was used to produce the first benthic habitat maps for Fagatele Bay National Marine Sanctuaries in the American Samoa.

Various marine structures were derived using the classification dictionary.



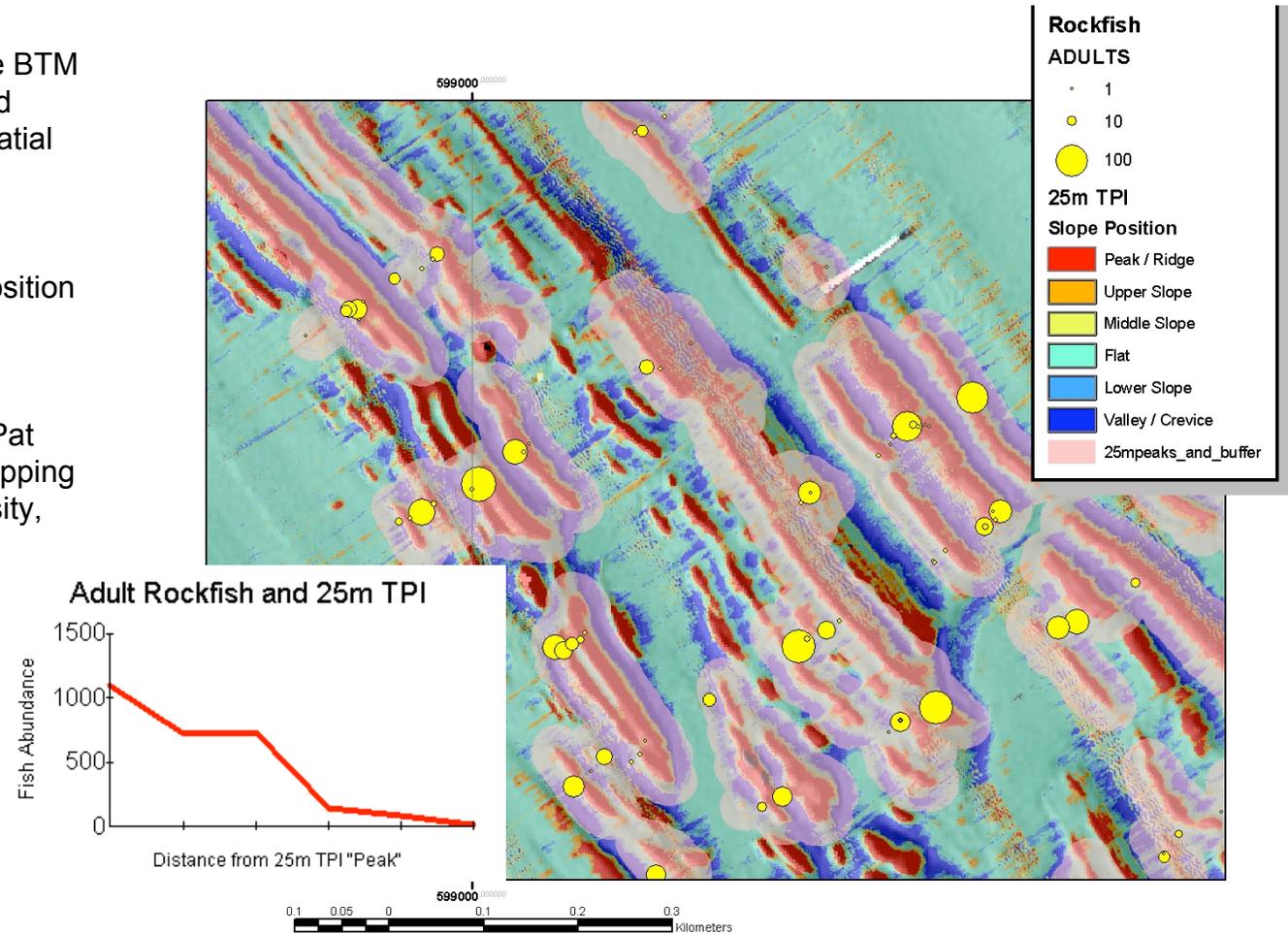
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Examples of benthic terrain modeling

Methods employed using the BTM can also be manually created exclusively using ArcGIS Spatial Analyst extension.

This example illustrates the application of bathymetric position to examine adult rockfish distribution in Monterey, CA.

Analysis was performed by Pat Iampietro at the Seafloor Mapping Lab, California State University, Monterey Bay.



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Benthic Terrain Modeler

Exercise A – The Set-Up

This exercise you will install the Benthic Terrain Modeler, Launch ArcMap, activate the Spatial Analyst extension and set up your ArcMap Project.

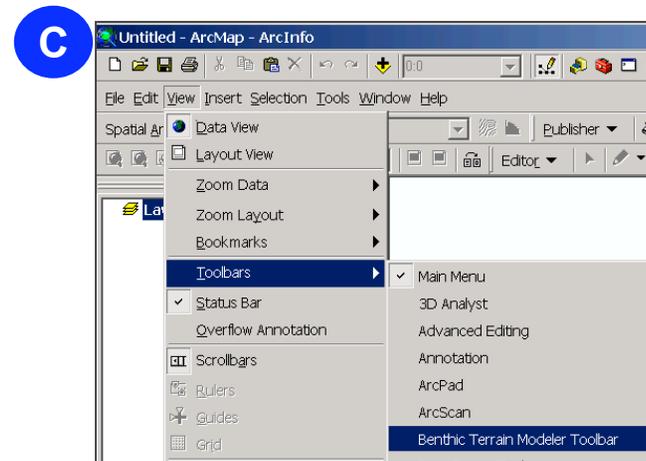
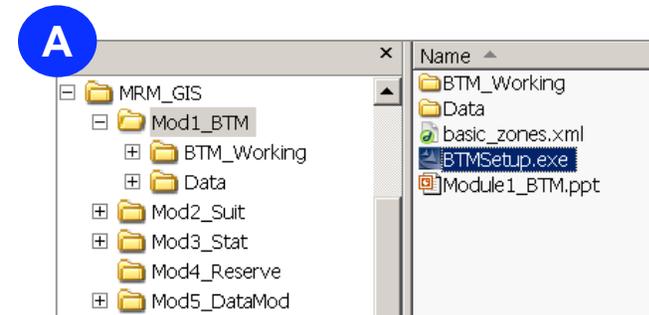
A Install the Benthic Terrain Modeler

- Navigate to the **Mod1_BTM** folder.
- Double-click on the **BTMSetup.exe** file to launch the BTM installer.
- Accept the default settings for the installation, complete the installation as prompted.

Launch ArcMap

C Load the BTM tool

- Click on **View > Toolbars > Benthic Terrain Modeler Toolbar**.



Exercise A – The Set-Up Continued

D. Load and activate the Spatial Analyst Extension

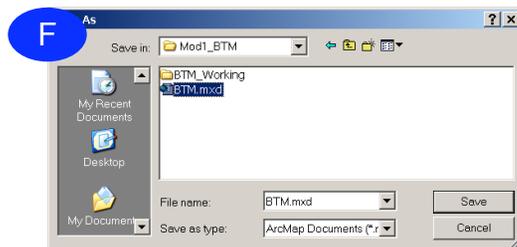
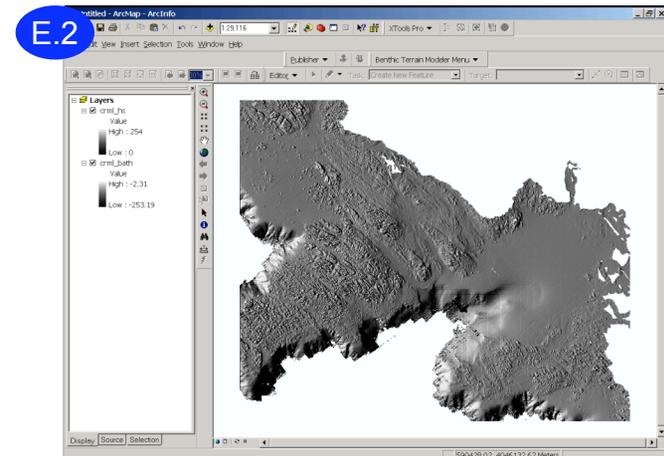
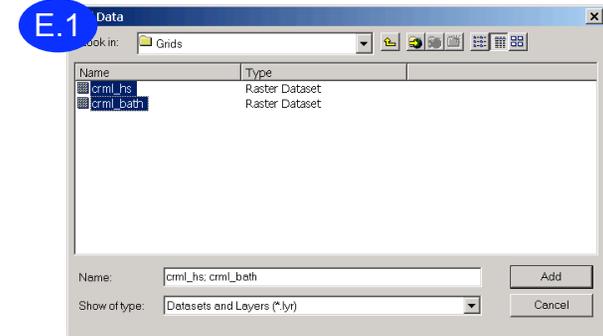
- Click on **View > Toolbars > Spatial Analyst**
- Click on **Tools > Extensions**. Make sure there is a check next to the Spatial Analyst box

E. Add the bathymetric and hillshade data for our study area

1. Navigate to the **MRM_GIS > Data > Grids** folder
2. Add the **crml_hs** and **crml_bth** data your ArcMap Project

F. Save your project in the BTM_Mod1 folder

- File > Save > BTM.mxd**



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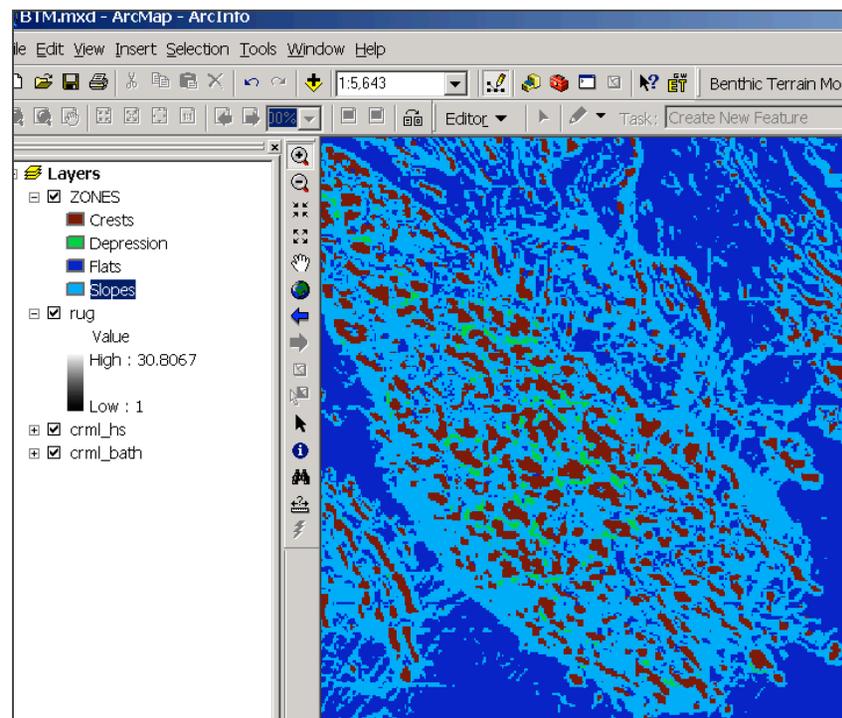


Exercise B – Calculating Bathymetric Position Index (BPI)

In this exercise you will use the Benthic Terrain Classification Wizard to calculate a benthic position index grid

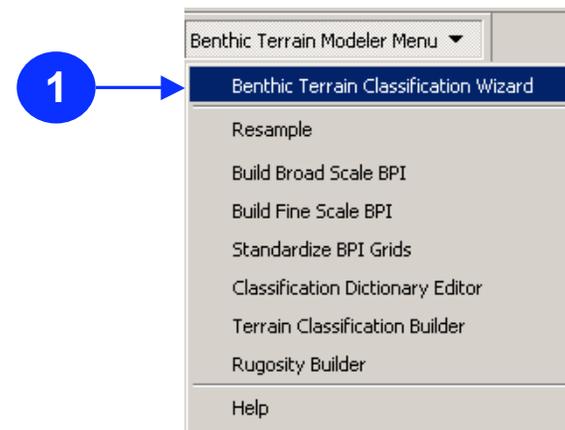
Summary of Process Steps

1. Launch the BTM.mxd project that you set up in Exercise A
2. Launch the Benthic Classification Wizard
3. Create Broad and Fine Scale BPI grids
4. Standardized the BPI grids
5. Use an existing classification dictionary to classify the BPI grids into terrain zones.



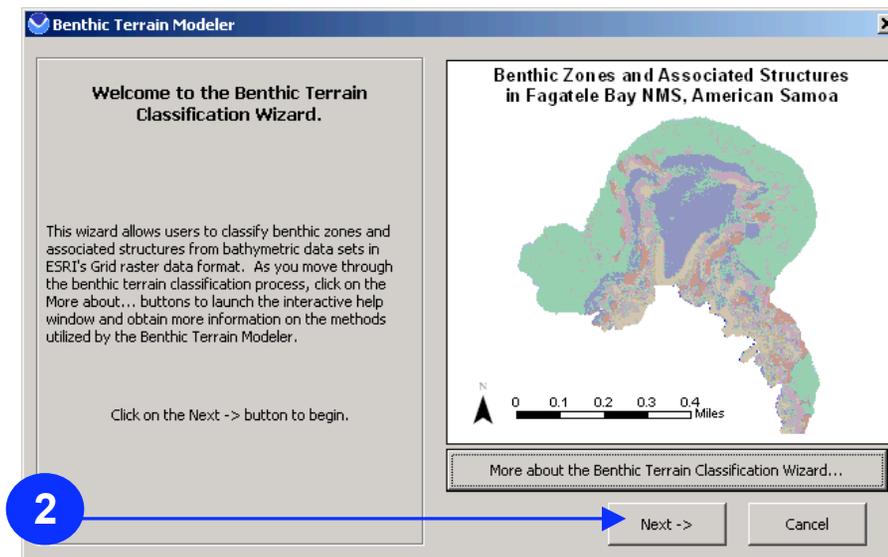
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Start the process by using the Benthic Terrain Classification Wizard menu. The Wizard will guide you through all of the major steps of the analysis. The remaining menu choices allow you to perform any of the steps individually.

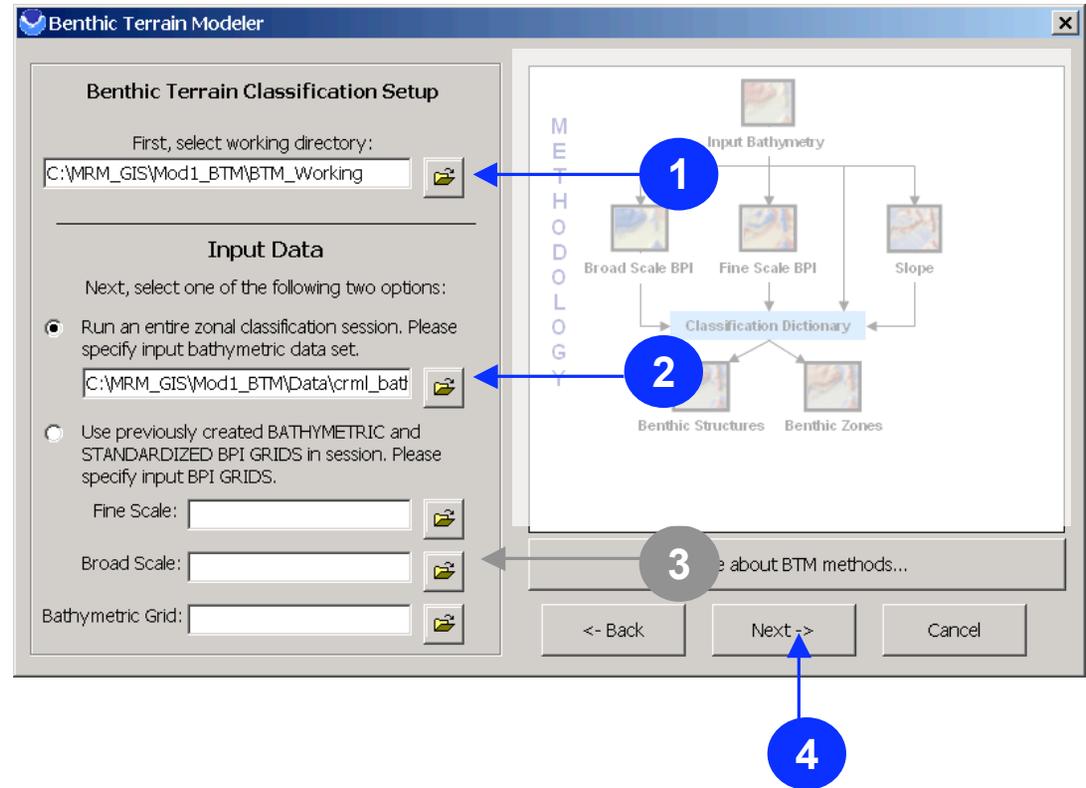


- 1 Click on the **Benthic Terrain Classification Wizard**

- 2 Click the **Next** button to launch the Wizard



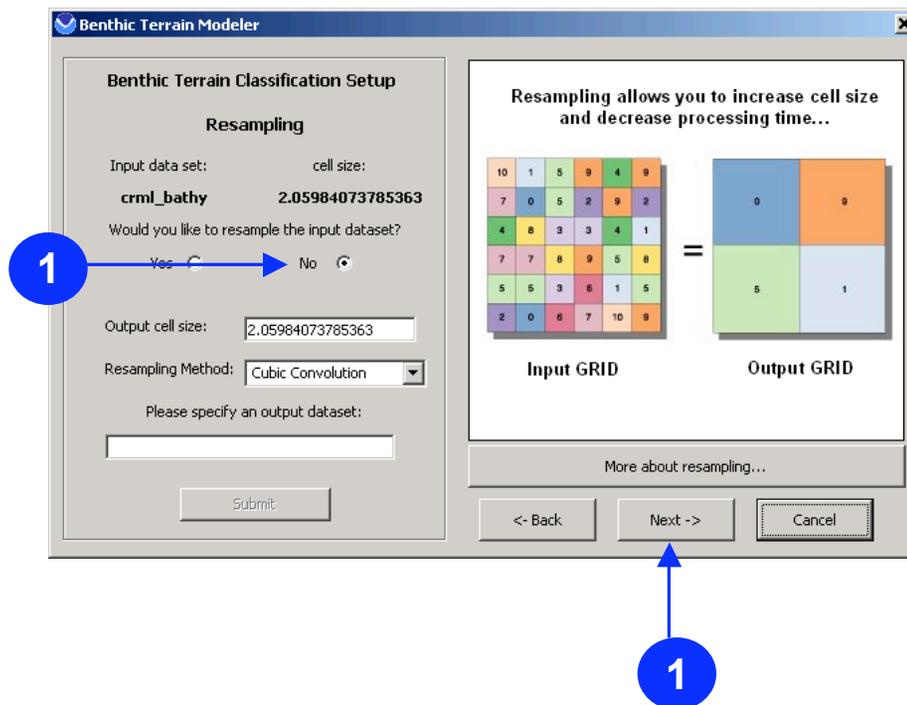
- 1 Set your working directory to **Mod1_BTM\BTM_Working**. All data from the analysis will be created in this directory.
- 2 Select the bathymetric grid you will be using as the input data. Navigate to the **Mod1_BTM\Data** folder and select **crml_bth** grid
- 3 (Optional) If you have previously created BPI GRIDS, you can specify these GRIDS in this area.
- 4 Click on the **Next** button.



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This step is optional. You can resample your bathymetric GRIDs to increase the cell size. We will not resample our GRID for this exercise.

- 1 Make sure the radio dial for **No** is selected.
- 2 Click on the **Next** button.



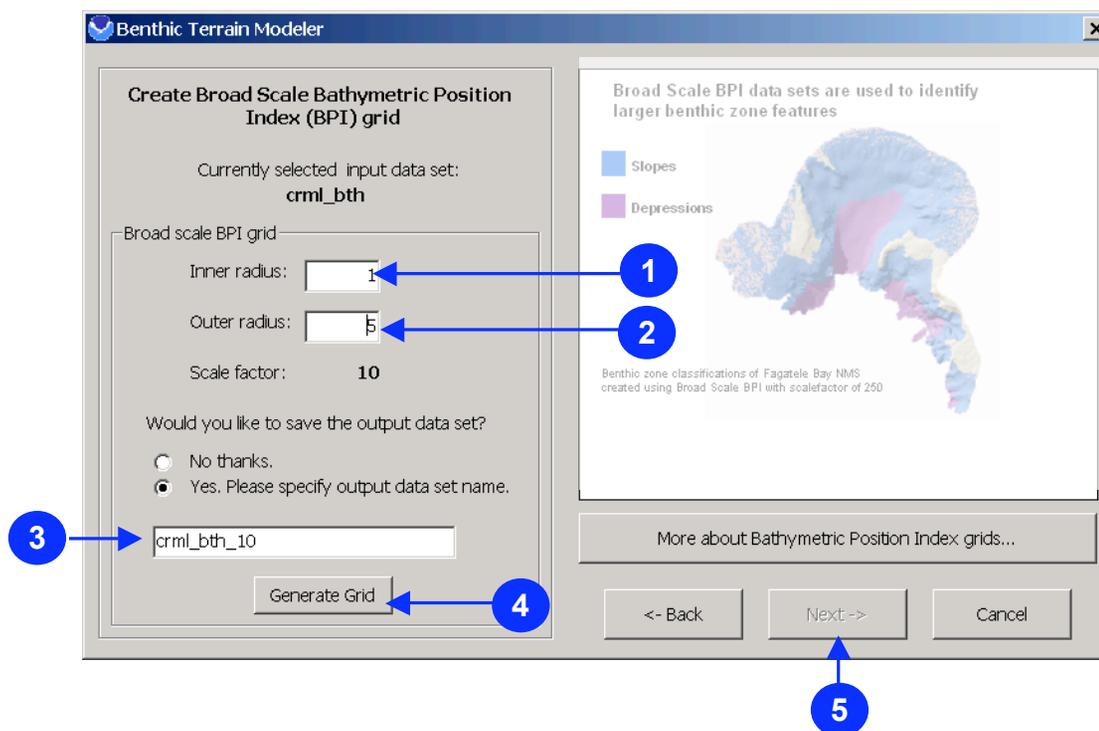
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Create a Broad Scale BPI

The creation of Bathymetric Position Index (BPI) data sets at two different scales is central to the methods behind the benthic terrain classification process. BPI is a derivative of the input bathymetric data set, and is used to define the location of specific features and regions relative to other features and regions within the same data set.

A broad scale BPI data set allows you to identify smaller features within the benthic landscape.

- 1 Type in **1** for the Inner radius
- 2 Type in **5** for the Outer radius
- 3 Name the output data set **crml_bth_10**
- 4 Click on **Generate GRID**
- 5 Click on **Next**
- 6 Once the calculation is completed, **add data to** your map.



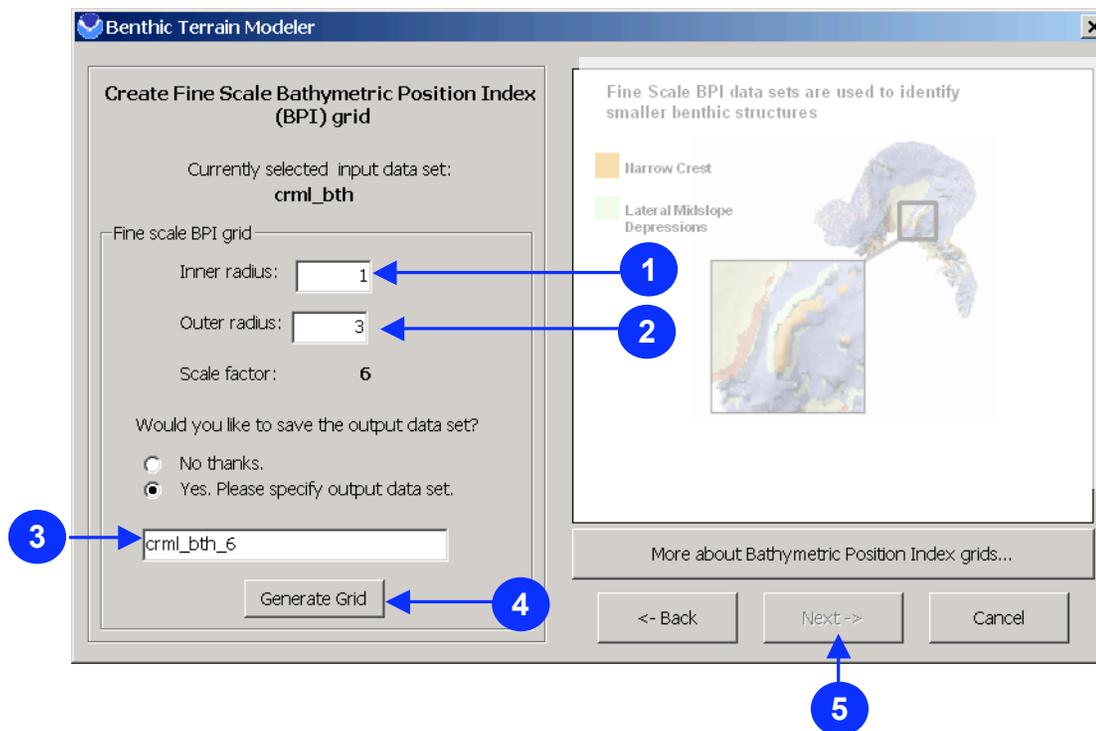
Benthic Terrain Modeler

Create a Fine Scale BPI

The creation of Bathymetric Position Index (BPI) data sets at two different scales is central to the methods behind the benthic terrain classification process. BPI is a derivative of the input bathymetric data set, and is used to define the location of specific features and regions relative to other features and regions within the same data set.

A fine scale BPI data set allows you to identify larger regions within the benthic landscape.

- 1 Type in **1** for the Inner radius
- 2 Type in **3** for the Outer radius
- 3 Name the output data set **crml_bth_6**
- 4 Click on **Generate GRID**
- 5 Click on **Next**
- 6 Once the calculation is completed, add data to your map.

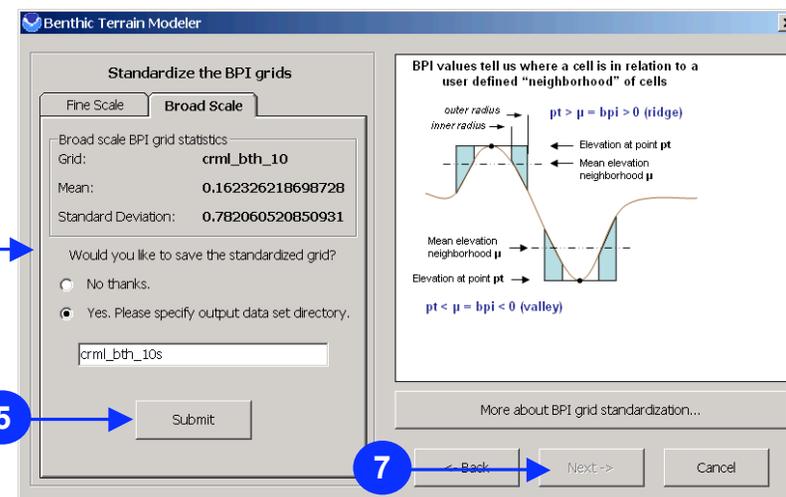
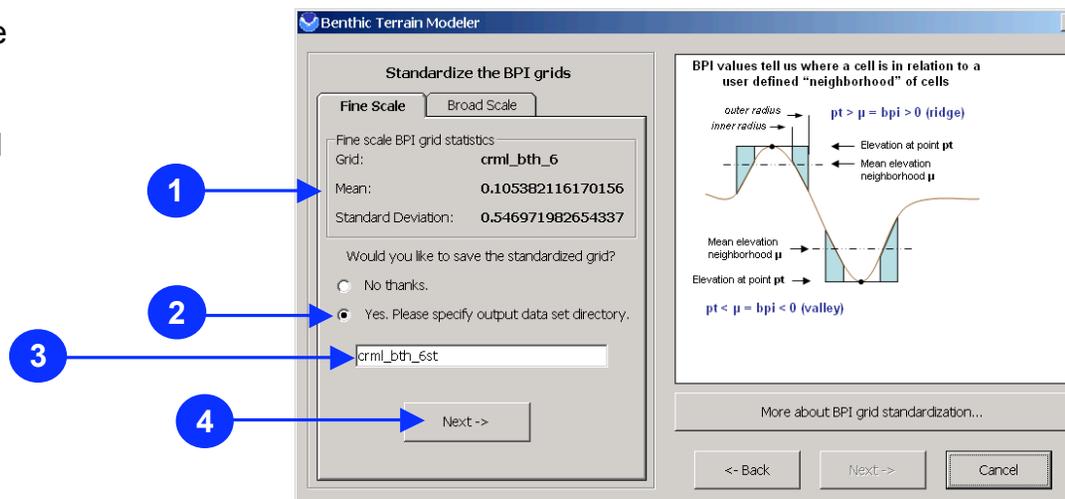


Benthic Terrain Modeler

Standardizing BPI Grids

Create standardized grids for both the fine and broad scale grids.

- 1 Review the statistics for the fine scale BPI grid
- 2 Specify output data set
- 3 Specify the name of the output grid as ***crml_bth_6st***
- 4 Click **Next ->** to activate the Broad Scale BTP Tab
- 5 Repeat the three steps above to set the parameter for broad scale BPI grid standardization. Name the output grid ***crml_bth_10s***
- 6 Click **Submit** to start the standardization process
- 7 Click **Next ->** to move on the to the next window



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Classification Dictionary

Once BPI data sets been standardized, the next step is to classify the standardized BPI to various benthic zones and/or structures. Classification is based on BPI parameters, slope and depth. You can specify an existing Classification dictionary, or you can create a new dictionary. We will use an existing dictionary

Upon initialization, the Data Dictionary Editor Tool will load an empty, default classification dictionary (defdict.xml) that the user can expand and modify.

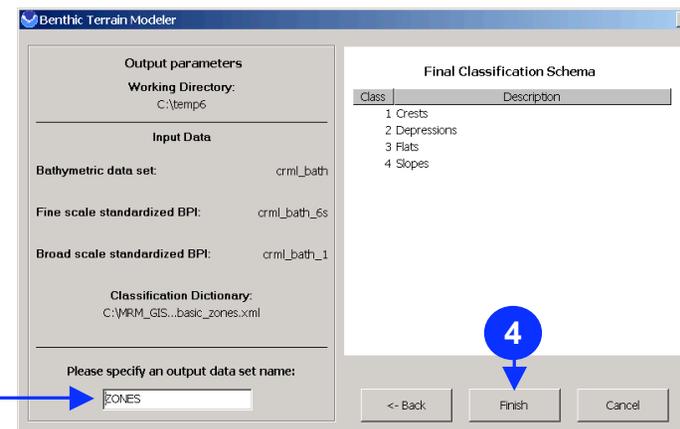
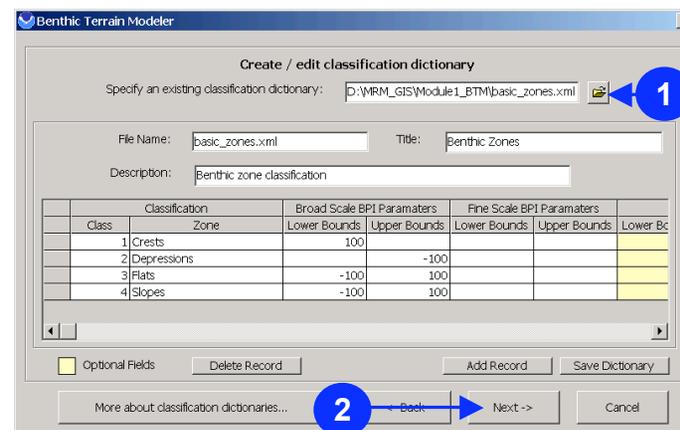
1 We will use a previously created classification dictionary, click on the **Open File** button and navigate to the **Module1_BTM** directory and select the **basic_zones.xml** file.

2 Click the **Next ->** button

3 Specify the name of the new grid

4 Click **Finish**

5 Add the data to your map



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Examine the output data and review questions

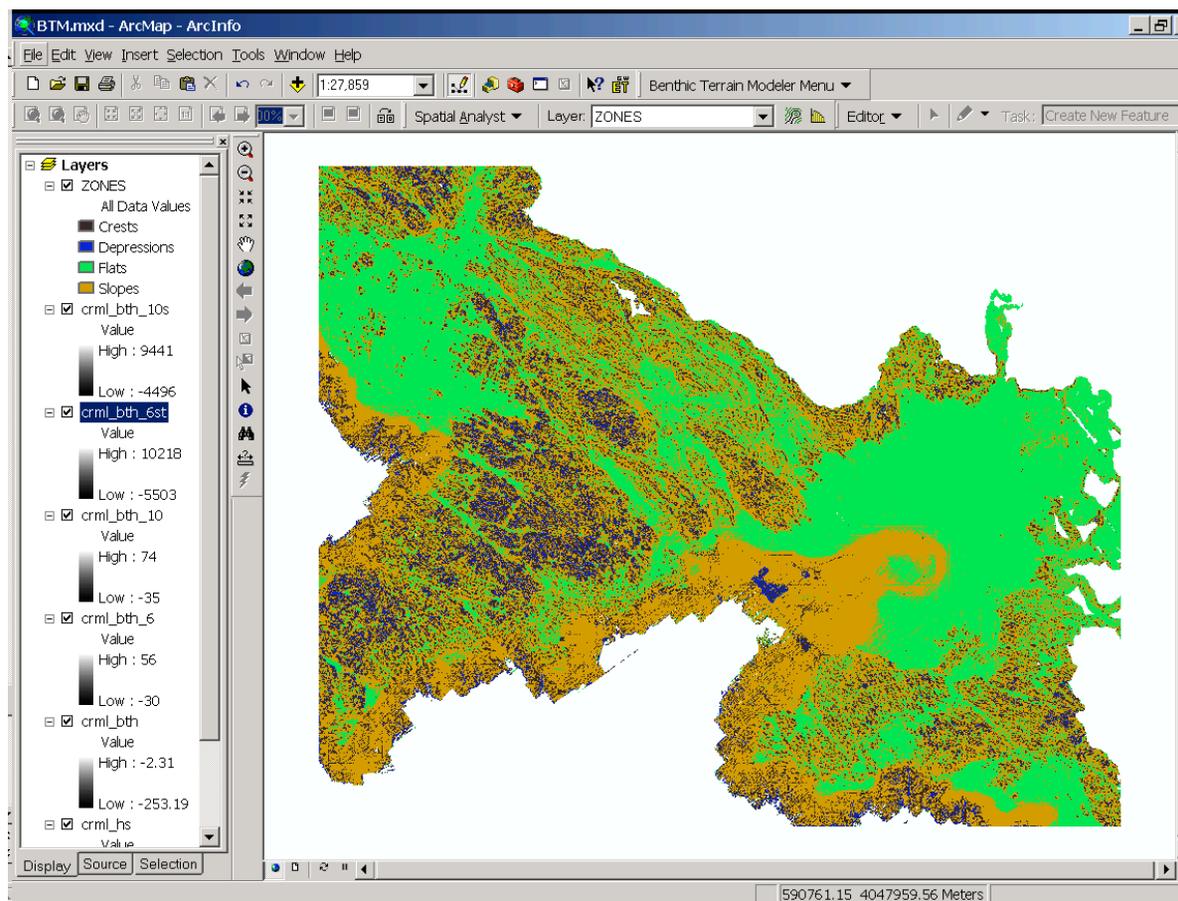
Examine the **ZONES** layer in the Table of Contents section of the application window. The **ZONES** grid has been classified and symbolized to depict areas that are crests, depressions, flats and slopes.

Examine the intermediate data layers created to produce the final ZONES layers.

Which grid layer represents seafloor depth?

What is the difference between crml_bth_10 and crml_bth_6?

What is the difference between crml_bth6 and crml_bth6st?



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Rugosity

The last step will be to create a rugosity grid.

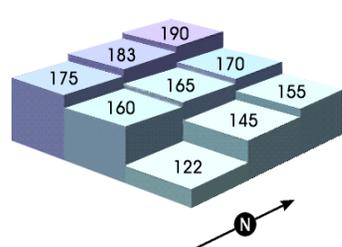
Rugosity can be best defined as the ratio of surface area to planar area. Basically, rugosity is a measure of terrain complexity or the "bumpiness" of the terrain. In the benthic environment, rugosity can be used to aid in the identification of areas with high biodiversity, depending on the scale of the input bathymetry.

The BTM uses a process developed by Jeff Jenness to derive rugosity from an input bathymetric data set. This novel methodology creates an output that is similar to a Triangulated Irregular Network (TIN), but does not require the ArcGIS 3D Analyst extension for its creation (figure 1). Similar to BPI data set creation, rugosity derivation relies, in part, on a neighborhood analysis using a 3 grid cell by 3 grid cell neighborhood. An algorithm is passed through the Raster Map Algebra Operation object within Spatial Analyst that calculates the planar distance between the center point of the center cell and of each of the eight surrounding cells in the neighborhood.

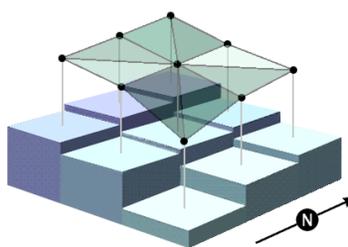
Next, using the Pythagorean Theorem, the surface distance is calculated for each planar distance using the difference in elevation between the cells. The result of this function is sixteen separate grid data sets with each cell value equal to this surface distance. The next step in the process is to calculate the area formed by three adjacent sides. The result is eight triangular surface area grids. These grid datasets are combined to obtain a surface area data set for the input bathymetric data set. The final step in the process is to create a data set that represents the ratio of surface area to planar area. This final data set represents rugosity for the study area.

210	190	170	155	140	135
204	183	165	145	125	120
200	175	160	122	110	100
208	187	165	150	126	120

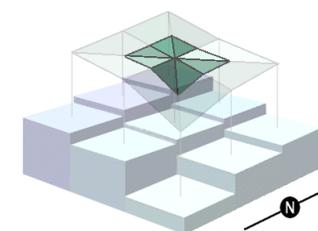
Surface area based on elevations of 8 neighbors



3D view of grid



Center pts of 9 cells connected
To make 8 triangles



Portions of 8 triangles
overlapping center cell used for
surface area

Graphics courtesy of Jeff Jenness, Jenness Enterprises, and Pat Iampietro, California State University, Monterey Bay

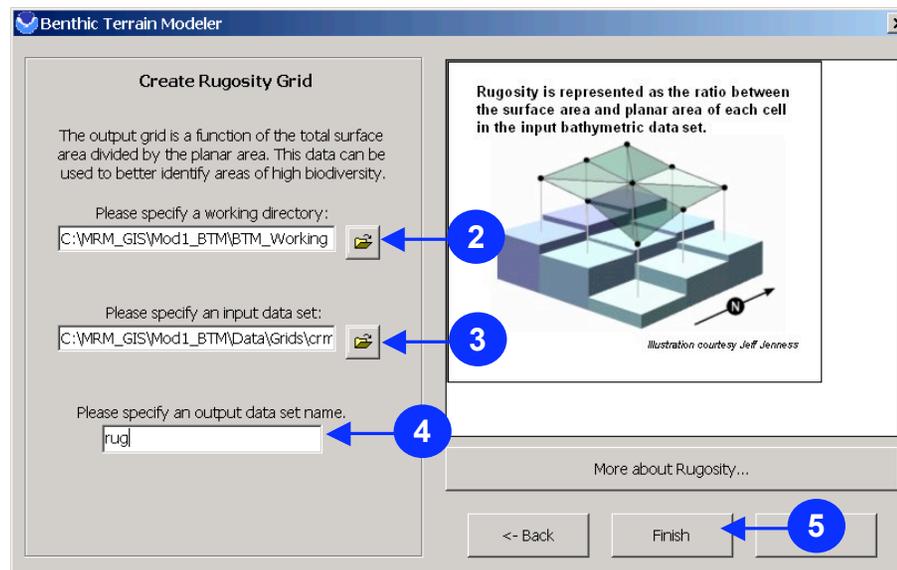
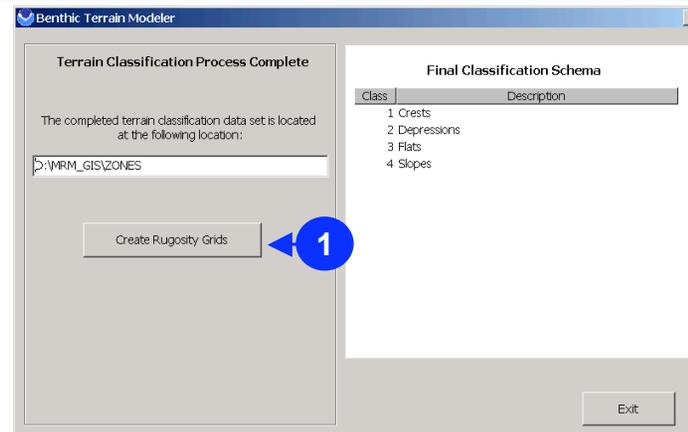


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Rugosity

- 1 Click on the **Create Rugosity Grids** button
- 2 Set your working directory to **Mod1_BTM\BTM_Working**
- 3 Select the bathymetric grid you will be using as the input data. Navigate to the **Mod1_BTM\Data** folder and select **crml_bth** grid
- 4 Specify the name of the output data as **rug**
- 5 Click **Finish** to create the rugosity grid

Add the data to your map



Benthic Terrain Modeler

Examine the output data and review questions

Examine the ***rug*** layer in the Table of Contents section of the application window. Classify the rug layer using the slope (red to blue) color ramp located in the layers property symbology tab. The red area of the rug grids are areas that are highly “bumpy”.

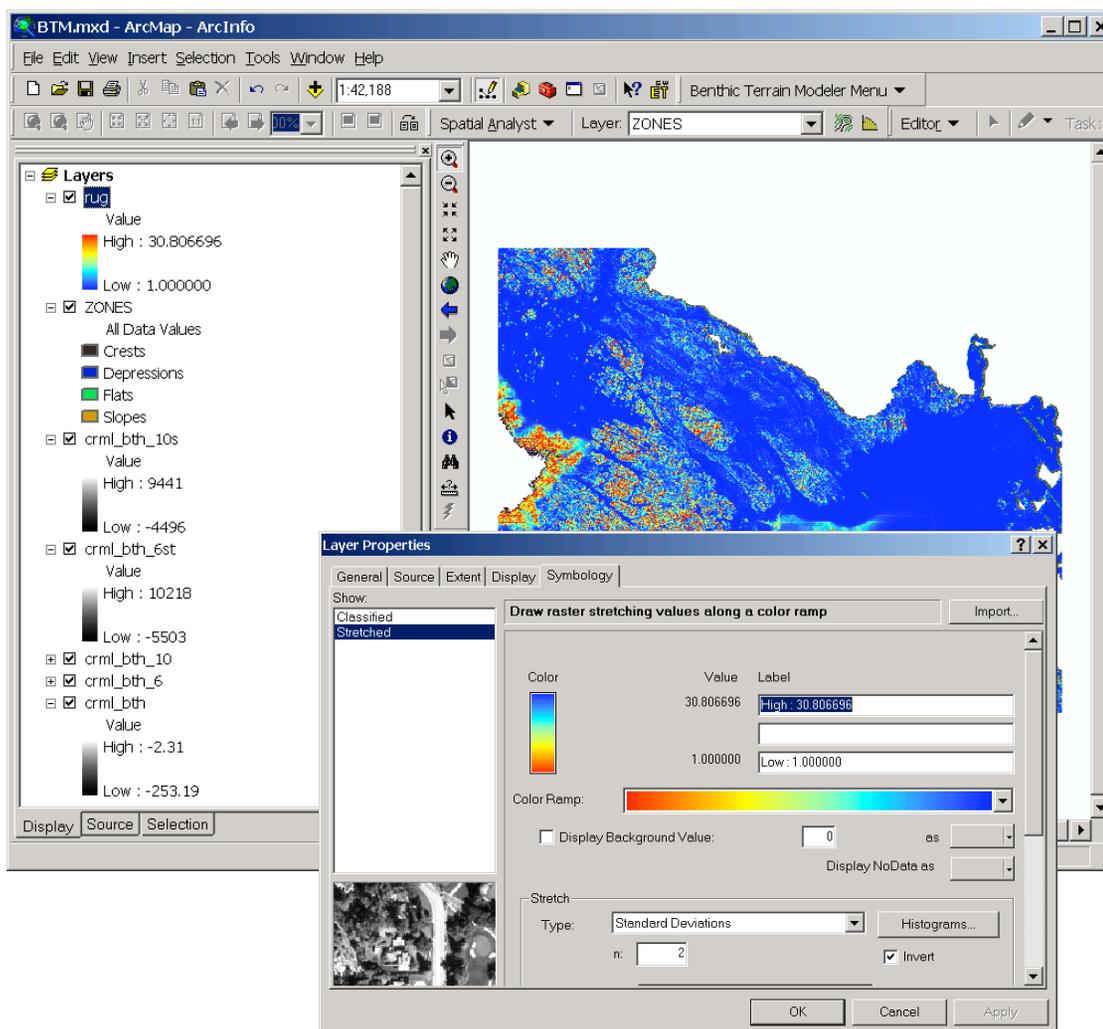
Right-click the ***rug*** layer and click on ***Properties...***

Click on the ***Symbology Tab***

Select the ***Stretched***

Select the slope color ramp from the Color Ramp drop down menu.

Check the ***Invert*** box



Benthic Terrain Modeler

Examine the output data

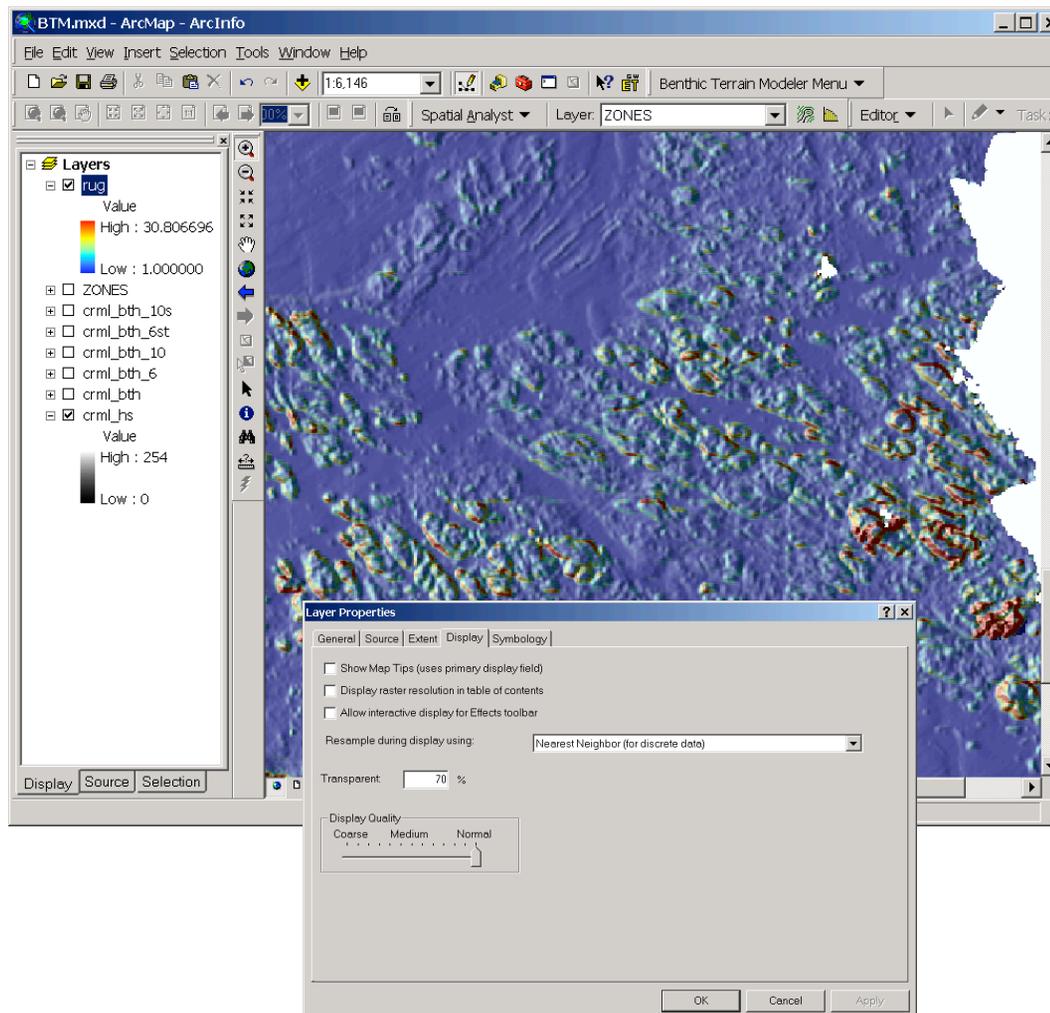
Examine the **rug** layer with the hillshade layer.

Uncheck all the layers except the rug and crml_hs layers.

Right-click on the rug layer and click on Properties...

In the Display tab, set the transparency to 70%.

Use the zoom tool to examine the rug layer. Do the rugosity values correspond to flat areas and areas that are high bottom variations (bumpy)?



Module Summary

In this module you used the Benthic Terrain Modeler tool to create a bathymetric position grid. This grid was used with a classification dictionary to create a new grid depicting various benthic terrain zones.

We also created a rugosity grid to measure the bottom complexity or “bumpiness”. These data layers can be used to examine the physical characteristics of the seafloor.

Some marine organisms are associated with different types of seafloor characteristics. For example, certain rockfish species are found on or near hard and highly complex structures. Other organisms such as certain flatfish species are associated with sandy flat bottoms. Using the BTM, we can quantitatively analyze the seafloor using multibeam bathymetric grids and begin examining species-habitat associations.

Project Team:

Dawn Wright, Oregon State University (OSU) Department of Geosciences
Emily Lundblad, OSU Department of Geosciences, now at Joint Institute for Marine and Atmospheric Research, Coral Reef Ecosystem Division at NOAA Fisheries
Emily Larkin, OSU Department of Geosciences
Ronald Rinehart, OSU Department of Geosciences
Lori Cary-Kothera, NOAA Coastal Services Center
Kyle Draganov, I.M. Systems Group, Inc.
Joshua Murphy, I.M. Systems Group, Inc.

References

The BTM was created as part of a cooperative agreement between Department of Geosciences at Oregon State University and the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center.

Related Web Sites

Davey Jones' Locker (Oregon State University)

<http://dusk.geo.orst.edu/djl/>

NOAA Coastal Services Center

<http://www.csc.noaa.gov/>

Bathymetric Grids were produced by The Seafloor Mapping Lab at California State University, Monterey Bay

<http://seafloor.csumb.edu/>



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About the Instructor

Dawn Wright received her Ph.D. in Physical Geography and Marine Geology from the University of California-Santa Barbara in 1994. She is currently professor of Geography and Oceanography at Oregon State University. Dr. Wright's research interests include geographic information science, marine geography, tectonics of mid-ocean ridges, and the processing and interpretation of high-resolution bathymetric, video, and underwater photographic images. She has completed oceanographic fieldwork in some of the most geologically-active regions of planet, including the East Pacific Rise, the Mid-Atlantic Ridge, the Juan de Fuca Ridge, the Tonga Trench, volcanoes under the Japan Sea and the Indian Ocean, and has also dived three times in the deep submergence vehicle Alvin. Dr. Wright serves on the editorial boards of the International Journal of Geographical Information Science, Transactions in GIS, and Geospatial Solutions, as well as on the National Academy of Sciences' National Needs for Coastal Mapping and Charting Committee. Her most recent books include "Undersea with GIS" (published by ESRI Press, 2002), "Marine and Coastal Geographical Information Systems" (with Darius Bartlett, Taylor & Francis, 2000), and "Place Matters: Geospatial Tools for Marine Science, Conservation, and Management in the Pacific Northwest" (with Astrid Scholz, forthcoming from Oregon State University Press in April 2005).

Dr. Wright is the past recipient of an NSF CAREER award, Excellence in Mentoring awards from the OSU College of Oceanic & Atmospheric Sciences, and Woman of the Year in Education from Clarity magazine.

