Map hurricane storm surges

Use global elevation data to predict how storm surges will flood coastlines.

Duration	Difficulty
30mins	Beginner

A storm surge is an abnormal rise in sea level caused by the high winds and low pressure of a storm pushing water onto land. Storm surges are usually the most destructive and deadly aspects of hurricanes, and when such a surge floods a dense city, the toll can be particularly high.

You can use elevation data to map storm surges and predict which areas will flood the next time a hurricane hits. This tutorial focuses on New York City as a study area, but the same workflow can be repeated for any coastal area.

This tutorial, was last tested on May 9, 2025, using ArcGIS Pro 3.5. If you're using a different version of ArcGIS Pro, you may encounter different functionality and results.

Requirements

- ArcGIS Pro (see options for software access)

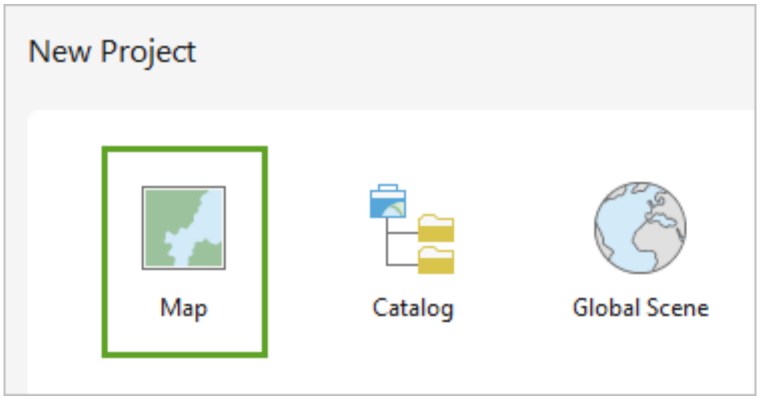
Create a new project and obtain elevation data

To map any kind of flooding, you'll need to know the elevation of the land in your study area. ArcGIS Living Atlas of the World provides global elevation data you can use to conduct your analysis. You'll create a project in ArcGIS Pro and acquire elevation data.

1. Open ArcGIS Pro.

   > **Note:**
   > If you don't have access to ArcGIS Pro or an ArcGIS organizational account, see options for software access.

2. On the start page, under **New Project**, click **Map**.

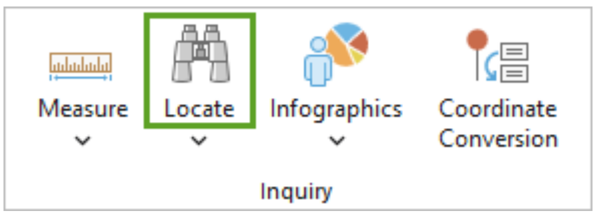


The **New Project** window appears.

3. In the **New Project** window, for **Name** type StormSurge and click **OK**.

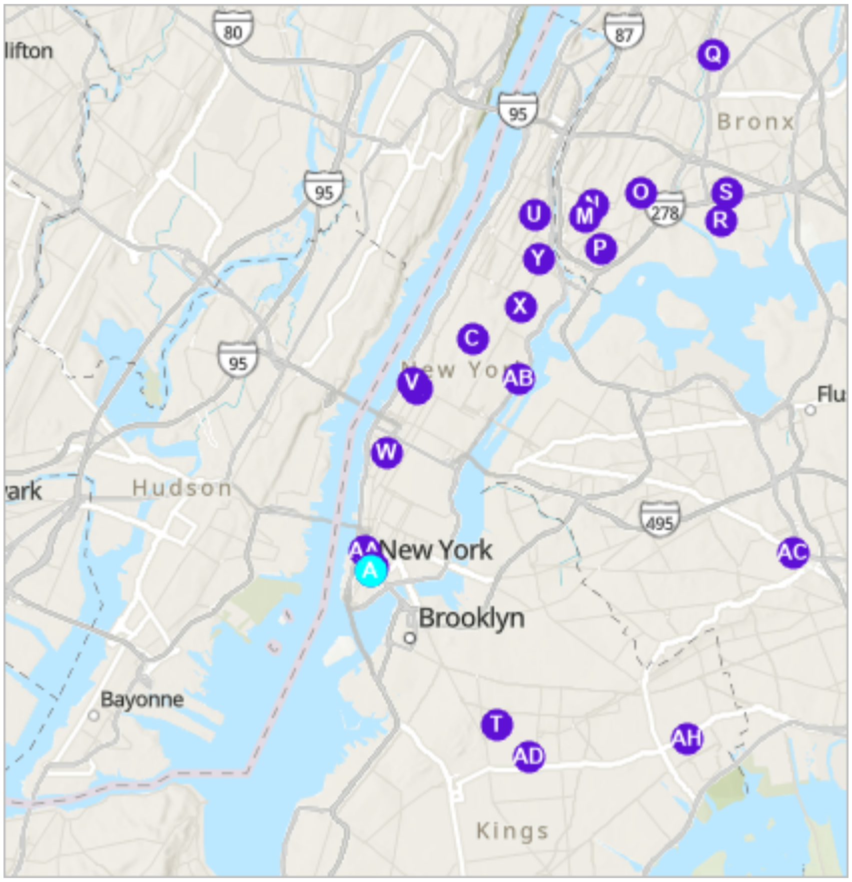
   The map opens.

4. On the ribbon, click the **Map** tab. In the **Inquiry** group, click the **Locate** button.



5. In the **Locate** pane, type New York City and press Enter.

   The map displays New York City.



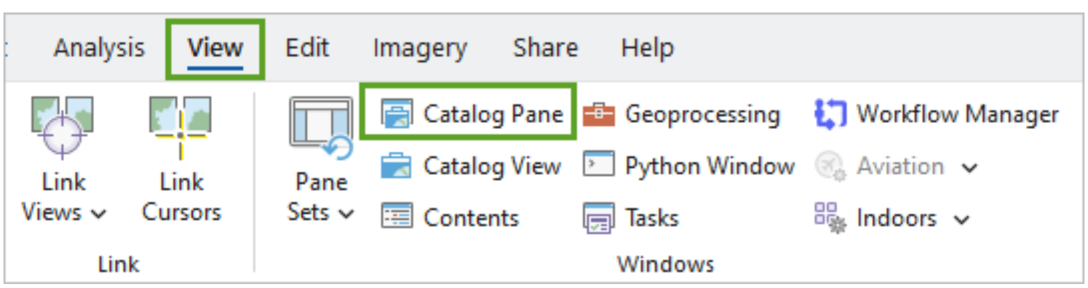
The default Topographic basemap helps you identify the different areas of New York City, such as Manhattan.

6. Close the **Locate** pane.

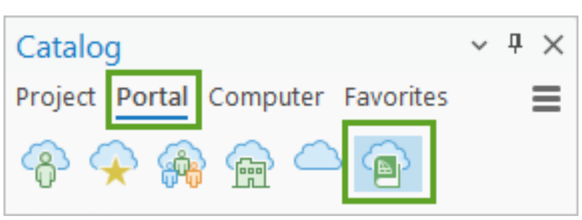
7. Zoom in to Manhattan with the mouse wheel button, and pan to obtain the extent displayed in the example image.

The extent shows the island of Manhattan, as well as parts of other New York City boroughs like Brooklyn to the south and Queens to the east. Next, you'll add the elevation data.

8. On the ribbon, click the **View** tab. In the **Windows** group, click **Catalog Pane**.



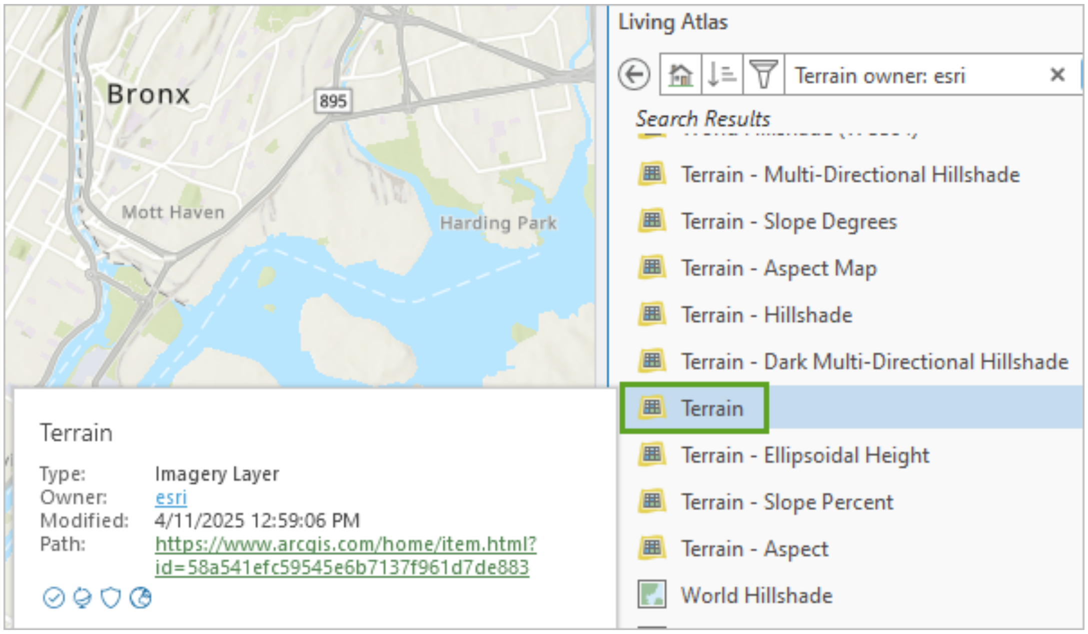
9. In the **Catalog** pane, click the **Portal** tab, and click the **Living Atlas** button.



ArcGIS Living Atlas is a curated collection of geographic information, including maps, apps, and data layers.

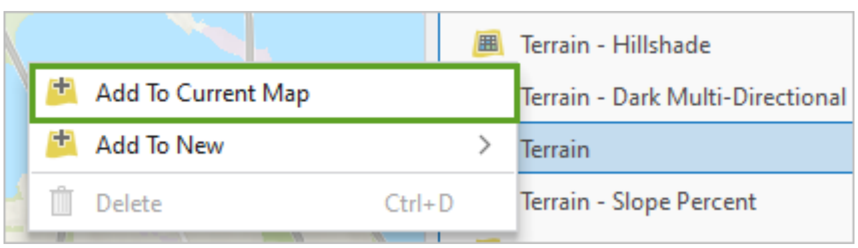
10. In the **Catalog** pane, in the search box, type Terrain owner:esri, and press Enter.

The list of search results contains an imagery layer named **Terrain**. It provides elevation data for the entire world at different resolutions as you zoom in and out.

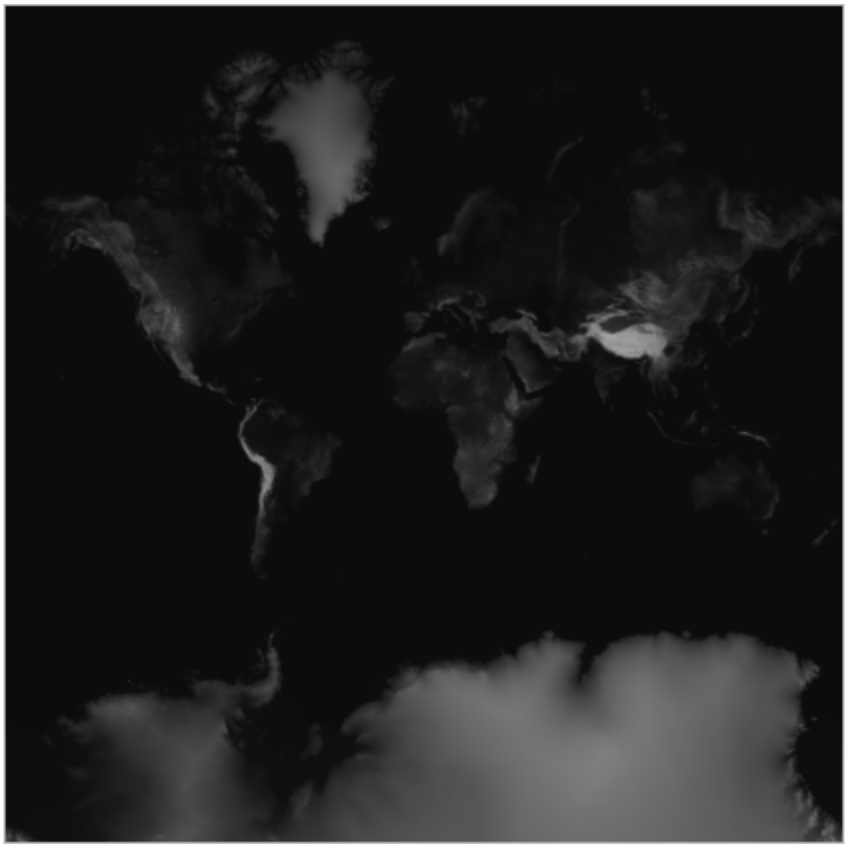


> **Note:**
>
> You can learn more about an item by pointing to its name in the results list.

11. Right-click the **Terrain** layer and choose **Add To Current Map**.

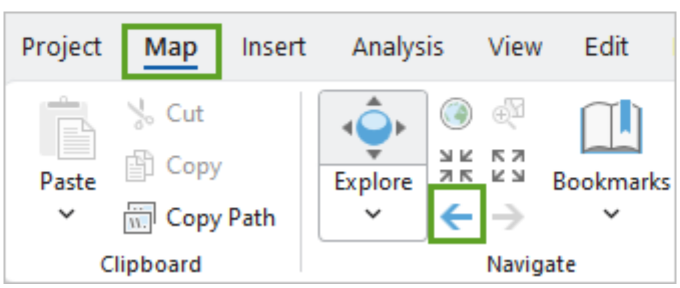


The layer is added to the map. The map extent changes to show the raster layer that covers the entire world.



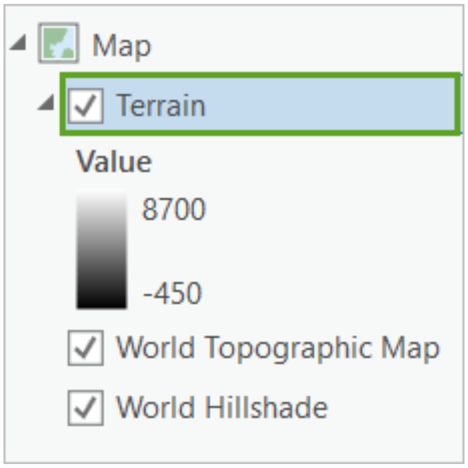
A raster layer is made of a grid where each cell is called a pixel and has a numeric value. In the case of the **Terrain** layer, the value of each pixel represents elevation in meters. The pixels with the highest values, such as the highest mountain peaks, appear in white. The pixels with the lowest values, such as land depressions below sea level, appear in dark gray or black.

12. On the ribbon, on the **Map** tab, in the **Navigate** group, click **Previous Extent** once to return the map extent to New York City.



The entire map appears black. This is because the elevation of New York is generally low when compared to the entire world. You'll change the display of the terrain layer to better see the differences in elevation in the New York City area.

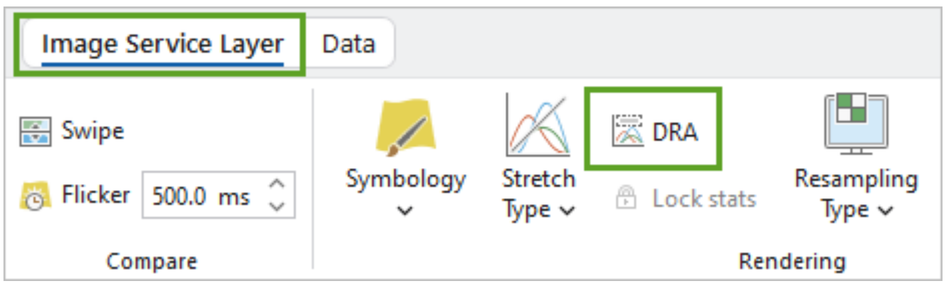
13. In the **Contents** pane, verify that the **Terrain** layer is selected.



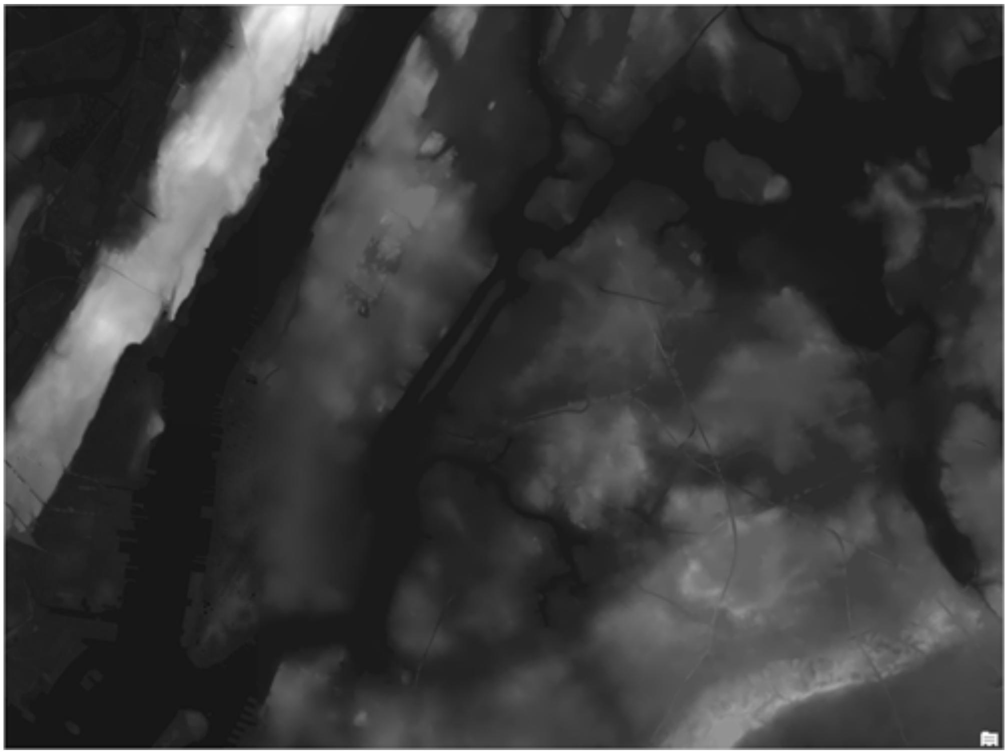
Note:

The selected layer is highlighted in blue.

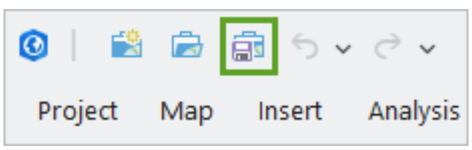
14. On the ribbon, click the **Image Service Layer** tab. In the **Rendering** group, click **DRA**.



DRA stands for dynamic range adjustment. In this mode, the color tones on the map are solely strictly based on the range of values in the current map extent. After a few moments, the map is updated, and you can now discern the local variation in elevation values visually.



15. On the **Quick Access Toolbar**, click **Save** to save the project.

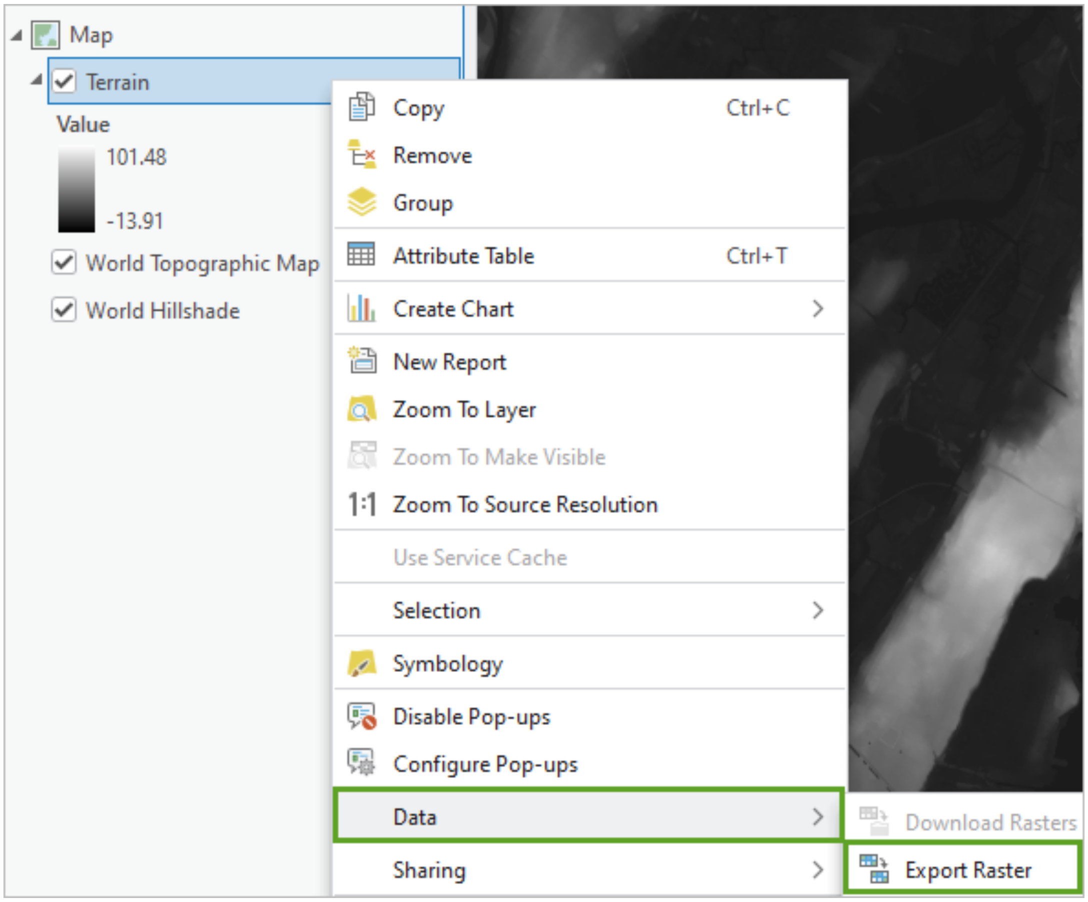


In this section, you created a project in ArcGIS Pro and added the **Terrain** imagery layer from ArcGIS Living Atlas, which provides elevation data for the whole world.

Export an elevation raster

Next, you'll export a file-based raster from the **Terrain** imagery layer that only covers your area of interest, so you can perform analysis with it.

1. In the **Contents** pane, right-click the **Terrain** layer, point to **Data**, and choose **Export Raster**.

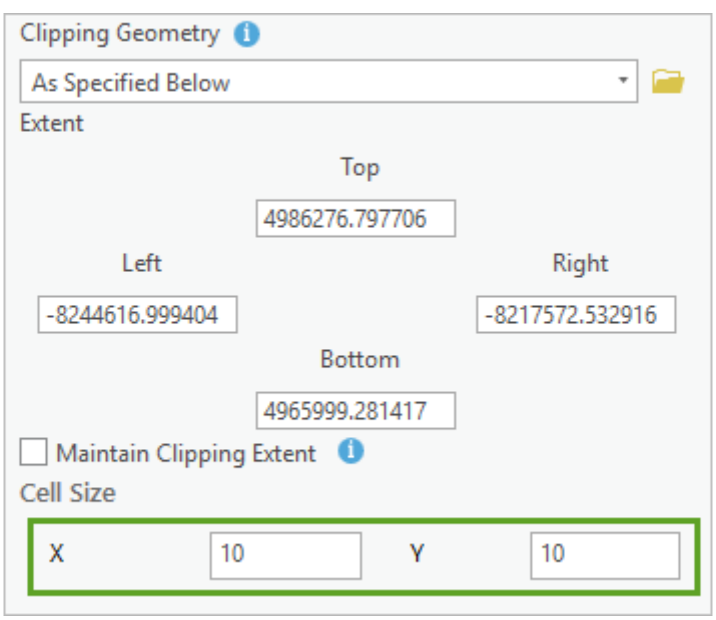


The **Export Raster** pane appears. You do not want to export a raster of the entire world, only for New York City.

2. Make sure your map is still centered on Manhattan as before. In the **Export Raster** pane, for **Clipping Geometry**, choose **Current Display Extent**.

   The four coordinates that define the bounding box to clip the raster update.

3. Under **Cell Size**, change both **X** and **Y** to 10.

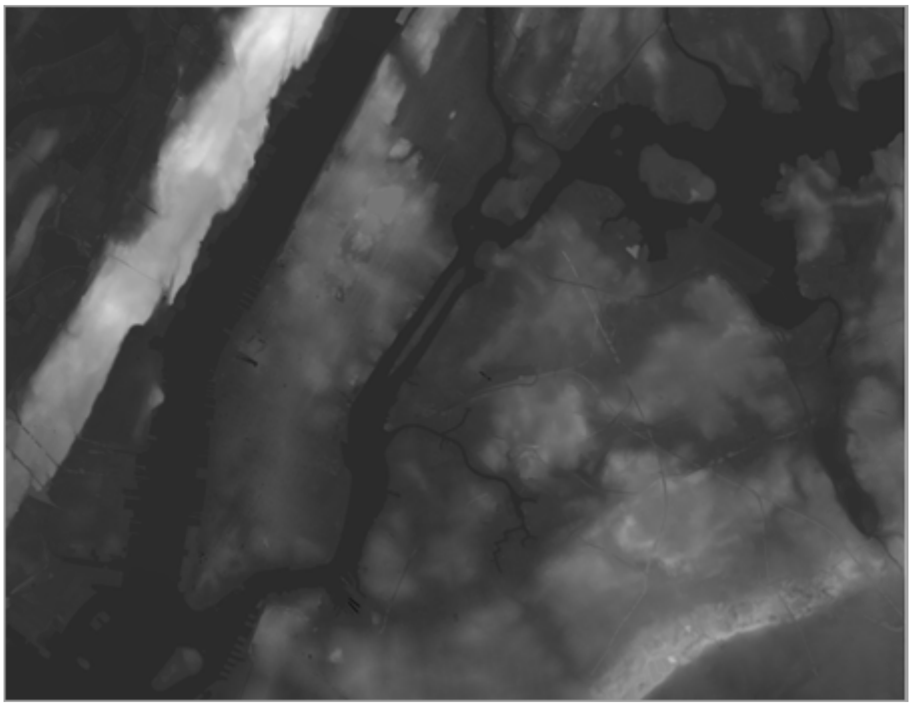


The cell size determines the resolution of the output raster. In this case, each pixel will cover a piece of the earth that is 10 meters by 10 meters, or 100 square meters.

4. Accept all of the other defaults and click **Export**.

> **Tip:**
> If you receive a warning that the output raster dataset exceeds the size limitation, you can either zoom in so your map covers a smaller area or increase the cell size.

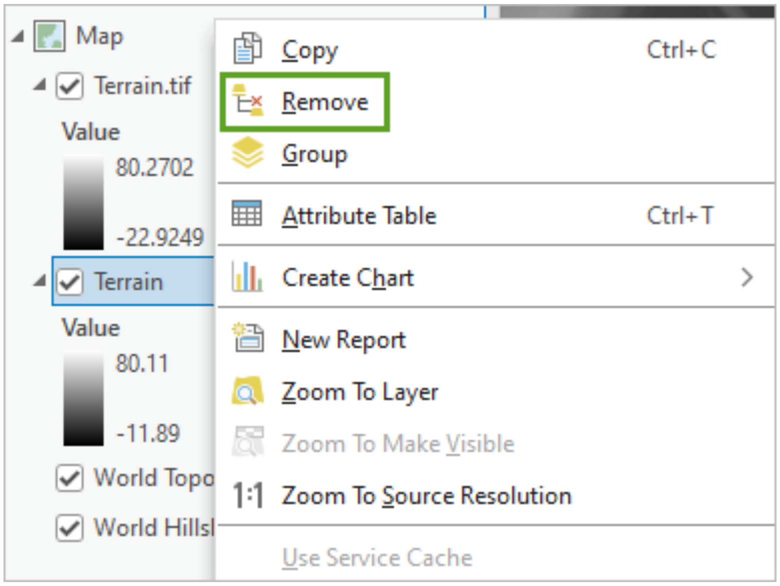
After a few moments the new raster, **Terrain.tif**, is added to the map. It is drawn with a range of black to white tones, using DRA rendering, like its source, the **Terrain** layer.



5. Close the **Export Raster** pane.

You'll now remove the original world-wide **Terrain** layer, as you don't need it any longer.

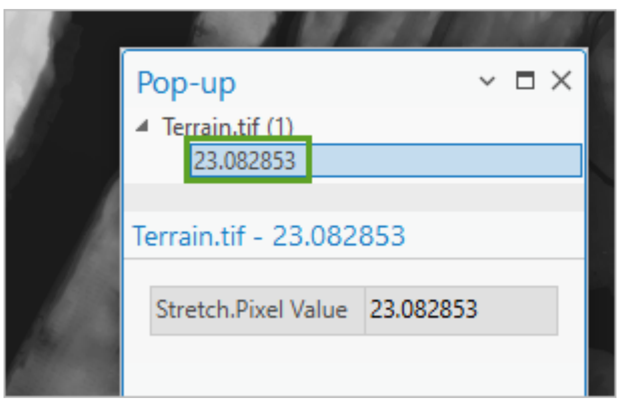
6. In the **Contents** pane, right-click the **Terrain** layer and choose **Remove**.



The **Terrain** layer disappears from the **Contents** pane. Next, you'll check some of the elevation values on your map.

7. On the map, click anywhere within the **Terrain.tif** layer.

   The **Pop-up** pane appears, displaying the elevation value for the specific pixel you clicked, for instance **23.08** meters.



8. Click several other points to see how the elevation varies across your area of study.
9. Close the pop-up.
10. Press Ctrl+S to save the project.

In this section, you saved a clipped raster, which provides elevation data for your area of study.

Map a 3-meter surge

Now that you have elevation data, you can use it to find low-lying coastal lands and predict which areas of New York City may flood when hit with a hurricane. First, you'll start with the scenario where a hurricane produces a water surge of 3 meters (or 9.8 feet). Considering that the water surrounding New York sits at an elevation of 0 meters, all the areas in the city that have an elevation of up to 3 meters would be flooded.

To find all areas with an elevation of 3 meters or less, you'll use the **Remap** tool applied to the **Terrain.tif** layer.

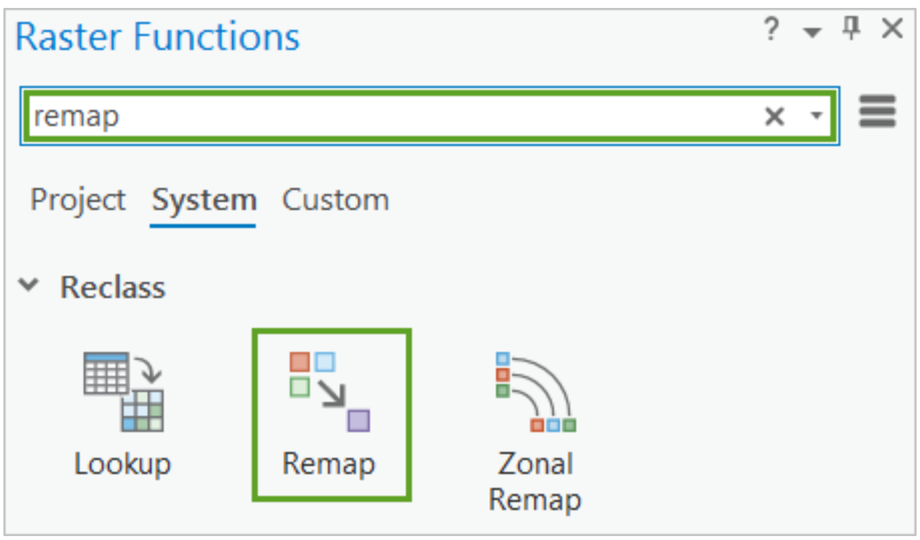
1. On the ribbon, click the **Analysis** tab. In the **Raster** group, click the **Raster Functions** button.

The **Raster Functions** pane appears.

Note:

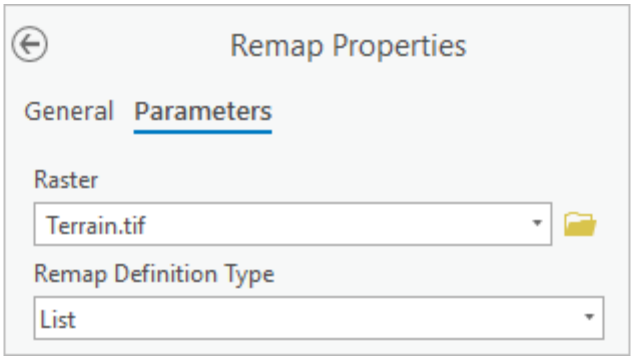
Raster functions are operations that apply processing directly to the pixels of raster datasets in memory, without writing out a new raster to disk. Since no intermediate datasets are created, these processes can be applied quickly.

2. In the **Raster Functions** pane, search for and open the **Remap** tool.

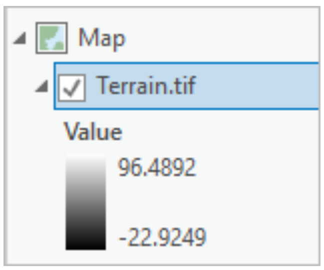


The **Remap Properties** pane appears. The **Remap** tool allows you to change or reclassify the pixel values of a raster and produce a new raster layer with the new values.

3. In the **Remap Properties** pane, click the **Parameters** tab, and for **Raster**, choose **Terrain.tif**. For **Remap Definition Type**, keep **List**.



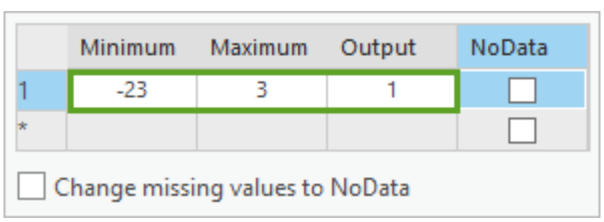
In the **Remap** table, you'll define the reclassification rules. Based on the legend for the **Terrain.tif** layer in the **Contents** pane, you can see that the lowest value possible for that layer is about **-22.9** meters and the highest is **96.5** meters.



Tip:

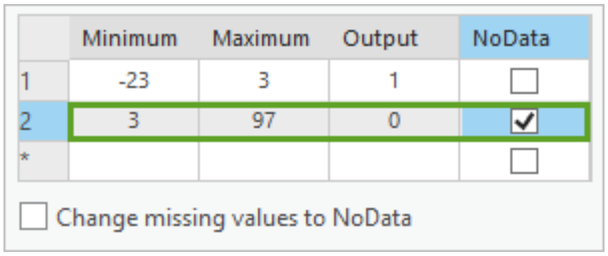
Based on the exact map extent you chose, the lowest and highest values for your layer might be somewhat different. Consequently, you should adapt the values in the two steps below.

4. In the **Remap Properties** pane, click the **Remap** table's row 1 cell for **Minimum**. Enter -23 (or another number lower than your minimum value) for **Minimum**, 3 for **Maximum**, and 1 for **Output**.



This rule means that any pixel with a value between -23 and 3 meters should get a value of 1 in the new raster. Those are the flooded areas.

5. For the second rule, click the star to create a new row. Then, in the cells of the new row, enter 3 for **Minimum**, and 97 (or another number higher than your maximum value) for **Maximum**. Leave 0 for **Output** and check the **NoData** check box.



	Minimum	Maximum	Output	NoData
1	-23	3	1	☐
2	3	97	0	☑
*				☐

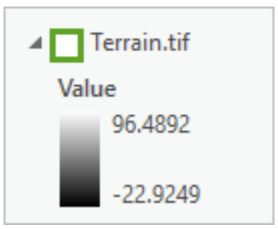
☐ Change missing values to NoData

This rule means that any pixel with a value between 3 and 97 meters should have no data. Those are the areas that are not flooded, and you are not interested in them, so you won't represent them with any data.

6. Click **Create New Layer**.

   A new layer, **Remap_Terrain.tif**, symbolized in gray, is added. You'll make some changes to the display to make the layer easier to see. First, you'll turn off the elevation layer.

7. In the **Contents** pane, turn off the **Terrain.tif** layer by unchecking the box.

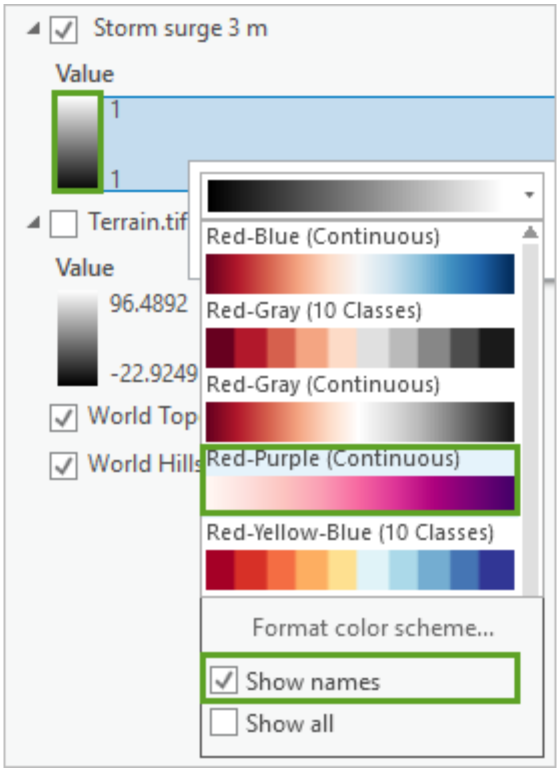


   You'll rename the new layer.

8. In the **Contents** pane, click the **Remap_Terrain.tif** layer name to select it, and click it again to enter the edit mode. Type Storm surge 3 m and press Enter.

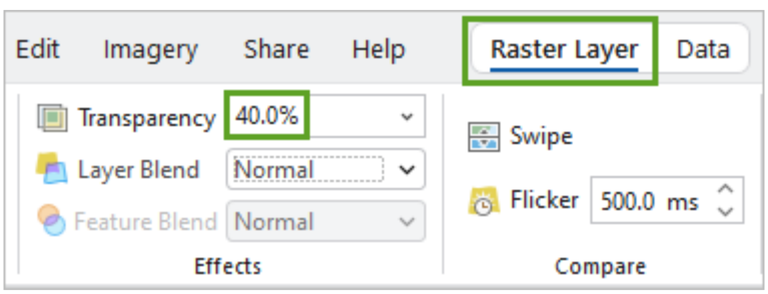
   Next, you'll change the layer's symbology.

9. Right-click the color ramp for the **Storm surge 3 m** layer, expand the drop-down list, and check **Show Names**. Scroll down the list of color ramps, and choose the **Red-Purple (Continuous)** ramp.

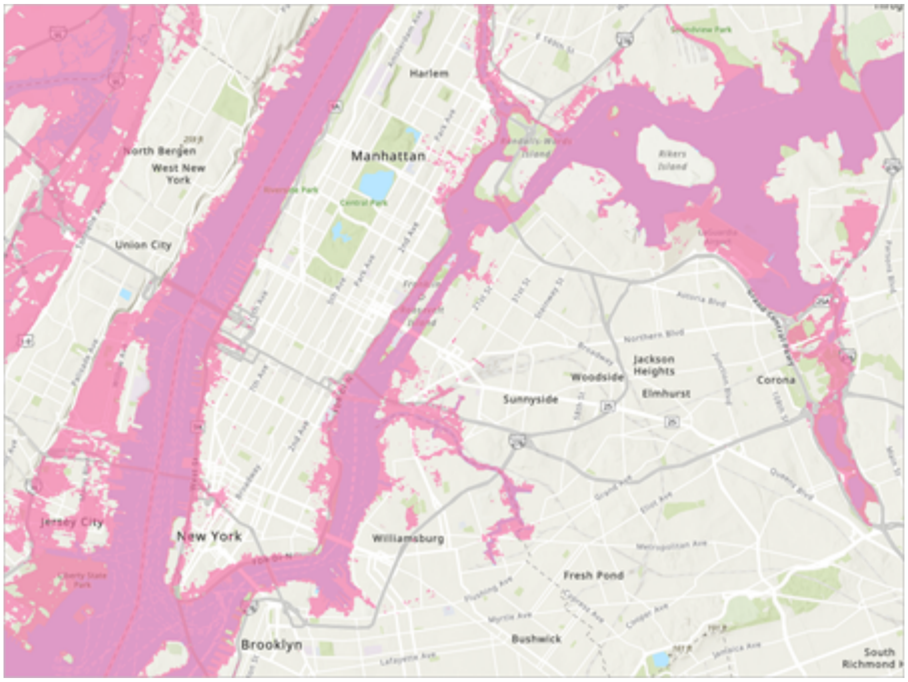


Because the only pixel value in this raster is 1, only one median color from that ramp will be used, and the layer changes to a uniform pink color. Next, you'll change the transparency.

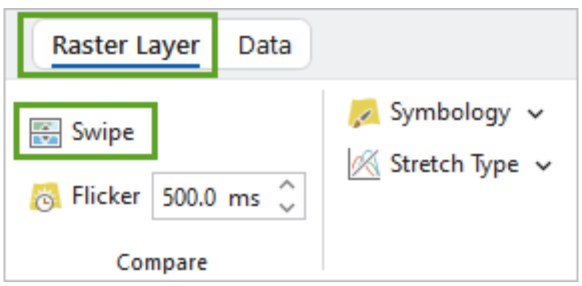
10. In the **Contents** pane, ensure that the **Storm surge 3 m** layer is selected. On the ribbon, click the **Raster Layer** tab. In the **Effects** group, set **Transparency** to **40.0%**.



The map now shows in light pink the areas of the city that may be flooded by a 3-meter storm surge.



11. On the **Raster Layer** tab, in the **Compare** group, click **Swipe**.

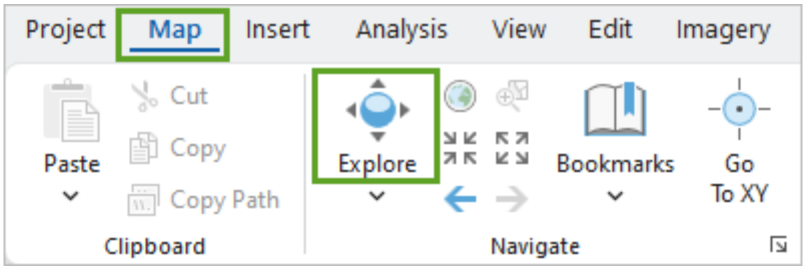


The cursor changes to a triangle, indicating the **Swipe** tool is active.

12. On the map, with the **Swipe** tool on, drag the map from side to side to reveal the basemap below and compare the flood areas to the preflood water boundaries.

You can also zoom in and pan to see in more detail which areas of Manhattan and surrounding neighborhoods appear flooded.

13. When you are done with your examination, on the ribbon, on the **Map** tab, in the **Naviga**[illegible], click the **Explore** button to exit swipe mode.

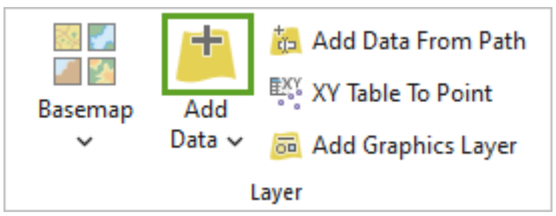


The cursor returns to its default symbol, indicating the **Swipe** tool is no longer active.

In October 2012, Hurricane Sandy passed through Jamaica, Cuba, and Bermuda. It caused extensive damage to most of the East Coast of the United States as it traveled north, before combining with a separate high-pressure storm from the north and making landfall in New York and New Jersey. More than 230 people were killed in the Caribbean, the United States, and Canada.

Next, you'll compare your 3-meter storm surge map to a map of actual flooding from Hurricane Sandy.

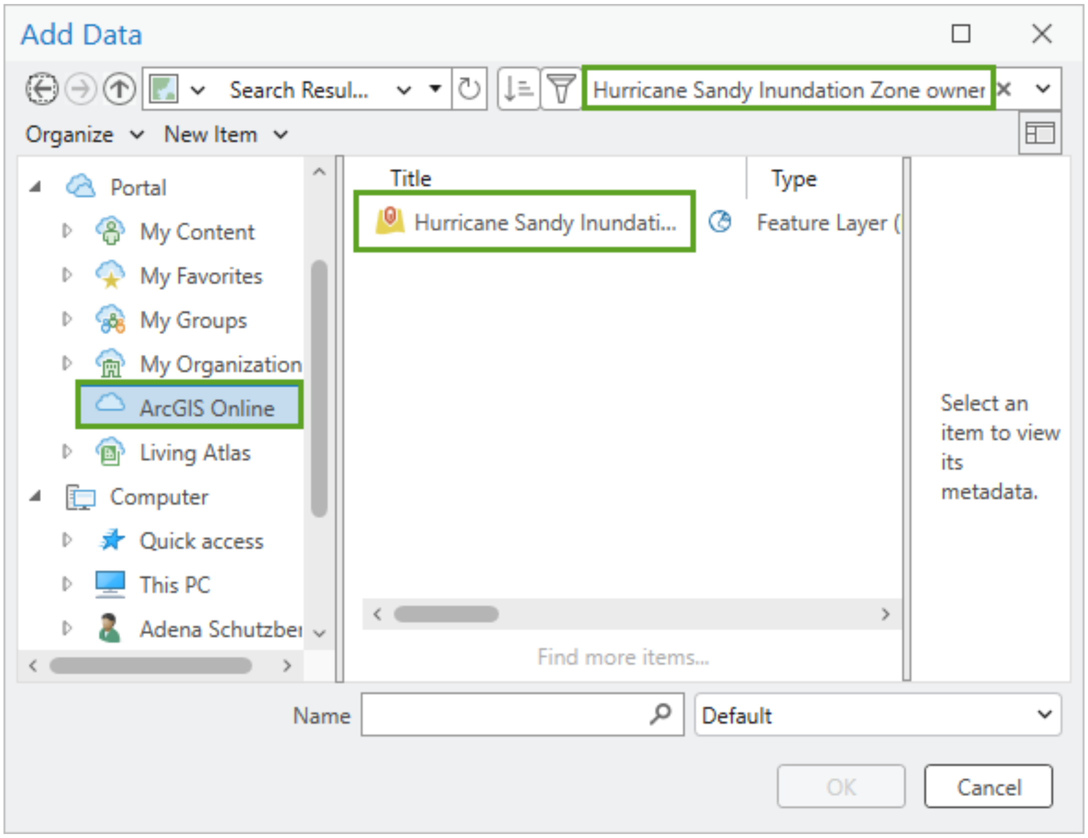
14. On the **Map** tab, in the **Layer** group, click **Add Data**.



The **Add Data** window appears.

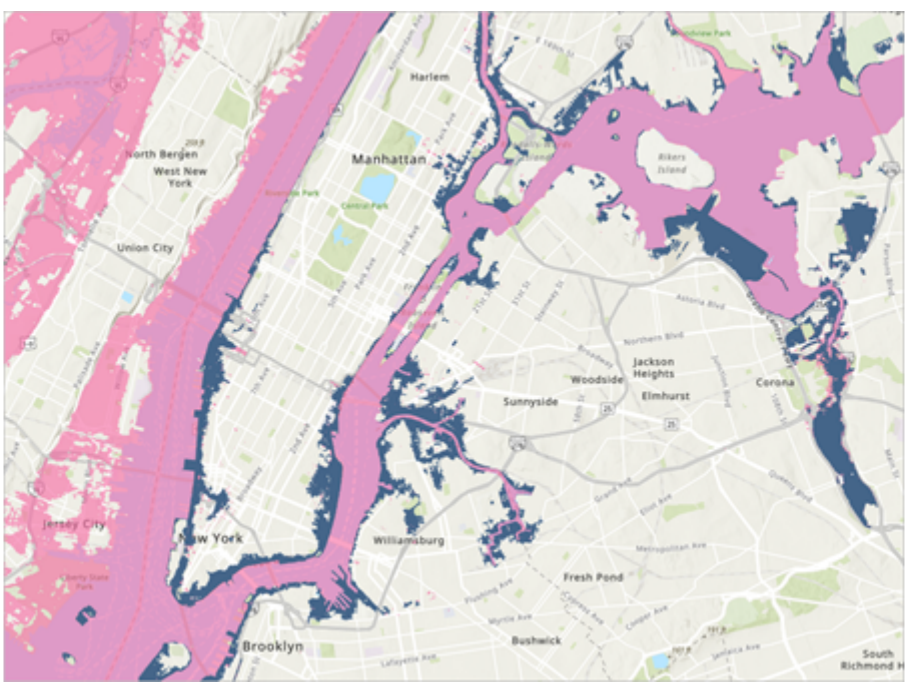
> **Note:**
> If you are an ArcGIS Enterprise user, on the ribbon, in the **Map** tab, in the Layer group click the **Add Data From Path** button. In the **Add Data From Path** window, for **Path** copy and past the following URL and click **Add**: https://services2.arcgis.com/j80Jz20at6Bi0thr/arcgis/rest/services/Hurricane_Sandy_Inundation_Zone/FeatureServer/0. You can skip step 15 and 16 and continue to step 17.

15. In the **Add Data** window, under **Portal**, click **ArcGIS Online**. In the search bar, type Hurricane Sandy Inundation Zone owner: Esri_Tutorials and press Enter. Click the feature layer **Hurricane Sandy Inundation Zone**.



16. Click **OK**.

The **Hurricane Sandy Inundation Zone** layer appears on the map. This feature layer comes from the [New York City Open Data portal]() and displays the areas inundated in New York City during Hurricane Sandy in 2012.



17. In the **Contents** pane, if necessary, click the **Hurricane Sandy** layer to select it. On the ri ick the **Group Layer** tab. In the **Compare** group, click **Swipe**. Explore the map with the **Swipe** tool.

How well does your 3-meter storm surge model match the real storm surge of Hurricane Sandy? The model is fairly close, but it looks like overall the surge from Hurricane Sandy was slightly larger than 3 meters.

> **Tip:**
> The **Hurricane Sandy** layer doesn't contain any flood data for the state of New Jersey, which is just west of New York City.

18. When you're done, on the ribbon, on the **Map** tab, in the **Navigate** group, click the **Explore** button to exit swipe mode.

> **Note:**
> Optionally, you can use the **Remap** tool again to generate a 3.5-meter storm surge layer, and see if the result matches the Hurricane Sandy layer more closely.

19. Press Ctrl+S to save the project.

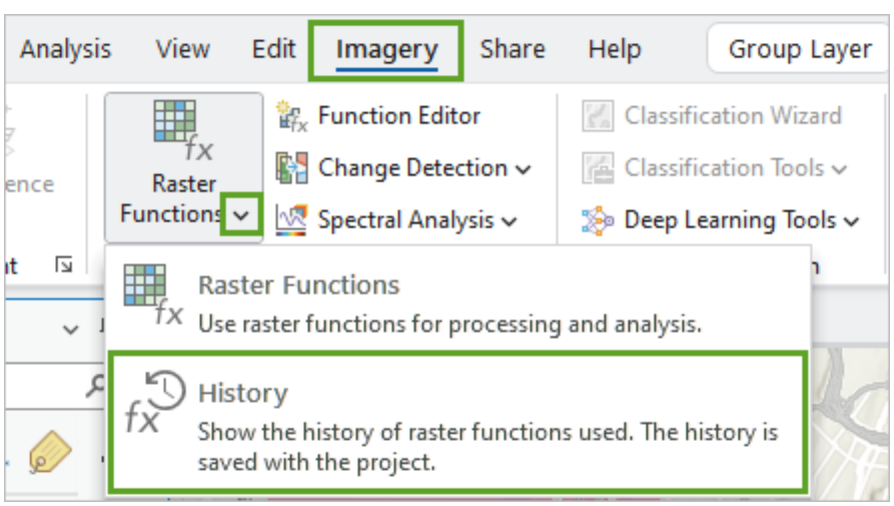
Most people in New York and New Jersey were caught by surprise by this storm, not expecting that their homes were at risk of flooding. Such a large storm had not been seen in their lifetimes. However, while a unique combination of weather factors made Sandy particularly destructive, storms with larger surges have hit the city in the past.

In this section, you used elevation data to create a flood map corresponding to a 3-meter storm surge, and then you compared it to the flood caused by Hurricane Sandy in 2012.

Map a 9-meter storm surge

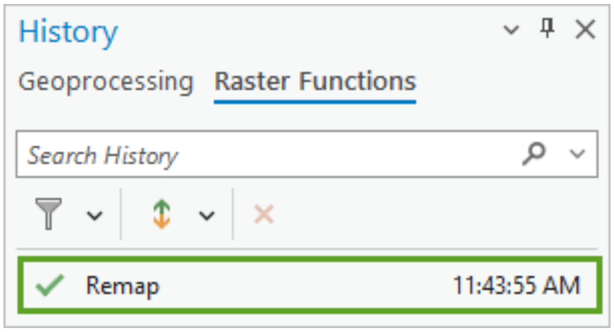
In 1893, New York City was hit by a hurricane that brought with it a 30-foot (9-meter) storm surge. This storm was powerful enough to almost completely submerge Hog Island, a former island along the Rockaway shore. Next, you'll map what such a large surge would look like in the present-day city.

1. On the ribbon, click the **Imagery** tab. In the **Analysis** group, click the **Raster Functions** drop-down arrow to expand the list, and choose **History**.



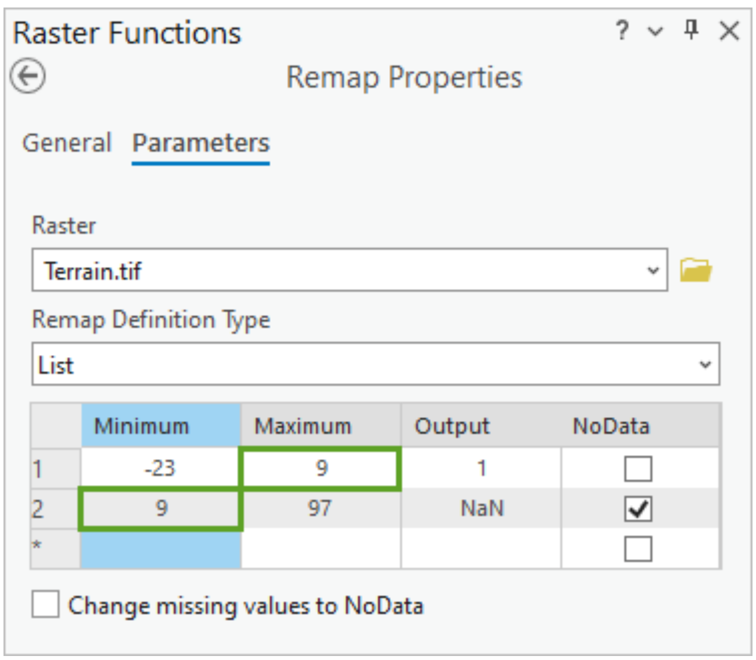
The **History** pane appears, showing the process you performed earlier in the workflow.

2. In the **History** pane, double-click **Remap**.



The **Remap** tool opens with all the information you had previously entered to create the **Storm surge 3 m** layer.

3. On the **Parameters** tab, for **Raster**, make sure that **Terrain.tif** is selected. In the table, replace the value 3 with 9 for both rules.



4. Click **Create new layer**.

A new layer, **Remap**, symbolized in gray, is added. You'll make some changes to the display to make the layer easier to see.

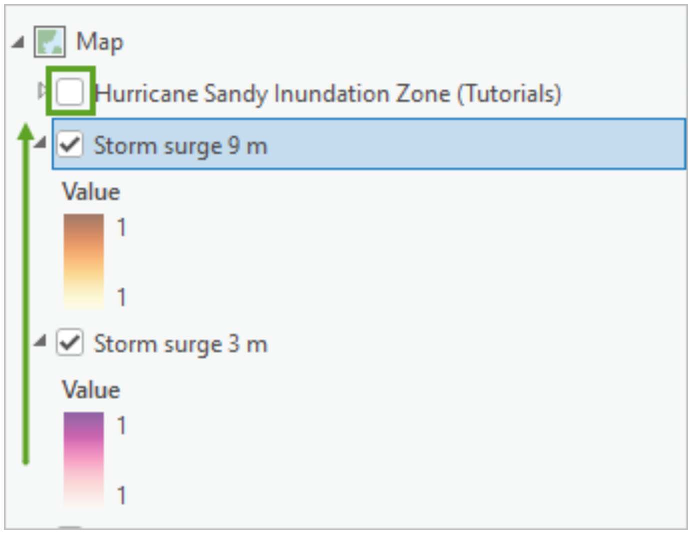
5. In the **Contents** pane, click **Remap** twice, and rename it Storm surge 9 m.
6. Right-click the color ramp for the layer and expand the drop-down list to pick the **Yellow-Orange-Brown (Continuous)** ramp.

The layer's color changes to orange.

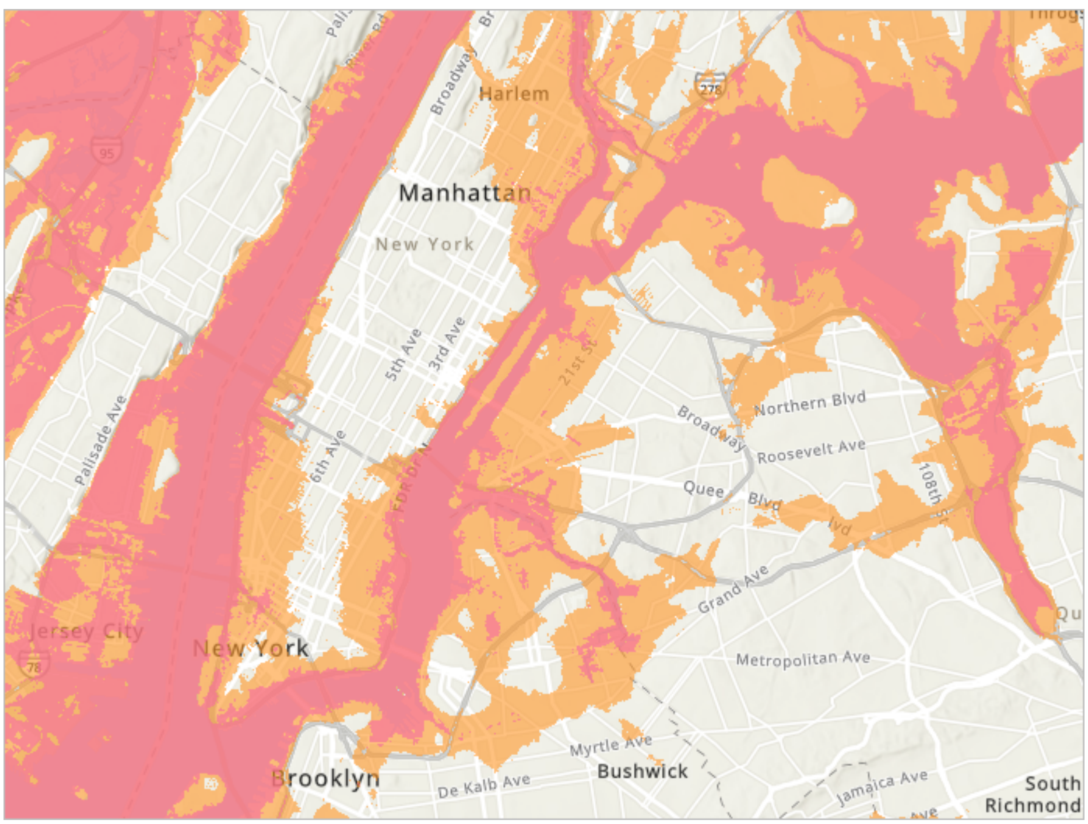
7. In the **Contents** pane, ensure that the **Storm surge 9 m** layer is selected. On the ribbon, click the

Raster Layer tab. In the **Effects** group, change the **Transparency** value to 40.0%.

8. In the **Contents** pane, turn off the **Hurricane Sandy Inundation Zone** layer. Drag **Storm surge 3 m** above the **Storm surge 9 m**.



The map now shows in orange the areas of the city that may be flooded by a 9-meter storm surge, and in pink the areas flooded by a 3-meter storm surge.



9. In the **Contents** pane, click **Storm surge 9 m** to select it. Click the **Raster Layer** tab. In the **Compare** group, click **Swipe**, and explore the map.

Because New York has historically seen a storm surge this high, it is not unreasonable to [illegible] such an event in the future.

10. When you're done, on the ribbon, click the **Map** tab. In the **Navigate** group, click the **Explore** button to exit swipe mode.
11. Press Ctrl+S to save the project.

In this tutorial, you completed a workflow to map the potential extent of a large storm surge in New York City. You obtained elevation data by adding the **Terrain** layer from ArcGIS Living Atlas to your map and exporting the extent of interest to a local raster. You used the **Remap** raster function to find the areas that are below certain elevations. Finally, you symbolized the new layers to visualize the flood areas.

Because the **Terrain** imagery layer covers the entire world, you can use this same workflow for any coastal area. You can also use this same process to model sea level rise. The Intergovernmental Panel on Climate Change (IPCC) has predicted that average global sea level could increase by 60 to 110 centimeters by 2100 if greenhouse gas emissions continue to increase significantly. What does a coastline near you look like when you flood any elevations below 1.1 meters? Remember that storm intensity, surge levels, and sea level rise are all different in different areas.

> **Note:**
> While the approach in this tutorial works well for simple coastlines, it would not give accurate flood predictions for an area protected with a dike or levee system, or where the water might encounter other types of obstacles. For a more sophisticated approach, see the Model coastal inundation impact tutorial.

You can find more tutorials like this on the Introduction to Imagery and Remote Sensing page.

Acknowledgements

- This tutorial was adapted from the SpatiaLABS tutorial Impacts of Sea Level Rise and Storms on Manhattan by Monika Calef.
- **Hurricane Sandy Inundation Zone** layer: This dataset was obtained from the New York City Open Data portal in Sep. 2019 and provided by New York City's Department of Small Business Services.
- **Terrain** layer sources: Airbus, USGS, NGA, NASA, CGIAR, NLS, OS, NMA, Geodatastyrelsen, GSA, GSI and the GIS User Community

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