MODEL FOR ESTIMATING THE SIZE AND CONFIGURATION OF TODDY POND AND ALAMOOSOOK LAKE DUE TO DECREASES IN THE WATER LEVEL

Kevin Turcotte
Surry, ME

INTRODUCTION

The possibility of the dams being removed from Toddy Pond and Alamoosook Lake has led to consternation for many people in the towns of Surry, Orland, Penobscot, and Blue Hill. It is important that we understand, and trust information related to possible dam removal.

My objective is to determine the size and configuration of Toddy Pond and Alamoosook Lake based on large decreases in the water level. Surface models were created for both waterbodies using a triangulated irregular network (TIN). The inputs to the model are:

1. Digital Elevation Model (DEM) to define waterbodies and surrounding terrain (USGS)
2. Waterbody depths at point locations as defined by Maine Department of Inland Fisheries and Wildlife
3. Waterbody depths at point locations as defined by long-time fishermen of Toddy and Alamoosook
4. Artificial Stream Paths (USGS)

The elevations in the DEM represent the topographic bare-earth surface. It is used to define the boundary and elevation of the waterbodies and provide the context of the surrounding terrain. The boundaries, the depth points, and the artificial stream paths are used to create a surface model that allows for estimates of area, volume, and shoreline configuration based on fluctuations in the water level. The model is constructed as a TIN and converted to a cell-based raster for additional processing.

Limitations

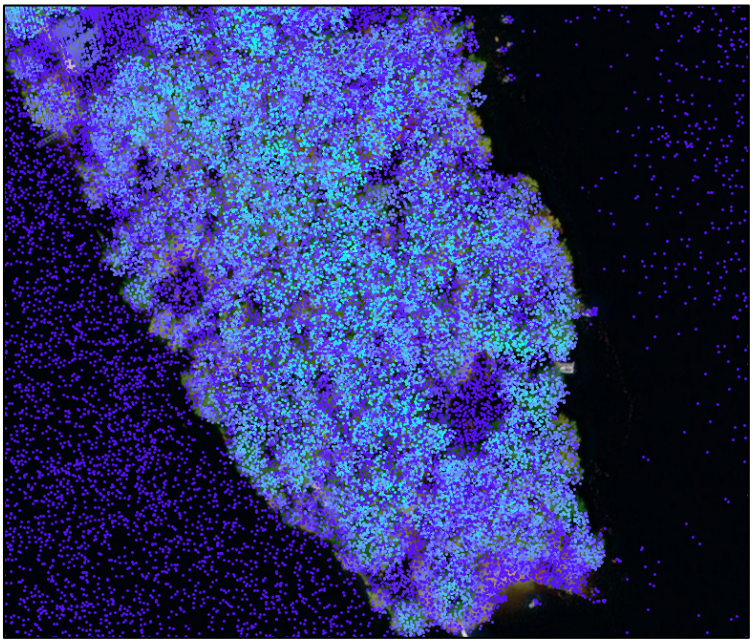
1. Depth locations from the Maine Fish and Wildlife were collected\surveyed between 1942 and 1999. There are 130 locations on Toddy Pond and 56 on Alamoosook Lake, far insufficient to model the bottoms of the waterbodies using the TIN model.
2. An additional 318 (Toddy) and 143 (Alamoosook) point depths were determined from memory by long-time fishermen of Toddy and Alamoosook. The ideal would be to survey the waterbodies using a depth finder synced with GPS.
3. Insufficient depth locations the narrows of both waterbodies. More points are needed to better represent lake bottoms in the narrows.
4. Insufficient depth locations on either side of the Route 1 bridge at Toddy Pond.
5. My lack of understanding of the role of the Route 1 bridge in the impoundment of Toddy Pond. The distance from the top of the dam structure to the bottom is about 8 feet. One of the map series is based on an 8-foot drop in the water level. It could be that removing the dam will result in a smaller drop in the water level based on an impoundment by the Route 1 bridge.
6. Insufficient information to map stream paths and flow after water level decreases.

DATA

<u>LIDAR data used to produce Digital Elevation Model</u>

Raw lidar data was not used in this project. The elevation model used here was created from lidar by the USGS.

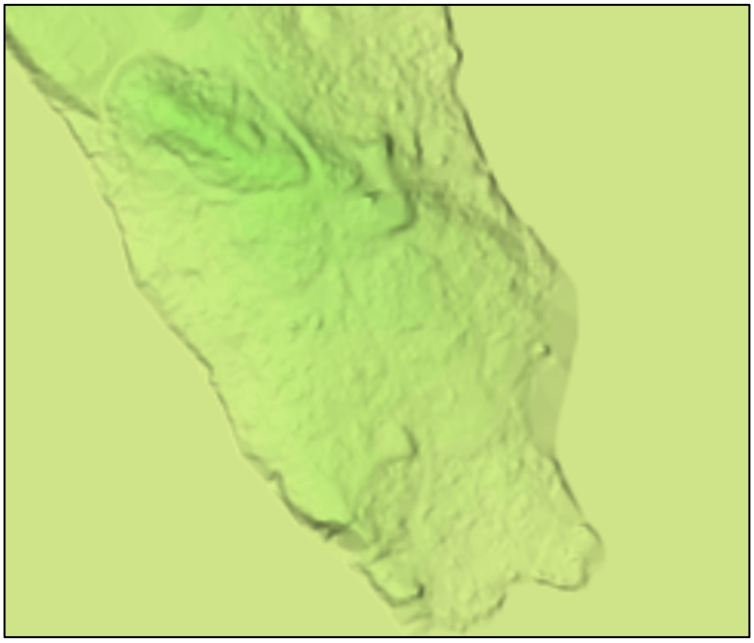
Haney Point (Loon Way) on the north shore of Middle Toddy Pond.



Lidar (Light Detection and Ranging) is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.

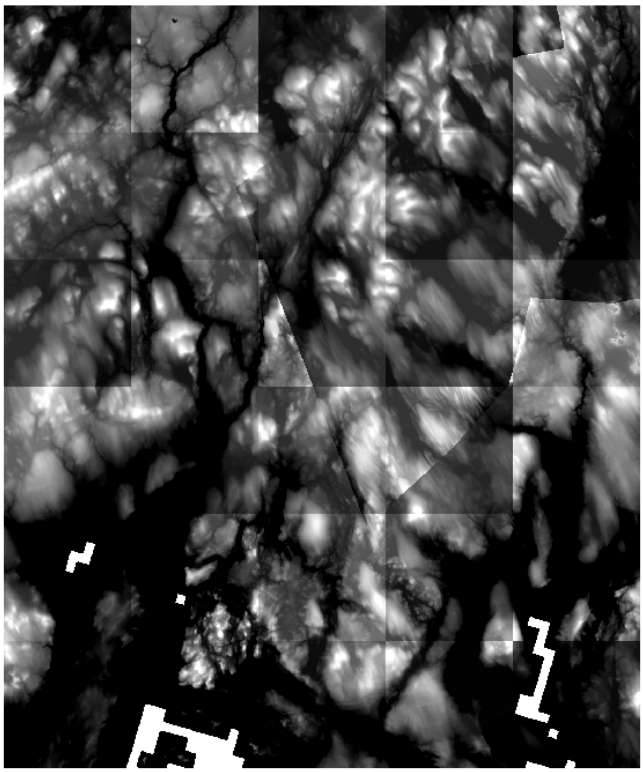
Lidar data is initially collected as a "point cloud" of individual points reflected from everything on the surface, including structures and vegetation.

Light Detection and Ranging is a technology used to create high-resolution models of ground elevation with a vertical accuracy of 10 centimeters (4 inches).

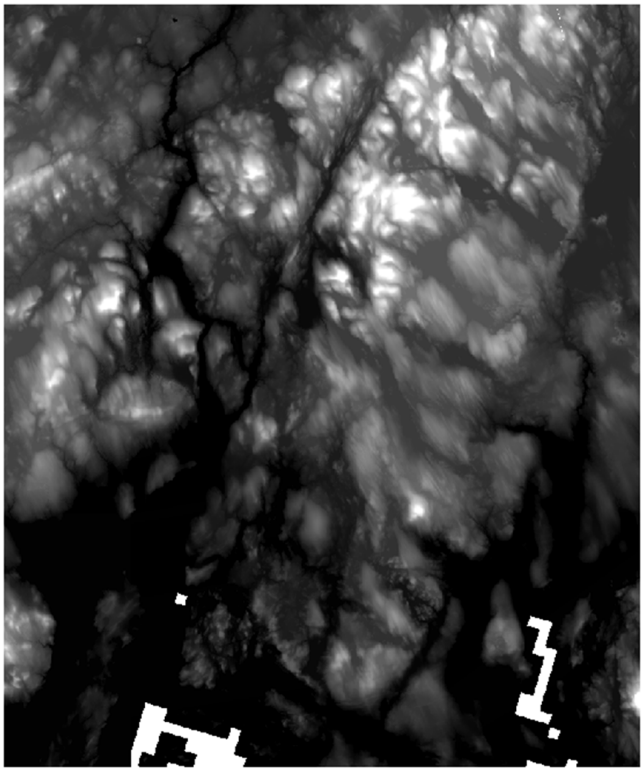


To produce a "bare earth" Digital Elevation Model (DEM), structures and vegetation are stripped away. DEM surface treatments include bridge removal, hydroflattening, and islands 0.4 ha (1 acre) or larger being delineated within waterbodies.

USGS 1-Meter DEMs derived from high resolution LIDAR (2015-2022)



This is a tiled collection of the 3D Elevation Program (3DEP) and is one-meter resolution (the size of each cell containing an elevation value). The elevations in this DEM represent the topographic bare-earth surface. USGS standard one-meter DEMs are produced exclusively from high resolution lidar source data of one-meter or higher resolution. The vertical accuracy has a root mean square error of 0.53 meters, though accuracy varies significantly across the U.S. because of differences in source quality, terrain relief, land cover, and other factors.



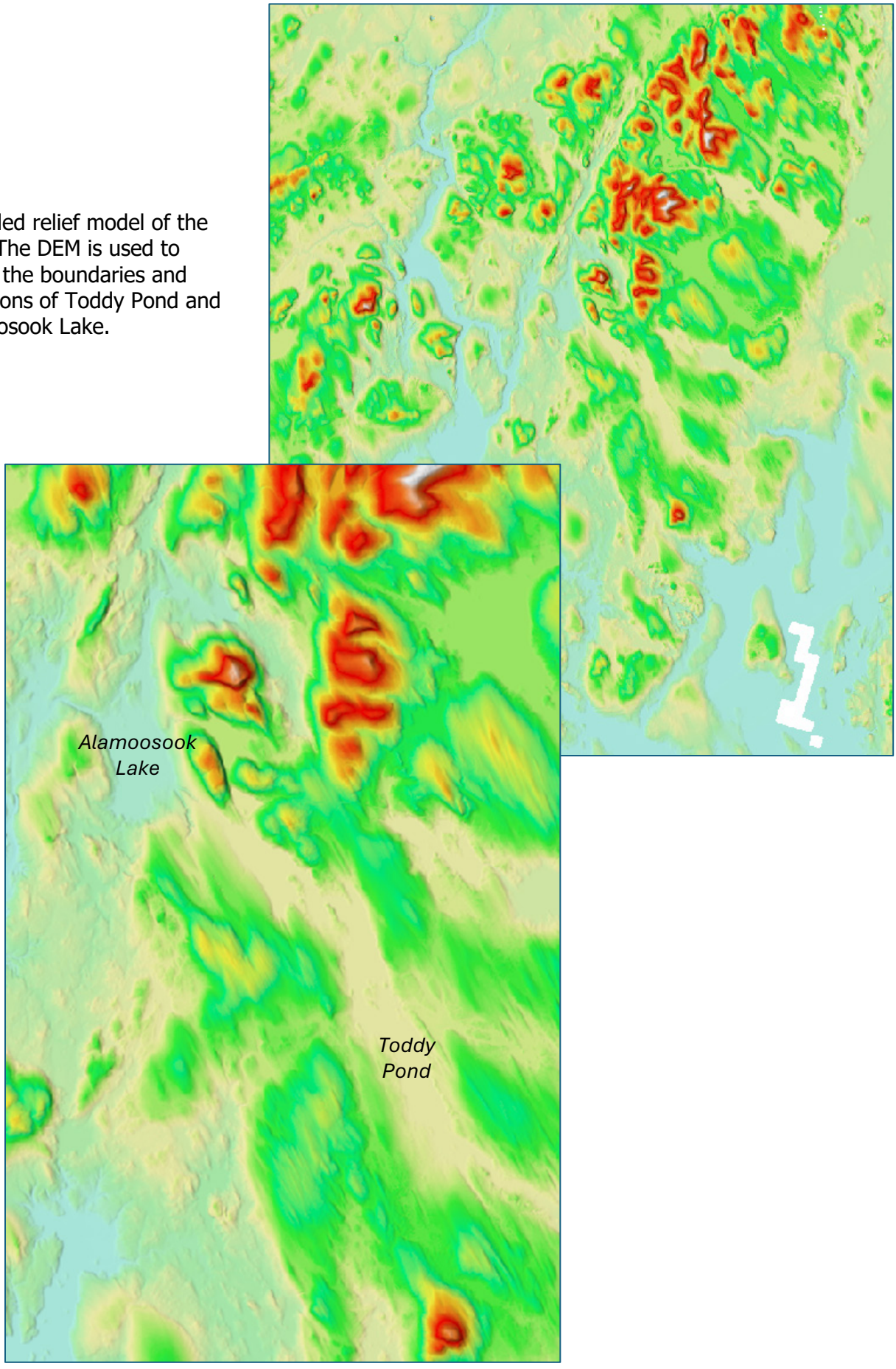
Forty-three tiles were downloaded in tiff format. The tiles were mosaiced into a single DEM that includes Toddy Pond, Alamoosook Lake and the surrounding terrain.

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

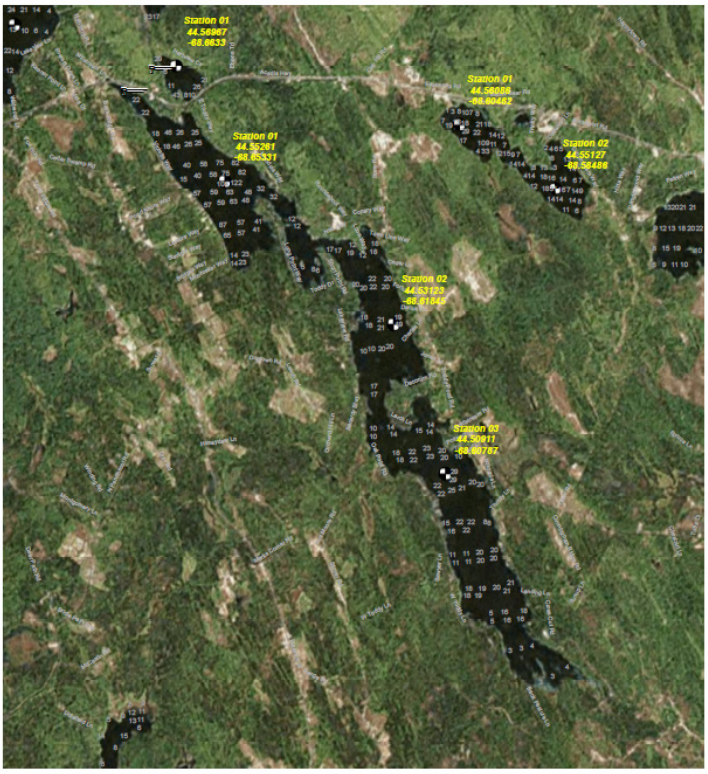
A shaded relief model of the DEM. The DEM is used to define the boundaries and elevations of Toddy Pond and Alamoosook Lake.



Water Depths - 1

Lake Depths surveyed by the Maine Department of Inland Fisheries & Wildlife were downloaded from the Lake Stewards of Maine website. Depths are indicated on a satellite image in a georeferenced PDF file. The survey was initially done in 1942 and revised several times up until 1999. I found no reference for the methods used to determine the depths or the elevations of Toddy or Alamoosook at the time of the survey(s).

The depths were manually added to a Geographic Information System as point features at the center of each depth label. There are 130 depths for Toddy and 56 at Alamoosook.



Toddy Pond MIDAS # 4340

Orland, Hancock Co. - Delorme Page 15 - 2409 acres

Boat Launch Lake Sample Stations # Depth (FT)

0 1 2 3 4 5 Miles

Alamoosook Lake MIDAS # 4336

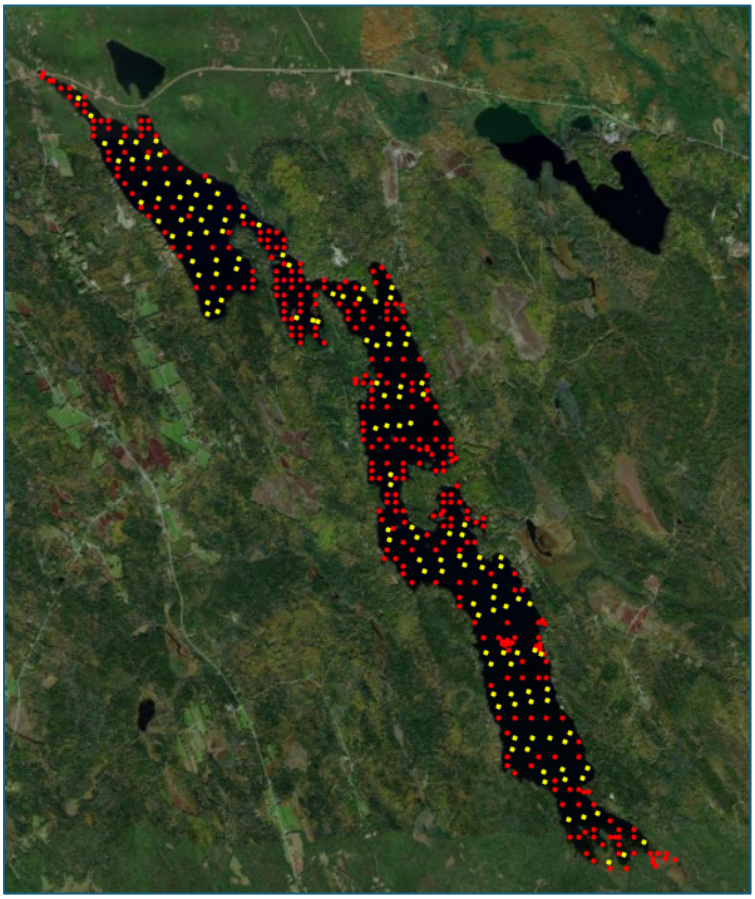
Orland,Hancock Co. - Delorme Page 23(E3) - 997 acres

LakeAccess State Boat Launch Lake Sample Stations # Depth (FT)

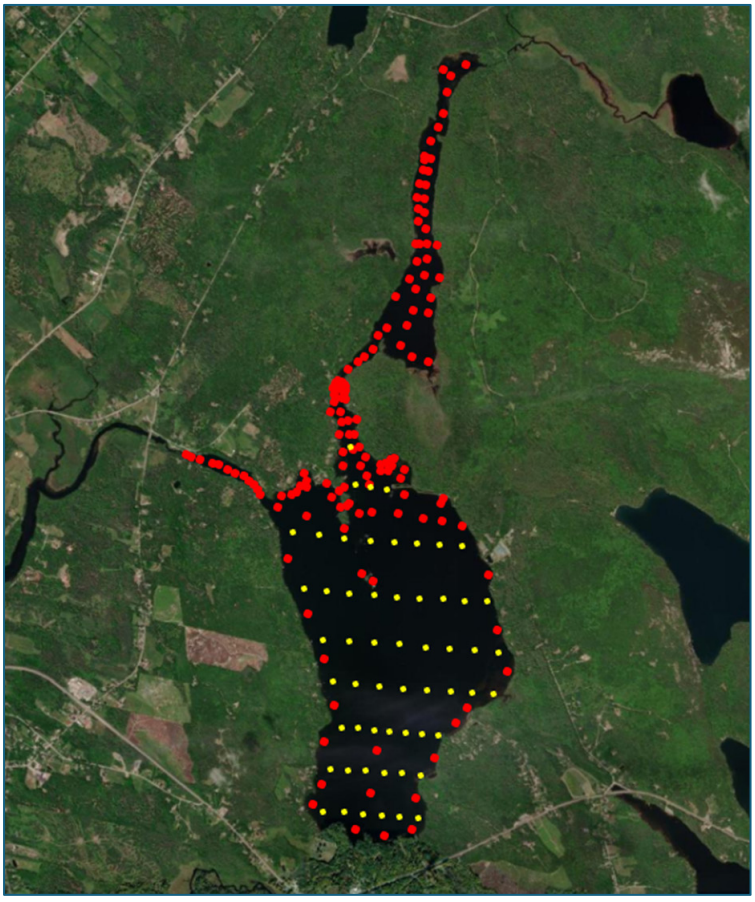
0 0.4 0.8 1.2 1.6 2 Miles

Water Depths - 2

It was determined that the depths provided by the state of Maine were not sufficient to build depth surface models for either waterbody. Additional depth points were added by long-time fishermen Brian Smith (Toddy Pond) and Wesley "Chip" Stubbs (Alamoosook Lake). They served as my human depth finders, whose observations are from memory. This was accomplished by created a grid of points 100 meters apart, and then selecting those that filled in the areas lacking point depths from the state of Maine. Additional depth points were added that were not represented in the grid. The depth points were manually added as point features using a Geographic Information System.



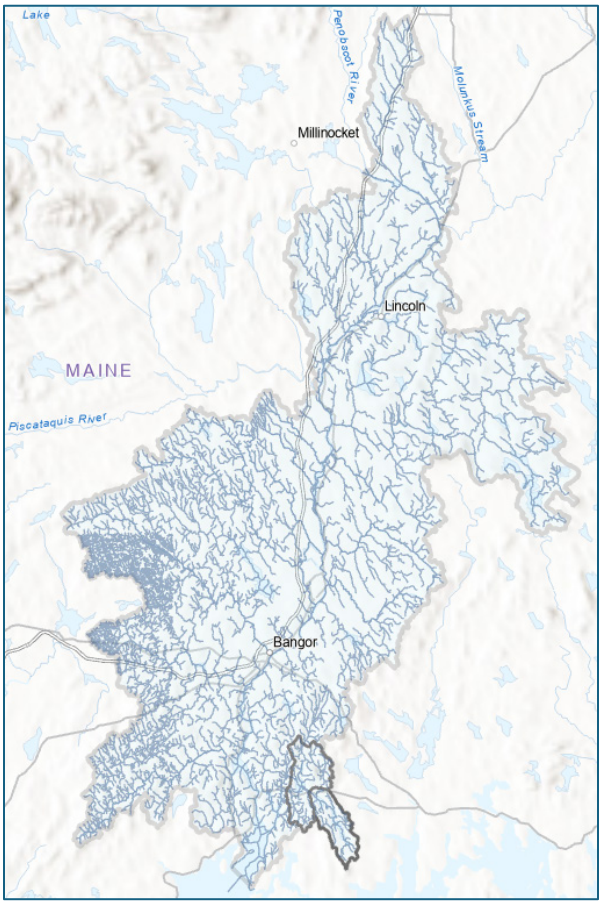
- 130 depths – State of Maine
- 318 depths – Brian Smith



- 56 depths – State of Maine
- 142 depths – Wesley "Chip" Stubbs

National Hydrography Dataset

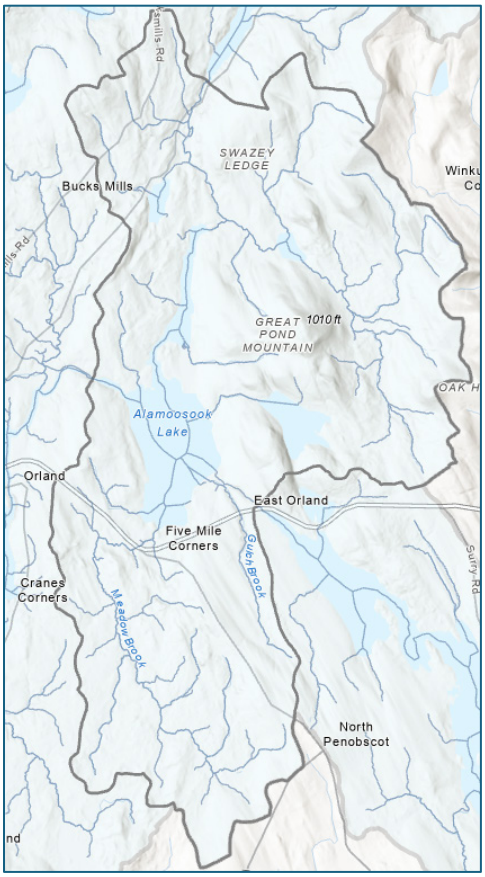
The National Hydrography Dataset (NHD) represents the water drainage network of the United States with features such as watersheds, rivers, streams, canals, lakes, ponds, coastline, dams, and stream gages.



Penobscot River Subbasin

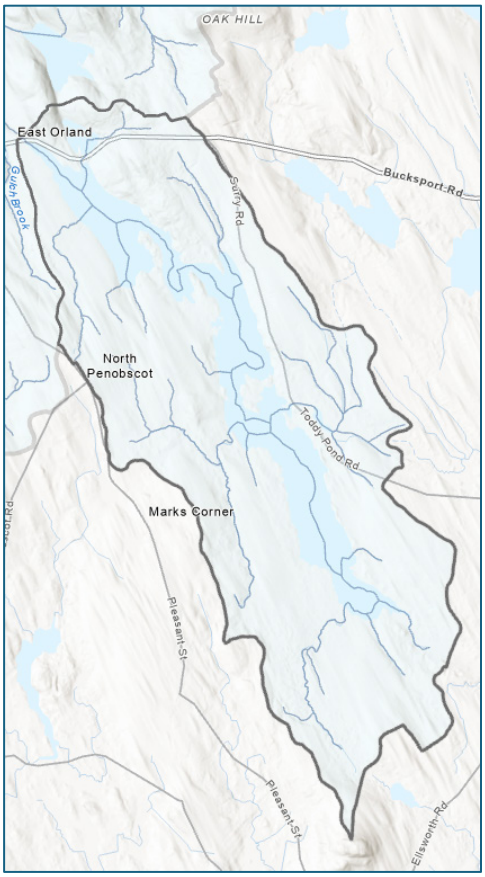
Within the Penobscot River Subbasin, there are 10 Watersheds (not shown) and 71 Subwatersheds including the Alamoosook Lake and Toddy Pond Subwatersheds.

Alamoosook Lake Subwatershed



NHDFlowline is the fundamental flow network consisting predominantly of stream/river and artificial path vector features. An Artificial Path is an abstraction to facilitate hydrologic modeling through open waterbodies. The flowlines are used as inputs to the surface models for the waterbodies.

Toddy Pond Subwatershed

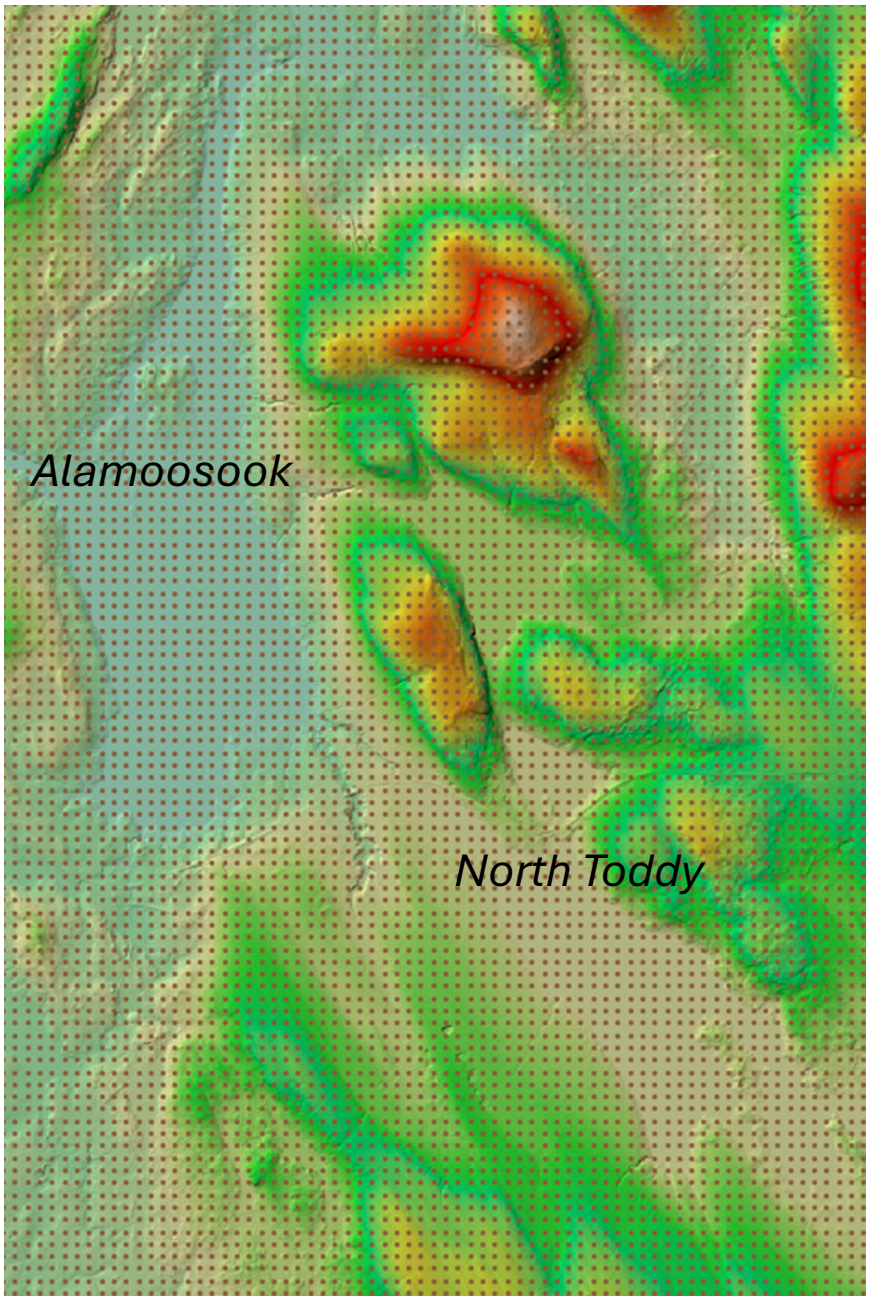


METHODS – SHORELINE EXTRACTION

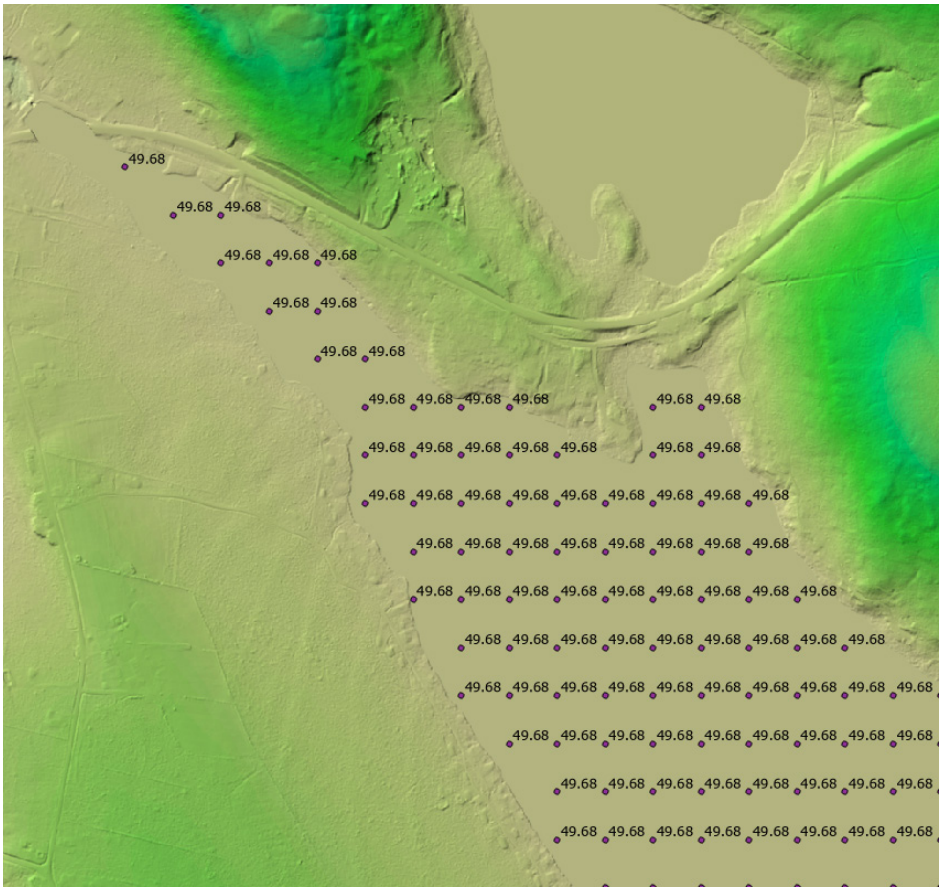
Shoreline Determination

Data sources are available that represent the Toddy and Alamoosook areas and shorelines, including those produced by the USGS. None of the sources I evaluated for use coincided with the 1-meter DEM used here, or the 10-meter USGS DEM. That is, it was common that the mapped shorelines often extended inland over large changes in elevation (i.e., 5-20 feet). For that reason, determining the initial shoreline configuration and elevation of the waterbodies was accomplished using the 1-meter DEM.

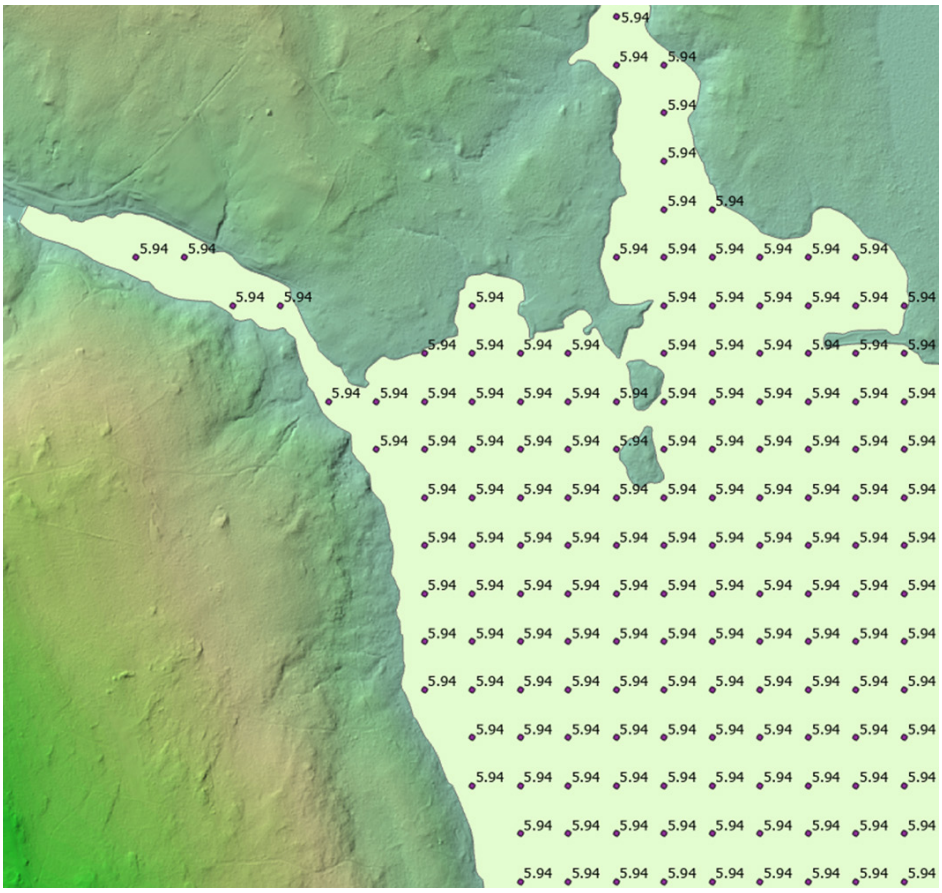
Recall that the USGS processes the DEM with methods that include hydro-flattening, bridge removal, and islands being delineated if they meet the area requirement minimum of 1 acre. A grid of points spaced at 100 meters was created for an area that included Alamoosook and Toddy, and the elevations at those points were extracted from the DEM.



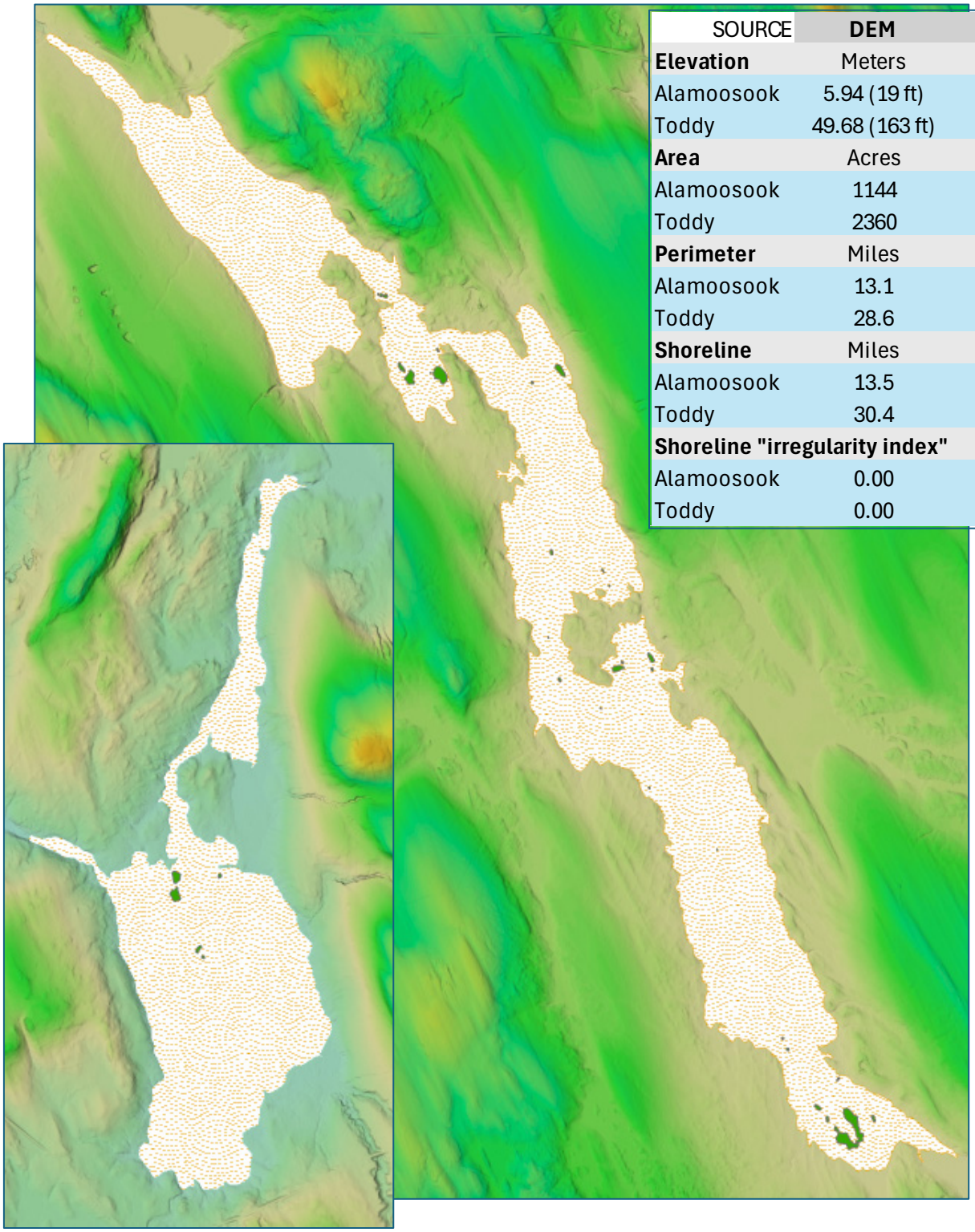
The elevation of Toddy Pond was comprised of 1 value, 49.68 meters (163 feet). Online sources report the elevation of Toddy Pond as 164 feet. A portion of North Toddy is shown here with elevations shown at 100-meter intervals. All other sections of Toddy Pond have the same elevation.



The elevation of Alamoosook Lake was comprised of 1 value, 5.94 meters (19.48 feet). Online sources report the elevation of Alamoosook Lake as 19.68 feet. A portion of Alamoosook is shown here with elevations shown at 100-meter intervals. All other sections of Alamoosook have the same elevation.



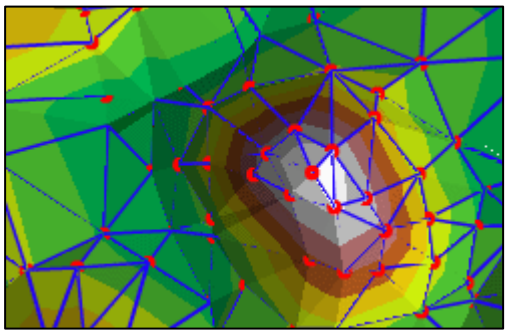
Cell-based tools and functions were used to extract the areas that represent Toddy Pond and Alamoosook Lake. Polygon (area) and line features were created to represent the shoreline and islands that were delineated in the DEM. As expected, only larger islands were delineated from the DEM. Islands that were not delineated by the DEM were extracted from existing digital map data and merged with the DEM-derived islands. Toddy had 8 of 23 islands while Alamoosook had 2 of 5 delineated by the DEM. The perimeters of the waterbodies and islands are important inputs to the model used to determine the extents of possible water level drops. I suggest that the DEM-derived shorelines are as accurate or more accurate than most other sources. The configuration statistics of both waterbodies align with other published sources.



SOURCE	DEM	Stewards
Elevation	Meters	Meters
Alamoosook	5.94 (19 ft)	6 (20 ft)
Toddy	49.68 (163 ft)	50 (164 ft)
Area	Acres	Acres
Alamoosook	1144	997
Toddy	2360	2408
Perimeter	Miles	Miles
Alamoosook	13.1	9.2
Toddy	28.6	31.3
Shoreline	Miles	Miles
Alamoosook	13.5	11.8
Toddy	30.4	27.5
Shoreline "irregularity index"		
Alamoosook	0.00	2.46
Toddy	0.00	4

METHODS – MODEL

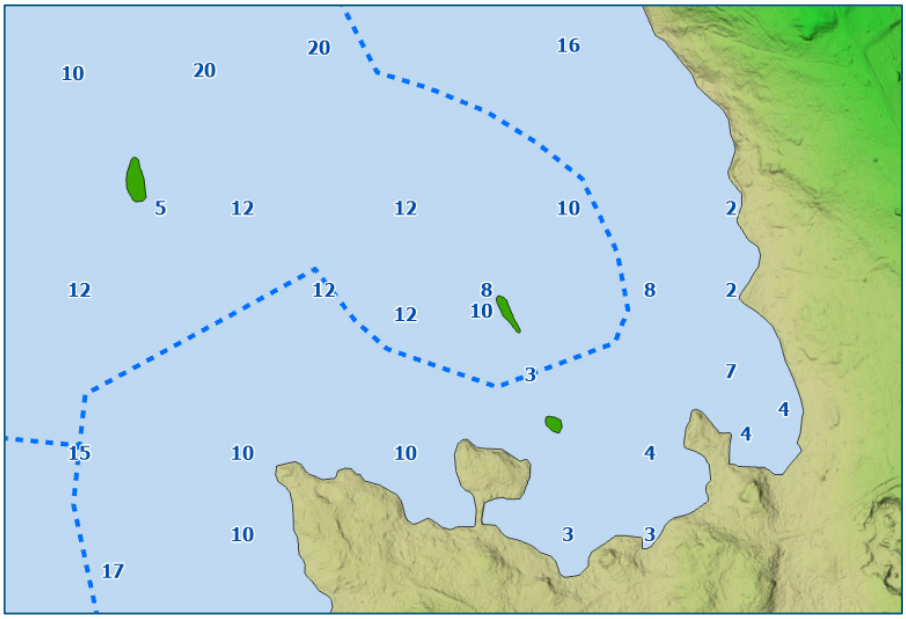
Constructing the TIN



A surface model allows for estimates of area, volume, and shoreline configuration based on fluctuations in the water level. The model is constructed as a triangulated irregular network (TIN).

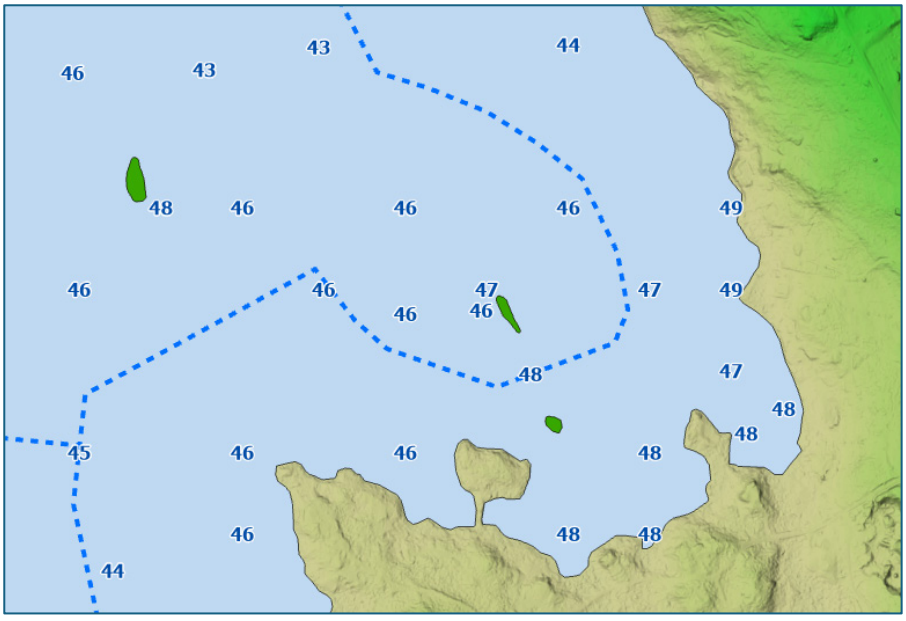
TINs are a form of vector-based digital geographic data created by triangulating a set of vertices (points). The vertices are connected with a series of edges to form a network of triangles (ESRI). The vertices of the triangles store the elevation values. The model is explained using an area of Toddy Pond as an example.

Depth points in feet

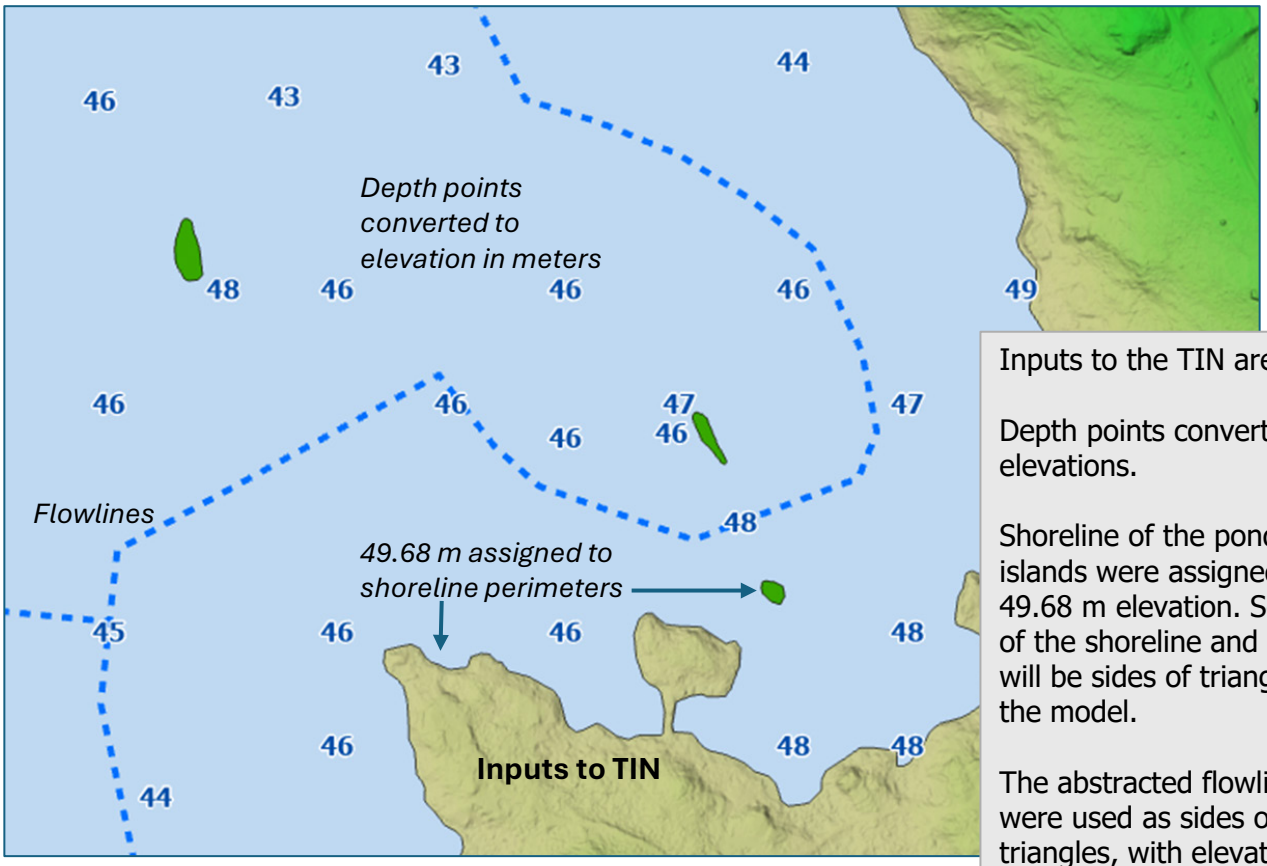


Southern portion of Middle Toddy Pond

Depth points were converted to elevations by subtracting the depth values (in meters) from 49.68 meters (163 feet). I have no information on what the elevation of Toddy Pond was when the depth readings were recorded.



Depth points converted to elevation in meters



Inputs to the TIN are:

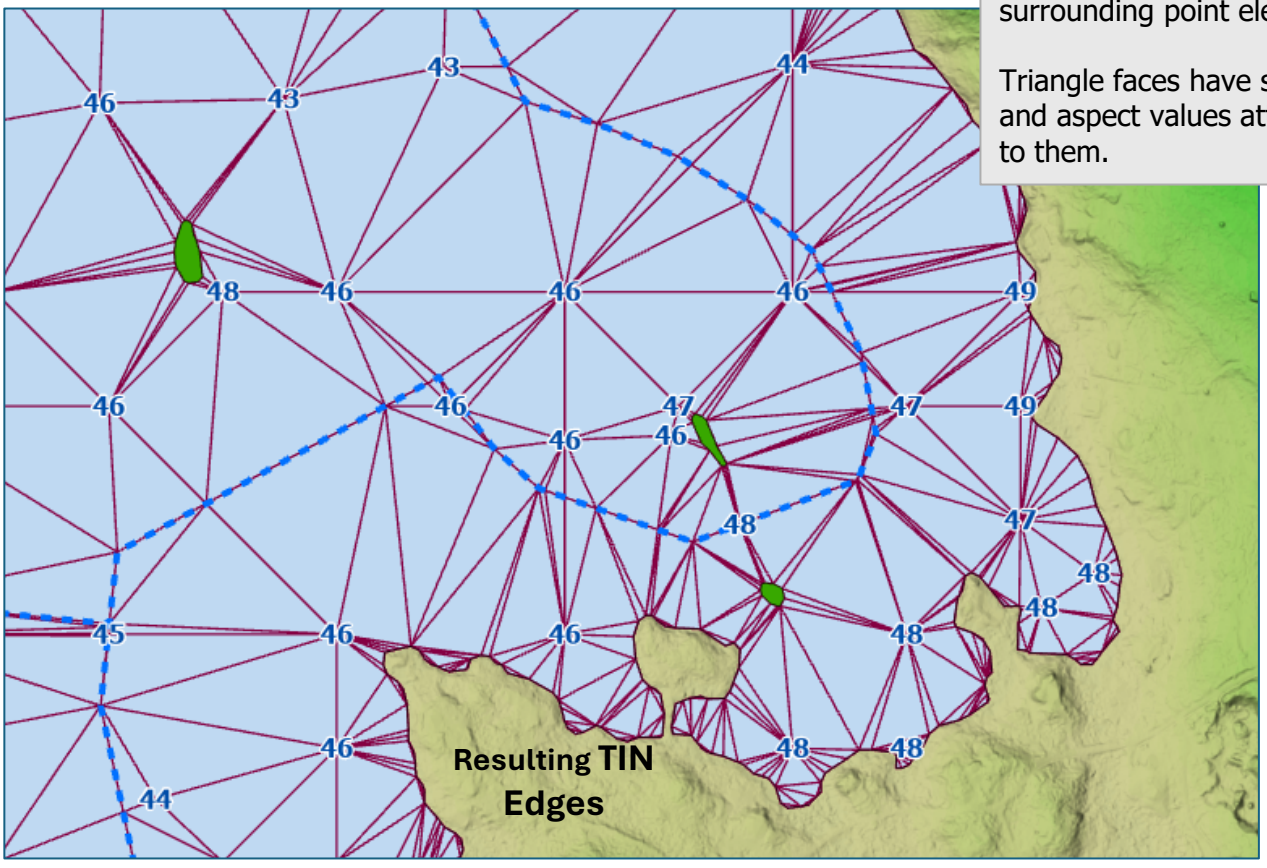
Depth points converted to elevations.

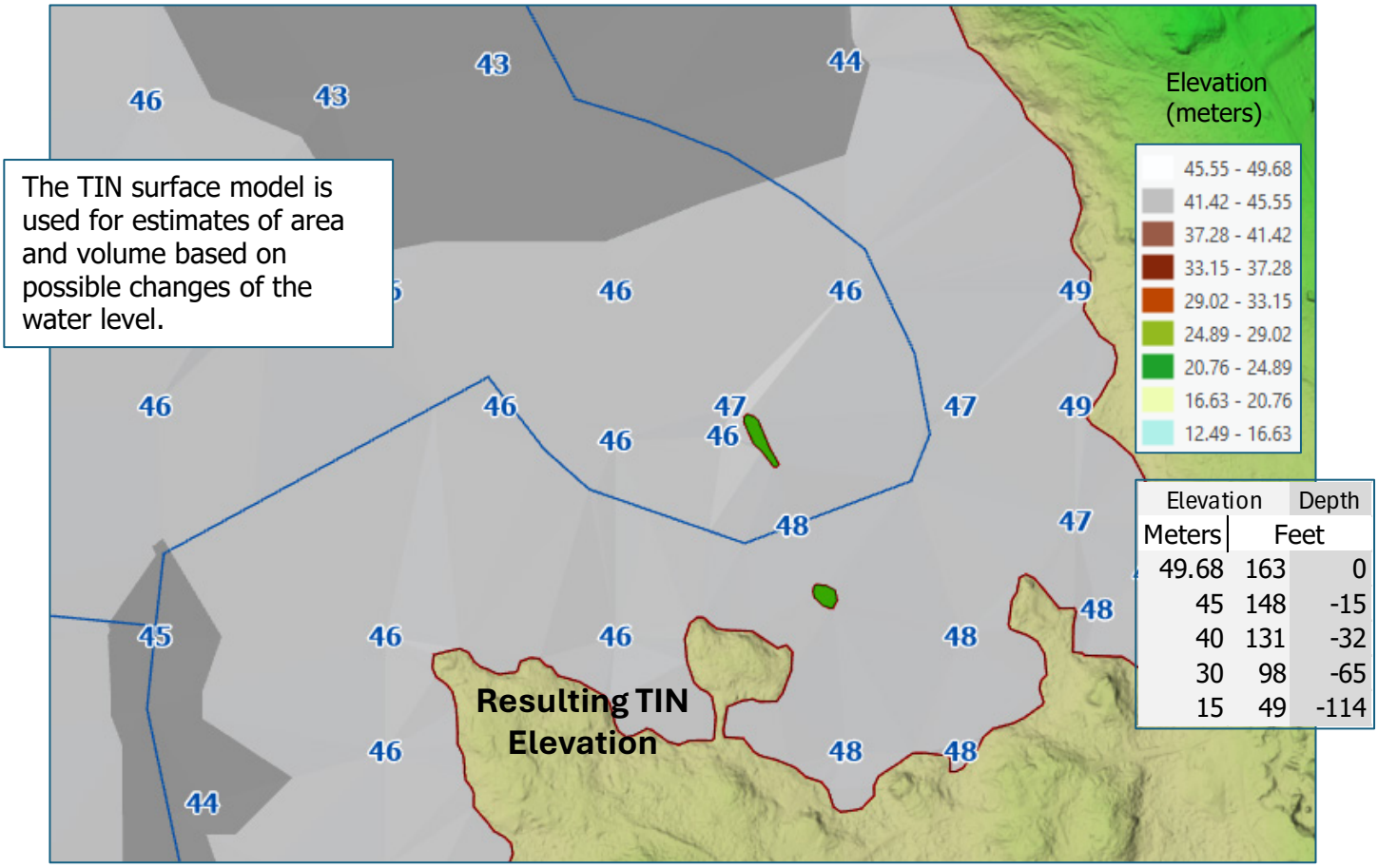
Shoreline of the pond and islands were assigned a 49.68 m elevation. Segments of the shoreline and islands will be sides of triangles in the model.

The abstracted flowlines were used as sides of triangles, with elevations at the vertices interpolated from surrounding point elevations.

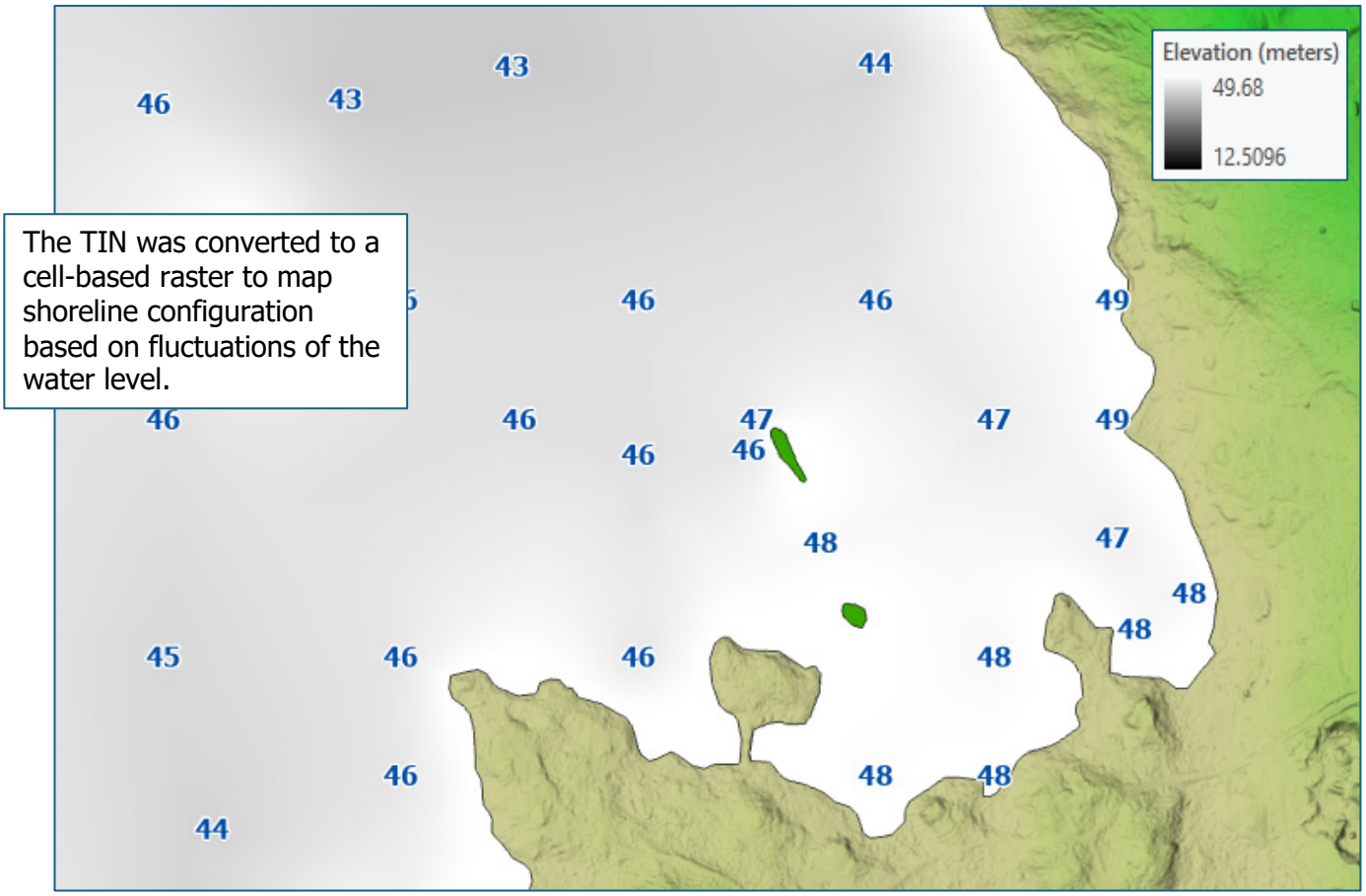
Triangle faces have slope and aspect values attached to them.

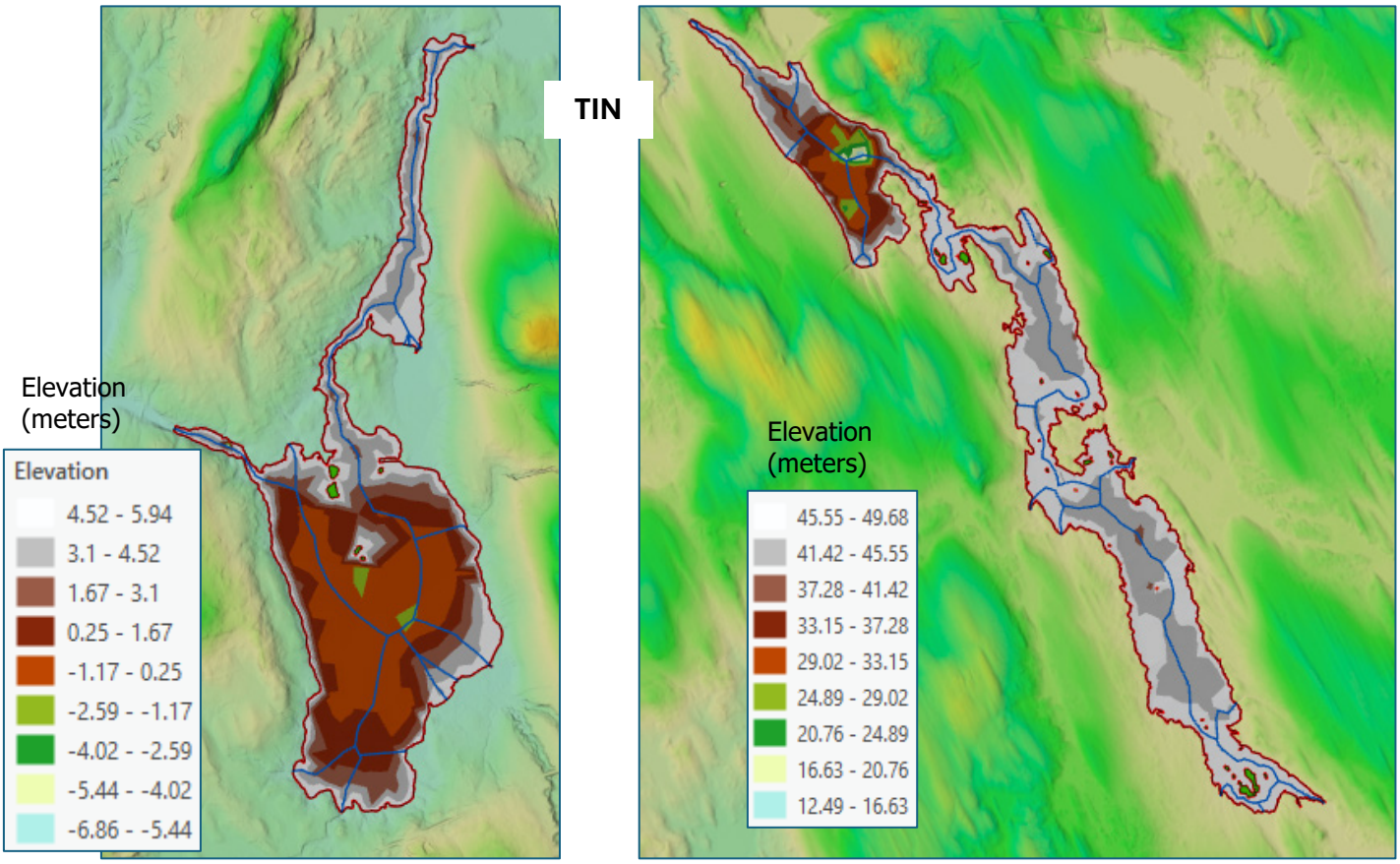
Southern portion of Middle Toddy Pond

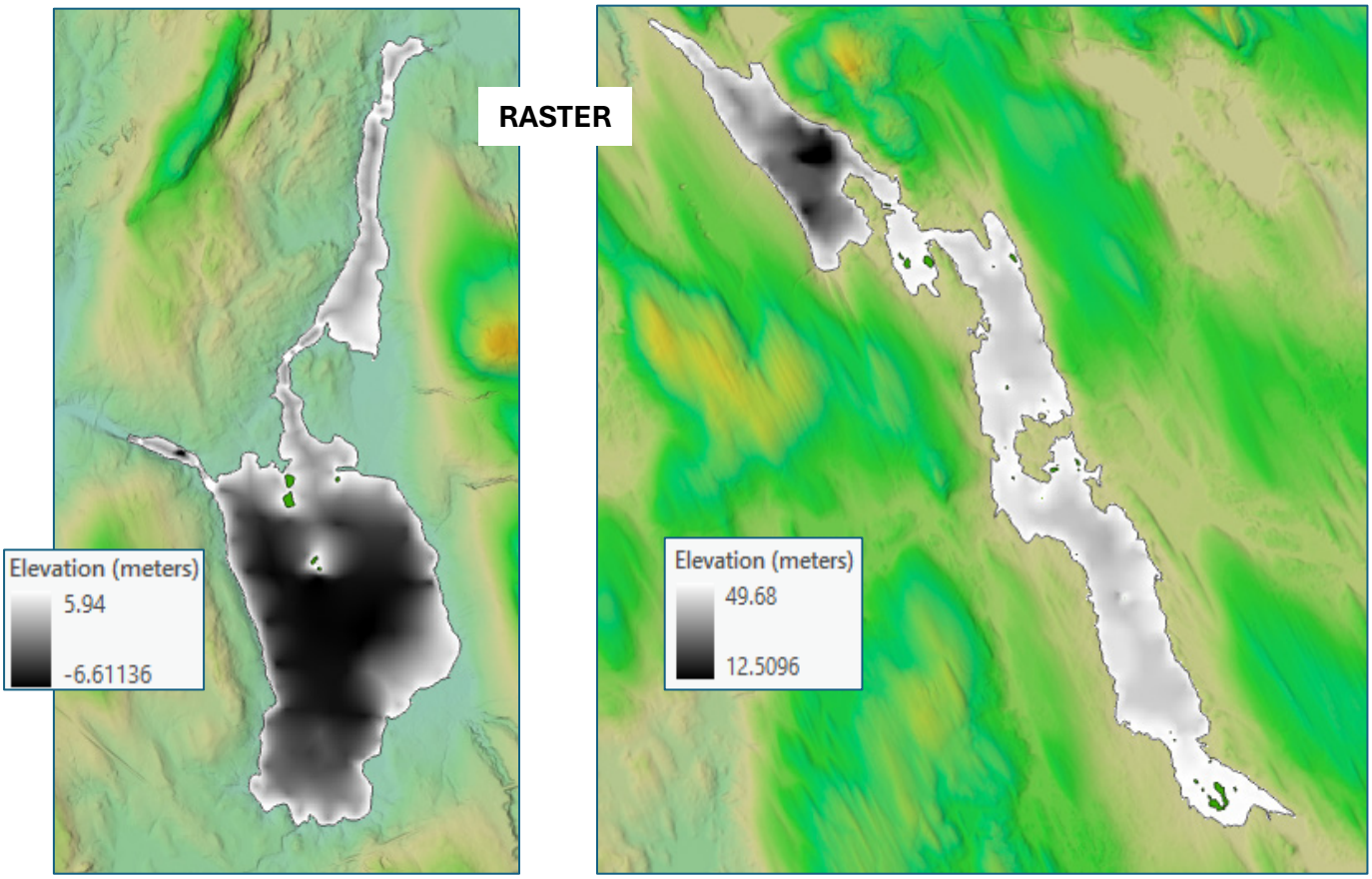




Southern portion of Middle Toddy Pond




TIN
Elevation (meters)
Elevation
4.52 - 5.94
3.1 - 4.52
1.67 - 3.1
0.25 - 1.67
-1.17 - 0.25
-2.59 - -1.17
-4.02 - -2.59
-5.44 - -4.02
-6.86 - -5.44
Elevation (meters)
45.55 - 49.68
41.42 - 45.55
37.28 - 41.42
33.15 - 37.28
29.02 - 33.15
24.89 - 29.02
20.76 - 24.89
16.63 - 20.76
12.49 - 16.63


RASTER
Elevation (meters)
5.94
-6.61136
Elevation (meters)
49.68
12.5096

RESULTS

Three series of maps were created, and they are available online.

Depth Map Series

The map series includes depth points from the Maine Department of Inland Fisheries & Wildlife, Brian Smith (Toddy Pond) and Chip Stubbs (Alamoosook Lake), and depth surface maps created from those points. The depth information is fundamental to producing maps showing shoreline changes based on water level drops.

The TIN and the cell-based raster model were used to produce a series of maps and statistics regarding area and volume with changes in the elevation of the water.

Water Level Series

The Toddy Pond water level map series starts with a base elevation of 163 feet and then maps at 159, 155, 151 and 147 feet. The Alamoosook Lake level map series starts with a base elevation of 19.5 ft and then maps at 15.5, 11.5, 7.5 and 3.5 feet. A map of each waterbody at the DEM-derived elevation is followed by maps representing drops of 4, 8, 12 and 16 feet.

Area and Volume

The area and volume were calculated for the TIN models at the different water levels.

Toddy Pond

Water Elevation (feet)	**Area (acres)** TIN	**Volume (cubic meters)** TIN
163	2360	51,130,170
159	1884	40,749,710
155	1584	32,207,824
151	1240	25,157,516
147	954	19,730,692

Alamoosook Lake

Water Elevation (feet)	**Area (acres)** TIN	**Volume (cubic meters)** TIN
19.5	1144	17,830,012
15.5	949	12,665,406
11.5	753	8,475,980
7.5	615	5,140,259
3.5	468	2,444,196

Distance to Water Map Series

Map series showing North, Middle, and South Toddy highlighting distances from 163 ft elevation shoreline to water at 155 ft elevation (8 ft drop). A single map highlights Alamoosook Lake distances from 19.5 ft shoreline to water after an 8 ft drop to an elevation of 11.5 ft.

DATA SOURCES

Toddy Pond Depths:

Lake Stewards of Maine – Data download from:
Lake Overview - Toddy Pond (Upper & Lower Toddy Ponds) - Blue Hill, Orland, Penobscot, Surry, Hancock, Maine - Lakes of Maine
Lake Overview - Alamoosook Lake - Orland, Hancock, Maine - Lakes of Maine

Maine Dept. Environmental Protection, Maine Dept. Inland Fisheries & Wildlife, Maine Office of GIS, Augusta, Maine

Brian Smith, long-time fisherman of Toddy Pond, Surry, Maine

Wesley "Chip" Stubbs", long-time fisherman of Alamoosook Lake, Orland, Maine

1-Meter DEMs:

U.S. Geological Survey, 2019, 3D Elevation Program 1-Meter Resolution Digital Elevation Model (published 20200606), accessed May 22, 2024 at URL https://www.usgs.gov/the-national-map-data-delivery

Abstracted Stream Flowlines:

U.S. Geological Survey, 2019, National Hydrography Dataset (ver. USGS National Hydrography Dataset Best Resolution (NHD) for Hydrologic Unit (HU) 4 - 2001 (published 20191002)), accessed May 14, 2024 at URL https://www.usgs.gov/national-hydrography/access-national-hydrography-products

REFERENCES

Arundel, S.T., Archuleta, C.M., Phillips, L.A., Roche, B.L., and Constance, E.W., 2015, 1-meter digital elevation model specification: U.S. Geological Survey Techniques and Methods, book 11, chap. B7, 25 p. with appendixes, http://dx.doi.org/10.3133/tm11B7

Christy-Ann M. Archuleta and Silvia Terziotti. 2020. Chapter 12 of Section B, U.S. Geological Survey Standards, of Book 11, Collection and Delineation of Spatial Data. Elevation-Derived Hydrography—Representation, Extraction, Attribution, and Delineation Rules (usgs.gov)

SOFTWARE

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