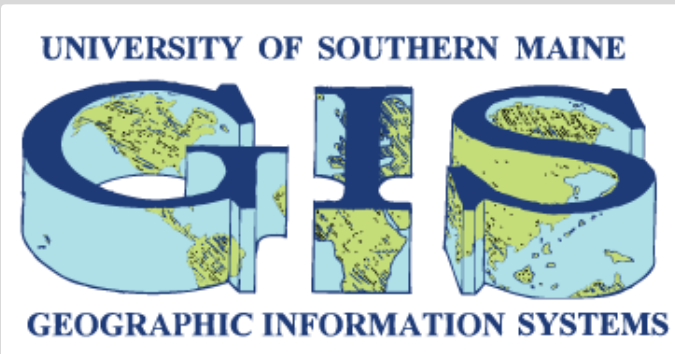




Bathymetric Mapping and a Comparison of Models for Beaver Dam Pond in Acadia National Park, Maine

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Abstract

Hydrologists and water resource managers use bathymetric models to calculate lake volumes, flushing and nutrient loading rates, and to create maps of lake depths. These bathymetric maps are especially helpful when planning water sampling and aquatic vegetation surveys so that effort can be focused on the appropriate depth zones. Water sampling and temperature and oxygen concentration depth profiles are often conducted at the deepest spot, whereas aquatic vegetation surveys are done in shallower water. Depth data for many lakes in Acadia National Park is completely lacking or not sufficient to create useful bathymetric models. One such water body is Beaver Dam Pond. Water depth and shoreline location data was collected in the field for Beaver Dam Pond. Depths were determined for multiple locations across the pond. Several different methods in ArcGIS were used to interpolate the bottom surface of the pond and create bathymetric models from the field depth data. Lake volumes associated with each model were calculated. The results of the different models were compared to determine how sensitive lake volume calculations, depth contours, and location of maximum depth were to model selection. These comparisons can provide guidance for model selection. Field measurements of water depth at several new locations on Beaver Dam Pond will be made later in the year to evaluate the accuracy of the various models created.

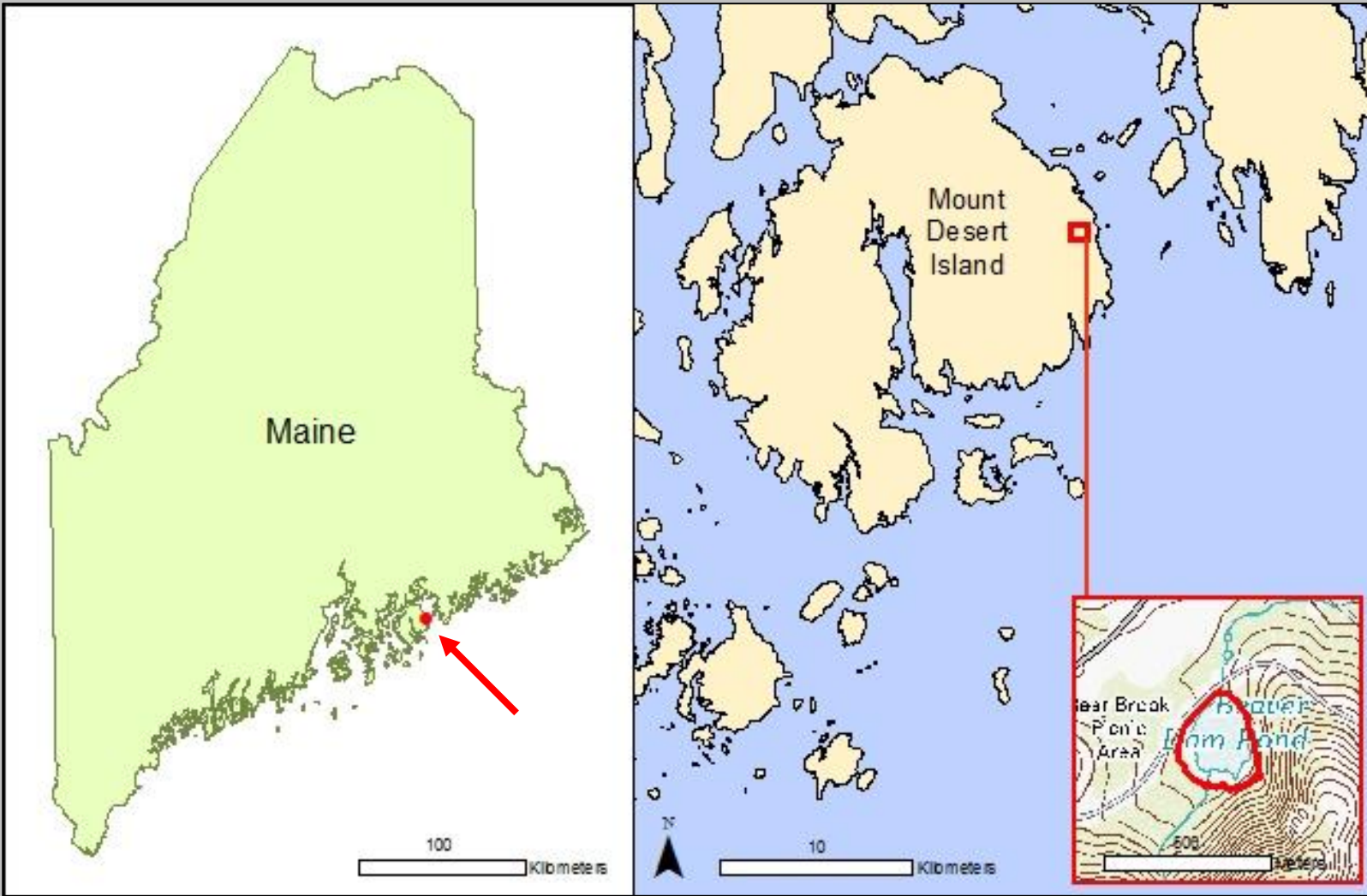


Figure 1. Location of Beaver Dam Pond in the state of Maine

Introduction

Bathymetric models represent the bottom surface of water bodies. They can be constructed by interpolating from depth measurements taken in the field at discrete locations. Various interpolation methods can be used including Kriging (Clark & Harper, 2000), splining (Huggett, 2009), inverse distance weighting, and triangulated irregular network (Baskin, 2005). Hydrologists and water resource managers use bathymetric models to calculate lake volumes, flushing and nutrient loading rates, and to create maps of lake depths. These bathymetric maps are especially helpful when planning water sampling and aquatic vegetation surveys so that effort can be focused on the appropriate depth zones.

Old bathymetric maps exist for many of the ponds in Acadia National Park (Maine Department of Inland Fisheries and Wildlife, 1962). However, there are a few ponds for which bathymetric data is missing. One such water body is Beaver Dam Pond (Figure 1). We collected water depth and shoreline location data in the field for Beaver Dam Pond. Several different methods in ArcGIS were used to interpolate the bottom surface of the pond and create bathymetric models from the field depth data. The interpolation methods compared included Kriging, IDW (inverse distance weighting), TIN (triangulated irregular network), and splining.

Lake volumes associated with each model were calculated. The results of the different models were compared to determine how sensitive lake volume calculations and depth contours were to model selection. These comparisons provide guidance for model selection.



Figure 2. Trimble GPS and antenna used.

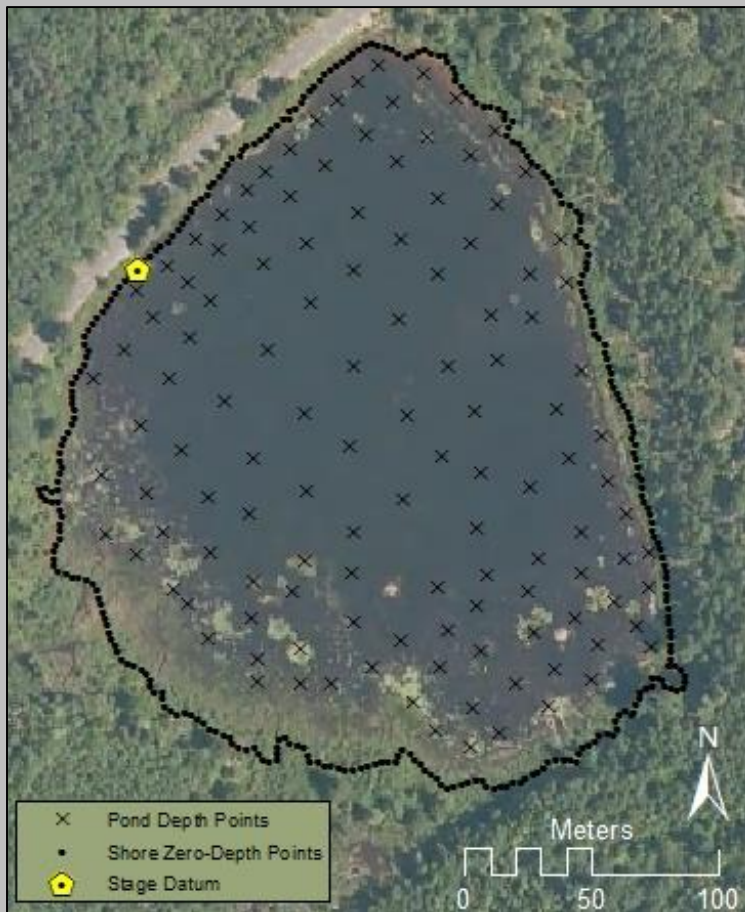


Figure 3 (right). Depth points and lake stage datum.

Data & Methods

Sampling and data processing procedures loosely followed those used by National Park Service employees in other parks (Kozlowski, 2013).

The water depth of Beaver Dam Pond was measured at locations spaced roughly 20 meters apart. A canoe was used to navigate to measurement locations. At each location a GPS point was recorded on a Trimble Nomad with a ProXR receiver and antenna and the depth was measured using a portable SupraProID fish finder (Figure 2). The water level in relation to a fixed datum was measured as well so that results could be related to lake stage. The water surface was 0.204 meters above the datum at the time of sampling on November

Interpolation Method	Semivariogram Model	Search Radius	Smoothering Factor	Other
Ordinary Kriging – LSR6	Linear	Variable 6 Points		
Ordinary Kriging – SSR6	Spherical	Variable 6 Points		
Ordinary Kriging – LFD40	Linear	Fixed Distance 40 m		
Ordinary Kriging – SFD40	Spherical	Fixed Distance 40 m		
Regular Spline	NA	12 Points		Weighting = 0.1
Spline With Barriers	NA	NA	0	Barrier = Shoreline Polygon
IDW (inverse distance weighted)	NA	Variable 6 Points		Power = 2
TIN (triangulated irregular network)	NA	NA		

Table 1. Methods used and settings in ArcGIS for interpolating pond depths from depth data collected at discrete locations in the field.



Figure 4. Beaver Dam Pond shoreline and half meter depth contours created from different bathymetric models.

21, 2013. The shoreline was walked with the GPS to record the path representing the zero depth edge of the pond.

The field GPS data was differentially corrected and shapefiles were created and imported into ArcGIS. A point shapefile was created to represent the mid-pond depth measurements and a polygon shapefile was created to represent the shoreline of the pond. A series of zero depth shoreline points were then created along the boundary of this polygon at 3 meter intervals. The shoreline points and the mid-pond depth points were merged into one shapefile (Figure 3). This shapefile was used to interpolate the depths across the entire pond using the various models tested.

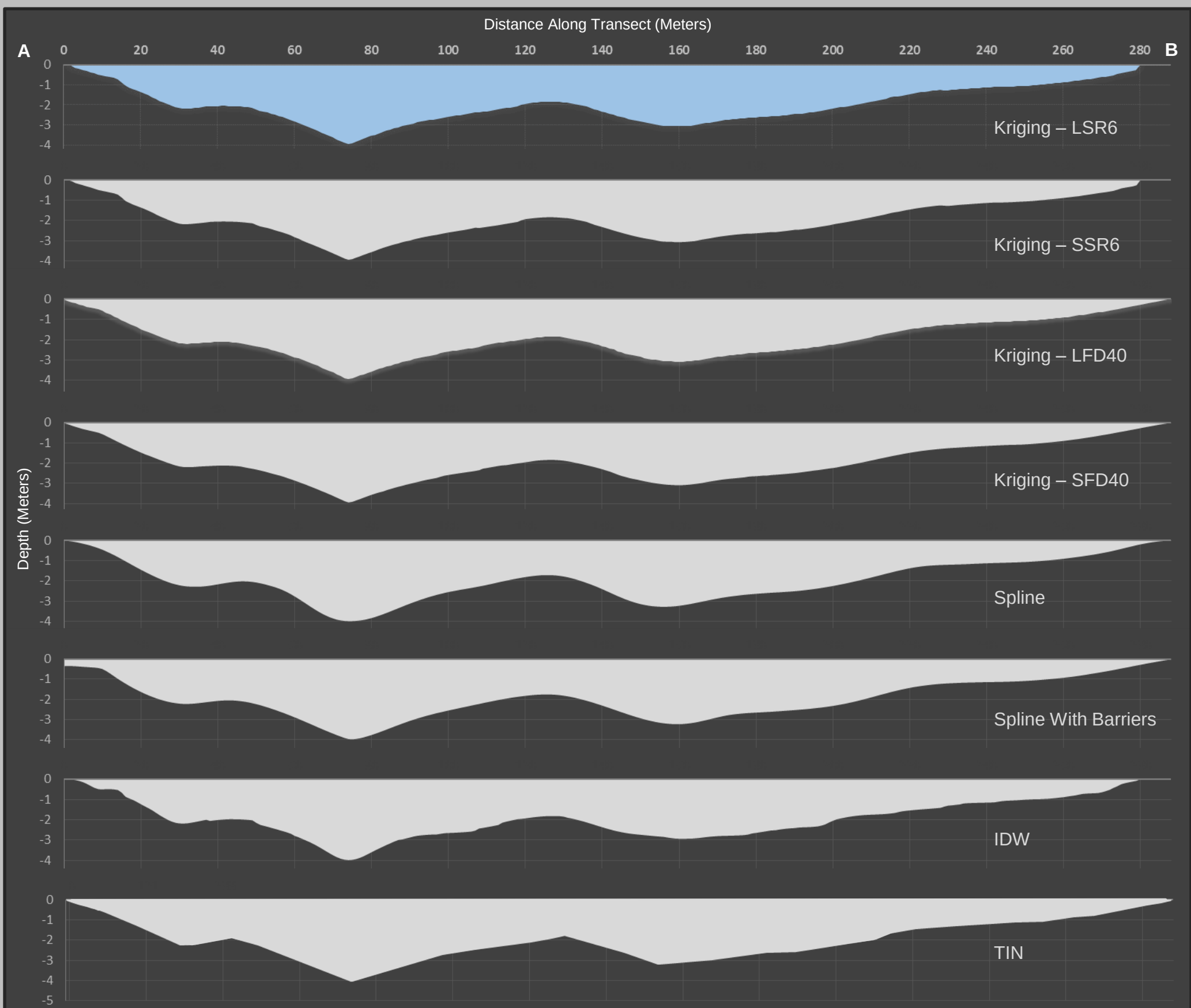


Figure 5. Depth profiles derived from the different interpolation methods at the cross section labelled AB in figure 4.

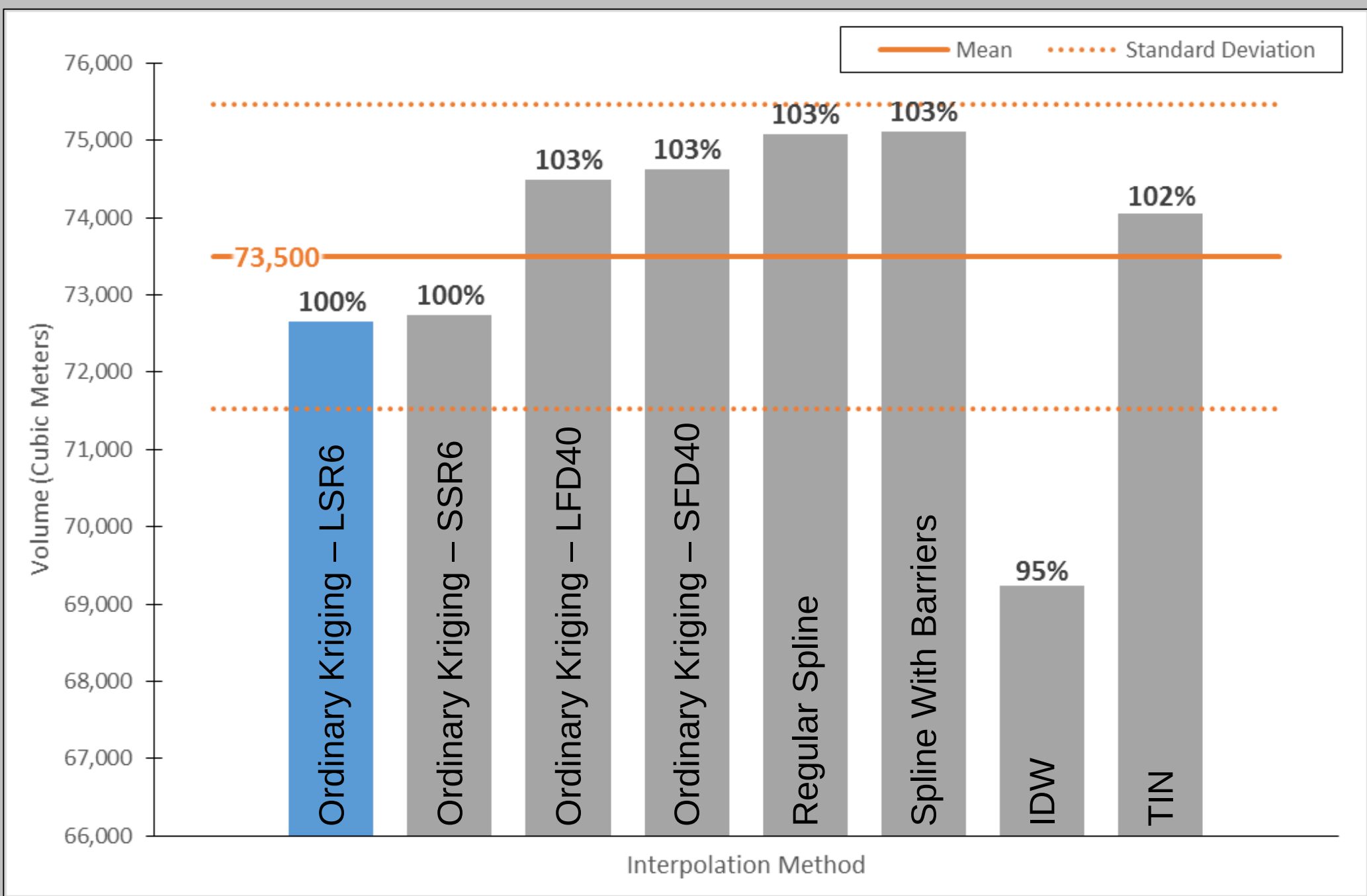


Figure 6. Beaver Dam Pond volumes calculated using different bathymetric models. Percentages represent volume in relation to the volume calculated using the ordinary Kriging LSR6 method of depth interpolation to create the bathymetric model.

Analysis & Results

Pond depths were interpolated using several spatial analysis methods in ArcGIS. An ordinary Kriging method using a linear semivariogram model and a search radius of 6 points was used to be consistent with the bathymetric modeling done for ponds at other parks in the region. This was considered the standard method against which the other methods were compared. Kriging methods with other settings were tried, as were interpolations using splining, IDW, and TIN. Specific settings used for each method are outlined in table 1.

Each interpolation method produced a bathymetric model of the depths for the whole pond. This can also be thought of as a model of the topography of the bottom of the pond. Half meter contour lines for each bathymetric model were created. These were overlaid to

illustrate the similarity between the results of the various methods (Figure 4). A pond cross section for each of the models was also calculated and graphically compared (Figure 5). Pond volumes were calculated from the models and compared (Figure 6). The mean of the pond volumes was 73,500 cubic meters with a standard deviation of 1,968 cubic meters. The volumes calculated from all the models tested were within 5% of the result from the standard Kriging method (ordinary Kriging – LSR6).

The final bathymetric map of Beaver Dam Pond with half meter contours was created using ordinary Kriging with a variable search radius of 6 points as the interpolation method (Figure 7).

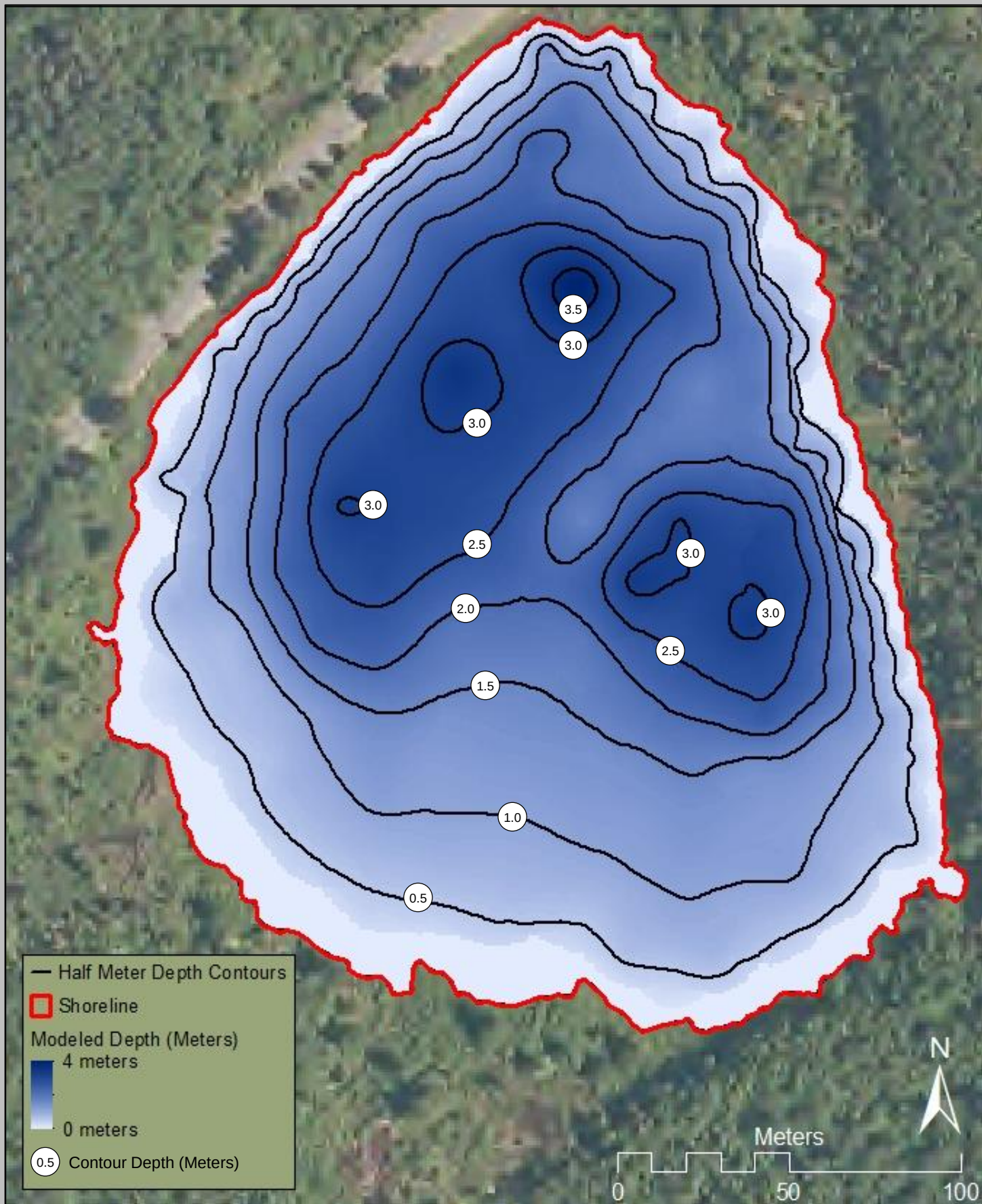


Figure 7. Beaver Dam Pond shoreline and half meter depth contours created using ordinary Kriging and a search radius of 6 points for interpolating depths.

Conclusions

Neither volume nor bottom contours seemed particularly sensitive to interpolation method. However, it seems reasonable to assume that the deepest point in the pond was not sampled which would warrant the selection of one of the inexact models (Kriging or spline) over one of the exact models (IDW and TIN). Although the ordinary Kriging model with the variable distance, 6 point search radius was the standard used for other ponds in the region, it seems that using a fixed distance search radius (ordinary Kriging – FD40) may be better due to the behavior of the models near the shore. The variable distance, 6 point search radius resulted in a band of zero depth where there actually was water. This is likely due to the 3 meter spacing of the zero depth shore points which meant that for many locations near the shore, the 6 closest points used for interpolation were zero depth shore points and the nearest mid-pond points were not considered.

If greater detail describing the bottom surface of the pond was desired, more pond depth measurements could be taken. A rough spacing of 20 meters seemed an appropriate balance of field effort and model detail for our purposes. The next step is to measure the pond depth at several new points on Beaver Dam Pond and see how well these models predict the measured depth. Because the pond's water level in relation to a fixed datum was recorded at the same time the original field depth measurements were taken, these bathymetric models can be adapted to other lake stages.

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