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Modoc National Wildlife Refuge pond bathymetry: Comparing bathymetric models generated from topographic data collected by recreational sonar fish finder and a Real-Time Kinematic Global Position System sensors in support of the USFWS Water Resources Inventory and Assessment program

for

United States Fish & Wildlife Service

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Executive Summary

High resolution bathymetric data are critical to accurately measuring depth and storage capacity of wetlands, ponds, and reservoirs at National Wildlife Refuges. Recent advancements in sonar technology and Global Positioning System (GPS) indicate low-cost, recreational fish finders with sonar and GPS capabilities may provide viable alternatives as bathymetric data collection platforms. This study compared bathymetric models generated from topographic data collected with: 1) a recreational Lowrance HDS Gen 2 sonar fish finder, and 2) a survey grade Real-time Kinematic (RTK) GPS unit using traditional topographic surveying techniques, at the Middle 395 and Headquarters ponds at the Modoc National Wildlife Refuge (MNWR) in August and October of 2013. The purpose of the study was to assess the suitability of the fish finder, which is low cost, for generating bathymetric data from wetlands and ponds at the MNWR.

Digital Elevation Models (DEMs) of each pond were developed from pond bottom topographic data generated through the RTK GPS and sonar surveys. A smoothed DEM was used for contour creation and for graphical display, but was not used for analysis. The magnitude of elevation differences was calculated between concurrent DEMs developed for each pond, and the distribution of these differences were analyzed.

The mean differences in depth between sonar and RTK were 0.032 m (1.26 in) and -0.006 m (.236 in) for Middle Pond and Headquarters Pond, respectively. The biggest discrepancy in depth occurs at around 0.5 m (1.64 ft) below the water surface elevation, likely due to the inaccuracy of the sonar unit when approaching the shallow water boundary. The largest differences in depth for both ponds were found along shallow shorelines at the edge of the analysis area, with over 90 percent of DEM pixels with significant difference from the mean located within a buffer distance (distance from water's edge) of 10 m (32.8 ft) and 6 m (19.7 ft) for Middle and Headquarters Pond, respectively. This finding was to be expected as sonar surveys and boat navigation in shallow water are problematic. There was a positive data bias from the sonar survey which required fitting data to a control point model, which was specific for each pond.

Differences in volumetric calculations between sonar and RTK ranged from -.82 to 4.8 percent. At Headquarters Pond, the RTK and sonar surfaces yielded an estimated volume of 5,677.30 m^3 (4.603 acre-ft) and 5,630.73 m^3 (4.565 acre-ft) respectively. At Middle Pond, the RTK and sonar surfaces yielded an estimated volume of 18,750.4 m^3 (15.20 acre-ft) and 19,659.2 m^3 (15.94 acre-ft), respectively.

The recreational sonar system appears to be a viable alternative to the traditional RTK survey method. The sonar system would be preferable in ponds with areas larger than 4 hectares (10 acres) and deeper ponds with average depths greater than 0.6 m (2 ft) where the shallow water limitation is encountered less frequently and where an RTK survey would be resource intensive to implement.

Introduction

High resolution bathymetric data are critical to accurately measuring the storage capacity of ponds and reservoirs throughout the western United States National Wildlife Refuges. At the Modoc National Wildlife Refuge (MNWR), the management of seasonal wetland complexes can benefit from knowledge of the volume of water required for desired periods of inundation and distribution of water depths. High-resolution bathymetric data can inform such questions; however, the scope and scale of collection efforts make these data difficult and expensive to obtain using traditional topographic [Real Time Kinematic (RTK) Global Positioning System (GPS), total station] and bathymetric (single and multi-beam sonar, acoustic doppler) surveying techniques (Bangen, et al. 2104). However, recent advancements in sonar technology and GPS indicate low-cost, recreational fish finders with sonar and GPS capabilities may provide viable alternatives as bathymetric data collection platforms. Little work has been done with recreational sonar units to determine whether they can provide the necessary accuracy and precision required for bathymetric surveys.

Working with the U.S. Fish and Wildlife Service in a managed wetland system at the MNWR provided a unique opportunity to compare bathymetric models generated from topographic data collected with: 1) a recreational Lowrance HDS Gen 2 sonar fish finder (Lowrance Marine Electronics, http://www.lowrance.com/en-US/), and 2) a survey grade RTK GPS unit using traditional topographic surveying techniques. Performing this experiment in managed seasonal wetlands allowed us to collect RTK data quickly in dry conditions and return for a sonar survey after the ponds had been flooded. The RTK data were used to generate a high resolution elevation dataset that could be used to validate the sonar data. The hypothesis was that sonar unit could provide comparable bathymetric data to that of the industry standard RTK topographic surveying in a more efficient and cost effective manner.

Study area

The Modoc National Wildlife Refuge is comprised of 7,021 acres of land adjacent to the South Fork of the Pit River in Modoc County, California (Figure 1). The refuge is a mosaic of permanent/semi-permanent and seasonal wetlands, wet meadows, riparian and sagebrush-steppe habitats, and Dorris Reservoir. A majority of the managed habitat is wetland (seasonal, semi-permanent, and wet meadow) (USFWS, 2009). Water to manage wetland habitats is derived from direct diversion of seasonal flows in the South Fork of the Pit River and Pine Creek, and diversions to storage in Dorris Reservoir which are re-diverted to wetland habitats from April through September (Esralew et al, 2013)

The selection criteria used for ponds to test in this study consisted of three constraints, ponds had: 1) an areal extent of 4 hectares (10 acres) or less for RTK topographic survey feasibility; 2) an average depth greater than 0.6 m (2 ft) for sonar feasibility at the time of study; and 3) managed as seasonal or semi-permanent wetlands. Bathymetric models were generated for two MNWR ponds that met this criteria, Headquarter Pond and Middle 395 Pond, after a dry RTK survey (August 20th-22nd, 2013) and a wet sonar survey (October 24th-25th, 2013). The Headquarter Pond is filled with water originating from Dorris Reservoir, while the Middle 395 Pond is filled from water originating in the South Fork Pit River. Due to the timing of this study during a year of serious drought and reduced storage volumes in Dorris Reservoir, and low flow in the South Fork Pit River, desired water surface elevations for each pond were not met. As a result, the analysis areas of the ponds were reduced to areas where the selection criteria was met and the sonar survey was feasible.

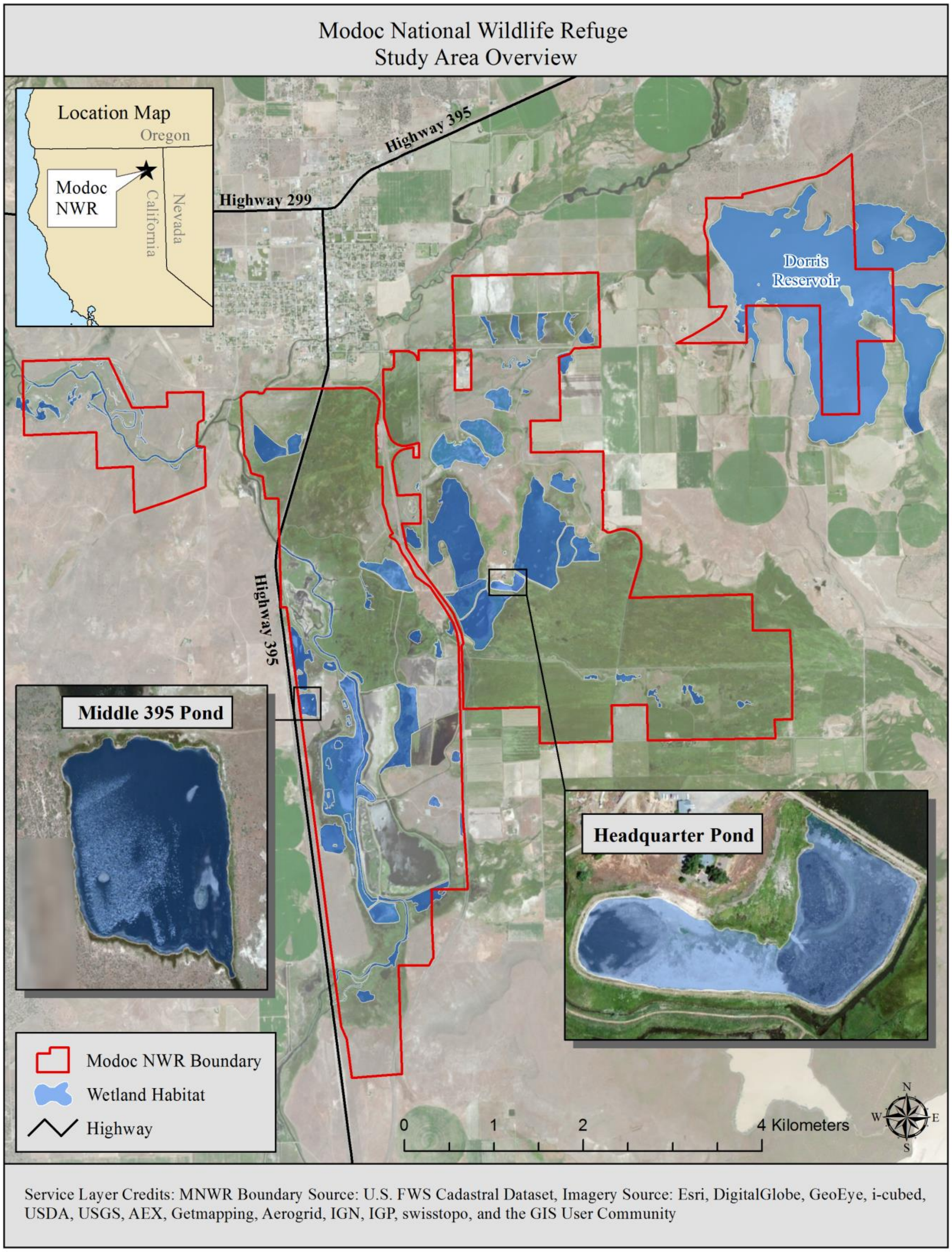


Figure 1. Overview map of wetland habitat at MNWR.

Methods

Bathymetric models were developed for the Headquarter and Middle 395 ponds with data generated using traditional topographic and bathymetric survey techniques. Topographic data were generated from ground-based Real Time Kinematic (RTK) Global Positions System (GPS) surveys, while bathymetric data were collected from a boat with a Lowrance HDS Gen2 sonar unit. Methodological details are provided below.

Real time Kinematic Surveys

A Topcon HyperLite+ Real Time Kinematic (RTK) GPS unit was used to survey both wetland units (Headquarter pond, and Middle 395 pond) at MNWR before seasonal flood up. The survey took place on August 20th-22nd, 2013. Due to the smoothly contiguous bottom surfaces of the ponds, topographic data were collected uniformly across a 4 m (13ft) grid of points (Valle and Pasternack, 2006). All surveyed topographic points were geographically referenced to a National Geodetic Survey (NGS) topographic benchmark ("GEO CLIFF"; PID DH6403) located along the west side of CA Highway 395 adjacent to the refuge. The benchmark information for the survey marker GEO CLIFF can be found at http://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=DH6403 (accessed July 2014). The manufacturer's specified error of the RTK unit in good conditions (clear view of the sky, and sufficient satellites) is less than 2 cm (< 1 in) both vertically and horizontally relative to the known NGS benchmark. Latitudinal and longitudinal data were referenced to the North American Datum of 1983 (NAD83), while elevation data were referenced to the North American Vertical Datum of 1988 (NAVD88). Topographic data were transformed "on the fly" using the Universal Transverse Mercator (UTM) Zone 10 North projection. GPS ellipsoid height values (NAD83) were converted to the NAVD vertical datum using the GEOID09 hybrid model for the Continental United States[1].

Lowrance HDS Gen2 Sonar Fish Finder

A Lowrance HDS Gen2 sonar unit with an 83/200 kHz transducer was used to survey the same two wetland units (Headquarter pond, and Middle 395 pond) at MNWR after flood up. The survey took place on October 24th-25th, 2013. The sonar unit was mounted onto a small, shallow draft, 'whaler' type boat and the transducer was affixed to the transom using a repurposed trolling motor transom mount (see cover photo). The boat was propelled by a Minn Kota trolling motor and transects were driven in the boat with a desired spacing of 4 m (13 ft). The sonar transducer was set to 200 kHz and sonar data were collected passively with a refresh rate of ~15 times per second. A Lowrance LGC 2000 external GPS receiver was affixed onto the transducer mount directly above the transducer to eliminate error of the horizontal distance to the sonar head unit (with internal GPS). The sonar unit integrates heading information measured with an internal compass to improve the sensitivity of the GPS. The LGC 2000 receiver has a GPS refresh rate of 5 times per second and utilizes the Wide Area Augmentation System (WAAS) which improves the accuracy of the GPS data. The specified horizontal error for WAAS enabled GPS systems is less than 3 m (9.8 ft) in good conditions. The conditions during the surveying

[1] GEOID09 is a refined hybrid model of the geoid in the United States and other territories, and is intended for converting between the NAD83 ellipsoid reference frame and various vertical datums, including NAVD88 (National Geodetic Survey, 2011, http://www.ngs.noaa.gov/GEOID/GEOID09/, accessed August 2014)

period of no tree canopy, flat topography, and 10+ satellites were satisfactory to expect less than 3 m (9.8 ft) horizontal error.

GPS and sonar data were saved as a sonar log file ('.sl2' file extension) to an SD Card mounted on the sonar unit. These data were downloaded to a PC and read using Lowrance Sonar Viewer (LSV) software. The LSV software allows for csv output which stored depth and position information in a spreadsheet. Rounding of location coordinates values to whole meters in the LSV software resulted in multiple soundings per unique coordinate.

The R Statistical Program (www.r-project.org) was used to average these multiple records for each unique point, generating an average water depth for each measurement location. Transducer depth below the water surface elevation was accounted for by adding 7.6 cm (3 in) to the measured depths. The adjusted depths were used to generate pond bottom elevations relative to a real world vertical datum (NAVD88). Pond bottom elevations were calculated by subtracting measured water depths from a planar water surface elevation measured from a temporary benchmark surveyed via RTK GPS.

Sonar Data Transformation

Error is inherent in raw topographic data, and there can be considerable bias between elevation (z) data generated with different surveying techniques. For this study, topographic data generated with the RTK GPS were considered more precise than the sonar data (see Bangen, et al., 2014). The accuracy of sonar-derived elevation data (i.e. bias) was assessed by calculating differences between sonar point elevations and a series of 20 control points in each pond (e.g. Brasington, et al., 2003). The latitude and longitude of each control point was measured with a Trimble GeoXM GPS unit horizontally accurate to 1 m (3.28 ft) after post processing, while control point elevation was established by differencing depth measurements made using a stadia rod at geographic locations with the water surface elevation surveyed with the RTK GPS. The control points were matched with the nearest sonar point, and a linear regression model was computed, establishing a numerical relationship between sonar derived elevations and control point elevations (Figure 2). Using established numerical relationships for each pond, the sonar points were then transformed by the coefficients of the model (Middle 395 pond: $y = 0.954x + 60.3$, $R^2 = 0.872$; Headquarter Pond: $y = 1.02x - 31.0$, $R^2 = 0.925$) and the transformed values were outputted to a csv and used for subsequent DEM generation and analysis. The transformed data in the format of Northing, Easting, and Elevation was converted to a spatial format using the ArcGIS 'Display XY' tool, reprojected to North American Datum (NAD) 1983 Universal Transverse Mercator (UTM) Zone 10 North projection and saved as a shapefile.

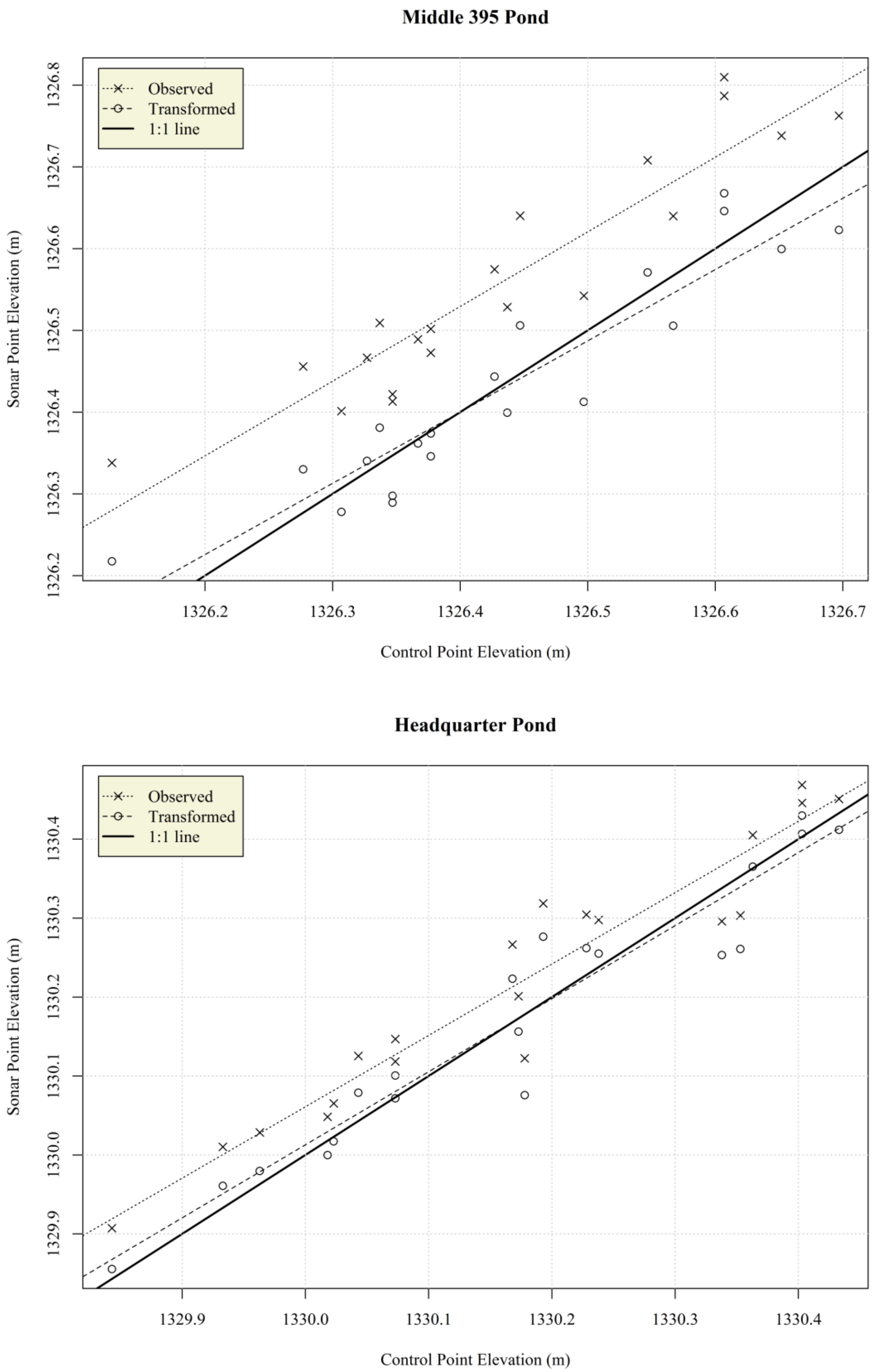


Figure 2. Sonar point transformation from sonar and control point regression relationship.

Pond Digital Elevation Model (DEM) generation

Digital Elevation Models (DEMs) of each pond were developed from pond bottom topographic data generated through the RTK GPS and sonar surveys. Concurrent DEMs were generated in the geographic information system (GIS) ArcMap 10.2 by interpolating triangular irregular networks (TINs) from topographic data points, and subsequently editing each TIN and converting the TINs to 1 m (3.28 ft) resolution rasters using a linear interpolation method (see Bangen, et al. 2014). The TINs were manually edited with the removal of outlying TIN nodes and the addition of hard breaklines to remove artifacts of the data and to better represent the shape of the wetland especially around the edges. Furthermore, when a shallow depth of approximately 0.3 m (~ 1ft) was approached during the sonar surveys, several false depth measurements of approximately 1 m (3.28 ft) were recorded prior the cessation of sounding in water depths shallower than 0.3 m (~1 ft). These false measurements were manually removed during the TIN editing process so that the final surface would not reflect these inaccuracies. Due to the timing of the study with low water surface elevations, which resulted in reduced area accessible by the sonar system, DEMs were clipped to the analysis extent that encompassed the area surveyed by sonar (see Figure 4).

Additionally, for display only, the focal statistics tool in ArcMap 10.2 was used to smooth the DEM pixels using a mean of a circle with a 2 pixel radius around the focal pixel. The smoothed DEM was used for contour creation and for graphical display, but was not used for analysis. Figures 5 and 6 provide a visual comparison of the RTK and Sonar derived DEMs for the respective ponds.

DEM Comparisons

Simple differencing was used to calculate the magnitude of elevation differences between concurrent DEMs developed for each pond. Differencing was performed in ArcMap 10.2 using the raster calculator tool, with the following equation used to create a DEM of difference (DoD) (see Wheaton, et al. 2010):

Eq (1): $DoD = Elevation_{rtk} – Elevation_{Sonar}$

DoD’s presented herein represent the full magnitude of elevation differences between the concurrent DEMs generated using different survey techniques. Simple differencing does not take into account potential error/uncertainty associated with the generation of DEMs from repeat topographic surveys (see Wheaton, et al. 2010).

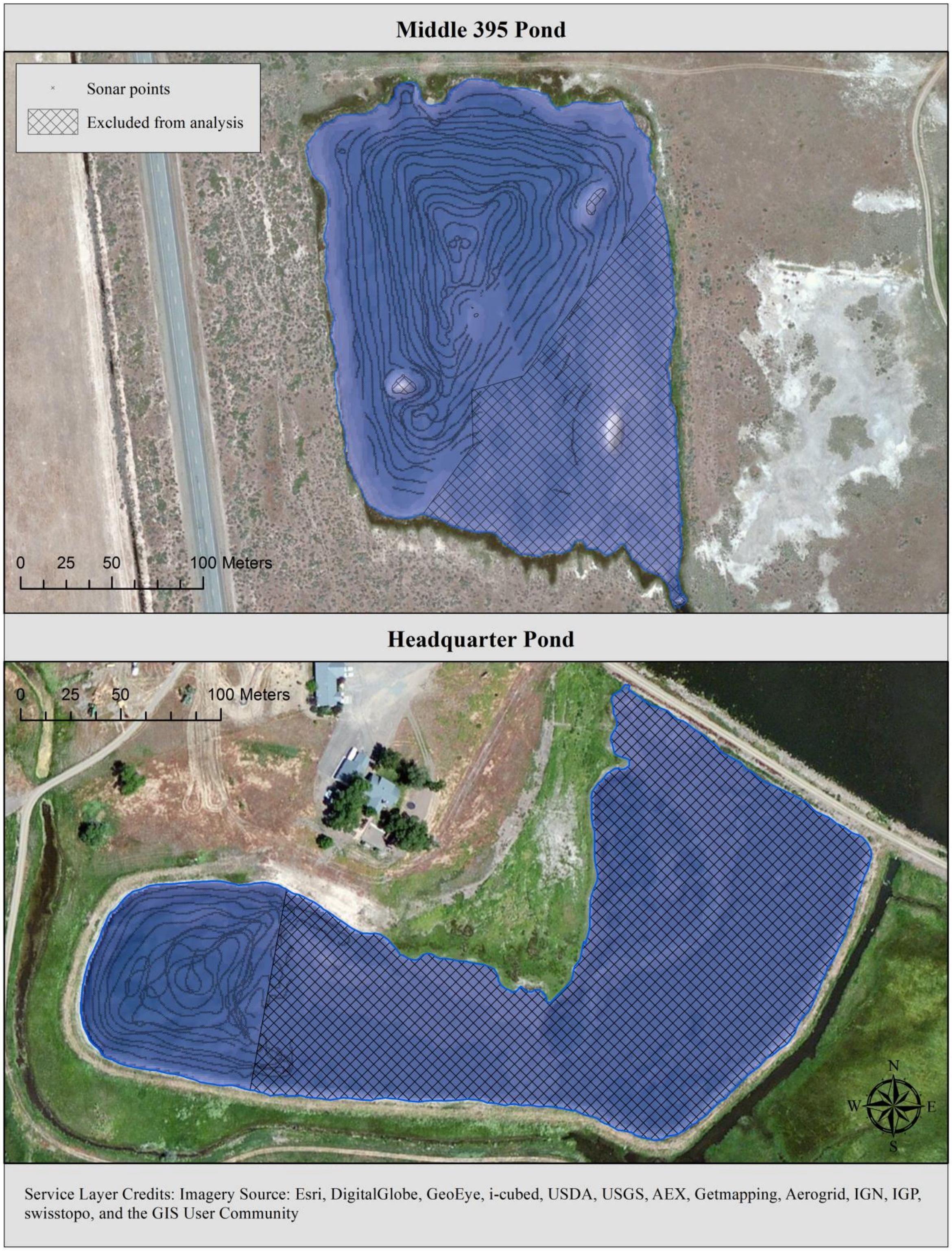


Figure 3. Map showing sonar survey coverage and area excluded from analysis in Middle 395 Pond (above) and Headquarter Pond (below).

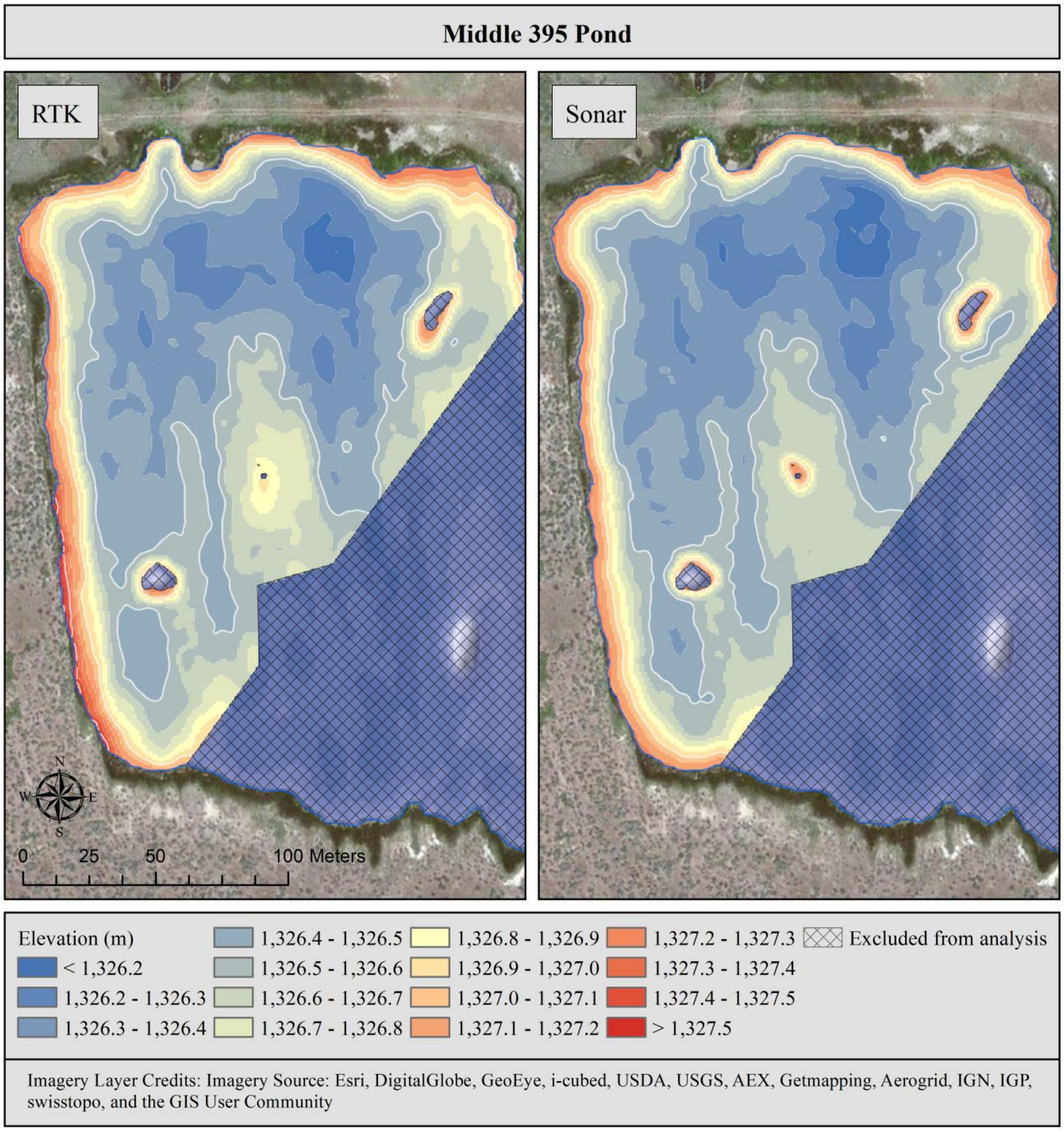


Figure 4. Visual comparison of RTK and Sonar derived DEMs for Middle 395 Pond.

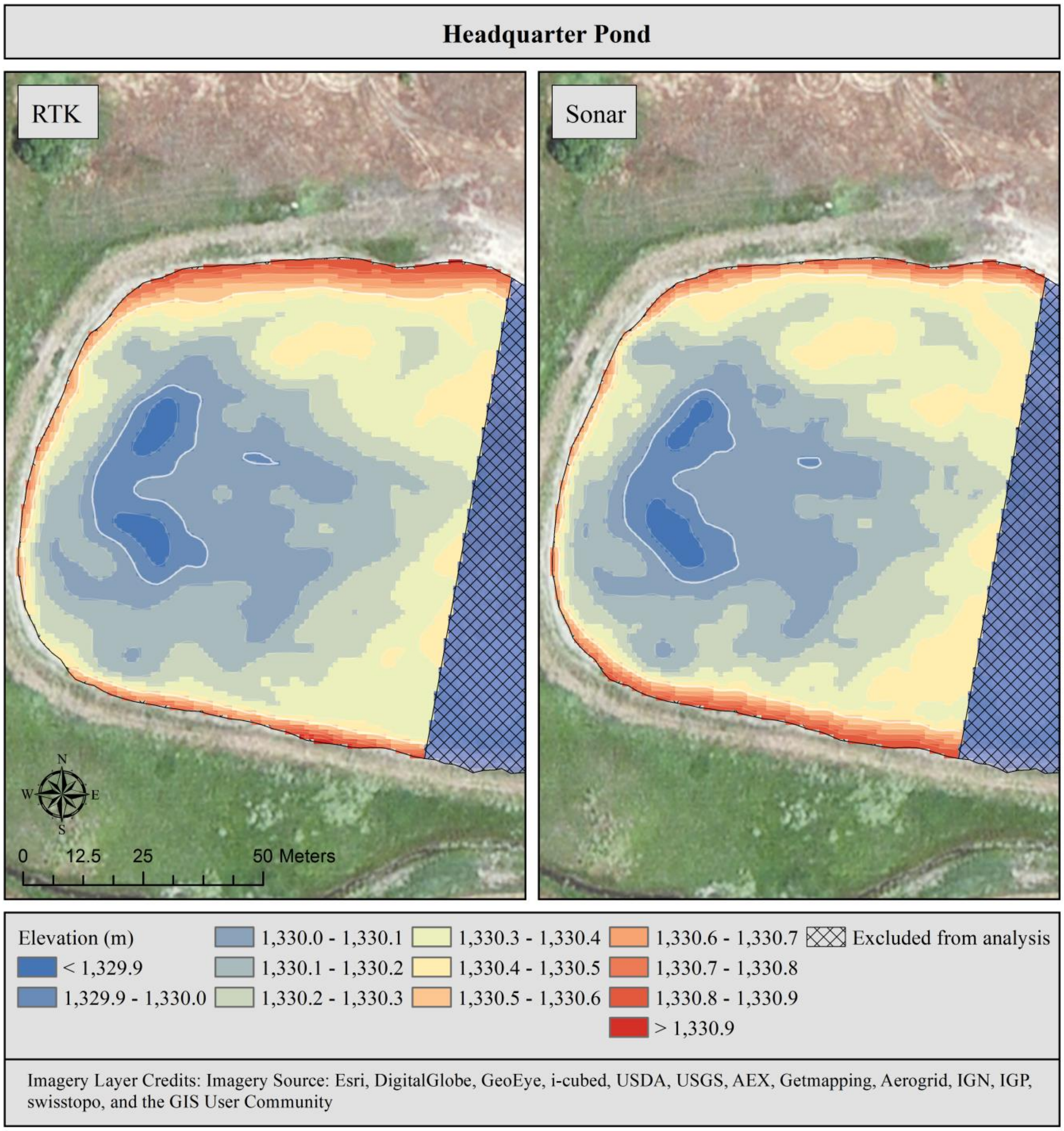


Figure 5. Visual comparison of RTK and Sonar derived DEMs for Headquarter Pond.

Results

Residual Analysis

Sonar point elevations were biased relative to manual control point elevations in each pond. Measured errors were positively signed (Figure 2), suggesting depths generated from sonar data were routinely overestimated. For the Middle 395 Pond, mean error was 0.126 m (0.41 ft). Mean error for the Headquarter pond was 0.045 m (0.15 ft). Transforming sonar elevations using an established regression relationship (see Figure 2) adjusted the mean error to approximately zero and allowed for quantitative comparison of DEMs.

DEM Comparisons

Concurrent DEMs developed for each pond using both RTK and sonar topographic survey methods are presented in Figures 4 and 5. While the entirety of each pond was initially surveyed using the RTK GPS, large areas of each pond were unable to be accessed for subsequent boat-based sonar surveys due to unanticipated shallow water depths. As such, analysis of elevation differences ($\Delta z = elevation_{RTK} - elevation_{Sonar}$) between concurrent DEMs were limited to portions of each pond specified in Figure 3. Qualitative visual comparisons of DEMs developed for each pond (Figures 4 and 5) suggest both survey techniques (RTK and sonar) generated similar elevation models/pond bottom bathymetries.

Results of differencing concurrent DEMs developed for the Middle 395 and Headquarter Ponds are visually presented in Figure 5. Quantitative analyses of the DoDs are presented in the DoD pixel analysis section below.

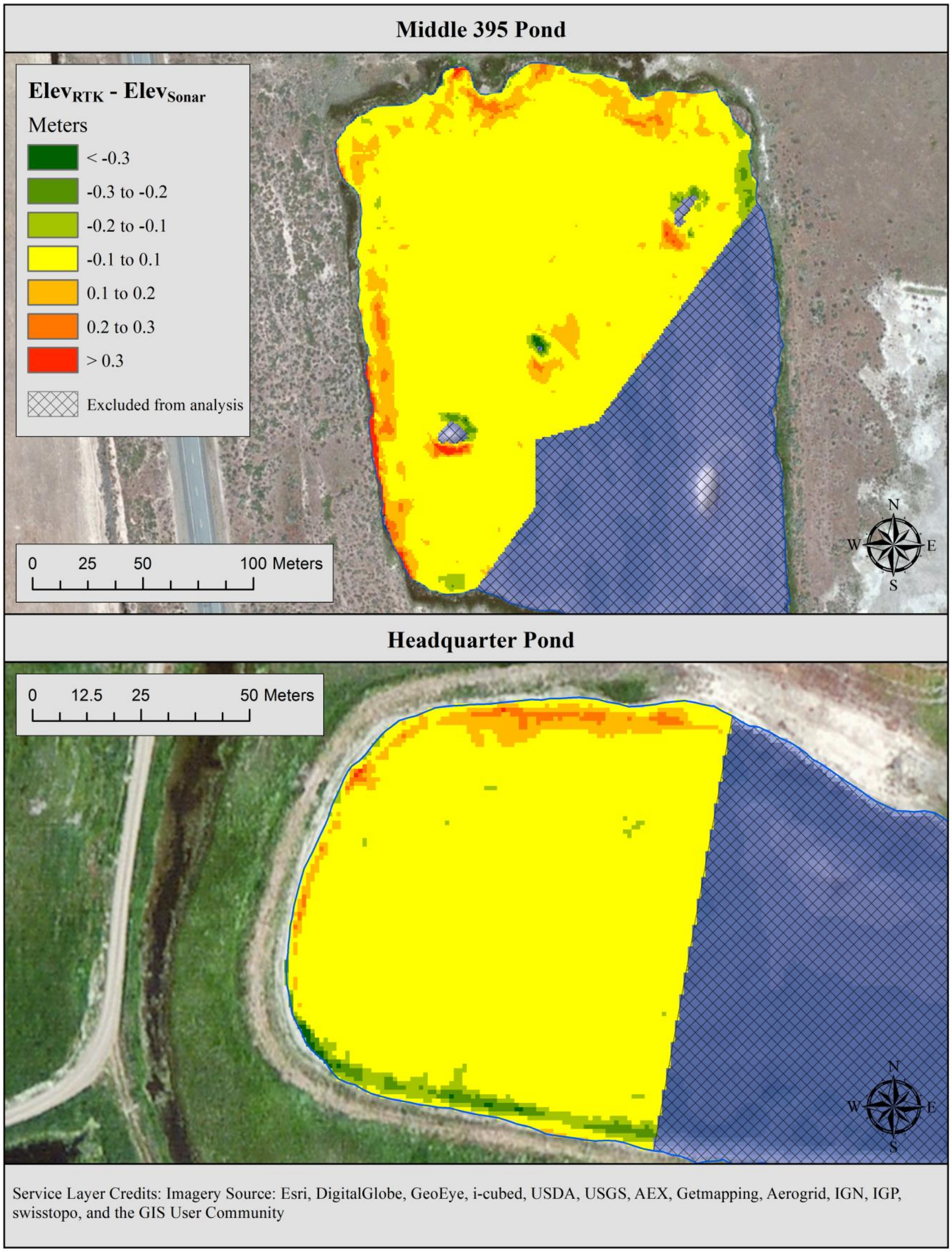


Figure 6. Map showing DoDs (Elevation$_{RTK}$ - Elevation$_{sonar}$) for Middle 395 Pond (top) and Headquarter Pond (bottom).

DoD Pixel analysis

Middle 395 Pond

Analysis of pixel difference magnitudes (Δz) indicate that the mean Δz for the Middle 395 Pond was 0.032 m (1.26 in; 1 standard deviation = 0.073 m (2.87 in); 2 standard deviations = 0.146 m (5.75 in)). The proportion of the pixels that fell within the specified error of the RTK, 0.02 m (0.79 in), was 33.1%. These data suggests reasonable agreement between elevation models developed from RTK and sonar survey data.

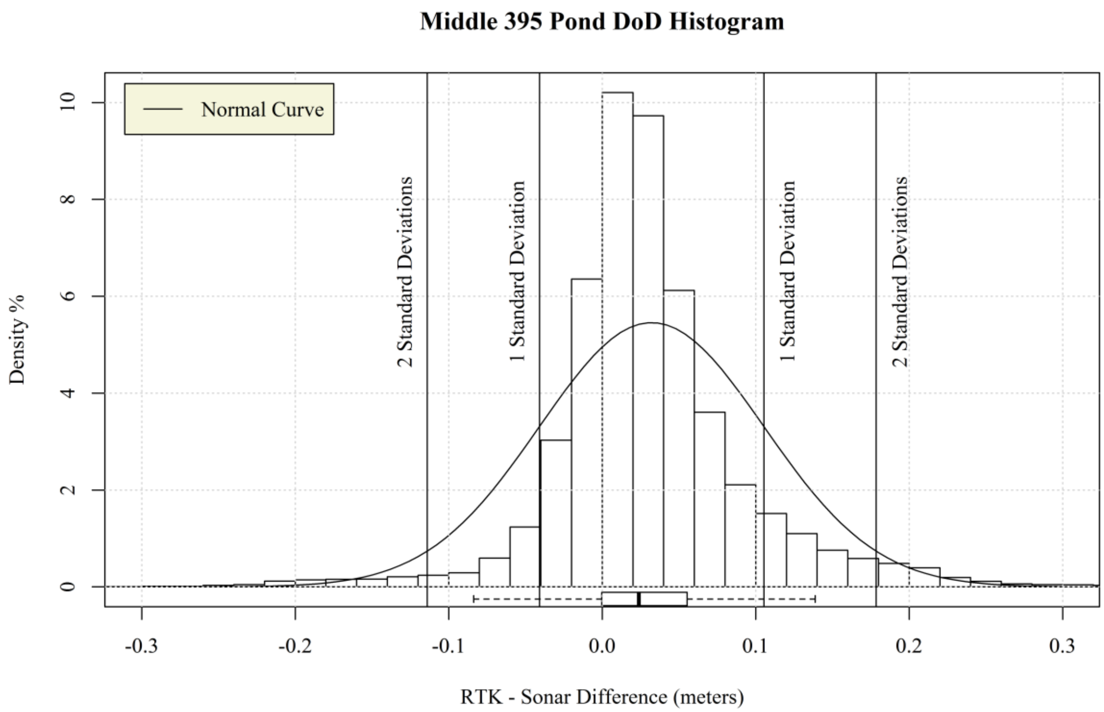


Figure 7. Middle 395 Pond DoD pixel distribution ($\text{Elevation}_{\text{RTK}} - \text{Elevation}_{\text{Sonar}}$).

Qualitative observations (see Figure 6) indicate the largest Δz magnitudes can be found near the edges of the analysis area (i.e. near the pond shore and adjacent to islands). This suggests potential bias/error of measurements and resulting model creation in shallow shoreline areas inaccessible by boat (see sonar transect paths in Figure 3). Since Δz magnitudes greater than 1 standard deviation from the mean located along the pond edge are both negatively and positively signed, this error/bias is likely derived from raster pixel interpolation differences (RTK versus sonar) along the pond edges, Positive Δz values indicate modelled sonar depths are greater than modelled RTK depths at a given location (i.e. sonar pixel elevation magnitudes are less than concurrent RTK pixel elevation magnitudes), while negative Δz values indicate sonar depths are less than RTK depths (i.e. sonar pixel elevation magnitudes are greater than concurrent RTK pixel elevation magnitudes). Large, positive Δz values are generally found in edge areas where the sonar DEM identifies a more abrupt pond shallowing than that identified by the RTK DEM (e.g. northern edge of the Middle 395 Pond). Conversely, large negative Δz values are typically found in edge areas where the sonar DEM identifies a more gradual pond shallowing than that identified by the RTK DEM (e.g. northeast corner of the Middle 395 Pond).

Quantitative comparison of the derived bathymetric surfaces indicate that over 90 percent of the pixels with a difference over 1 and 2 standard deviations from the mean are located within a buffer distance of 13 m (42.6 ft) and 10 m (32.8 ft) of the water's edge respectively (see Figure 7). Furthermore, 90 percent of the pixels with a difference over 1 and 2 standard deviations from the mean come from areas shallower than 0.65 m (2.13 ft) and 0.6 m (1.97 ft) respectively. This suggests potential bias/error of measurements and resulting model creation in shallow shoreline areas

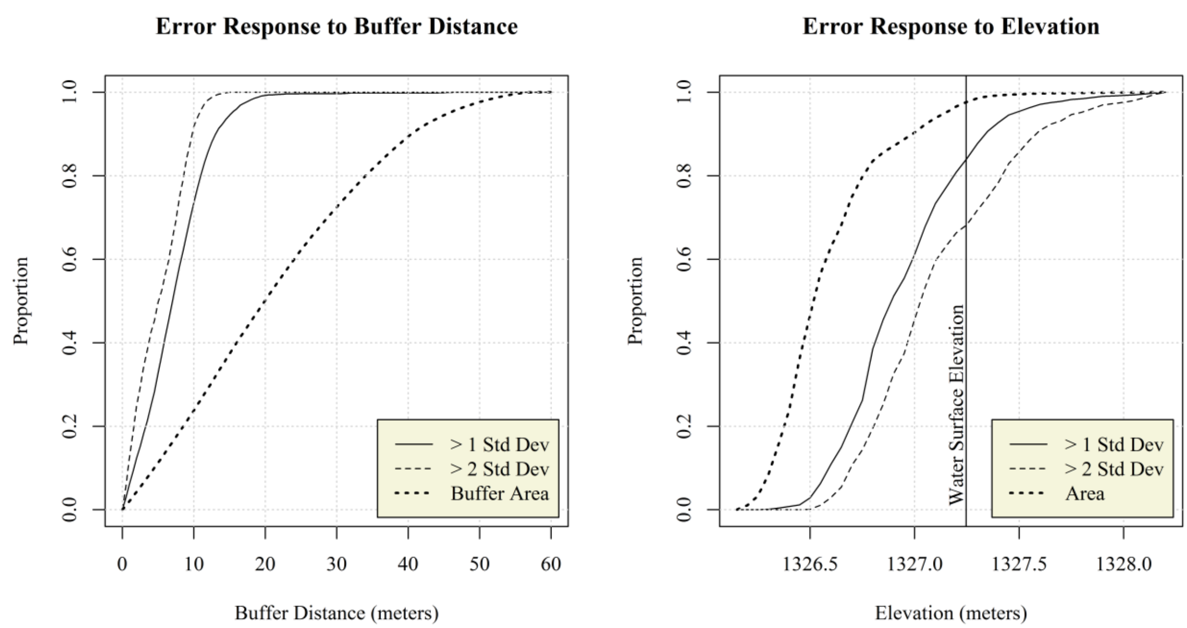


Figure 8. Middle 395 pond error response to buffer distance (left) and elevation (right) presented as the proportion of the error greater than 1 and 2 standard deviations respectively from the mean. The proportion of the total area within the buffer distance or above the specified elevation respectively is displayed for reference.

Headquarter Pond

Analysis of pixel difference magnitudes (Δz) indicate that the mean Δz for the Headquarter Pond was -0.006 m (0.236 in; 1 standard deviation = 0.069 m (2.71 in); 2SD = 0.138 m (5.43 in)). The proportion of the pixels that fell within the specified error of the RTK, 0.02 m (0.79 in), was 31.8%. These data suggest better agreement between elevation models compared to those developed for the Middle 395 Pond. The better performance of the sonar model in the Headquarter Pond may have been due to less edge complexity and no islands in the analysis area.

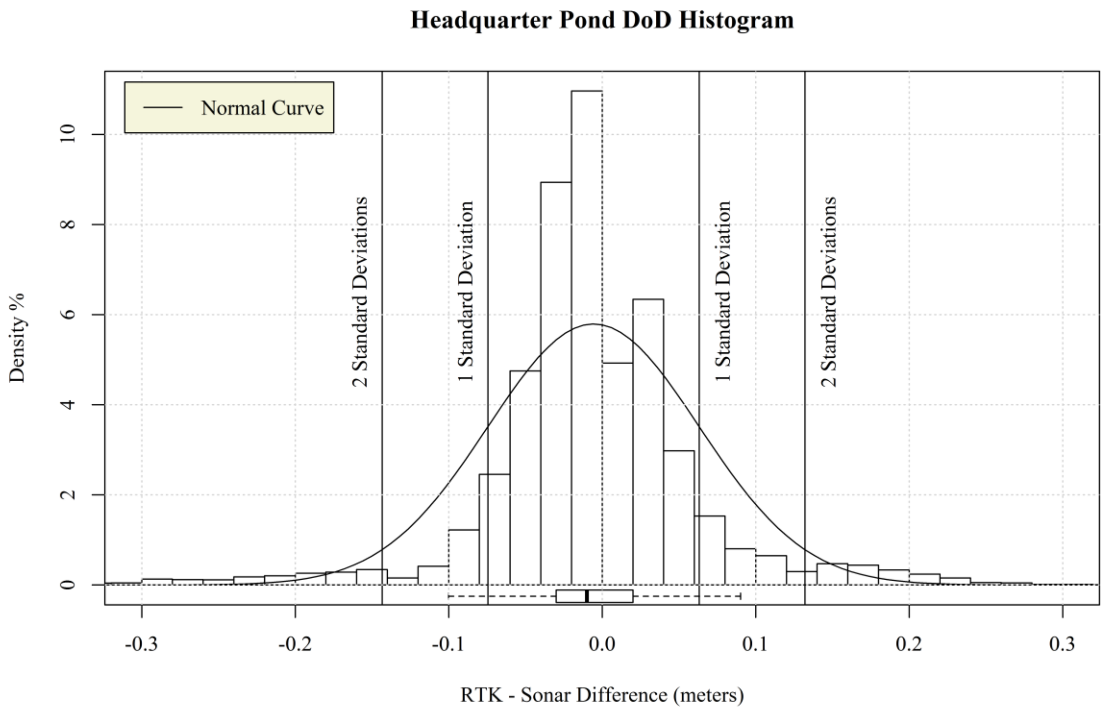


Figure 9. Headquarter Pond DEM of Difference pixel distribution (ElevationRTK – ElevationSonar).

Similar to the Middle 395 Pond model, the largest Δz values for the Headquarter Pond were found along shallow shorelines at the edge of the analysis area (see Figure 6). Without islands, these “edge” areas were located along the north, west and south pond boundaries (the eastern boundary of the analysis area is deeper “open” water). Like observations from the Middle 395 Pond, Δz magnitudes at the pond edges are both negatively and positively signed. As previously discussed, positive Δz values indicate modelled sonar depths are greater than modelled RTK depths at a given location (i.e. sonar pixel elevation magnitudes are less than concurrent RTK pixel elevation magnitudes), while negative Δz values indicate sonar depths are less than RTK depths (i.e. sonar pixel elevation magnitudes are greater than concurrent RTK pixel elevation magnitudes). The positive Δz values are generally found in edge areas where the sonar DEM identifies a more abrupt pond shallowing than that identified by the RTK DEM (e.g. northern and western edges of the Headquarters Pond). Conversely, large negative Δz values are found in edge areas where the sonar DEM identifies a more gradual pond shallowing than that identified by the RTK DEM (e.g. southern edge the Headquarter Pond).

Quantitative comparison of the bathymetric surfaces indicates that over 90 percent of the pixels with a difference over 1 and 2 standard deviations from the mean are located within buffer distance of 10.5 m (34.4 ft) and 6 m (19.7 ft) of the water’s edge respectively (Figure 10). Furthermore, 90 percent of the pixels with a difference over 1 and 2 standard deviations from the mean come from areas shallower than 0.6 m (1.97 ft) and 0.5 m (1.64 ft) respectively. Once again, this suggests potential bias/error of measurements and resulting model creation in shallow shoreline areas.

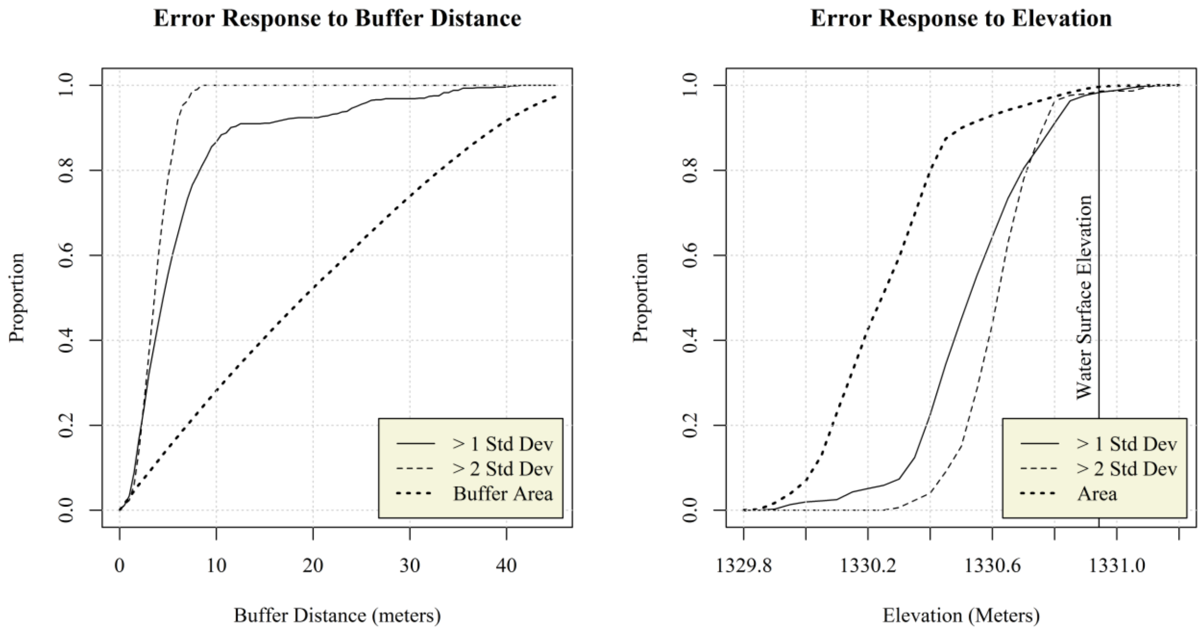


Figure 10. Headquarter pond error response to buffer distance (left) and elevation (right) presented as the proportion of the error greater than 1 and 2 standard deviations respectively from the mean. The proportion of the total area within the buffer distance or above the specified elevation respectively is displayed for reference.

Volumetric analysis

<u>Middle 395 Pond</u>

RTK and sonar-derived bathymetric surfaces were used to generate estimates of the volumetric holding capacity of the Middle 395 Pond. The RTK derived DEM yielded an estimated volume for the analysis area of 18,750.4 m^3 (15.20 acre-feet). The sonar DEM yielded an estimated volume of 19,659.2 m^3 (15.94 acre-feet). The absolute difference was 908.8 m^3 (0.74 acre-feet), and the difference per unit volume (RTK volume used as the reference value) was 4.8% (Table 1).

<table>
<tr><th colspan="3">Table 1. Middle 395 pond</th></tr>
<tr><th>Method</th><th>Analysis Area (m^2 / acres)</th><th>Volume (m^3 / acre-feet)</th></tr>
<tr><td>RTK</td><td rowspan="3">28256.0 m^2 / 6.98 acres</td><td>18,750.4 m^3 / 15.20 acre-feet</td></tr>
<tr><td>Sonar</td><td>19,659.2 m^3 / 15.94 acre-feet</td></tr>
<tr><td>Difference</td><td>908.8 m^3 / 0.74 acre-feet</td></tr>
<tr><td colspan="3">Percent Difference per unit volume = 4.8%</td></tr>
</table>

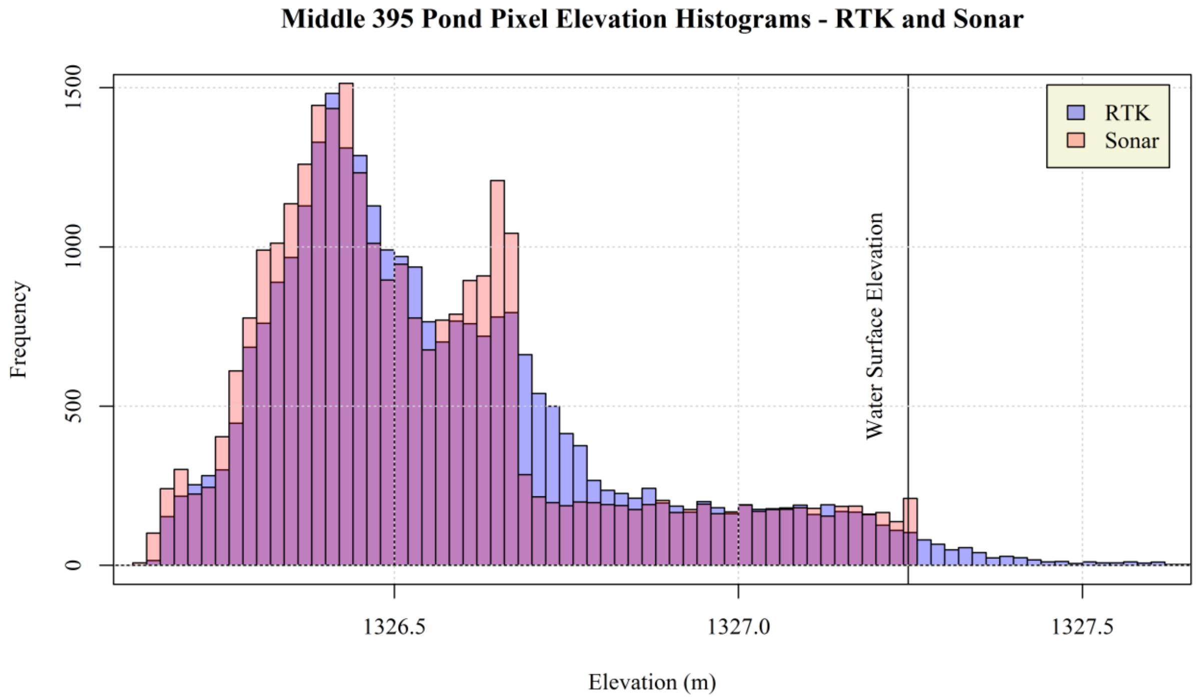
Headquarter Pond

The RTK and sonar surfaces yielded an estimated volume of 5,677.30 m^3 (4.603 acre-feet) and 5,630.73 m^3 (4.565 acre-feet) respectively. The absolute difference was 46.57 m^3 (0.038 acre-feet) and the percent difference per unit volume (RTK volume used as the reference value) was -0.82% (Table 2).

Table 2. Headquarter pond		
Method	**Analysis Area (m^2 / acres)**	**Volume (m^3 / acre-feet)**
RTK	8268.2 m^2 / 2.04 acres	5,677.30 m^3 / 4.603 acre-feet
Sonar		5,630.73 m^3 / 4.565 acre-feet
Difference		-46.57 m^3 / -0.038 acre-feet
Percent difference per unit volume = -0.82%		

Elevation Distribution

The distributions of pixel elevation from the derived RTK and sonar elevation models demonstrate a large degree of overlap especially in the deeper areas (see Figure 11). The biggest discrepancy occurs at around 0.5 m (1.64 ft) below the water surface elevation, likely due to the inaccuracy of the sonar unit when approaching the shallow water boundary. Despite the discrepancy, the sonar derived surface appears to produce a reasonable distribution of depths which could be useful for aquatic habitat analysis.



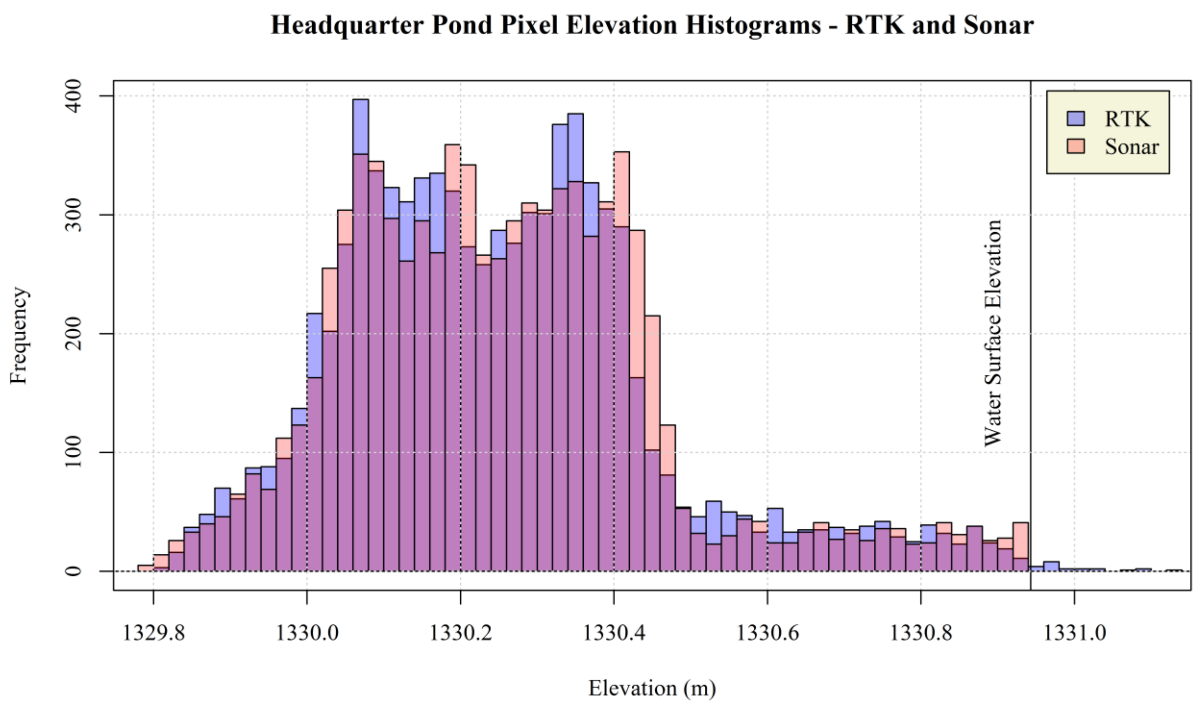


Figure 11. Distribution of pixel elevation from derived RTK and sonar elevation models for Middle 395 Pond (above) and Headquarter Pond (below).

Economic Comparison

The equipment cost of the RTK which retails for around $30,000 is much higher than a recreational sonar system which can be purchased with a small watercraft for $1,500 (see Table 3). Survey time in the wetlands is reduced by the boat based sonar system which can cover a lot of water in a short time. Also, RTK survey time would have increased if the ponds had not been dry during the survey which allowed easy movement between points. However, extra post-processing steps such as matching control points and performing raw data transformation require more data handling time with the sonar versus the RTK which outputs data that requires only a simple format conversion to be usable in a GIS. Additionally, to obtain real world elevations from the sonar system, a water surface elevation must be established using a known benchmark or RTK; otherwise the data will be only be available as relative depths.

Table 3. Economic comparison

	RTK	**Boat based Sonar**
Equipment cost	$30,000 - $50,000	$1,500
Survey Time	1.8 hrs per acre per rover (4 meter grid over dry substrate)	0.3 hrs per acre (4 meter transect spacing)
Processing time	2hrs per pond	8hrs per pond
Required Software	Proprietary Surveying and GIS software	ArcGIS, R Statistical Program (free), Lowrance Sonar Viewer (free)

Discussion

The purpose of the study was to assess the suitability of a low-cost, recreational fish finder for generating bathymetric data from wetlands/ponds at the MNWR. Quantitatively comparing bathymetric data generated with the Lowrance HDS Gen 2 sonar fish finder to detailed bathymetric data generated with a survey grade RTK GPS allowed us to characterize the suitability of the fish finder to determine pond volumes and depth distributions at MNWR and other refuges.

Volumetric and DoD pixel difference analysis validates the hypothesis that the sonar system can be used as an efficient alternative to RTK surveys, or other comparable topographic surveying techniques. The volumetric differences of 4.8% and -0.8% for the Middle 395 and Headquarter ponds, respectively, are within reasonable accuracy for smaller reservoirs. Analysis of the DoD pixel distribution showed that a majority of the difference between the pixels was within 0.1 m (3.93 in) and that the spatial distribution of the tails of the DoD distribution (greater than one standard deviation) was coming from the shallow near shore areas. This finding was to be expected as sonar surveys and boat navigation in shallow water are problematic. The shallow water limitation is likely progressively minimized as water bodies get larger and deeper through the minimization of shallow edge areas where much of the error occurs.

In this study, there was a positive data bias from the sonar survey which may require fitting data to a control point model. This shift is not likely uniform, and is probably site specific. Control point accuracy is also predicated on the accuracy of the water surface elevation and the assumption of no variation in water surface elevation during the survey.

The reasonable equipment cost of the sonar system is appealing along with the ability to survey a large amount of water in a short time period. However, extra data processing steps in the office require more data handling time with the sonar versus the RTK. Additionally, to obtain accurate real world elevations from the sonar system, a water surface elevation must be established using a known benchmark or RTK; otherwise the data will be only be available as relative depths.

In conclusion, the recreational sonar system appears to be a viable alternative to the traditional RTK survey method. The sonar system would be preferable in ponds with areas larger than 4 hectares (10 acres) and deeper ponds with average depths greater than 0.6 m (2ft) where the shallow water limitation is encountered less frequently and where an RTK survey would be difficult, expensive, and time consuming to implement. Traditional RTK surveys would remain the preferred approach in small, shallow ponds.

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