APPENDIX A - TOPOBATHYMETRIC DEM DEVELOPMENT

INTRODUCTION

Production of the Johns Lake topobathymetric digital elevation model (DEM) for Minimum Flows and Levels (MFLs) modeling involved three phases. The product of the first phase, a DEM of the Johns Lake Interconnected Channel and Pond Routing version 4 (ICPR4) model footprint (Figure A-1, Panel A), was developed in 2019 by District staff with elevation data provided by Collective Water Resources (CWR). Subsequently, a second phase was initiated by District staff to improve the bathymetric portion of that DEM (Figure 1, Panel B). The two DEMs were mosaiced together to create the updated topobathymetric DEM for ICPR4 modeling (Figure 1, Panel C). The dotted line around the lake area, seen in Panel C in Figure 1, is a map component to identify the location of new bathymetry data. A third phase was also required to reduce the footprint and resolution of the ICPR4 DEM for geospatial analysis with the Hydroperiod Tool (HT) (ESRI 2019).

The production of the topobathymetric DEM for the first phase was completed in 2019 and is described in Task B of the hydrologic modeling report for Johns Lake (Leta et al. 2022). A multi-step process was used to develop the DEM from disparate data sources compiled by CWR. This DEM (Figure A-1, Panel A) is shown with the bathymetric portion removed and is referred to herein as the upslope portion of the DEM.

A focused DEM was developed in the second phase to improve the Johns Lake bathymetric portion from the first phase (Figure A-1, Panel B). The third phase combined DEM was developed to facilitate MFLs metric assessment (e.g., comparisons of habitat area under different pumping conditions) with the HT, and to improve the performance of the updated Johns Lake ICPR4 model, completed in 2021.

All geospatial work for the second and third phases was completed in ArcMap 10.8.1. Bathymetry data were collected in feet (ft) or converted to ft North American Vertical Datum of 1988 (NAVD88) for interpolation. The final Johns Lake DEM for ICPR4 modeling is a 10 by 10 ft grid, spatial reference systemNAD_1983_HARN_StatePlane_Florida_East_FIPS_0901_Feet, linear unit in feet (ft) NAVD88 (US). Two final DEMs were produced for ICPR4 modeling, one in vertical units in ft, the other in meters (m). The topobathymetric DEM used for the MFLs HT analyses (i.e., the third development phase) is a 10 m grid derivative of the ICPR4 DEM (NAVD88), horizontal and vertical units in meters, explained in detail below.

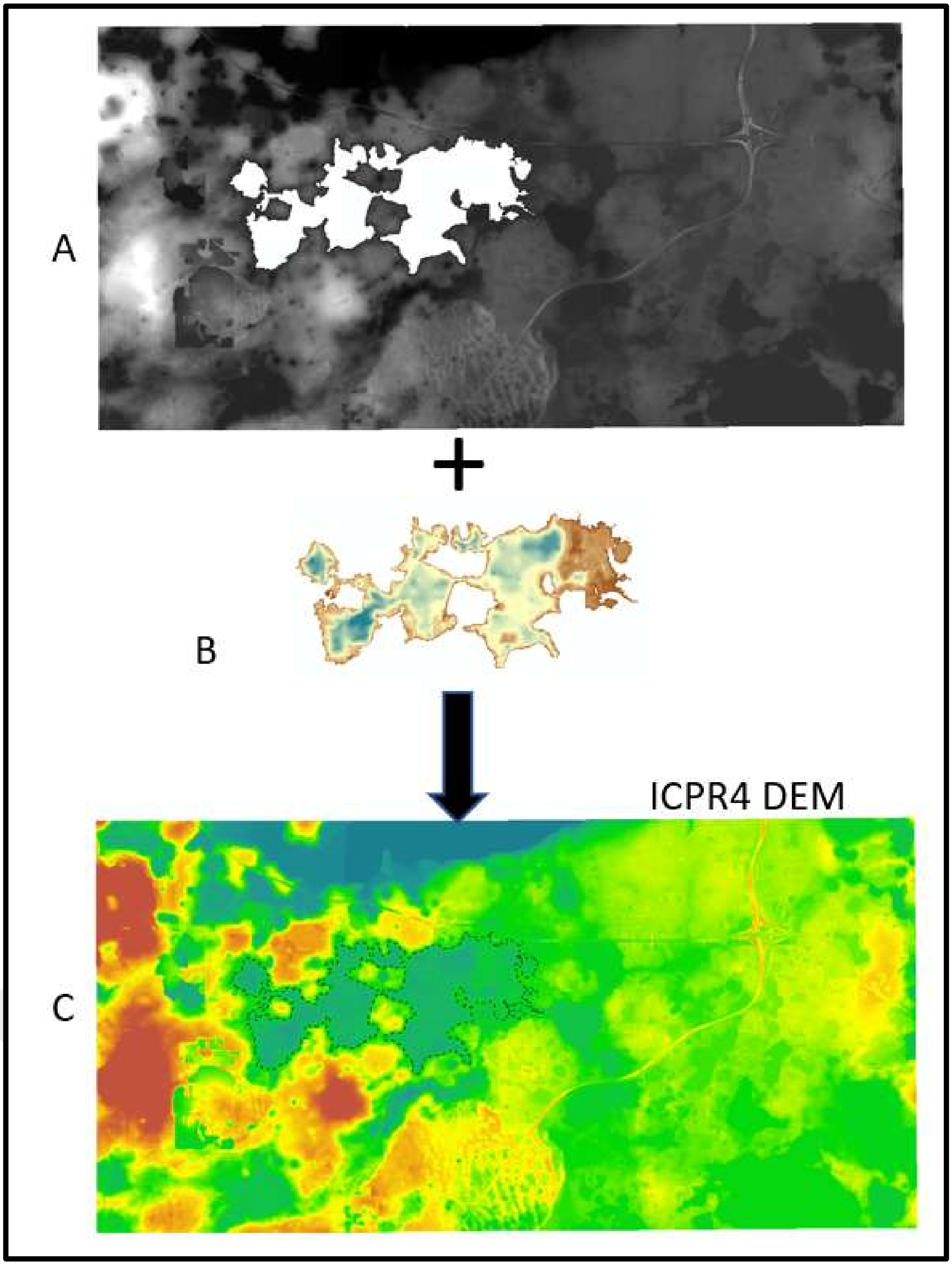

Figure A-1: Combination of the two DEMs for ICPR4 modeling. Symbology was chosen to enhance differentiation of data. Panel A is the first phase “footprint” DEM with the bathymetric area (lake) removed for clarity. Panel B is the bathymetric DEM developed separately (phase two). Panel C is the combined DEM by ArcMap's “mosaic to new raster” function.

BATHYMETRY

The bathymetric portion (Figure A-1, Panel B) of the DEM (phase two) was developed by interpolation, combining several disparate bathymetry datasets that were either acquired or created using different methodologies (described below). All lines (contours, digitized) were converted to points for interpolation. All bathymetry data were cross-validated against the two sets of survey data provided by the MFLs program to determine spatial compatibility. All data are in NAVD88.

Bathymetry data list

The datasets used for the bathymetric portion of the Johns Lake topobathymetric DEM (ICPR4 and HT) include the following:

1) LIDAR-derived contours (source: SJRWMD)
    a. Lake County, ca. 2006
    b. Orange County, compiled from multiple sources, ca. 2004 - 2008
2) Survey (source: SJRWMD, MFLs program)
    a. Original – differentially corrected LakeWatch data, ca. 1998
    b. 2020; collected by MFLs staff
3) 2021 MFLs data; “Heads up” digitized aerial photographs (source: SJRWMD)
    a. 1984
    b. 2014

Bathymetry contour data

The District maintains elevation data in both DEM format and as contour lines accessed through ESRI’s Spatial Data Engine (SDE). When the Johns Lake topobathymetric DEM project was in development, only the Lake County portion in the area of interest was available as a DEM (ca. 2006), while both Orange and Lake counties were available as contour lines (Lake ca. 2007; Orange ca. 2004 – 2008). The original source data for both contour datasets is LIDAR. (Note: the USGS Florida Peninsular LIDAR data were in development when this DEM was in production.)

The initial purpose of using the contour data was to find a common elevation feature from the two counties’ (Lake and Orange) datasets for the entire lake area to define the “lake edge.” A testament to the validity of the two separately developed contour datasets for Lake and Orange counties is how well the 96, 100, and 105 ft contour lines from the two sets align around Johns Lake, enabling the 96 ft contour to be used as the “lake edge”. Additionally, a 96 ft contour line derived from the phase one ICPR4 DEM (Figure A1, Panel A) aligned nearly perfectly with the District’s Lake and Orange County contour data; this indicates that common elevation data sources were used to create the DEM from the data compiled by CWR (2019) in the first phase for the “upslope” portion of the Johns Lake topobathymetric DEM for ICPR4 modeling.

The lowest elevation contour line around Johns Lake from the Lake County dataset is 96 ft NAVD88. In contrast, the Orange County dataset includes many contour lines below that elevation within the lake area (Figure A-2). This indicates the water level was lower when the LIDAR was flown for the Orange County contours. The validity of the elevation of these "interior" (not upslope) contour lines was compared to MFLs bathymetry survey data, enabling the use of the contour lines in addition to survey points to create the lake bathymetric interpolation in the second phase. The linework was converted to points and thinned for interpolation. The thinning process was necessary because all contour line vertices are converted to points in the GIS process, creating a condition of superfluous input; using all the data would overwhelm the subsequent interpolation process. These contour-derived bathymetry points were especially essential for the wetlands in the far eastern end of the lake where relatively few survey points were available (discussed below and shown in Figure A-6). The 96 ft contour line (lake edge) was also converted to points to interpolate the bathymetric surface (DEM).

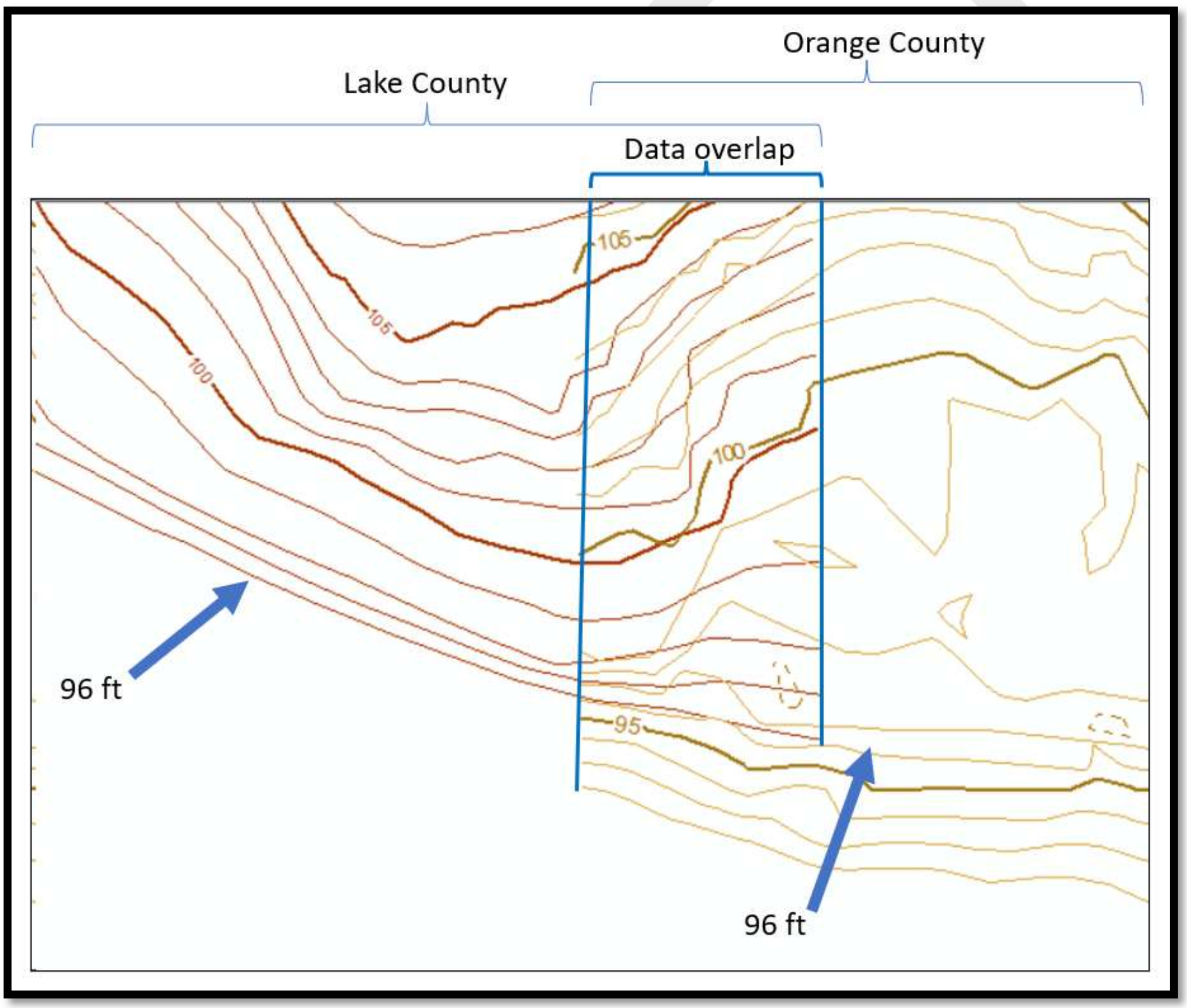

Figure A-2: Comparison of the contour lines from the two counties, Lake and Orange. Based on the use of the 96 ft contour line to define the lake edge, below the 96 ft contour is the lake area and above the 96 ft contour is the "upslope" area. The graphic demonstrates the compatibility of the two disparate LIDAR-derived datasets.

Bathymetry survey data

The original set of District survey data for Johns Lake is shown in Figure A-3, panel A; SJRWMD IT/GIS differentially corrected LakeWatch data collected ca. 1998 was used to create contours and a depth map for the lake. Three more survey campaigns were undertaken by District staff in 2020 and 2021 to better represent the bathymetry of Johns Lake (Figure A-34, Panels B and C). The 2020 and 2021 datasets are considered to be the “gold standard” for the elevation (bathymetry) of the lake and all datasets were validated (contours) or assigned elevation (digitized lines from aerial photographs) as needed by comparing them to the survey data. The three survey datasets (2020 and 2021) were used to validate the differentially corrected LakeWatch data thus enabling its use for the interpolation.

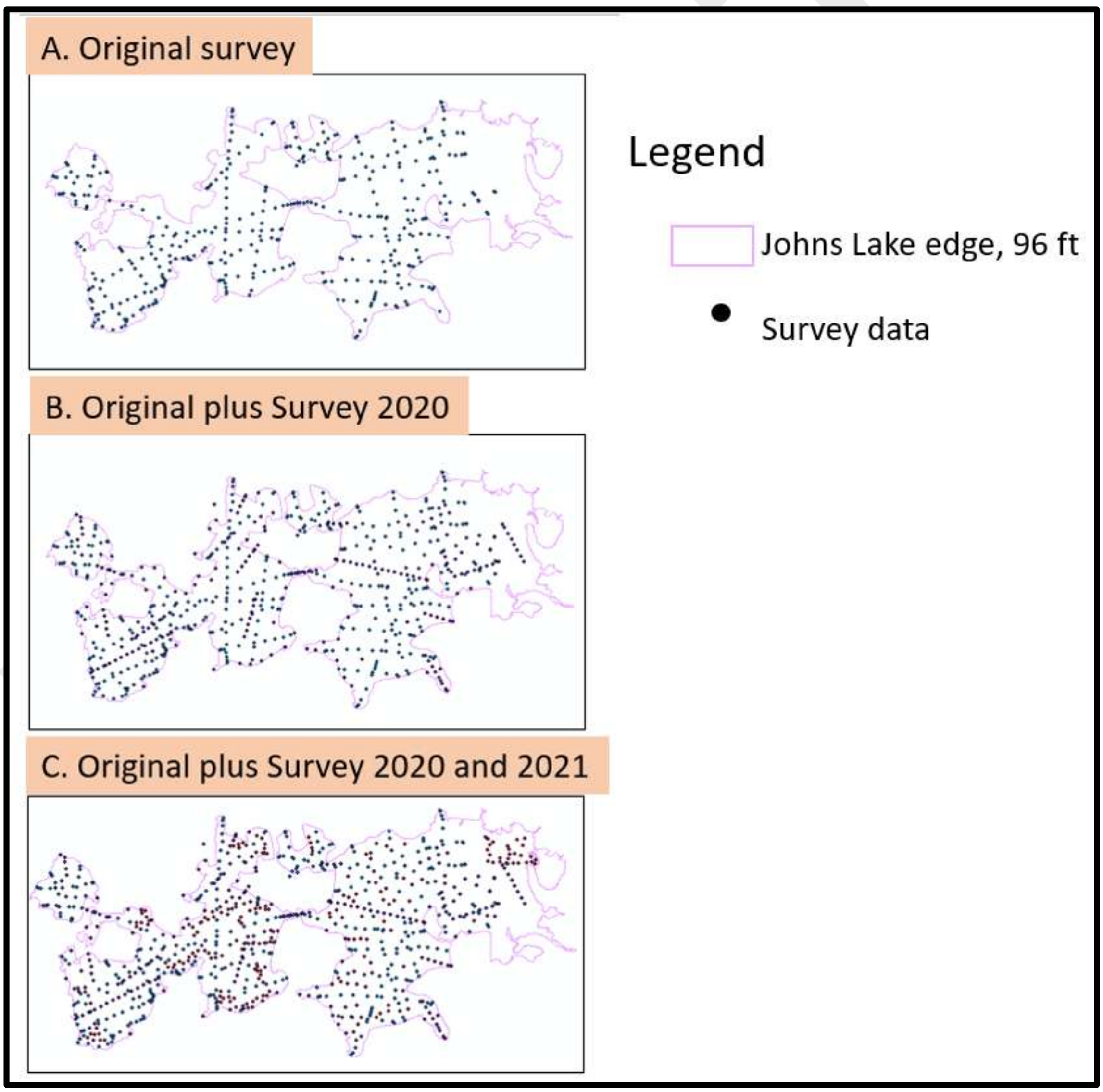

Figure A-3: Survey data for Johns Lake bathymetry interpolation. Note that the easternmost portion of the lake has comparatively few survey points in all three datasets. All data in NAVD88.

Heads up digitized data from aerial photography

To improve representation of the shoreline around the lake, aerial photographs taken during low water level events were used for “heads up” digitizing additional shoreline edges (Figure A-4) in ArcMap. Digitized photography from 1984 and 2014 was selected due to low water conditions and clarity of photography. These edge lines were assigned elevation values based on the nearest set of survey data. All data were converted to points for interpolation.

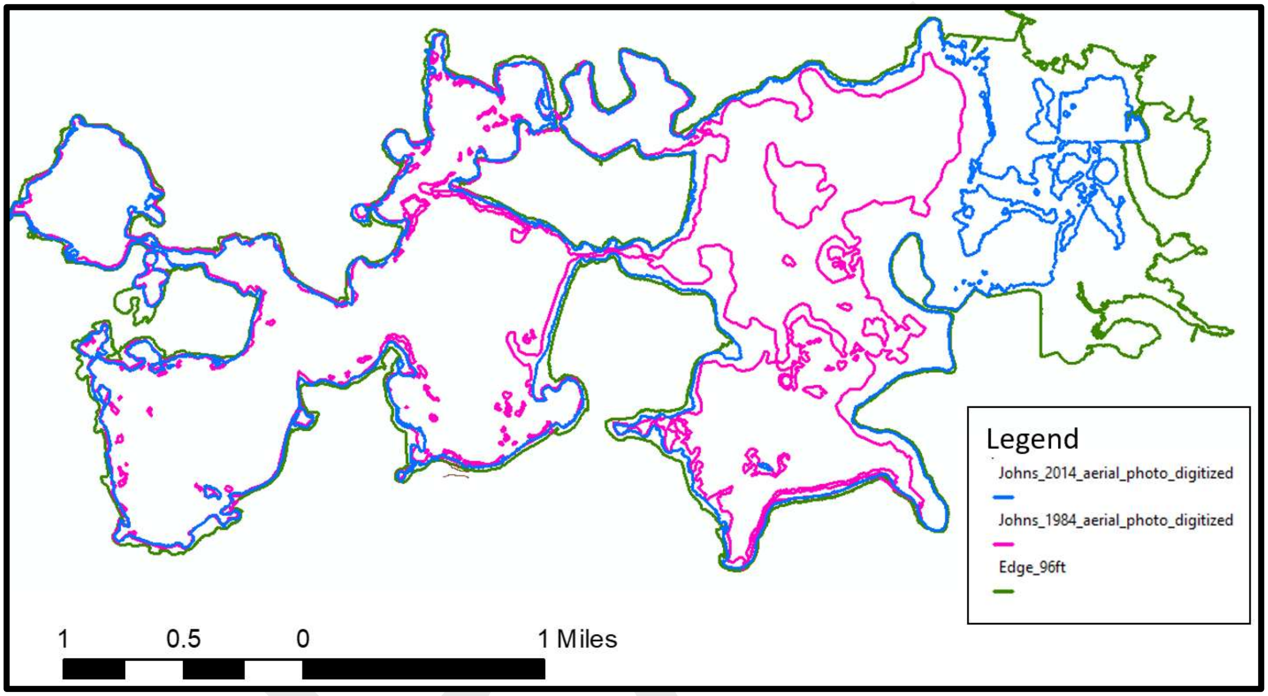

Figure A-4: Linework created using heads-up digitizing from aerial photographs at low water. Elevation was assigned by the nearest set of survey points (NAVD88). All lines were converted to points for interpolation.

Interpolation of bathymetry data

After compilation of the bathymetry points from survey (Figure A-3), aerial photo linework (Figure A-4) and lake edge contour lines (Figure A-2) it was determined that the eastern wetland area was not sufficiently represented for habitat analysis for use with the Hydroperiod Tool (HT). That area was densely represented by contour lines in the Orange County contour dataset. The elevations of the contour lines were validated by the 2020 and 2021 MFLs survey data (Figure A-3, (2020, 2021 Panels B and C in Figure A-3). The contour lines in the eastern wetland area were converted to points, thinned to eliminate superfluous data and reduce the impact on the interpolation and added to the final dataset for interpolation (Figure A-5). The bathymetry points were interpolated to a raster surface (DEM) using the Natural Neighbor method. Natural Neighbor was chosen due to its fidelity to the elevation values of the input data, strict adherence to the range in elevation of the input data and for its comparatively simple algorithm compared to other interpolation methods.

Extraneous areas (outside the lake edge) created by the interpolation method were removed (Figure A-1, Panel B). The entire dataset of bathymetry points is shown in Figure A-5

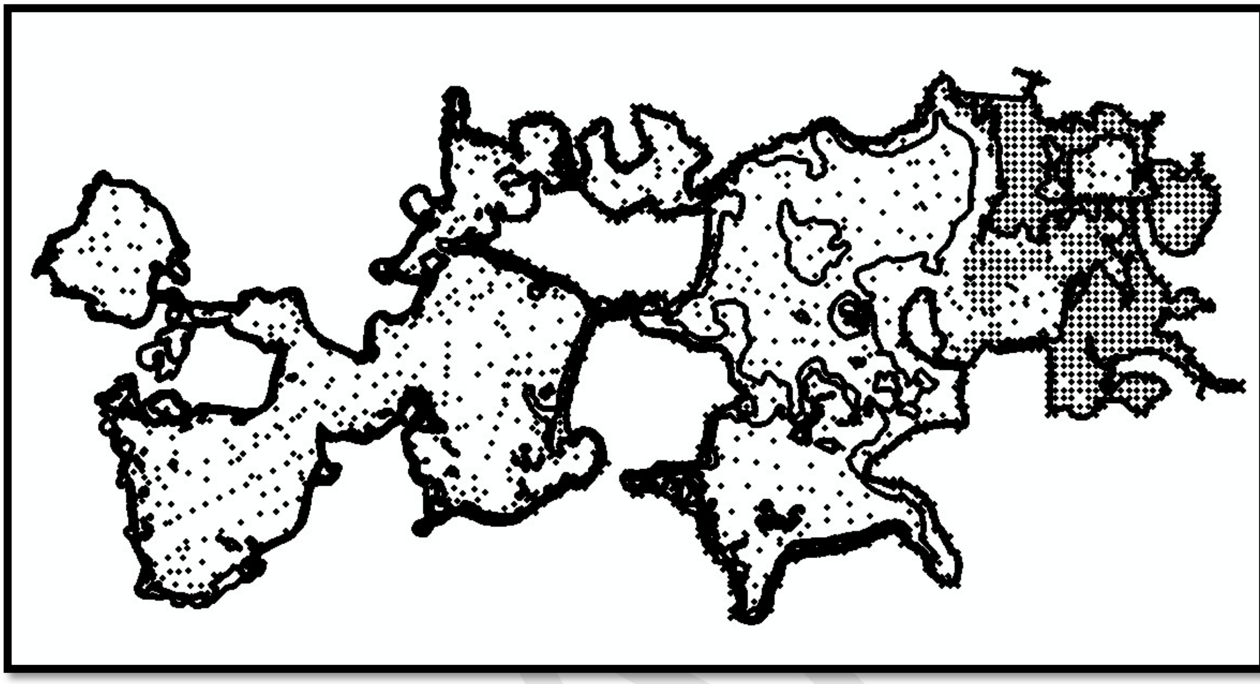

Figure A-5: The complete set of points for bathymetric interpolation.

Mosaic to new raster

The area upslope of the 96 ft lake edge was clipped in ArcMap from the phase one contractor-assisted DEM labeled A in Figure A-1; the area interior to the lake edge was derived from the bathymetric DEM (Panel B, Figure A-1) described above in phase two.

To ensure a smooth spatial transition (no "shelves" or "stairsteps"; no gaps) between the upslope and bathymetric DEMs at the lake edge, a 5-meter area of overlap between the two DEMs was created by buffering off the bathymetric DEM edge. The "Mosaic to new raster" function in the Data Management Toolset in ArcMap was used to create the DEM for ICPR4 modeling. The "Profile Graph" tool in ArcMap 3D Analyst was used to test for a continuous and smooth transition between the two DEM sources at the lake edge.

TOPOBATHYMETRIC DEM FOR HYDROPERIOD TOOL ANALYSES

The method to create the DEM for use with the HT (phase three) varied slightly from the ICPR4 topobathymetric DEM. The ICPR4 DEM for Johns Lake includes a large area upslope of the lake (Figure A-1, Panel A). At the same time, the MFLs program requires elevation only up to 100 ft (NAVD88) beyond the lake edge for habitat analyses and lake area and volume calculation (see Figure A-6 for observed stage period of record). Furthermore, geospatial processing with the HT of the entire ICPR4 footprint. would be time-prohibitive. An alternate method to create the upslope portion of the DEM (above the 96 ft shoreline or lake edge) was necessary to accommodate the HT function, involving a resampling procedure of a portion of the upslope (greater than 96 ft) ICPR4 DEM. Resampling is a common technique in GIS used to change raster resolution; no new values are created as the data are either aggregated or interpolated from the original raster (DEM) to a larger grid cell size. Additionally, a processing issue with HT is solved by enlarging the grid cell size of the resulting DEM from 10 ft to 10 m. A method was developed to take a “subset” or resample of the upslope portion. A set of points based on a 10 m grid was created for the upslope portion of the DEM to include the 100 ft elevation. The points were overlaid over the upslope portion of the ICPR4 DEM and the “extract value to points” function in ArcMap was used to create a set of points for interpolation of the upslope area (Figure A-7) to the larger raster (DEM) grid. These points were combined with the bathymetry points previously described (Figure A-5), followed by interpolation by Natural Neighbor to create the DEM shown in Figure A-8.

The final Johns Lake HT output stage range used for the MFLs is shown in Figure A-9, with an inundation of the lake at the lowest stage (84 ft) and the highest stage (98.5 ft).

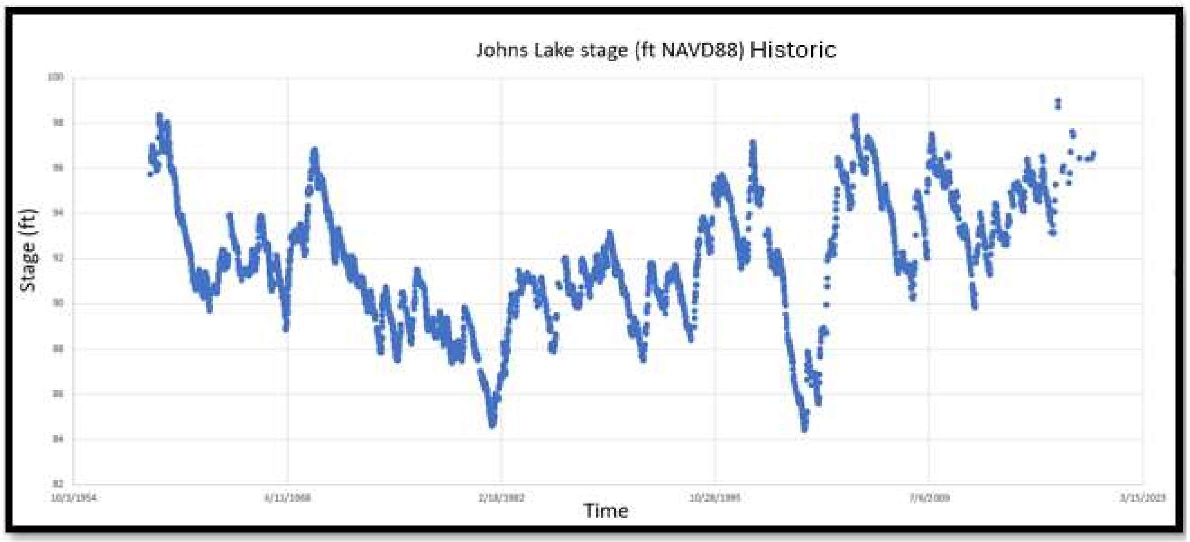

Figure A-6: Johns Lake observed stage data; used for Hydroperiod Tool operation.

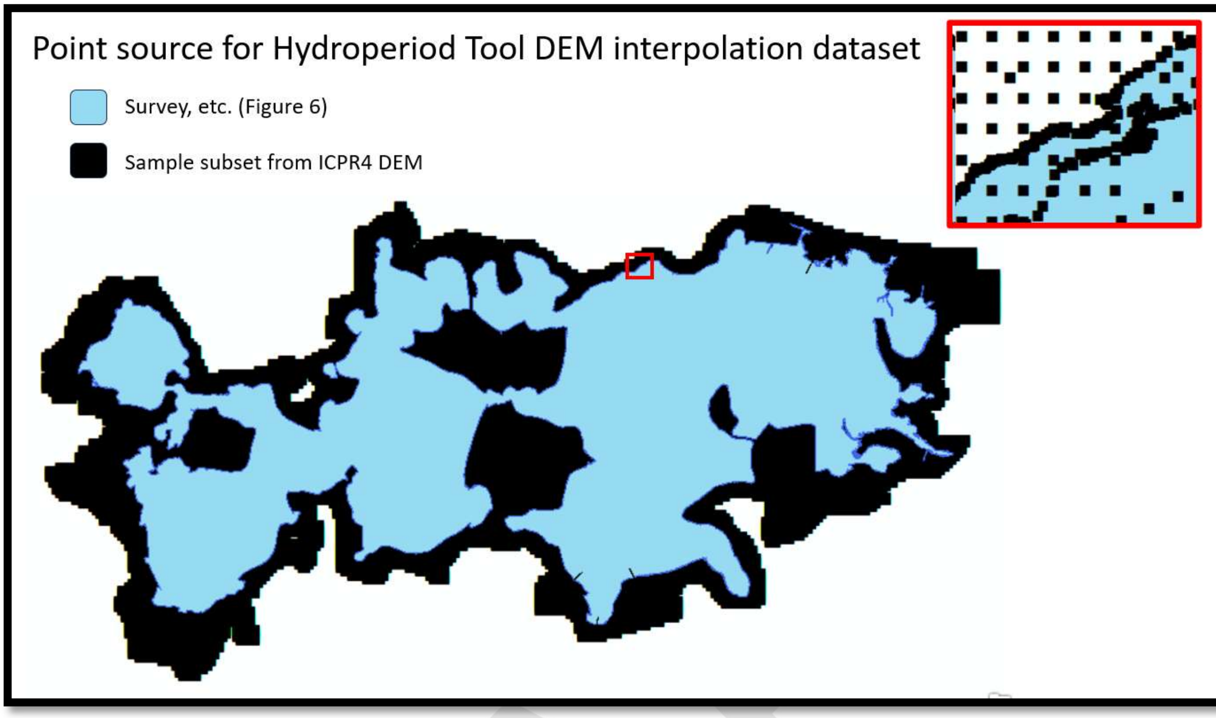

Figure A-7: Data sources for interpolation of the Johns Lake topobathymetric DEM for Hydroperiod Tool analysis. Inset displays the sampling method for the upslope portion of the DEM adjacent to the lake area in blue which is represented by the bathymetry points described above (survey, contour line and aerial photography derived points).

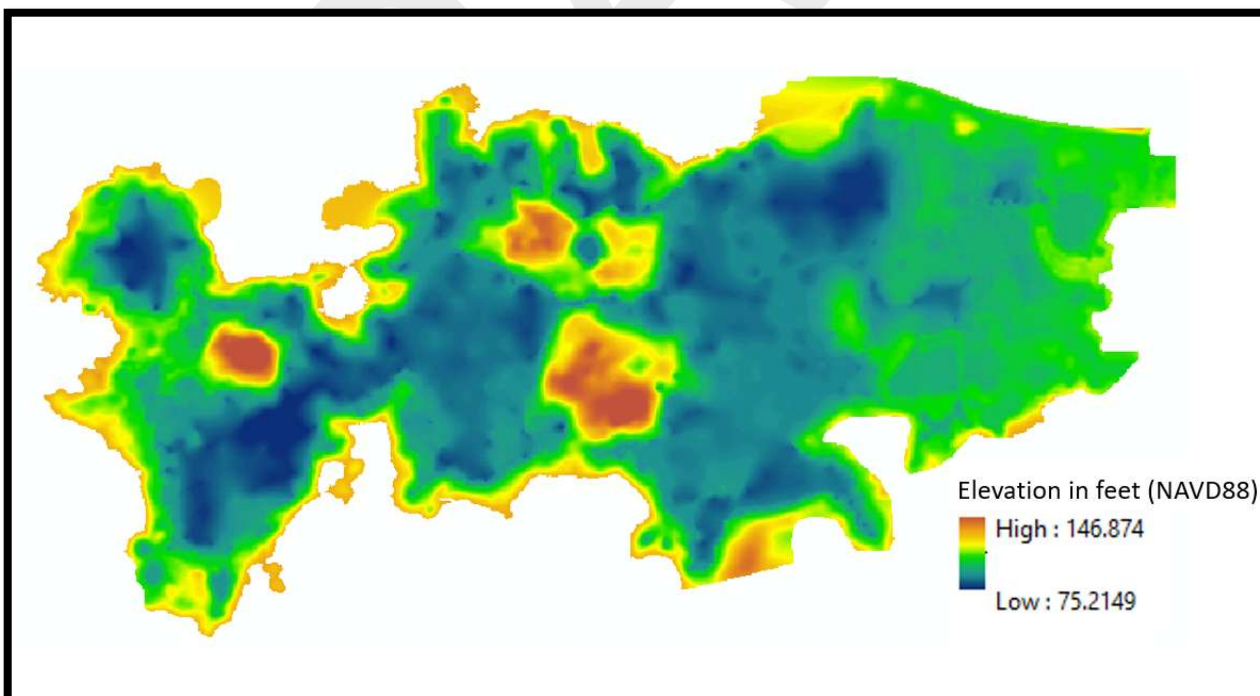

Figure A-8: Johns Lake topobathymetric DEM for HT analysis.

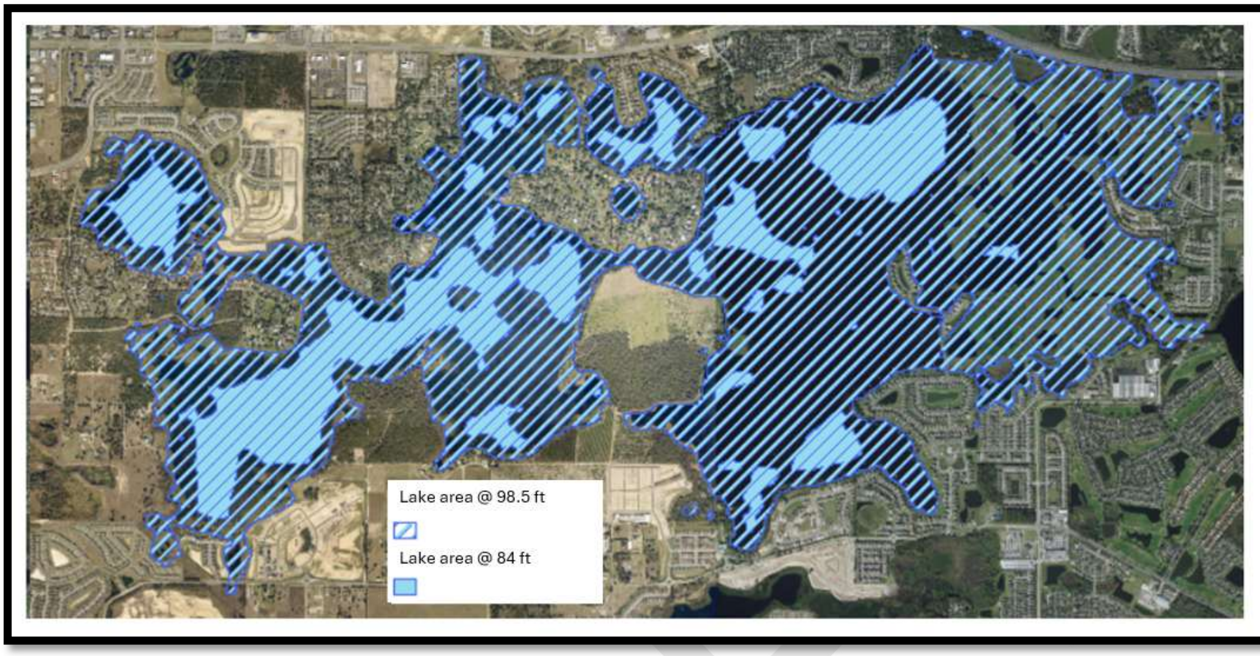

Figure A-9: Johns Lake HT output: Johns Lake inundation at 84 ft and 98.5 ft NAVD88.

REFERENCES:

Collective Water Resources, 2019. Hydrologic Modeling Services for Lakes Johns and Avalon.

ESRI. 2019. Arc Hydro: Hydroperiod Tool. 380 New York Street, Redlands, CA.

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