Lake Marian Bathymetry Study

Prepared for:

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Cover Photo: Lake Marian, facing north from the dam at Woodridge Road, April 2022

Background

Lake Marian is the smallest of four lakes within the Lake Linganore Community, New Market, Maryland. The 3.5-acre lake is located within the Woodridge Village and dammed at the southern end along Woodridge Road. The lake's 660-acre watershed extends to the north and encompasses land beyond Gas House Pike. The northern most portion of the watershed is primarily agricultural land-use which shifts to forest-dominated acreage south of Gas House Pike. However, in recent years much of the forested watershed immediately to the north of Lake Marian has been replaced with single-family homes in the Linganore Villages of Woodridge and Aspen (north of Eaglehead Drive). The watershed drains into the northern end of Lake Marian and exits the lake at its southern end, eventually draining directly into Linganore Creek.

Figure 1: Lake Marian within the Lake Linganore Community, New Market, MD (Google Maps, accessed 6/2022)

Hood College-Center for Coastal and Watershed Studies (Hood-CCWS) completed a bathymetric survey of Lake Marian on April 30, 2022 for the Lake Linganore Homeowner Association (LLHOA). This report presents the findings of the survey with calculations of relevant bathymetric parameters and associated maps.

Methods

In order to determine the current shape of the lake basin, Hood-CCWS utilized an autonomous surface vehicle (ASV) capable of programmable navigation to collect depth soundings throughout the lake. The survey craft was developed by the Hood College Computer Science Department. The ASV possesses a single, inboard electric motor mounted in a model fiberglass powerboat hull (See Figure 2).

The hull is outfitted with a 160 kHz, Garmin Intelliducer, Depth/Temp, NMEA 0183 thru-hull transducer. This transducer is able to measure depth up to 700 feet. The accuracy of depth measurements varies with sampling depth, with increasing accuracy as depth increases. (The accuracy of depth measurements was assessed by comparisons with manual soundings before deploying the survey craft.) The ASV contains two on-board GPS receivers – one for navigation and the other for collecting location data associated with each depth sounding. Given the specifications of these GPS units, we anticipate locational accuracy within approximately 2 meters. Depth soundings were collected using a sonar fathometer. All depth readings were associated with point locations derived from GPS. Navigation and control of the sensor payload was performed by a pair of on-board microcontrollers. The on-board data collection capacity can accommodate thousands of depth observations and their associated location information.

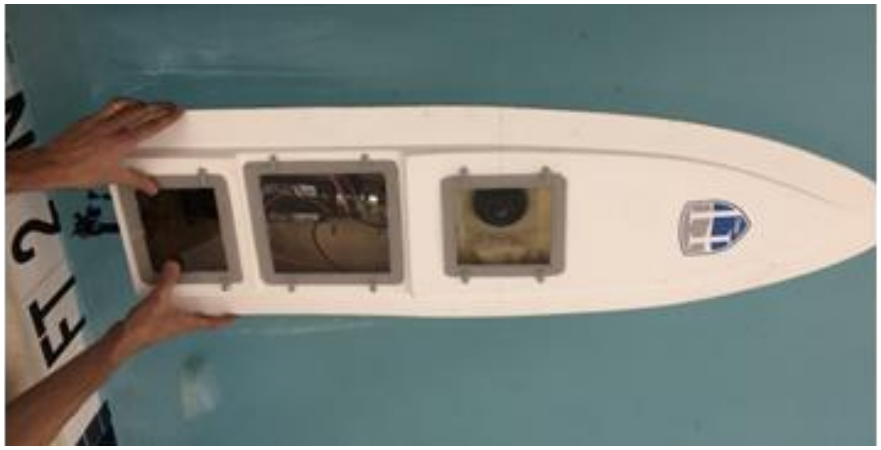

Figure 2: Image of the prototype ASV developed and employed for bathymetric studies by the Hood College Department of Computer Science.

On April 30, 2022, ASV-generated bathymetry data were collected on Lake Marian along parallel transects in a grid pattern resulting in over 5000 depth measurements. In select locations, a tow-and-record pattern (kayak towing the boat while collecting data), was used to avoid obstructions and reach closer to the lake perimeter. Some perimeter sites were too shallow (<3 ft) to record measurements and several lake locations contained entanglement hazards (e.g., over hanging or partially submerged trees) for the ASV, so measurements were taken less frequently in these areas. (See Figure 3).

Figure 3: Example of entanglement hazard encountered during Lake Marian bathymetric survey, April 30, 2022.

Raw data from the bathymetry survey were transformed for GIS analysis. ArcGIS spatial software was used to construct the bathymetric map. The outline of the lake was digitized using 6-inch imagery collected in 2020 by the Maryland Geographic Information Office. This outline was assigned a depth of 0 ft and served as the boundary for subsequent GIS analysis of the collected data. Multiple interpolation methods were used to create digital elevation models (DEMs) of the lake's basin from the depth measurements. The Kriging method resulted in the closest match to the collected data. This interpolation method calculates the spatial correlation of collected data points to predict the values for depth at every point in the lake.

Contours at 1-ft intervals were constructed from the DEM. GIS analysis was used to determine the total surface area and volume of the lake, as well as surface area and volume at each 1-ft depth contour. Depth-volume and depth-area curves were created based on these values, and additional bathymetric statistics were determined using GIS analysis

Results and Discussion

Bathymetry Survey

Figure 4 provides a contour map of the current basin of Lake Marian from data collected in April 2022. In general, the lake is shallower in the northern end, gradually deepening toward the south end. This basin morphology would be expected considering the northern inflow and southern dam with outflow.

The average and maximum depths of the lake at the time of the survey were 0.90 ft. and 8.5 ft., respectively (Table 1). The calculated surface area of the lake is 150,699 square feet or 3.46 acres. Table 2 depicts the changes in surface area circumscribed by increasing depths. The total volume of the lake is just over 135×10^3 cubic feet (which can also be expressed as 1012×10^3 gallons).

Table 1: Bathymetric summary for Lake Marian.

Bathymetric Statistics	
Surface Area (ft^2)	150,699.00
Maximum Length (ft)	985.71
Maximum Width (ft)	211.23
Mean Length (ft)	713.44
Mean Width (ft)	152.88
Mean Depth (ft)	0.90
Maximum Depth (ft)	8.47
Relative Depth	1.93
Shoreline Length (ft)	2,352.83
Shoreline Development	1.71

Table 2: Lake Marian surface areas and lake volume for each depth interval from surface to bottom.

Lake Depth (ft)	Surface Area (ft^2)	Cumulative Volume* (x 10^3 ft^3)	Cumulative Volume* (x 10^3 gallons)
0	150,699.00	135.32	1,012.26
1	124,251.47	108.84	814.18
2	97,739.35	84.61	632.90
3	75,715.99	64.83	484.95
4	58,100.42	47.58	355.91
5	41,213.00	27.79	207.88
6	18,375.28	7.62	57.01
7	761.28	0.29	2.15
8	10.81	0.00	0.03
8.47	0.00	0.00	0.00

*Cumulative volume calculated from the greatest depth to the surface

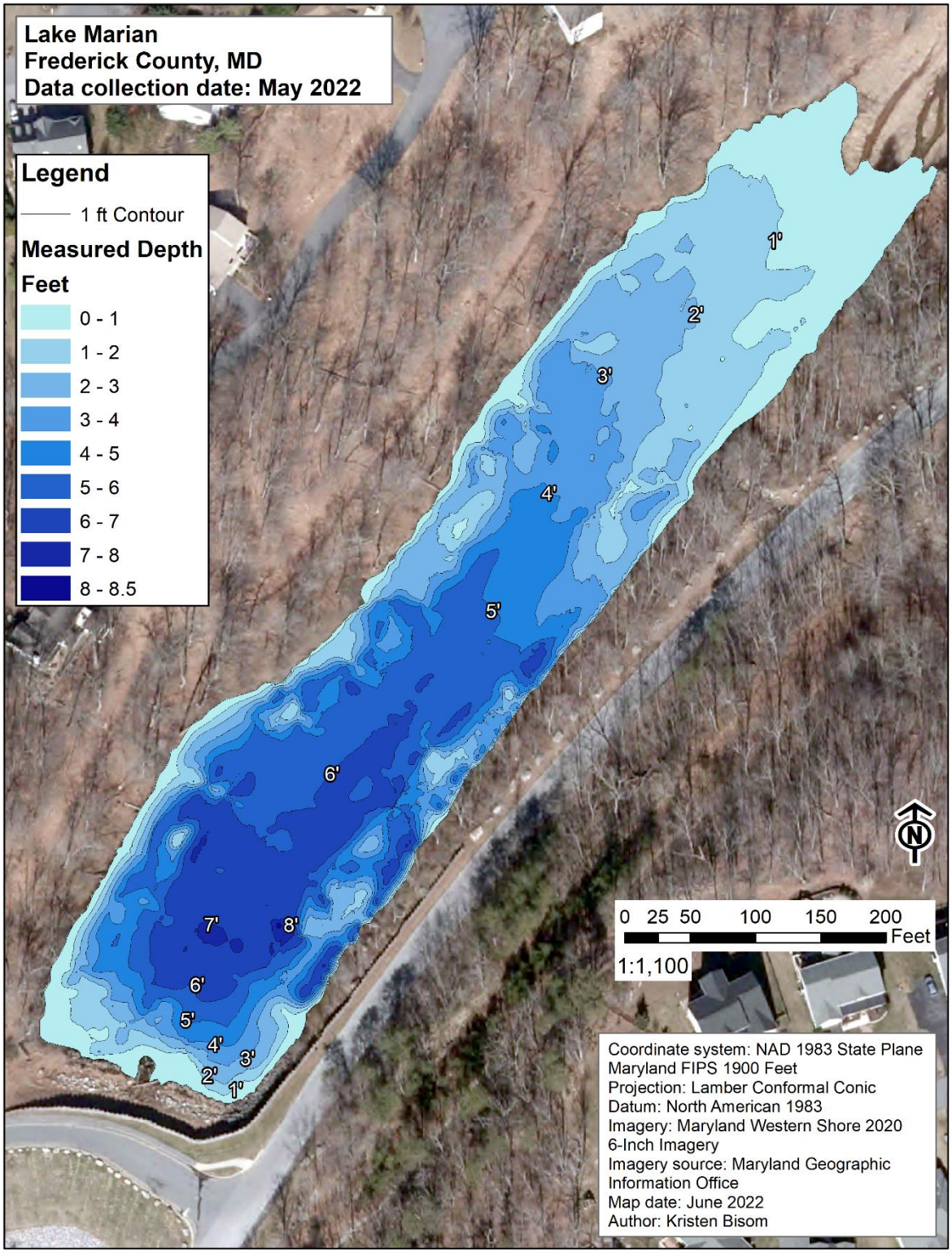

Figure 44: Overview of Lake Marian contour map of current lake basin from data collected April 2022

Depth versus volume and depth versus surface area curves are provided in Figures 5 and 6, respectively. These relationships can be used in lake management decisions that might include application of compounds for mitigation of harmful algal blooms (for example hydrogen peroxide dosage calculations). They can also provide the basis for understanding whole lake ecological processes.

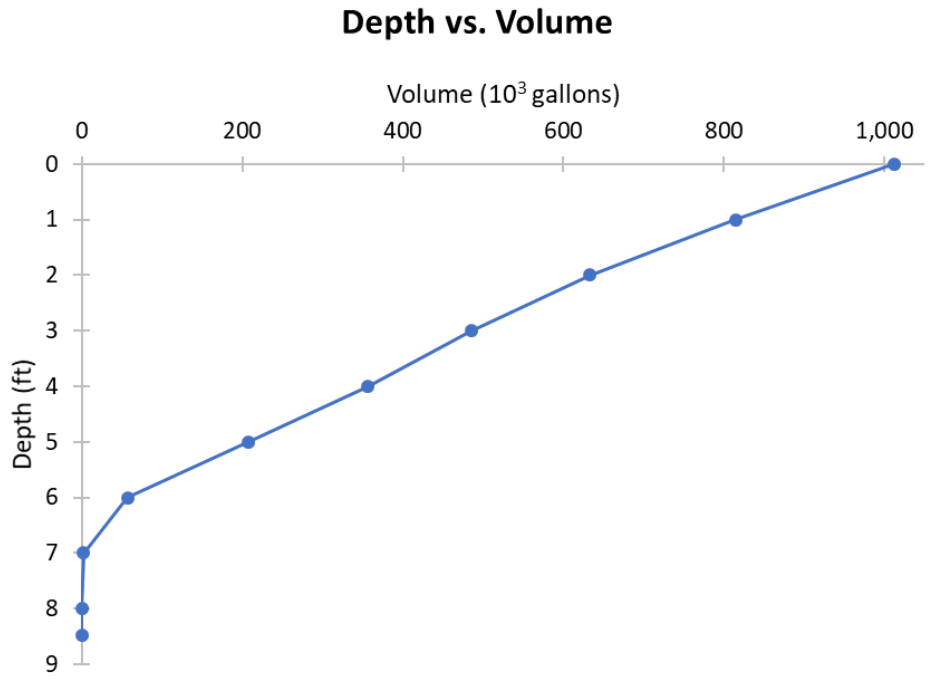

Figure 55: Lake Marian volume vs depth curve, April 2022

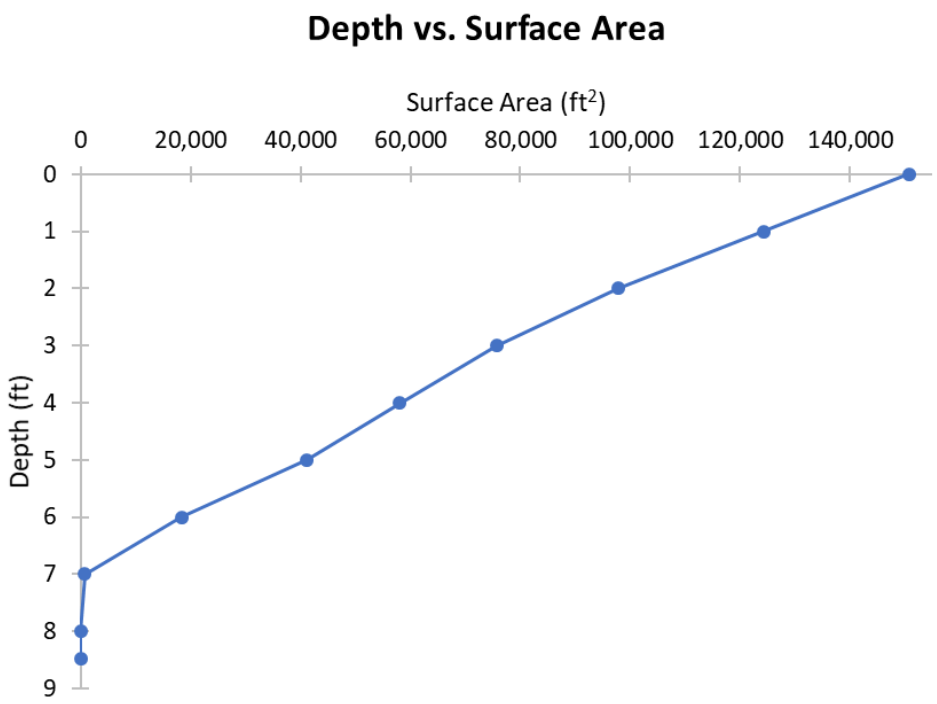

Figure 66: Lake Marian surface area vs depth curve, April 2022

Implications for Lake Biology

The influence of lake bathymetry on the biology of Lake Marian is conjectural at this point because we currently lack even a basic knowledge of the way in which physical and chemical parameters vary in the lake with depth and season. However, knowledge of the shape of the lake basin leads us to believe that some or all of the following conditions may be in play in Lake Marian at least during some seasons of the year.

- The very shallow portion in the northern end of the lake may be a result of its original construction specifications, or it may be a result of siltation from sediment-loading from its watershed. If the latter is the case, recent replacement of forested acreage with housing units within the watershed would be likely to increase sediment loading (both due to construction activities and increases in impervious surface within the housing developments). Continued sedimentation in the lake, if not managed, could eventually lead to the development of a freshwater marsh at the lake's northern end which would replace current (albeit shallow) open water. This eventuality could be mitigated by construction and maintenance of a forebay for sediment trapping.
- Depending upon the extent of light penetration into the lake, the shallow average depth of Lake Marian, particularly as seen in the northern section of the lake, could be setting the stage for extensive growth of submerged, rooted aquatic vegetation. These rooted communities,

depending on the species present, could interfere with the recreational use of the lake (for example boating, fishing and swimming).

- The deeper portions of the southern section of the Lake Marion, while not as deep as Lakes Merle or Anita Louise, most likely exhibit temperature stratification during the summer season. This gradient range could be sufficiently large and temporally stable to inhibit deep mixing of water during the summer and much of the fall. Stratification stability will be dependent upon the air temperature, precipitation and wind events occurring during the summer and fall.
- Again, depending on the extent of light penetration into the lake and the extent of summer stratification, we can expect a large portion of Lake Marian's volume to be experiencing active algal growth during the growing season. This algal production will eventually die, sink to the bottom, and decay. The relatively smaller volume of deep waters in the lake will likely not contain enough dissolved oxygen to support the bacterial degradation of the settling algal biomass, resulting in low to no oxygen in the bottom waters. This situation could be exacerbated by nutrient inputs from the watershed – particularly fertilizers used on the lawns in the Woodridge and Aspen villages.
- If low to no dissolved oxygen (hypoxia or anoxia) is found in the waters near the bottom of Lake Marian during summer stratification, the release of phosphorus from the sediments into the overlying water could intensify nutrient enrichment in the whole lake.
- Lastly, the deeper southern portion of Lake Marian could act as a refuge for populations of cold-tolerant cyanobacteria such as *Planktothrix* sp. which could become problematic during the late fall or winter.

These are many of the same issues that are currently known to exist in Lake Anita Louise and Lake Merle. We would recommend seasonal sampling of the water column in Lake Marian for a period of one year to initially assess their presence or absence in this lake as well.

References

Google Maps (n.d.) Location map of Lake Marian, New Market, MD. Last accessed June 2022. https://www.google.com/maps/@39.419009,-77.3280164,785m/data=!3m1!1e3

Maryland Geographic Information Office (n.d.) Western Shore 2020 Six Inch Imagery. Last accessed May 2022. https://imap.maryland.gov/pages/orthoimagery

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