Technical Memorandum

Task 2.3: Bathymetric Survey and Sediment Hydroacoustic Study of Canyon Lake

Objectives

The overall objective of this task was to better understand the basin characteristics of Canyon Lake. Specific objectives were to:

- Develop up-to-date bathymetric map
- Derive up-to-date storage curve for the reservoir
- Estimate volume of sediment deposited and its distribution
- Characterize distribution of sediment properties across the basin

Approach

A hydroacoustic survey was conducted at Canyon Lake over 2-days on December 16-17, 2014. The survey was conducted using a BioSonics DTX echosounder with multiplexed 38- and 430-kHz single beam transducers with integrated pitch-roll sensors and a 201-kHz split beam transducer (Table 1). Transducers were operated at 5 pps on each frequency, with 0.4 ms pulse duration. Transducers were mounted 0.5 m below the water surface with position recorded using a JRC 202W real-time differential GPS. Data were acquired using BioSonics VisualAcquisition v.6.0 software on a Dell ATG laptop. Calibrations were conducted each day using tungsten carbide spheres of known target strength. Data files were processed using BioSonics VBT software.

Table 1. Transducer configurations used in this study.

Property	DTX-38	DTX-200	DTX-420
Frequency (kHz)	38	201	430
Beam angle (°)	10.0	6.6	7.0
Source level (dB μPa^{-1})	217.0	221.3	220.0
Receive sensitivity (dbC μPa^{-1})	-41.1	-57.6	-62.9
Pulse length (ms)	0.4	0.4	0.4
Pings per second (pps)	5	5	5

Water column and sediments were also sampled. Water temperature and conductivity profiles were measured daily with an YSI CastAway CTD. Bottom sediments were sampled with an Ekman dredge at 5 sites across the lake, homogenized and subsampled into 500-mL widemouth glass jars with Teflon lined screw top lids, and returned to the lab for basic characterization. Phosphorus in bottom sediments of lakes exists in numerous forms, including a mobile form (mobile-P) that includes soluble/exchangeable forms as well as that associated with iron (Fe)(III) phases that can be released upon reduction of Fe(III) under low dissolved oxygen (DO) conditions (Reitzel et al., 2005; Pilgrim et al., 2007). Mobile-P in surficial sediments has been shown to be strongly correlated with internal recycling rates (Pilgrim et al., 2007), with the mobile-P pool reduced by amounts consistent with that released to the water column (Reitzel et al., 2005).

Sediment grab samples were subsampled for dry-weight determination and extracted for mobile-P following Pilgrim et al. (2007). Water content was determined on subsamples that were heated overnight at 105 °C. Total C and N were measured by dry-combustion methods using a Thermo Flash EA NC soil analyzer (Nelson and Sommers, 1982). Inorganic C and $CaCO_3$ were determined manometrically following Loeppert and Suarez (1996), with organic C taken as the difference between total C and inorganic C. Duplicate analyses were conducted at a rate of at least one every 10 samples within an analytical batch.

Results

Bathymetry

Depth varied widely across the lake, with predictably greatest values located near the dam in the main basin of the lake, exceeding 17 m at full pool (Fig. 1). The north and east basins possessed lower depths, with less than about 11 m in the east basin near the causeway, and less than about 7 m throughout the north basin (Fig. 1).

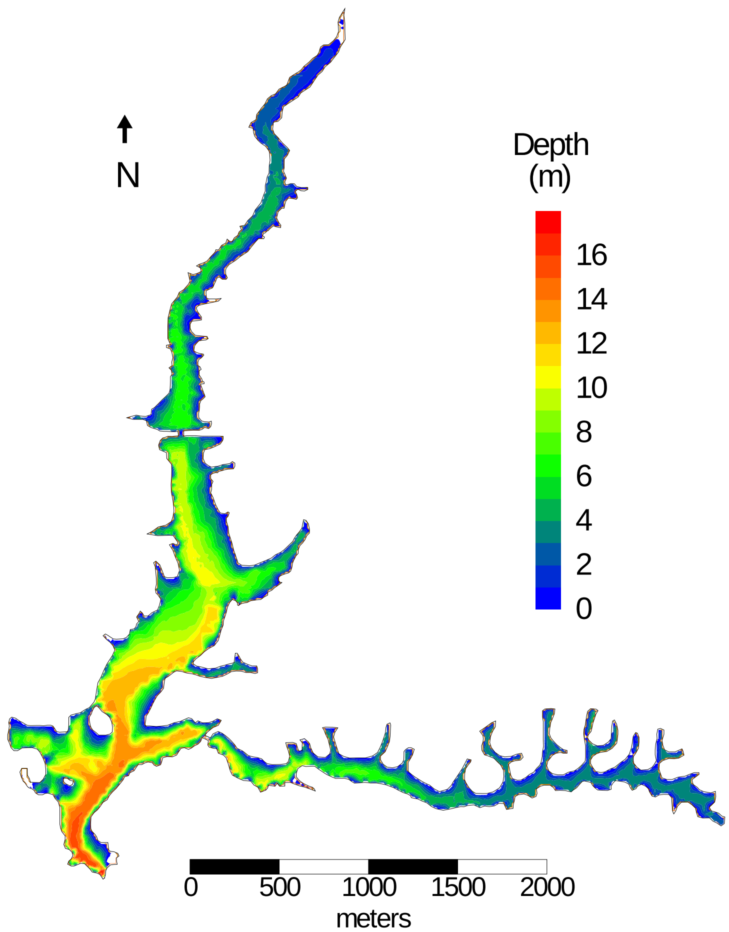

Fig. 1. Bathymetry of Canyon Lake.

Very shallow conditions were present near the inflows of the San Jacinto River and Salt Creek, reflecting natural topography and the deposition of material eroded from the watershed. Bathymetric measurements also revealed the original channel for the San Jacinto River which was located on the western side of the lake through the north basin and into the main basin (Fig. 1). The channel was not clearly defined near the mid-portion of the main basin due presumably to deposition of material there, likely derived from construction activities during development of the community. The channel is again evident in the southern part of the lake, representing its deepest region (Fig. 1).

The bathymetric data were used to develop an up-to-date storage curve and elevation-area curve for the lake (Fig. 2). Included is storage curve provided by EVMWD (Fig. 2a, dashed line). The interpolation assumed the shoreline throughout the north basin and most of the main basin to grade to 0 m at full pool, while the shoreline of east basin was defined by sea walls with an assumed depth of 0.6 m. The basin elevation ranged from a minimum value of 1323.36 ft (above MSL), immediately adjacent to the dam face, to the spillway elevation of 1381.76 ft. The full pool volume of Canyon Lake was calculated to be 8758 acre-feet, a value that is 3110 acre-feet less than EVMWD's prior storage curve apparently developed in 1993. The downward displacement of lake volume at a given surface elevation represents loss of storage; measurements thus indicate that the lake has lost significant storage over time.

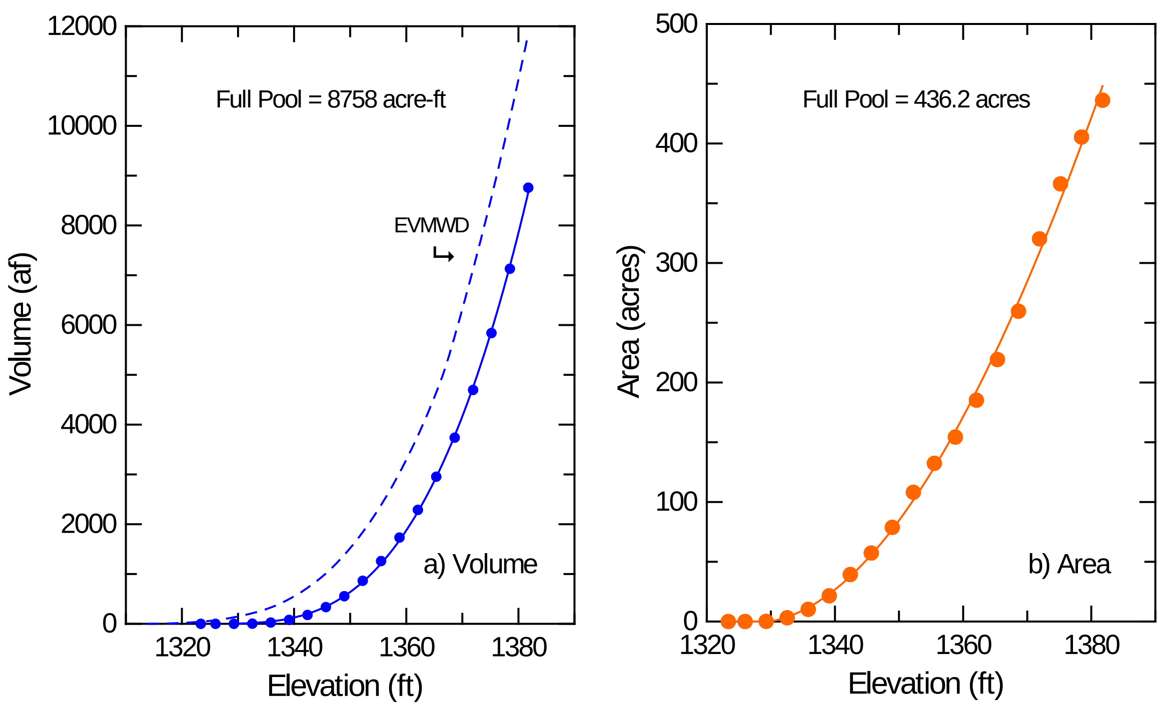

Fig. 2. Canyon Lake hypsography: a) volume vs. elevation (dashed line is EVMWD data from 1993), and b) surface area vs. elevation.

The lake volume was well-fit (r^2=0.9998) by the 3rd-order polynomial of the form:

$$Vol\ (af) = -129913027.7 + 293417.3*Elev - 220.9033*Elev^2 + 0.0554373*Elev^3 \quad (1)$$

The surface area at full pool was calculated to be 436.2 acres (Fig. 2b). Lake surface area was reasonably described (r^2=0.9980) with the 3rd-order polynomial:

$$Area\ (acres) = 1271585.1 - 2645.223*Elev + 1.82046*Elev^2 - 0.00041385*Elev^3 \quad (2)$$

In addition, the elevation-area-volume relations for the individual basins were also developed. The main basin contributes the largest area and volume to the lake, at 252.8 acres and 6439.8 acre-feet, representing 58.0% of the total area and 73.5 % of the total volume, respectively (Table 1). The east and north basins collectively comprise over 40% of the lake area, but contribute only about 25% of the total lake volume (at full pool) (Table 2).

Table 2. Individual basin and total lake metrics.

	Area (acres)	Volume (acre-ft)	Mean Depth (ft)	Maximum Depth (ft)
Main Basin	252.8 (58.0%)	6439.8 (73.5%)	25.5	58.4
East Basin	102.5 (23.5%)	1406.8 (16.1%)	13.78	38.7
North Basin	80.9 (18.5%)	911.2 (10.4%)	11.3	26.2
Total	436.2 (100%)	8757.9 (100%)	20.1	58.4

Storage curves for individual basins were also extracted from bathymetric data (Fig. 3).

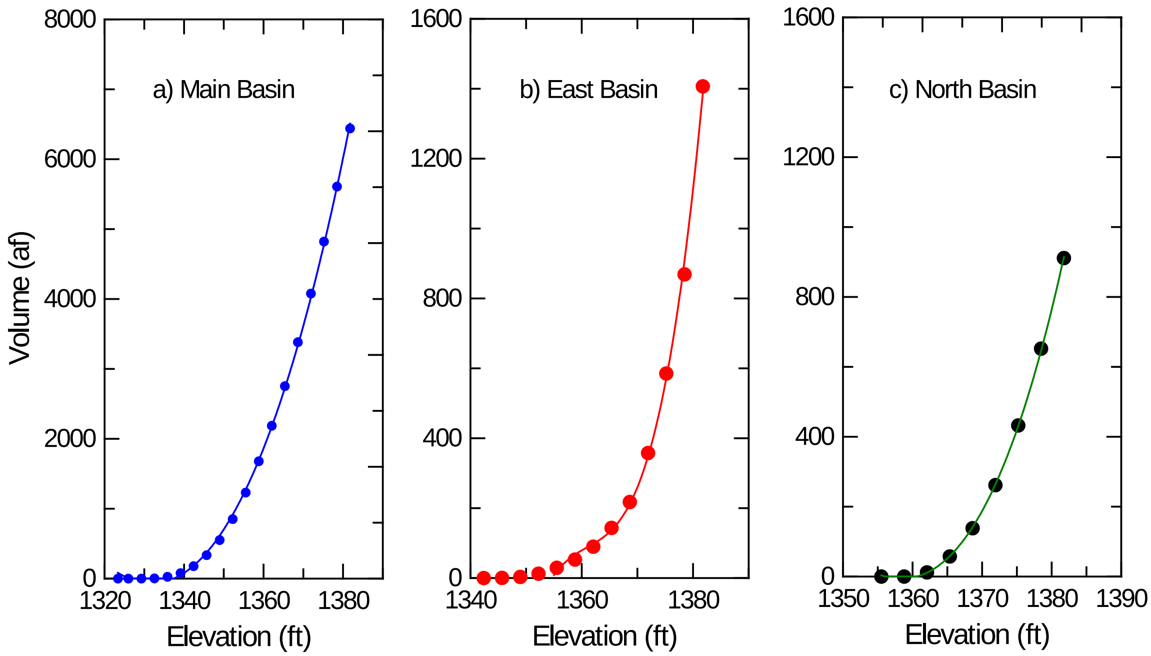

Fig. 3. Volume-elevation relationships for a) main basin, b) east basin and c) north basin.

The volumes of the individual basins were also reasonably-described (r^2>0.998) by 3rd-order polynomials:

$$Vol_{main} = -18099718.1 + 43668.02*Elev - 34.9638*Elev^2 + 0.0092954*Elev^3 \quad (3)$$

$$Vol_{east} = -312755907.3 + 689395.0*Elev - 506.541*Elev^2 + 0.1240641*Elev^3 \quad (4)$$

$$Vol_{north} = -50991062.6 + 114231.5*Elev - 85.2843*E*Elev^2 + 0.0212201*Elev^3 \quad (5)$$

Sediment Thickness

Thickness of the sediment was derived from echograms based upon the penetration and attenuation of the 38-kHz sound wave within the sediments. Very hard sediments limit penetration of the sound wave, while fine-textured organic-rich sediments with high water contents allow penetration of the sound wave to considerable depths within the sediments before reverberation from harder weathered bedrock or soil. Thickness of the sediment ranged from 0 – 8 m, and varied across the basin in a complex way, with some evidence of infilling of the original San Jacinto River and Salt Creek channels, deposition of material derived from grading and construction within the local watershed and from erosion from upper watersheds (Fig. 4).

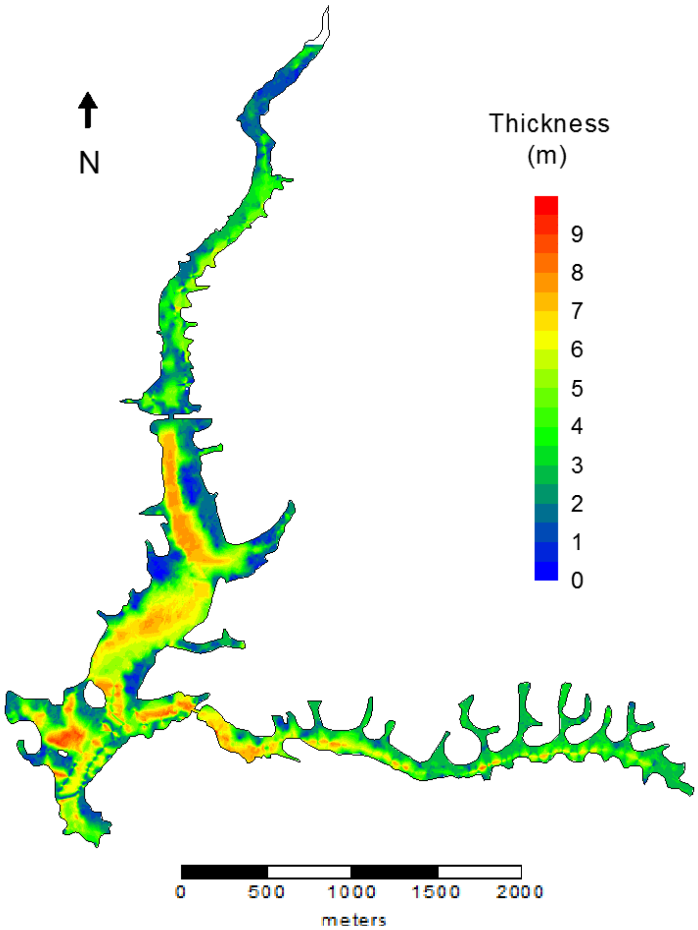

Fig. 4. Sediment thickness in Canyon Lake.

Based upon these measurements, it is estimated that sedimentation over the past 88 yrs since the dam was constructed has reduced the capacity of the reservoir by >5000 acre-feet and potentially as much as 8000 acre-feet or more.

Sediment Organic C Content

The attributes of the bottom echo have been found to be correlated with surficial sediment physical and chemical properties (Anderson and Pacheco, 2011). For example the fractal (box) dimension of the bottom echo at 430-kHz was very strongly correlated with the organic C content of surficial bottom sediments. The regression equation developed in that study was used to estimate the organic C content of sediments in Canyon Lake (Fig. 5).

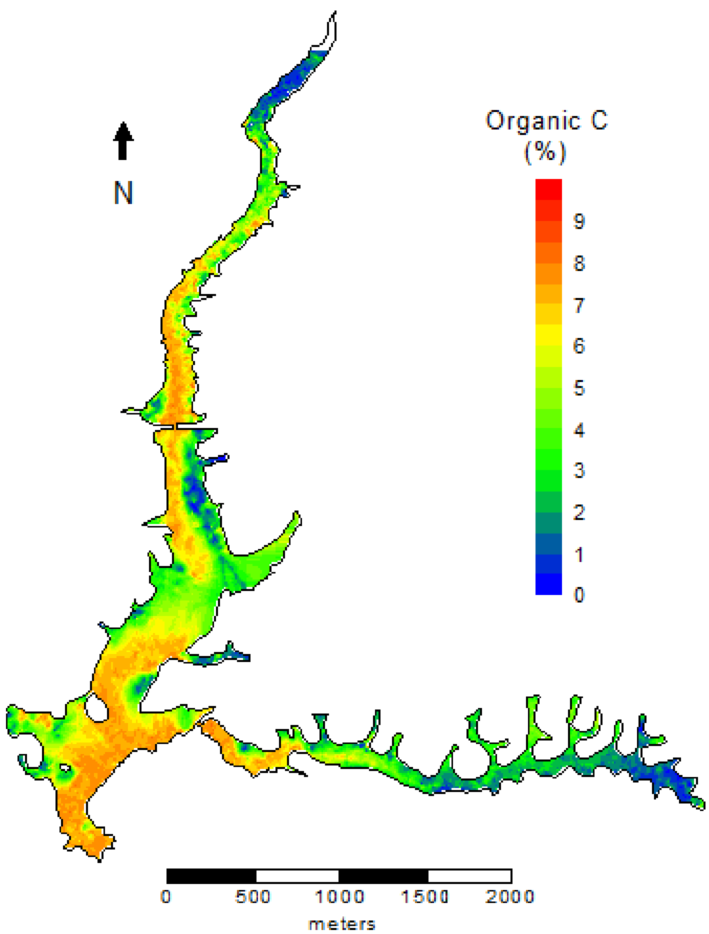

Fig. 5. Sediment organic C content in Canyon Lake.

Organic C contents of surficial sediments were very low near the influent of San Jacinto River and Salt Creek (<1%) as a result of deposition of coarse-textured material eroded from the watershed, and due to scouring and further transport of finer-textured material during inflow events. Organic C contents increased at greater distances into east and north basins, with strong focusing of organic matter in the deeper waters of the main basin, especially near the dam (Fig. 5).

Sediment Mobile-P Content

The mobile-P content of sediments has been found to be strongly correlated with P flux from sediments under low DO conditions and is now commonly used to guide alum treatments of lakes. Mobile-P was quanitifed on sediment grab samples from 5 sites on the lake when hydroacoustic measurements were also conducted. A nonlinear relationship was found between the fractal dimension of the bottom echo envelope and mobile-P content (Fig. 6).

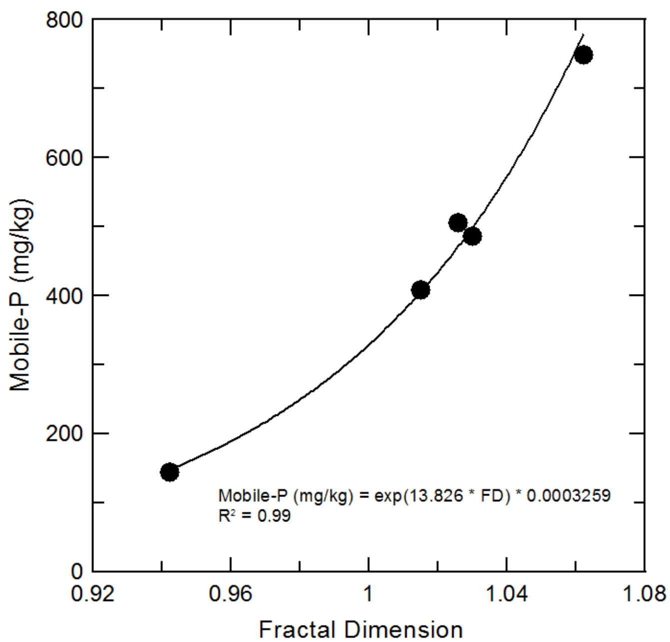

Fig. 6. Mobile-P content in surficial sediment vs. fractal dimension of bottom echo at 430-kHz.

This allowed us to remotely sense mobile-P content of sediments and to develop a map of its distribution across the lake (Fig. 7). Mobile-P content of surficial sediments was enriched in original river channel in the north basin; mobile-P was also elevated in deeper sediments near closer to dam (Fig. 7). Understanding of the distribution of mobile-P helps guide alum treatment for sediment P inactivation. Thus, alum treatments designed to inactivate mobile-P in the main basin sediments of Canyon Lake would be most effective when targeting the large inventories at the southern end of the lake. The limited exchange between basins during most of the year (excluding large runoff and flushing events) requires that each basin be treated essentially as an independent lake.

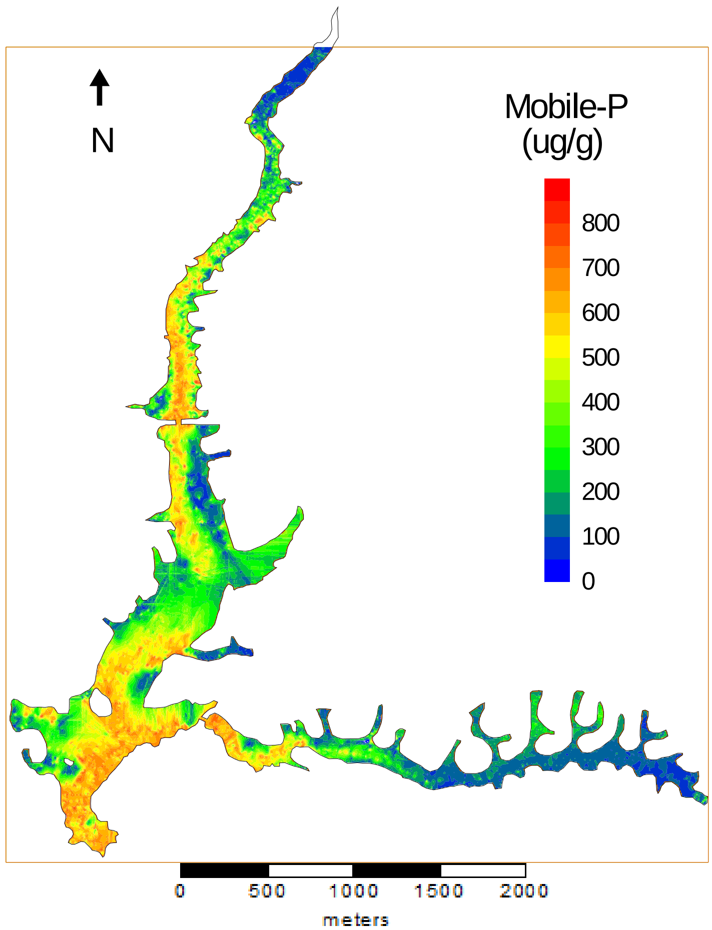

Fig. 7. Sediment mobile-P content in Canyon Lake.

Conclusions

The hydroacoustic study provided valuable new insights in the characteristics of Canyon Lake:

- The hydroacoustic survey provides up to date bathymetry and elevation-area-volume relations for Canyon Lake
- Measurements also provided new detailed understanding of the distribution, properties and thickness of sediment within the lake
- Sedimentation is projected to have reduced storage capacity by >5000 acre-feet and potentially as much as 8000 acre-feet or more since dam construction in 1927

- Sediments enriched in mobile-P and organic matter were deposited in deeper regions of lake, and represent regions of greater nutrient flux and oxygen demand

References

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