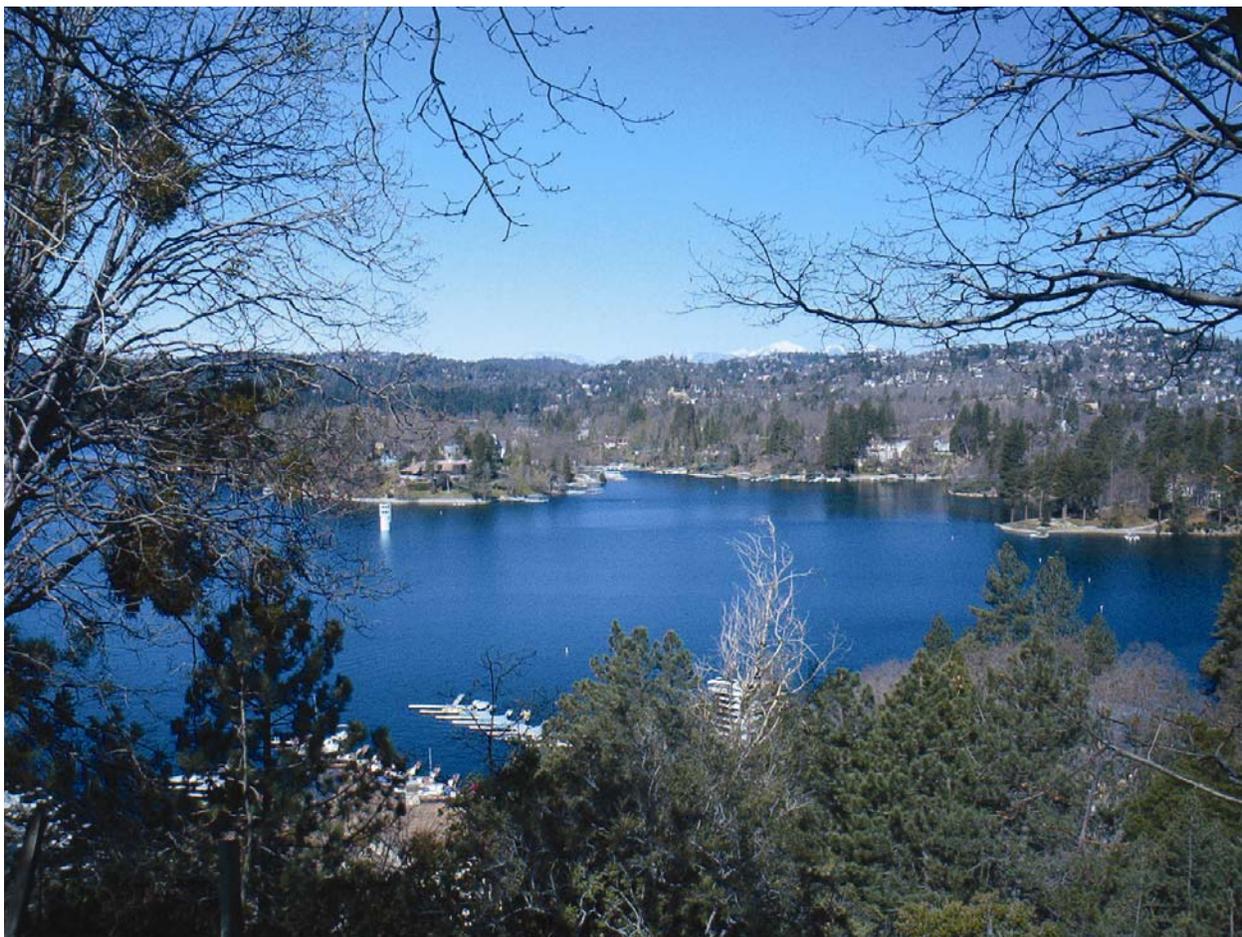


RECLAMATION

Managing Water in the West

Technical Report No. SRH-2009-9

Lake Arrowhead 2008 Reservoir Survey



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

March 2009

REPORT DOCUMENTATION PAGE

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14. ABSTRACT Reclamation surveyed Lake Arrowhead in September 2008 to develop updated reservoir topography and compute the present storage-elevation relationship (area-capacity tables). The underwater survey was conducted near water surface elevation 5,103.7 feet (ALA project datum). For this study, elevations are referenced to the ALA vertical datum, unless otherwise noted. The ALA vertical datum was computed to be 8.0 feet less than the National Geodetic Vertical Datum of 1929 (NGVD29) and 11.2 feet less than the North American Vertical Datum of 1988 (NAVD88). The underwater survey used sonic depth recording equipment interfaced with a real-time kinematic (RTK) global positioning system (GPS) that provided continuous sounding positions throughout the underwater portion of the reservoir covered by the survey vessel. Shallow water shoreline collection was severely limited by occupied boat slips lining the reservoir perimeter. Collection of shoreline data was also limited by thick bottom vegetation that existed throughout the reservoir in depths around fifteen feet and less. The reservoir topography was mapped by merging the above water data with a digital water surface image obtained from 2005 aerial photography flown at reservoir elevation 5,107.0 feet (ALA project datum). As of September 2008, at reservoir water surface elevation 5,106.7 feet, the surface area was 767 acres with a total capacity of 46,855 acre-feet. Elevation 5,106.7 is considered the spillway crest or full reservoir elevation.					
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Lake Arrowhead 2008 Reservoir Survey

prepared by

Ronald L. Ferrari



**U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Water and Environmental Resources Division
Sedimentation and River Hydraulics Group
Denver, Colorado**

March 2009

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Reclamation Report

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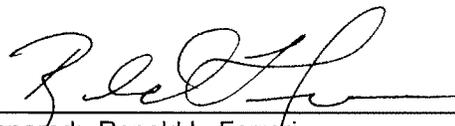
BUREAU OF RECLAMATION

**Technical Service Center, Denver, Colorado
Sedimentation and River Hydraulics Group, 86-68240**

Technical Report No. SRH-2009-9

**Lake Arrowhead
2008 Reservoir Survey**

**Lake Arrowhead Dam
Lake Arrowhead, California**



Prepared: Ronald L. Ferrari
Hydraulic Engineer, Sedimentation and River Hydraulics Group 86-68240

3/5/09
Date



Peer Review: Kent L. Collins
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3/5/09
Date

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Lake Arrowhead 2008 Reservoir Survey

Introduction

Lake Arrowhead and its dam, located in the San Bernardino National Forest in San Bernardino County, are on Little Bear Creek about 30 miles northeast of Fontana and about 65 miles northeast of Los Angeles in southern California (Figure 1). Lake Arrowhead was formally known as Lake Little Bear with initial development in the 1890's to provide a diverted water supply for the San Bernardino area. These diversions never materialized and the completed reservoir was renamed Lake Arrowhead, becoming a resort community. The recreational use of the reservoir is controlled by the Arrowhead Lake Association (ALA). The Lake Arrowhead Community Services District (LACSD) withdraws water from the reservoir for treatment and distribution to local residents for potable use.



Figure 1 - Lake Arrowhead Location Map (LACSD).

Lake Arrowhead Dam is a 200-foot earthen dam described as semi-hydraulic with a steel-reinforced cement core. The spillway is located on the north side of the reservoir and drains into Willow Creek, Figures 2 and 3. The original spillway overflow crest was at elevation 5,107.7 feet¹, but was modified in 1968 to crest elevation 5,106.7 (GEI Consultants, Inc, 2004). Prior to filling, the trees and bushes were cleared from Little Bear Valley for the new reservoir. The USGS gage at Willow Creek reports a Lake Arrowhead drainage area of 6.76 square miles that extends upstream from the reservoir to an elevation of around 6,000 feet.



Figure 2 - Lake Arrowhead Spillway with reservoir spilling (LACSD).

Summary and Conclusions

This Reclamation report presents the results of the September 2008 survey of Lake Arrowhead. The primary objectives of the survey were to gather data needed to:

- compute area-capacity relationships
- develop reservoir topography

¹All elevations in this report are in feet. Unless noted, the elevations in this report are based on the Lake Arrowhead datum, established during construction, which is around 8.0 feet lower than NGVD29 and 11.2 feet lower than NAVD88.



Figure 3 – From Lake Arrowhead spillway structure looking towards reservoir, 9/2008, (LACSD).

A control survey was conducted using the on-line positioning user service (OPUS) and RTK GPS to establish a horizontal and vertical control network near the reservoir for the bathymetric survey. OPUS is operated by the National Geodetic Survey (NGS) and allows users to submit GPS data files that are processed with known point data to determine positions relative to the national control network. The GPS base was set over a temporarily driven piece of rebar on a dirt mound located east of the dam and highway 173 between Lake Arrowhead and Papoose Lake. The coordinates for this point were processed using OPUS, and from this base the complete bathymetric survey was conducted. The OPUS generated coordinates were verified by RTK GPS observation shots on a previously established datum point “ALA #7” that is located above the boat ramp at the ALA marina on the northern end of the dam, Figure 4.

The horizontal control was established in California state plane coordinates, zone 5, on the North American Datum of 1983 (NAD83). The vertical control was tied to NAVD88 in feet. RTK GPS water surface measurements were compared to the reservoir water surface recorded by the ALA gage and found to be around 11.2 feet higher. NGS published data in the study area shows the NAVD88 elevations are around 3.16 feet higher than NGVD29 elevations. Previous surveys determined the ALA datum to be around 8.0 feet lower than NGVD29. For this study, elevation differences were rounded off to the nearest tenth of a foot (0.1).

The 2008 underwater survey, from September 3 through September 11, was conducted between reservoir elevation 5,103.7 and 5,103.8 or around three feet below spillway crest elevation 5,106.7. The water surface was measured by the ALA gage located near the dam along with RTK GPS water surface measurements throughout the 2008 survey. The bathymetric survey used sonic depth recording equipment interfaced with RTK GPS for determining the reservoir sounding locations that were navigated by the survey vessel.

Extensive development around the reservoir limited access by the survey vessel along the shoreline, preventing complete coverage during the bathymetric collection effort. The reservoir has over 1,000 boat slips and most were occupied during the September 2008 collection. Time was taken to collect within and between the boat slips that allowed access by the survey vessel. The system continuously recorded depth and horizontal coordinates as the survey boat navigated along computer generated grid lines that covered much of the open areas of the underwater portion of reservoir. The positioning system provided information to allow the boat operator to maintain a course along these lines that were set at 100 foot increments. The water surface elevations recorded by the ALA's reservoir gage and confirmed by RTK GPS measurements during the time of collection were used to convert the sonic depth measurements to true reservoir bottom elevations. Limited above and below water topography was obtained on foot using the RTK GPS system around some of the boat slip areas that hindered the bathymetric collection. These additional points were used during contour development and as a guide for interpolating additional points as needed to generate the shoreline topography.

Standard surveying techniques were used to collect and develop a 2005 digital orthophoto of the Lake Arrowhead contour with the reservoir water surface at elevation 5,107.0. The water surface on the 2005 aerial photograph was digitized under an ALA contract. The 2005 developed contour at elevation 5,107.0 was used during the bathymetric collection where it was found that its features lined up with the established 2008 survey. The 5,107.0 digitized contour was also used for development of the 2008 reservoir topography and the resulting area-capacity values presented in this report.

The 2008 Lake Arrowhead topography is a combination of the digitized orthophoto water surface at elevation 5,107.0, the 2008 bathymetric and RTK GPS measurements, and points interpolated along the shoreline to develop realistic contours where the shoreline data was limited. The 2008 area and capacity tables were produced from a computer program that used the measured surface areas from the 2008 developed topography and a curve-fitting technique to compute area and capacity at prescribed elevation increments (Bureau of Reclamation, 1985).

Table 1 contains a summary of Lake Arrowhead and watershed characteristics for the 2008 survey. The 2008 survey determined that the reservoir has a total

storage capacity of 46,855 acre-feet with a surface area of 767 acres at water surface elevation 5,106.7.

Control Survey Data Information

For the 2008 hydrographic survey of Lake Arrowhead a control survey was conducted using OPUS and RTK GPS to establish a horizontal and vertical control network near the reservoir. OPUS is operated by the National Geodetic Survey (NGS) and allows users to submit GPS data files that are processed with known point data to determine positions relative to the national control network. The RTK GPS base was set over a temporarily driven piece of rebar on a high bank that overlooked the reservoir and was located east of the dam between Lake Arrowhead and Papoose Lake. The coordinates for this point were processed for the 2008 survey days using OPUS, and from this base additional points were established and checked during the survey. The OPUS generated coordinates were further verified by RTK GPS observations on the ALA datum point number 7, “ALA #7,” located near the ALA boat ramp and dam, Figure 4. This point was established by a detailed GPS field survey under the direction of Bradley L. Brier, Inc. in May of 2006. Their survey results were slightly adjusted to conform to a previously establish control network (pre-GPS). The September 2008 OPUS horizontal control was also slightly adjusted to conform to this pre-GPS survey and the 2008 elevations were adjusted to the ALA vertical datum.

ALA #7 (California State Plane Coordinates, Zone 5, Feet)

North	1,918,954.78 (Bradley L. Brier control survey)
East	6,813,205.66 (Bradley L. Brier control survey)
(NGVD29) Elevation	5,131.67 (Bradley L. Brier control survey)
(NAVD88) Elevation	5,134.83 (BOR 9/2008 survey)
(ALA datum) Elevation	5,123.6 (BOR 9/2008 survey)

The horizontal control, in NAD83, was tied to the California zone 5 state plane coordinate system in feet and to the pre-GPS survey mentioned above. The vertical control, in feet, was tied to NAVD88, NGVD29 and the ALA vertical datum. Unless noted, all elevations in this report are referenced to the ALA vertical datum that for this study is around 8.0² feet lower than NGVD29 and around 11.2 feet lower than NAVD88.

²For this study, all elevations were tied to the ALA datum and rounded off to the nearest tenth of a foot.



Figure 4 - ALA #7 control point located near the ALA marina.

Hydrographic Survey Equipment and Method

The hydrographic survey equipment was mounted on an aluminum vessel with the transducer and GPS unit located on the bow, allowing shallow depth collection closer to the shoreline when the vessel was able to navigate between and around the numerous boat slips. Figure 5 provides an aerial view of the numerous boat slips in one portion of the reservoir. The photo was taken when only a few boats were present. During the September 2008 collection, the majority of these slips had boats docked within, thereby limiting the areas where the survey vessel was able to nose-in near the shore. The hydrographic system included a GPS receiver with a built-in radio, a depth sounder, a helmsman display for navigation, a computer, and hydrographic system software for collecting the underwater data. On-board batteries powered all the equipment. The shore equipment included a second GPS receiver with an external radio. The shore GPS receiver and antenna were mounted on survey tripods over a known datum point and powered by a 12-volt battery.



Figure 5 - Lake Arrowhead view of boat docks.

The Sedimentation and River Hydraulics Group uses RTK GPS with the major benefit being precise heights measured in real time to monitor water surface elevation changes. The RTK GPS system employs two receivers that track the same satellites simultaneously just like with differential GPS. The basic outputs from a RTK receiver are precise 3-D coordinates in latitude, longitude, and height with accuracies on the order of 2 centimeters horizontally and 3 centimeters vertically. The output is on the GPS WGS-84 datum that the hydrographic collection software converted into California's state plane coordinates, zone 5, in NAD83.

The Lake Arrowhead bathymetric survey was conducted from September 3 through 11, 2008 between water surface elevation 5,103.7 and 5,103.8 (ALA datum). The bathymetric survey was conducted using sonic depth recording equipment, interfaced with a RTK GPS, capable of determining sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved along established grid lines throughout the reservoir. The survey vessel's guidance system provided directions to the boat operator to assist in maintaining a course along predetermined lines.

As each line was traversed, the depth and position data were recorded on the laptop computer hard drive for subsequent processing. The water surface elevations at the dam, recorded by the ALA gage and RTK GPS measurements, were used to convert the sonic depth measurements to lake-bottom elevations. The elevations are all tied to ALA's vertical datum that is around 8.0 feet lower than NGVD29 and 11.2 feet lower than NAVD88. All elevation shifts were rounded off to the nearest tenth of a foot for this analysis and report.

There were coves and areas along the shoreline throughout the reservoir that were not covered by the survey vessel due to the numerous occupied boat slips, shallow

water conditions and shoreline vegetation. Prior to the September 2008 collection, the vegetation that existed around the shoreline was sprayed and had died off and settled on the reservoir bottom. This affected the depths where digital depth measurements were recorded on top of the dense vegetation. During processing, the areas where this occurred were adjusted to true reservoir bottom depths using the paper depth charts to distinguish between the vegetation and reservoir bottom. During survey along each line, the depth and position data were recorded on the laptop computer hard drive for this subsequent processing. Final processing of the 2008 September collected data resulted in around 116,000 points (Figure 6).

The 2008 underwater data was collected using a depth sounder that was calibrated by adjusting the speed of sound through the water column which can vary with density, salinity, temperature, turbidity, and other conditions. The measured depths were also checked by lowering a weighted, marked cable below the sounder's transducer. The collected data were digitally transmitted to the computer collection system through a RS-232 port. The depth sounder also produced an analog hard-copy chart of the measured depths. These graphed analog charts were analyzed during post-processing, and when the analog charted depths indicated a difference from the computer recorded bottom depths, the computer data files were modified. Additional information on collection and analysis procedures are outlined in Chapter 9 of the *Erosion and Sedimentation Manual* (Ferrari and Collins, 2006).

A very small portion of the upper elevations of the reservoir, not covered by the 2008 boat survey, was surveyed on foot in September of 2008. Standard land surveying techniques, using RTK GPS, were used to measure topography along the shoreline including above and below water reservoir bottom areas. Shallow under water areas were surveyed by walking along the boat docks and lowering GPS units mounted on top of extended survey rods. Land surveys were performed in selected areas where survey vessel access was limited by occupied boat slips. Steep topography and thick vegetation in some areas prevented data collection by land due to satellite blockage. However, the land survey was primarily limited by the amount of time required for this collection technique and access issues. Many boat slips were not accessible by land due to locked gates. One means to collect additional data along the shoreline would be to conduct a bathymetric survey in early spring or fall when fewer boats are on the reservoir. Remaining boat docks would limit shoreline access even during these times however. Aerial survey during a period of very low reservoir content is the best method to map the shoreline, but that would still require interpolation beneath the boat slip structures.

GPS water surface measurements were also collected on Papoose Lake, downstream of Lake Arrowhead Dam, in September 2008. The measurements determined that the water surface on Papoose Lake was four feet lower than Lake Arrowhead's water surface.

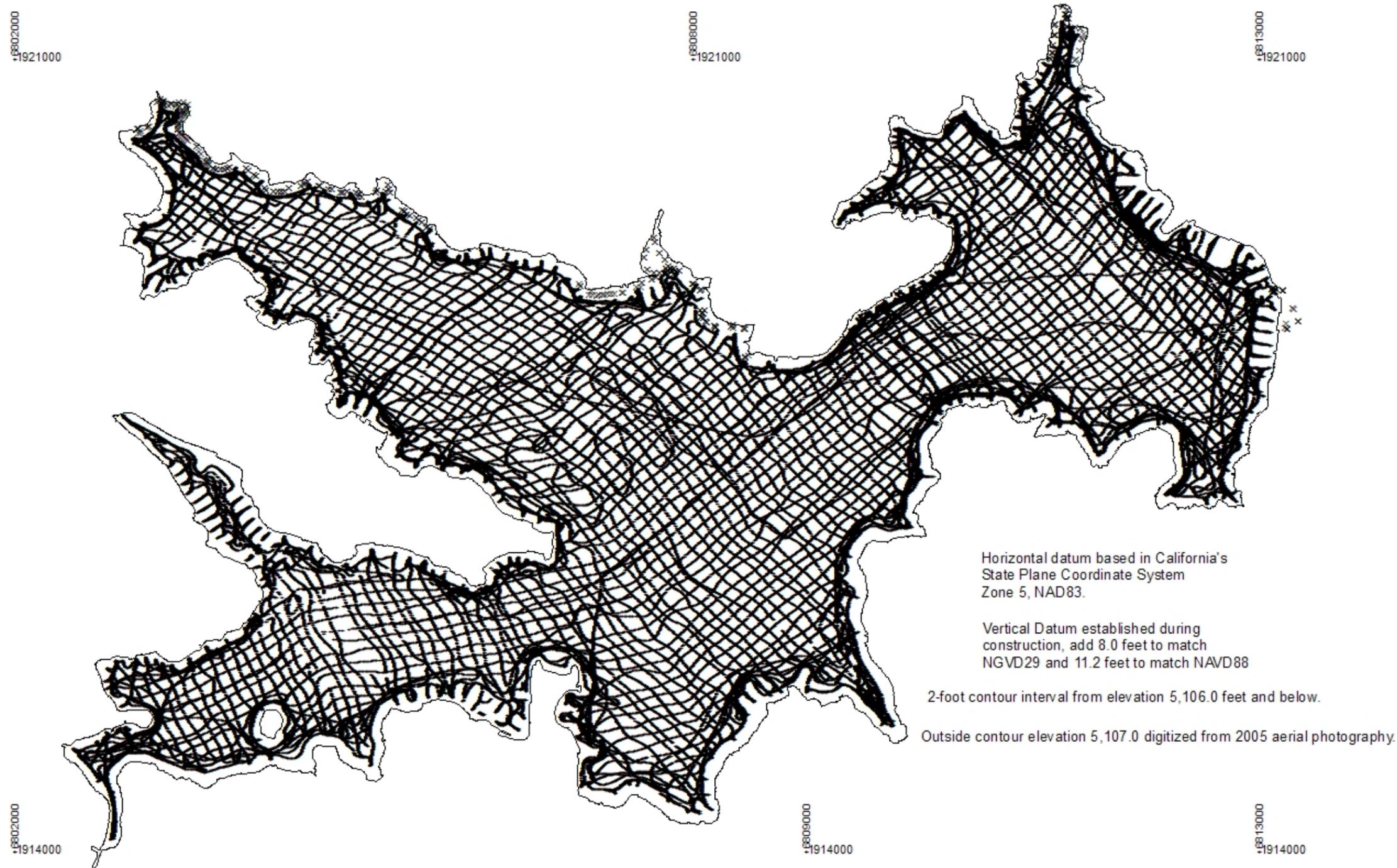


Figure 6 - Lake Arrowhead 2008 survey data points.

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Reservoir Area and Capacity

Topography Development

The topography of Lake Arrowhead was developed from the 2008 above and below water survey data and the digitized water surface from the 2005 aerial photography that was flown at reservoir water surface elevation 5,107.0. The digitized 5,107.0 water surface contour was used as a hard boundary for the 2008 developed contours, allowing contours to only be developed within the reservoir area outlined by this hardclip contour. During the analysis, the 2008 collected data and aerial photography was used to aid in adding data points along the shoreline and in small coves around the reservoir where survey was limited by the numerous boat docks. Data interpolation was the only way to develop contours representing the true area at this time. Obtaining actual data in these areas would require additional collection by means such as aerial LiDAR (Light Detection and Ranging) with the lake level drawn down, bathymetric LiDAR when reservoir water is as clear as possible, additional land collection using a total station, and/or additional bathymetric collection when reservoir is near full and when limited vessels are on the water. The numerous boat slips and underwater vegetation would hinder data collection for all these methods.

The digitized water surface contour, elevation 5,107.0, was used to perform the hardclip around the survey data points from elevation 5,107.0 and below within Lake Arrowhead. The hardclip was used during the triangular irregular network (TIN) development to prevent interpolation outside the enclosed polygon. The 5,107.0 contour was selected for the hardclip boundary since it was the closest data available to represent the water surface during the 2008 underwater survey. Limited RTK GPS ground data collected above and below elevation 5,107.0 was used to better confirm the digitized contour and also used as a guide to interpolate additional points as needed for development of reliable contours along the shoreline.

Other available shoreline data included the 2002 contours around Lake Arrowhead. Detailed information on how these contours were developed was limited. During this analysis, the 2002 data set was superimposed with all other available data with mixed results. Due to the uncertainties it was decided for the 2008 analysis to not include the 2002 data.

Contours for the reservoir below elevation 5,107.0 were developed from the TIN generated within ARCGIS, Figure 7. A TIN is a set of adjacent non-overlapping triangles computed from irregularly spaced points with x,y coordinates and z values. A TIN is designed to deal with continuous data such as elevations. The TIN software uses a method known as Delaunay's criteria for triangulation where

triangles are formed among all data points within the polygon clip. The method requires that a circle drawn through the three nodes of a triangle will contain no other point, meaning that each data point is connected to its two nearest neighbors to form triangles. This method preserves all the collected data points. The TIN method is discussed in detail in the ARCGIS user's documentation, (ESRI, 2007).

The linear interpolation option of the ARCGIS TIN and CONTOUR commands was used to interpolate contours from the Lake Arrowhead TIN. The areas of the enclosed contour polygons at one-foot increments were computed from the survey data for elevations 4,955.0 through 5,107.0. The surface area of the digitized orthophoto water surface contour, elevation 5,107.0, minus the island area, was used for the 2008 area and capacity computations. The reservoir contour topography at 2-foot intervals from elevation 5,106 and below is presented on Figure 8. The outer contour is the digitized elevation 5,107.0 water surface. First development of the contours within ARCGIS was directly from the created TIN using all the enclosed data points and resulted in a somewhat jagged representation of the contours. Using the smooth line options within ARCMAP, the initial contours were somewhat smoothed and are presented on Figure 8.

The steepness of the reservoir bottom shown on Figures 7 and 8 is further illustrated on a plot of the Little Bear Creek thalweg alignment as it runs from the upper reservoir towards the dam, Figure 9. The plot shows the reservoir bottom elevation dropping over 150 feet from the upper reservoir to the dam, a distance of less than 3.5 miles.

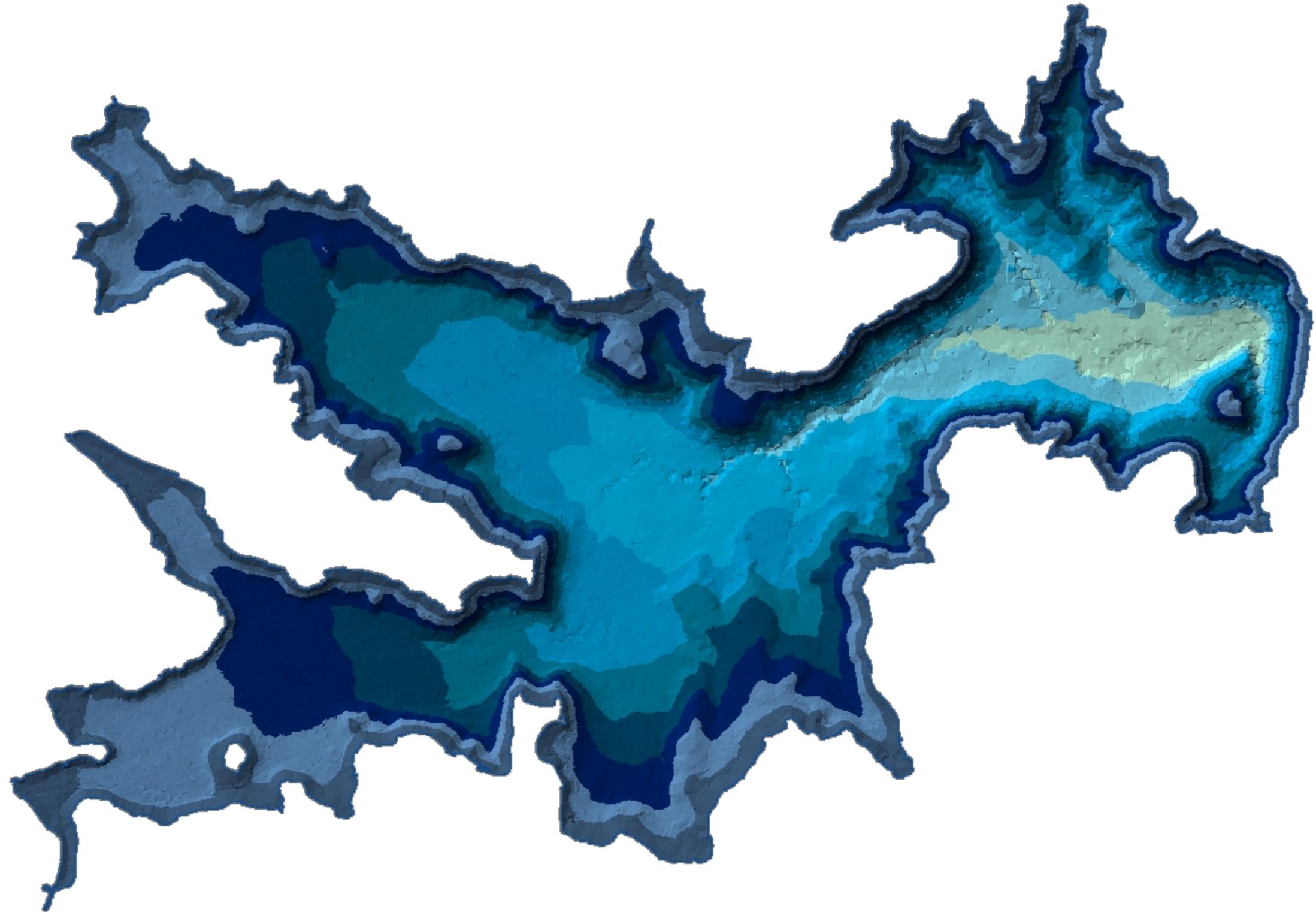


Figure 7 - Lake Arrowhead generated TIN.

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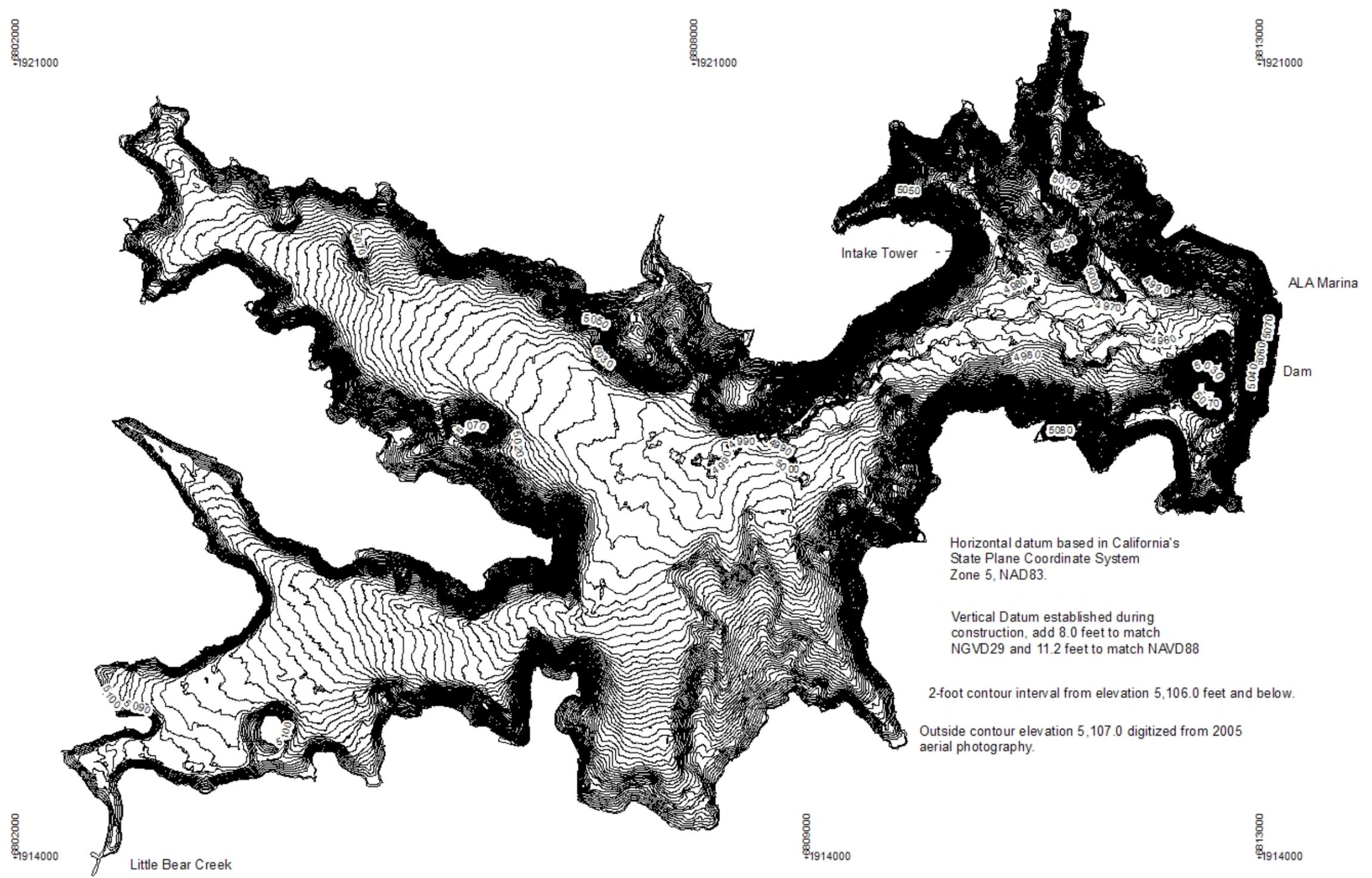


Figure 8 - Lake Arrowhead 2-foot contour map.

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Reservoir Area and Capacity

2008 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP (Bureau of Reclamation, 1985). The ACAP program can compute the area and capacity at elevation increments from 0.01 to 1.0 foot by linear interpolation between the given contour surface areas. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit. The error limit was set at 0.000001 for Lake Arrowhead. The capacity equation is then used over the full range of intervals fitting within the allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from the basic area curve over that interval) is utilized until it exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. Through differentiation of the capacity equations, which are of second order polynomial form, final area equations are derived:

$$y = a_1 + a_2x + a_3x^2$$

where: y = capacity
 x = elevation above a reference base
 a₁ = intercept
 a₂ and a₃ = coefficients

Results of the Lake Arrowhead area and capacity computations are listed in the appendix for 0.1-foot elevation increments (Bureau of Reclamation, 2008). A description of the computations and coefficients output from the ACAP program is included with these tables. The results are also listed on table 1 and illustrated on the area and capacity plot, Figure 10. As of September 2008, at elevation 5,106.7, the surface area was 767 acres with a total capacity of 46,855 acre-feet.

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RESERVOIR SEDIMENT
DATA SUMMARY

Lake Arrowhead Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

D	1. OWNER ALA and LACSD ¹				2. STREAM Little Bear Creek				3. STATE California																				
A	4. SEC 14		TWP. 2N		RANGE 3W		5. NEAREST P.O. Lake Arrowhead				6. COUNTY San Bernardino																		
M	7. LAT 34° 15' 41"		LONG 117° 10' 03"		8. TOP OF DAM ELEVATION 5,116.2				9. SPILLWAY CREST EL 5,106.7 ²																				
R	10. STORAGE ALLOCATION		11. ELEVATION TOP OF POOL		12. 2008 SURFACE AREA, AC		13. 2008 CAPACITY, AC-FT		14. GROSS STORAGE ACRE-FEET		15. DATE STORAGE BEGAN																		
E	a. SURCHARGE										1913																		
S	b. FLOOD CONTROL																												
E	c. IRRIGATION																												
R	d. JOINT USE		5,106.7		767		46,855		46,855		16. DATE NORMAL OPERATIONS BEGAN																		
O	e. CONSERVATION										1921																		
I	f. INACTIVE																												
R	g. DEAD																												
B	17. LENGTH OF RESERVOIR 4.5 ⁴ MILES				AVG. WIDTH OF RESERVOIR 0.27 MILES																								
A	18. TOTAL DRAINAGE AREA 6.76 ³ SQUARE MILES				22. MEAN ANNUAL PRECIPITATION 40 INCHES																								
S	19. NET SEDIMENT CONTRIBUTING AREA 6.76 SQUARE MILES				23. MEAN ANNUAL RUNOFF INCHES																								
I	20. LENGTH MILES		AVG. WIDTH MILES		24. MEAN ANNUAL INFLOW ACRE-FEET																								
N	21. MAX. ELEVATION 6,000+		MIN. ELEVATION 5106.7		25. ANNUAL TEMP, MEAN °F RANGE °F to °F																								
S	26. DATE OF SURVEY		27. PER. YRS		28. PER. YRS		29. TYPE OF SURVEY		30. NO. OF RANGES OR INTERVALS		31. SURFACE AREA, AC.		32. CAPACITY ACRE - FEET		33. C/ RATIO AF/AF														
	9/2008		12.6		Contour (D)		2-ft ⁹		767		46,855																		
D	26. DATE OF SURVEY		34. PERIOD ANNUAL PRECIPITATION		35. PERIOD WATER INFLOW, ACRE-FEET			36. WATER INFLOW TO DATE, AF																					
	9/2008				a. MEAN ANN.			b. MAX. ANN.		c. TOTAL		a. MEAN ANN.		b. TOTAL															
A	26. DATE OF SURVEY		37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SEDIMENT DEPOSITS TO DATE, AF																							
	9/2008		a. TOTAL			b. AVG. ANN.		c. /MI ² -YR.		a. TOTAL		b. AVG. ANN.		c. /MI ² -YR.															
A	26. DATE OF SURVEY		39. AVG. DRY WT. (#/FT ³)		40. SED. DEP. TONS/ML ² -YR		41. STORAGE LOSS, PCT.		42. SEDIMENT INFLOW, PPM																				
	9/2008				a. PERIOD		b. TOTAL TO DATE		a. AVG. ANNUAL		b. TOTAL TO DATE		a. PER. b. TOT.																
D	26. DATE OF SURVEY																												
	43. DEPTH DESIGNATION RANGE IN FEET BELOW AND ABOVE CREST ELEVATION																												
				60-50		50-40		40-30		30-20		20-10		10-C		C-5													
PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION																													
D	26. DATE																												
	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR																												
		0-10		10-20		20-30		30-40		40-50		50-60		60-70		70-80		80-90		90-100		105-		110-		115-		120-	
PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION																													

Table 1 - Lake Arrowhead Reservoir Data Summary (1 of 2).

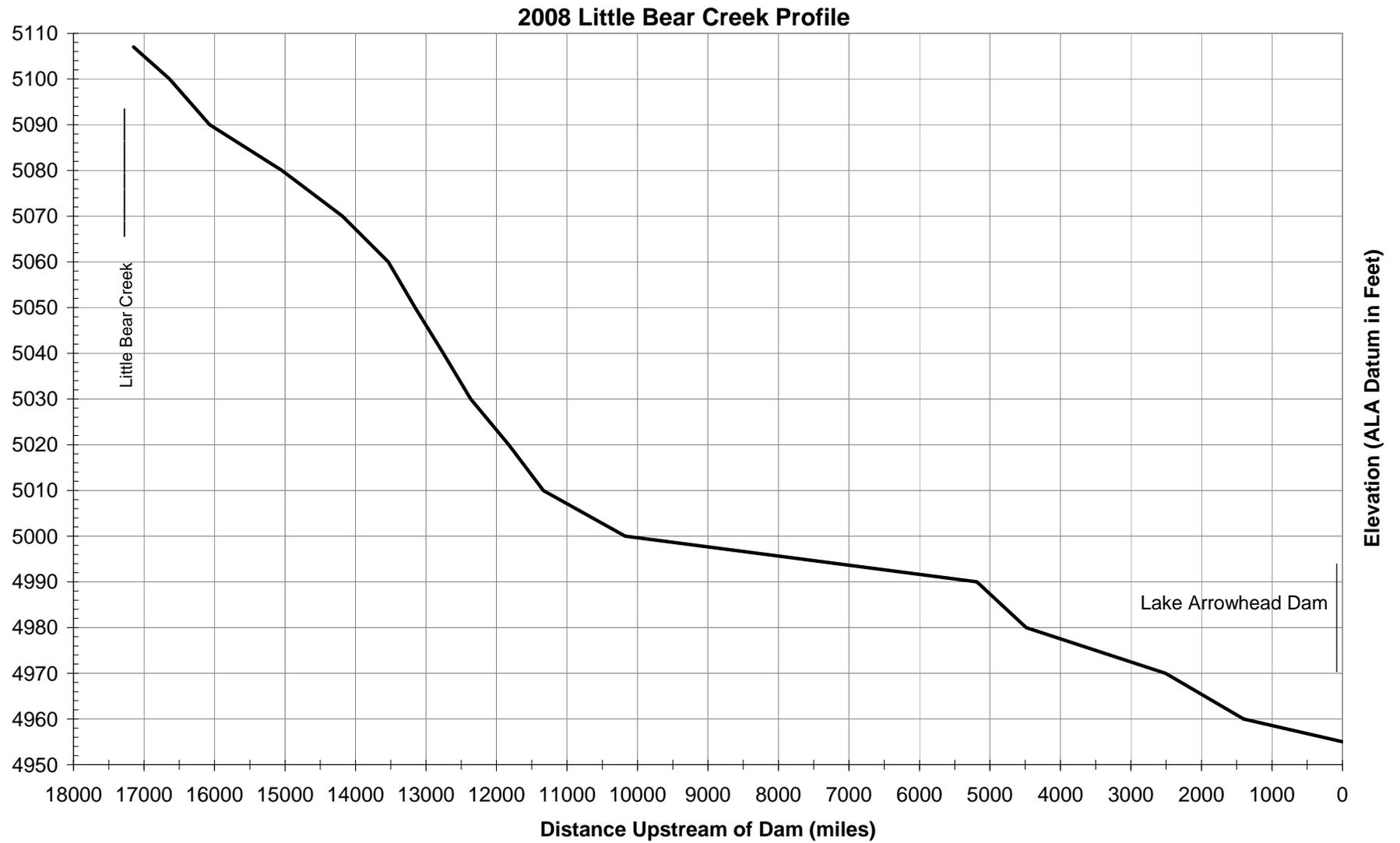


Figure 9 - Little Bear Creek Thalweg.

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2008 Area-Capacity Curves for Lake Arrowhead

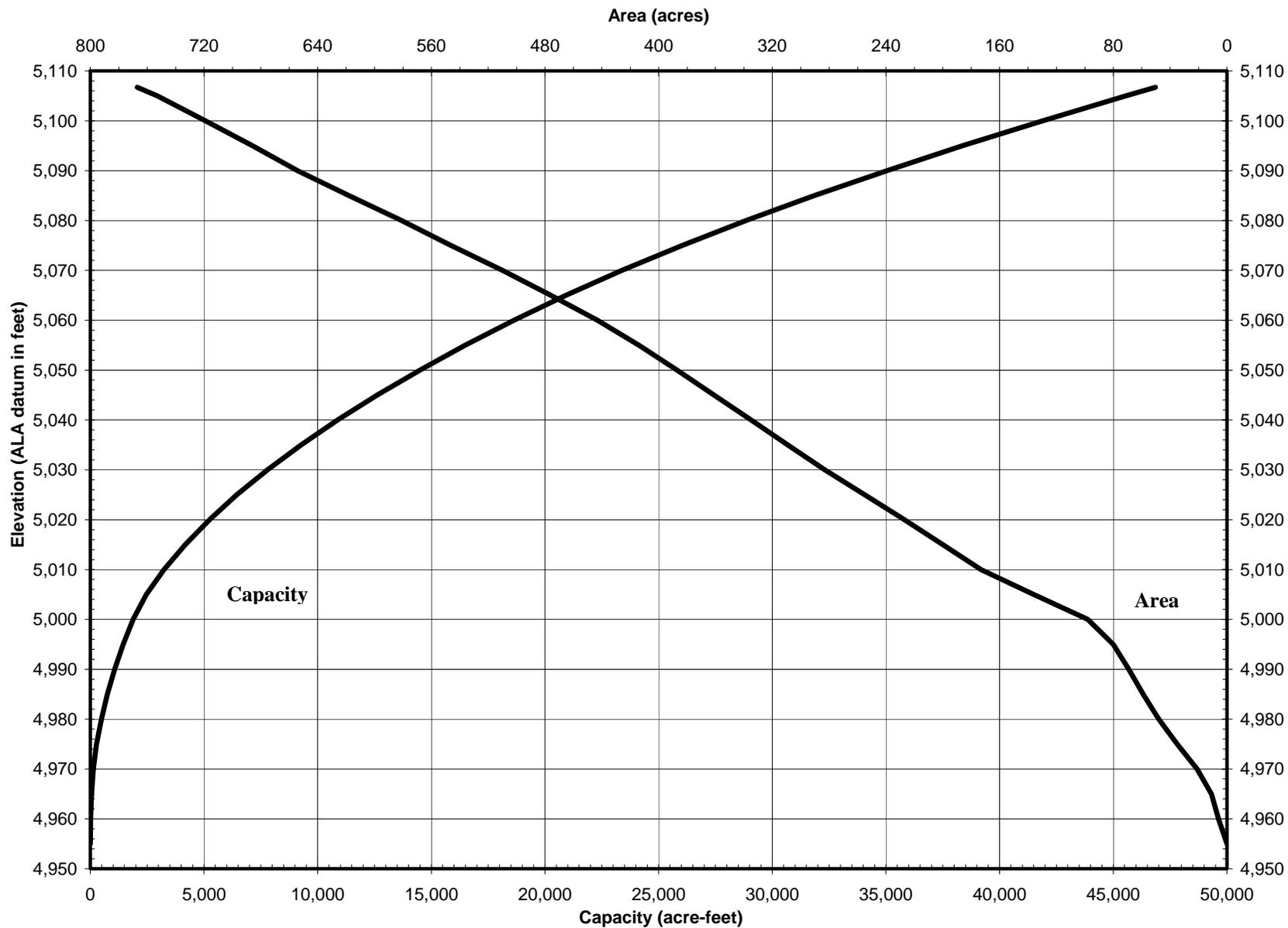


Figure 10 - Lake Arrowhead Area and Capacity Plots.

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References

American Society of Civil Engineers, 1962. *Nomenclature for Hydraulics*, ASCE Headquarters, New York.

Bradley L. Brier, Inc., May 2006. *Lake Arrowhead Mapping Control of May 2006*, Lake Arrowhead, CA. brad@briersurveying.com.

Bureau of Reclamation, 1985. Surface Water Branch, *ACAP85 User's Manual*, Technical Service Center, Denver CO.

Bureau of Reclamation, 1987(a). *Guide for Preparation of Standing Operating Procedures for Bureau of Reclamation Dams and Reservoirs*, U.S. Government Printing Office, Denver, CO.

Bureau of Reclamation, 1987(b). *Design of Small Dams*, U.S. Government Printing Office, Denver CO.

Bureau of Reclamation, 2008. *Project Data*, Denver Office, Denver CO. (www.usbr.gov/dataweb).

Corps of Engineers, 2002. *Engineering and Design Hydrographic Surveying*, EM 1110-2-1003, Department of the Army, Washington DC, (www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1003/toc.htm).

ESRI, 2006. **Environmental Systems Research Institute, Inc.** (www.esri.com)

Ferrari, R.L. and Collins, K. (2006). *Reservoir Survey and Data Analysis*, Chapter 9, Erosion and Sedimentation Manual, U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center, Sedimentation and River Hydraulics Group. Denver, Colorado. www.usbr.gov/pmts/sediment

GEI Consultants, Inc, 2004. *Lake Level Analysis Lake Arrowhead, California*, Bookman-Edmonston, Division of GEI Consultants, Inc. Glendale, CA.

Appendix

Lake Arrowhead
California
Area and Capacity Tables

The tables for Lake Arrowhead were generated by means of the area-capacity program ACAP, using the least squares method of curve fitting developed by the Bureau of Reclamation Technical Service Center. This program computes area at 1.0-, 0.1-, and 0.01-foot increments by linear interpolation between basic data contours. The respective capacities and capacity equations are than obtained by integration of the area equations. The initial capacity equation is tested over successive intervals to check whether it fits within an allowable error term. At the next interval beyond, a new capacity equation (integrated from the basic area equation over that interval) begins testing the fit until it too exceeds the error term. The capacity curve thus becomes a series of curves, each fitting a certain region of data. The final area equations are obtained by differentiation of the capacity equations. Capacity equations are of the form $y = a_1 + a_2x + a_3x^2$ where y is capacity and x is the elevation above an elevation base. The capacity equation coefficients for the reservoir are shown below ($\epsilon = 0.000001$).

LAKE ARROWHEAD - CALIFORNIA 2008 AREA-CAPACITY TABLES

EQUATION NUMBER	ELEVATION BASE	CAPACITY BASE	COEFFICIENT A1 (INTERCEPT)	COEFFICIENT A2 (1ST TERM)	COEFFICIENT A3 (2ND TERM)
1	4955.00	0	.0000	.0000	.4000
2	4956.00	0	.4000	.8000	.6250
3	4958.00	4	4.5000	3.3000	.5500
4	4960.00	13	13.3000	5.5000	.5000
5	4962.00	26	26.3000	7.5000	.6750
6	4964.00	44	44.0000	10.2000	.6000
7	4966.00	66	66.8000	12.6000	.9000
8	4968.00	95	95.6000	16.2000	1.2500
9	4970.00	133	133.0000	21.2000	1.4000
10	4972.00	181	181.0000	26.8000	1.4750
11	4974.00	240	240.5000	32.7000	1.3500
12	4976.00	311	311.3000	38.1000	1.3000
13	4978.00	392	392.7000	43.3000	1.2000
14	4980.00	484	484.1000	48.1000	1.1250
15	4982.00	584	584.8000	52.6000	1.0500
16	4984.00	694	694.2000	56.8000	.9500
17	4986.00	811	811.6000	60.6000	1.0000
18	4988.00	936	936.8001	64.6000	1.1250
19	4990.00	1070	1070.5000	69.1000	1.1000
20	4994.00	1364	1364.5000	77.9000	1.1500
21	4996.00	1524	1524.9000	82.5000	1.5000
22	4998.00	1695	1695.9000	88.5000	2.4750
23	5000.00	1882	1882.8001	98.4000	3.3000
24	5002.00	2092	2092.8000	111.6001	4.1500
25	5004.00	2332	2332.6001	128.2001	3.9999
26	5006.00	2605	2605.0000	144.2000	3.7500
27	5008.00	2908	2908.4000	159.1999	3.4750
28	5010.00	3240	3240.7000	173.1000	2.8750
29	5012.00	3598	3598.3999	184.6002	2.6249
30	5014.00	3978	3978.0999	195.1000	2.5250
31	5016.00	4378	4378.3999	205.2001	2.5999
32	5018.00	4799	4799.1997	215.5999	2.7250
33	5020.00	5241	5241.2999	226.4998	2.8001
34	5022.00	5705	5705.4999	237.7003	2.8999
35	5024.00	6192	6192.5000	249.3000	2.8000
36	5026.00	6702	6702.2997	260.5002	2.7750
37	5030.00	7788	7788.6998	282.6997	2.7252
38	5032.00	8365	8365.0000	293.6000	2.6751
39	5034.00	8962	8962.9005	304.2997	2.5251
40	5036.00	9581	9581.6007	314.3995	2.6503
41	5038.00	10221	10221.0011	325.0000	2.6250
42	5040.00	10881	10881.5010	335.5004	2.5498
43	5042.00	11562	11562.7011	345.7000	2.4750
44	5044.00	12264	12264.0009	355.6000	2.5001
45	5046.00	12985	12985.2014	365.5998	2.6500
46	5050.00	14490	14490.0125	386.7692	2.6875
47	5054.00	16080	16080.1008	408.2993	2.8754
48	5056.00	16908	16908.2006	419.8001	2.8252
49	5058.00	17759	17759.1013	431.1005	2.9498
50	5060.00	18633	18633.1009	442.9014	3.0994

EQUATION NUMBER	ELEVATION BASE	CAPACITY BASE	COEFFICIENT A1 (INTERCEPT)	COEFFICIENT A2 (1ST TERM)	COEFFICIENT A3 (2ND TERM)
51	5062.00	19531	19531.3009	455.2999	3.4000
52	5064.00	20455	20455.4996	468.9009	3.4496
53	5066.00	21407	21407.0880	482.7309	3.3625
54	5070.00	23391	23391.7776	509.6614	3.6751
55	5074.00	25489	25489.2010	538.9998	3.4503
56	5076.00	26581	26581.0019	552.8002	3.5248
57	5078.00	27700	27700.7245	566.8383	3.6249
58	5082.00	30026	30026.0994	595.9005	3.7748
59	5084.00	31233	31232.9998	611.0008	3.3996
60	5086.00	32468	32468.5995	624.6014	3.9243
61	5088.00	33733	33733.4991	640.3020	3.4243
62	5090.00	35027	35027.7888	654.0317	3.0623
63	5094.00	37692	37692.9030	678.4994	3.5751
64	5096.00	39064	39064.2029	692.8007	3.3246
65	5098.00	40463	40463.1009	706.1009	3.1247
66	5100.00	41887	41887.8237	718.5388	3.2748
67	5104.00	44814	44814.3771	744.8690	4.0171
68	5107.00	47085	47085.0978	768.7997	13.2007

2008 AREA-CAPACITY TABLES

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THE AREA TABLE IS IN ACRES

THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
4955	0.	0.	0.	0.	0.	0.	0.	1.	1.	1.
4956	1.	1.	1.	1.	1.	1.	2.	2.	2.	2.
4957	2.	2.	2.	2.	3.	3.	3.	3.	3.	3.
4958	3.	3.	4.	4.	4.	4.	4.	4.	4.	4.
4959	4.	5.	5.	5.	5.	5.	5.	5.	5.	5.
4960	6.	6.	6.	6.	6.	6.	6.	6.	6.	6.
4961	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.
4962	7.	8.	8.	8.	8.	8.	8.	8.	9.	9.
4963	9.	9.	9.	9.	9.	10.	10.	10.	10.	10.
4964	10.	10.	10.	11.	11.	11.	11.	11.	11.	11.
4965	11.	12.	12.	12.	12.	12.	12.	12.	12.	12.
4966	13.	13.	13.	13.	13.	14.	14.	14.	14.	14.
4967	14.	15.	15.	15.	15.	15.	15.	16.	16.	16.
4968	16.	16.	17.	17.	17.	17.	18.	18.	18.	18.
4969	19.	19.	19.	19.	20.	20.	20.	20.	21.	21.
4970	21.	21.	22.	22.	22.	23.	23.	23.	23.	24.
4971	24.	24.	25.	25.	25.	25.	26.	26.	26.	27.
4972	27.	27.	27.	28.	28.	28.	29.	29.	29.	29.
4973	30.	30.	30.	31.	31.	31.	32.	32.	32.	32.
4974	33.	33.	33.	34.	34.	34.	34.	35.	35.	35.
4975	35.	36.	36.	36.	36.	37.	37.	37.	38.	38.
4976	38.	38.	39.	39.	39.	39.	40.	40.	40.	40.
4977	41.	41.	41.	41.	42.	42.	42.	43.	43.	43.
4978	43.	44.	44.	44.	44.	44.	45.	45.	45.	45.
4979	46.	46.	46.	46.	47.	47.	47.	47.	48.	48.
4980	48.	48.	49.	49.	49.	49.	49.	50.	50.	50.
4981	50.	51.	51.	51.	51.	51.	52.	52.	52.	52.
4982	53.	53.	53.	53.	53.	54.	54.	54.	54.	54.
4983	55.	55.	55.	55.	56.	56.	56.	56.	56.	57.
4984	57.	57.	57.	57.	58.	58.	58.	58.	58.	59.
4985	59.	59.	59.	59.	59.	60.	60.	60.	60.	60.
4986	61.	61.	61.	61.	61.	62.	62.	62.	62.	62.
4987	63.	63.	63.	63.	63.	64.	64.	64.	64.	64.
4988	65.	65.	65.	65.	66.	66.	66.	66.	66.	67.
4989	67.	67.	67.	68.	68.	68.	68.	68.	69.	69.
4990	69.	69.	70.	70.	70.	70.	70.	71.	71.	71.
4991	71.	72.	72.	72.	72.	72.	73.	73.	73.	73.
4992	73.	74.	74.	74.	74.	75.	75.	75.	75.	75.
4993	76.	76.	76.	76.	77.	77.	77.	77.	77.	78.
4994	78.	78.	78.	79.	79.	79.	79.	80.	80.	80.

LAKE ARROWHEAD - CALIFORNIA

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2008 AREA-CAPACITY TABLES

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THE AREA TABLE IS IN ACRES

THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
4995	80.	80.	81.	81.	81.	81.	82.	82.	82.	82.
4996	82.	83.	83.	83.	84.	84.	84.	85.	85.	85.
4997	85.	86.	86.	86.	87.	87.	87.	88.	88.	88.
4998	88.	89.	89.	90.	90.	91.	91.	92.	92.	93.
4999	93.	94.	94.	95.	95.	96.	96.	97.	97.	98.
5000	98.	99.	100.	100.	101.	102.	102.	103.	104.	104.
5001	105.	106.	106.	107.	108.	108.	109.	110.	110.	111.
5002	112.	112.	113.	114.	115.	116.	117.	117.	118.	119.
5003	120.	121.	122.	122.	123.	124.	125.	126.	127.	127.
5004	128.	129.	130.	131.	131.	132.	133.	134.	135.	135.
5005	136.	137.	138.	139.	139.	140.	141.	142.	143.	143.
5006	144.	145.	146.	146.	147.	148.	149.	149.	150.	151.
5007	152.	152.	153.	154.	155.	155.	156.	157.	158.	158.
5008	159.	160.	161.	161.	162.	163.	163.	164.	165.	165.
5009	166.	167.	168.	168.	169.	170.	170.	171.	172.	172.
5010	173.	174.	174.	175.	175.	176.	177.	177.	178.	178.
5011	179.	179.	180.	181.	181.	182.	182.	183.	183.	184.
5012	185.	185.	186.	186.	187.	187.	188.	188.	189.	189.
5013	190.	190.	191.	191.	192.	192.	193.	194.	194.	195.
5014	195.	196.	196.	197.	197.	198.	198.	199.	199.	200.
5015	200.	201.	201.	202.	202.	203.	203.	204.	204.	205.
5016	205.	206.	206.	207.	207.	208.	208.	209.	209.	210.
5017	210.	211.	211.	212.	212.	213.	214.	214.	215.	215.
5018	216.	216.	217.	217.	218.	218.	219.	219.	220.	221.
5019	221.	222.	222.	223.	223.	224.	224.	225.	225.	226.
5020	227.	227.	228.	228.	229.	229.	230.	230.	231.	232.
5021	232.	233.	233.	234.	234.	235.	235.	236.	237.	237.
5022	238.	238.	239.	239.	240.	241.	241.	242.	242.	243.
5023	244.	244.	245.	245.	246.	246.	247.	248.	248.	249.
5024	249.	250.	250.	251.	252.	252.	253.	253.	254.	254.
5025	255.	255.	256.	257.	257.	258.	258.	259.	259.	260.
5026	260.	261.	262.	262.	263.	263.	264.	264.	265.	265.
5027	266.	267.	267.	268.	268.	269.	269.	270.	270.	271.
5028	272.	272.	273.	273.	274.	274.	275.	275.	276.	277.
5029	277.	278.	278.	279.	279.	280.	280.	281.	282.	282.
5030	283.	283.	284.	284.	285.	285.	286.	287.	287.	288.
5031	288.	289.	289.	290.	290.	291.	291.	292.	293.	293.
5032	294.	294.	295.	295.	296.	296.	297.	297.	298.	298.
5033	299.	299.	300.	301.	301.	302.	302.	303.	303.	304.
5034	304.	305.	305.	306.	306.	307.	307.	308.	308.	309.

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2008 AREA-CAPACITY TABLES

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THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
5035	309.	310.	310.	311.	311.	312.	312.	313.	313.	314.
5036	314.	315.	315.	316.	317.	317.	318.	318.	319.	319.
5037	320.	320.	321.	321.	322.	322.	323.	323.	324.	324.
5038	325.	326.	326.	327.	327.	328.	328.	329.	329.	330.
5039	330.	331.	331.	332.	332.	333.	333.	334.	334.	335.
5040	335.	336.	337.	337.	338.	338.	339.	339.	340.	340.
5041	341.	341.	342.	342.	343.	343.	344.	344.	345.	345.
5042	346.	346.	347.	347.	348.	348.	349.	349.	350.	350.
5043	351.	351.	352.	352.	353.	353.	354.	354.	355.	355.
5044	356.	356.	357.	357.	358.	358.	359.	359.	360.	360.
5045	361.	361.	362.	362.	363.	363.	364.	364.	365.	365.
5046	366.	366.	367.	367.	368.	368.	369.	369.	370.	370.
5047	371.	371.	372.	372.	373.	374.	374.	375.	375.	376.
5048	376.	377.	377.	378.	378.	379.	379.	380.	380.	381.
5049	381.	382.	383.	383.	384.	384.	385.	385.	386.	386.
5050	387.	387.	388.	388.	389.	389.	390.	391.	391.	392.
5051	392.	393.	393.	394.	394.	395.	395.	396.	396.	397.
5052	398.	398.	399.	399.	400.	400.	401.	401.	402.	402.
5053	403.	403.	404.	405.	405.	406.	406.	407.	407.	408.
5054	408.	409.	409.	410.	411.	411.	412.	412.	413.	413.
5055	414.	415.	415.	416.	416.	417.	418.	418.	419.	419.
5056	420.	420.	421.	421.	422.	423.	423.	424.	424.	425.
5057	425.	426.	427.	427.	428.	428.	429.	429.	430.	431.
5058	431.	432.	432.	433.	433.	434.	435.	435.	436.	436.
5059	437.	438.	438.	439.	439.	440.	441.	441.	442.	442.
5060	443.	444.	444.	445.	445.	446.	447.	447.	448.	448.
5061	449.	450.	450.	451.	452.	452.	453.	453.	454.	455.
5062	455.	456.	457.	457.	458.	459.	459.	460.	461.	461.
5063	462.	463.	463.	464.	465.	465.	466.	467.	468.	468.
5064	469.	470.	470.	471.	472.	472.	473.	474.	474.	475.
5065	476.	476.	477.	478.	479.	479.	480.	481.	481.	482.
5066	483.	483.	484.	485.	485.	486.	487.	487.	488.	489.
5067	489.	490.	491.	491.	492.	493.	493.	494.	495.	496.
5068	496.	497.	498.	498.	499.	500.	500.	501.	502.	502.
5069	503.	504.	504.	505.	506.	506.	507.	508.	508.	509.
5070	510.	510.	511.	512.	513.	513.	514.	515.	516.	516.
5071	517.	518.	518.	519.	520.	521.	521.	522.	523.	524.
5072	524.	525.	526.	527.	527.	528.	529.	530.	530.	531.
5073	532.	532.	533.	534.	535.	535.	536.	537.	538.	538.
5074	539.	540.	540.	541.	542.	542.	543.	544.	545.	545.

LAKE ARROWHEAD - CALIFORNIA

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2008 AREA-CAPACITY TABLES

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THE AREA TABLE IS IN ACRES

THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
5075	546.	547.	547.	548.	549.	549.	550.	551.	551.	552.
5076	553.	554.	554.	555.	556.	556.	557.	558.	558.	559.
5077	560.	561.	561.	562.	563.	563.	564.	565.	565.	566.
5078	567.	568.	568.	569.	570.	570.	571.	572.	573.	573.
5079	574.	575.	576.	576.	577.	578.	578.	579.	580.	581.
5080	581.	582.	583.	584.	584.	585.	586.	586.	587.	588.
5081	589.	589.	590.	591.	591.	592.	593.	594.	594.	595.
5082	596.	597.	597.	598.	599.	600.	600.	601.	602.	603.
5083	603.	604.	605.	606.	606.	607.	608.	609.	609.	610.
5084	611.	612.	612.	613.	614.	614.	615.	616.	616.	617.
5085	618.	618.	619.	620.	621.	621.	622.	623.	623.	624.
5086	625.	625.	626.	627.	628.	629.	629.	630.	631.	632.
5087	632.	633.	634.	635.	636.	636.	637.	638.	639.	640.
5088	640.	641.	642.	642.	643.	644.	644.	645.	646.	646.
5089	647.	648.	649.	649.	650.	651.	651.	652.	653.	653.
5090	654.	655.	655.	656.	656.	657.	658.	658.	659.	660.
5091	660.	661.	661.	662.	663.	663.	664.	664.	665.	666.
5092	666.	667.	668.	668.	669.	669.	670.	671.	671.	672.
5093	672.	673.	674.	674.	675.	675.	676.	677.	677.	678.
5094	679.	679.	680.	681.	681.	682.	683.	684.	684.	685.
5095	686.	686.	687.	688.	689.	689.	690.	691.	691.	692.
5096	693.	693.	694.	695.	695.	696.	697.	697.	698.	699.
5097	699.	700.	701.	701.	702.	703.	703.	704.	705.	705.
5098	706.	707.	707.	708.	709.	709.	710.	710.	711.	712.
5099	712.	713.	714.	714.	715.	715.	716.	717.	717.	718.
5100	719.	719.	720.	721.	721.	722.	722.	723.	724.	724.
5101	725.	726.	726.	727.	728.	728.	729.	730.	730.	731.
5102	732.	732.	733.	734.	734.	735.	736.	736.	737.	738.
5103	738.	739.	739.	740.	741.	741.	742.	743.	743.	744.
5104	745.	746.	746.	747.	748.	749.	750.	750.	751.	752.
5105	753.	754.	755.	755.	756.	757.	758.	759.	759.	760.
5106	761.	762.	763.	763.	764.	765.	766.	767.	767.	768.
5107	769.									

LAKE ARROWHEAD - CALIFORNIA

(ACAP92) COMPUTED

1/13/2009

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2008 AREA-CAPACITY TABLES

THE CAPACITY TABLE IS IN ACRE FEET

THE ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
4955	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4956	0.	0.	1.	1.	1.	1.	1.	1.	1.	2.
4957	2.	2.	2.	2.	3.	3.	3.	4.	4.	4.
4958	5.	5.	5.	6.	6.	6.	7.	7.	7.	8.
4959	8.	9.	9.	10.	10.	11.	11.	12.	12.	13.
4960	13.	14.	14.	15.	16.	16.	17.	17.	18.	19.
4961	19.	20.	21.	21.	22.	23.	23.	24.	25.	26.
4962	26.	27.	28.	29.	29.	30.	31.	32.	33.	34.
4963	34.	35.	36.	37.	38.	39.	40.	41.	42.	43.
4964	44.	45.	46.	47.	48.	49.	50.	51.	53.	54.
4965	55.	56.	57.	58.	59.	61.	62.	63.	64.	66.
4966	67.	68.	69.	71.	72.	73.	75.	76.	77.	79.
4967	80.	82.	83.	85.	86.	88.	89.	91.	92.	94.
4968	96.	97.	99.	101.	102.	104.	106.	108.	109.	111.
4969	113.	115.	117.	119.	121.	123.	125.	127.	129.	131.
4970	133.	135.	137.	139.	142.	144.	146.	149.	151.	153.
4971	156.	158.	160.	163.	165.	168.	171.	173.	176.	178.
4972	181.	184.	186.	189.	192.	195.	198.	200.	203.	206.
4973	209.	212.	215.	218.	221.	225.	228.	231.	234.	237.
4974	241.	244.	247.	250.	254.	257.	261.	264.	268.	271.
4975	275.	278.	282.	285.	289.	293.	296.	300.	304.	308.
4976	311.	315.	319.	323.	327.	331.	335.	339.	343.	347.
4977	351.	355.	359.	363.	367.	371.	376.	380.	384.	388.
4978	393.	397.	401.	406.	410.	415.	419.	424.	428.	433.
4979	437.	442.	446.	451.	456.	460.	465.	470.	475.	479.
4980	484.	489.	494.	499.	504.	508.	513.	518.	523.	528.
4981	533.	538.	543.	549.	554.	559.	564.	569.	574.	580.
4982	585.	590.	595.	601.	606.	611.	617.	622.	628.	633.
4983	638.	644.	649.	655.	660.	666.	672.	677.	683.	689.
4984	694.	700.	706.	711.	717.	723.	729.	734.	740.	746.
4985	752.	758.	764.	770.	776.	782.	788.	794.	800.	806.
4986	812.	818.	824.	830.	836.	842.	848.	855.	861.	867.
4987	873.	879.	886.	892.	898.	905.	911.	918.	924.	930.
4988	937.	943.	950.	956.	963.	969.	976.	983.	989.	996.
4989	1003.	1009.	1016.	1023.	1029.	1036.	1043.	1050.	1057.	1064.
4990	1071.	1077.	1084.	1091.	1098.	1105.	1112.	1119.	1126.	1134.
4991	1141.	1148.	1155.	1162.	1169.	1177.	1184.	1191.	1198.	1206.
4992	1213.	1220.	1228.	1235.	1243.	1250.	1258.	1265.	1273.	1280.
4993	1288.	1295.	1303.	1311.	1318.	1326.	1334.	1341.	1349.	1357.
4994	1365.	1372.	1380.	1388.	1396.	1404.	1412.	1420.	1428.	1436.

LAKE ARROWHEAD - CALIFORNIA

(ACAP92) COMPUTED

1/13/2009

2008 AREA-CAPACITY TABLES

12:25:26

THE CAPACITY TABLE IS IN ACRE FEET

THE ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
4995	1444.	1452.	1460.	1468.	1476.	1484.	1492.	1500.	1508.	1517.
4996	1525.	1533.	1541.	1550.	1558.	1567.	1575.	1583.	1592.	1600.
4997	1609.	1617.	1626.	1635.	1643.	1652.	1661.	1669.	1678.	1687.
4998	1696.	1705.	1714.	1723.	1732.	1741.	1750.	1759.	1768.	1778.
4999	1787.	1796.	1806.	1815.	1825.	1834.	1844.	1854.	1863.	1873.
5000	1883.	1893.	1903.	1913.	1923.	1933.	1943.	1953.	1964.	1974.
5001	1985.	1995.	2006.	2016.	2027.	2038.	2049.	2060.	2071.	2082.
5002	2093.	2104.	2115.	2127.	2138.	2150.	2161.	2173.	2185.	2197.
5003	2209.	2221.	2233.	2245.	2257.	2270.	2282.	2295.	2307.	2320.
5004	2333.	2345.	2358.	2371.	2385.	2398.	2411.	2424.	2438.	2451.
5005	2465.	2478.	2492.	2506.	2520.	2534.	2548.	2562.	2576.	2591.
5006	2605.	2619.	2634.	2649.	2663.	2678.	2693.	2708.	2723.	2738.
5007	2753.	2768.	2783.	2799.	2814.	2830.	2845.	2861.	2877.	2893.
5008	2908.	2924.	2940.	2956.	2973.	2989.	3005.	3022.	3038.	3054.
5009	3071.	3088.	3104.	3121.	3138.	3155.	3172.	3189.	3206.	3223.
5010	3241.	3258.	3275.	3293.	3310.	3328.	3346.	3363.	3381.	3399.
5011	3417.	3435.	3453.	3471.	3489.	3507.	3525.	3543.	3562.	3580.
5012	3598.	3617.	3635.	3654.	3673.	3691.	3710.	3729.	3748.	3767.
5013	3786.	3805.	3824.	3843.	3862.	3881.	3900.	3920.	3939.	3959.
5014	3978.	3998.	4017.	4037.	4057.	4076.	4096.	4116.	4136.	4156.
5015	4176.	4196.	4216.	4236.	4256.	4276.	4297.	4317.	4337.	4358.
5016	4378.	4399.	4420.	4440.	4461.	4482.	4502.	4523.	4544.	4565.
5017	4586.	4607.	4628.	4650.	4671.	4692.	4713.	4735.	4756.	4778.
5018	4799.	4821.	4842.	4864.	4886.	4908.	4930.	4951.	4973.	4995.
5019	5018.	5040.	5062.	5084.	5106.	5129.	5151.	5174.	5196.	5219.
5020	5241.	5264.	5287.	5310.	5332.	5355.	5378.	5401.	5424.	5447.
5021	5471.	5494.	5517.	5540.	5564.	5587.	5611.	5634.	5658.	5682.
5022	5706.	5729.	5753.	5777.	5801.	5825.	5849.	5873.	5898.	5922.
5023	5946.	5970.	5995.	6019.	6044.	6069.	6093.	6118.	6143.	6168.
5024	6193.	6217.	6242.	6268.	6293.	6318.	6343.	6368.	6394.	6419.
5025	6445.	6470.	6496.	6521.	6547.	6573.	6599.	6624.	6650.	6676.
5026	6702.	6728.	6755.	6781.	6807.	6833.	6860.	6886.	6912.	6939.
5027	6966.	6992.	7019.	7046.	7072.	7099.	7126.	7153.	7180.	7207.
5028	7234.	7262.	7289.	7316.	7343.	7371.	7398.	7426.	7453.	7481.
5029	7509.	7537.	7564.	7592.	7620.	7648.	7676.	7704.	7732.	7760.
5030	7789.	7817.	7845.	7874.	7902.	7931.	7959.	7988.	8017.	8045.
5031	8074.	8103.	8132.	8161.	8190.	8219.	8248.	8277.	8306.	8336.
5032	8365.	8394.	8424.	8453.	8483.	8512.	8542.	8572.	8602.	8631.
5033	8661.	8691.	8721.	8751.	8781.	8811.	8842.	8872.	8902.	8932.
5034	8963.	8993.	9024.	9054.	9085.	9116.	9146.	9177.	9208.	9239.

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ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
5035	9270.	9301.	9332.	9363.	9394.	9425.	9456.	9488.	9519.	9550.
5036	9582.	9613.	9645.	9676.	9708.	9739.	9771.	9803.	9835.	9867.
5037	9899.	9931.	9963.	9995.	10027.	10059.	10091.	10124.	10156.	10189.
5038	10221.	10254.	10286.	10319.	10351.	10384.	10417.	10450.	10483.	10516.
5039	10549.	10582.	10615.	10648.	10681.	10714.	10748.	10781.	10815.	10848.
5040	10882.	10915.	10949.	10982.	11016.	11050.	11084.	11118.	11152.	11186.
5041	11220.	11254.	11288.	11322.	11356.	11390.	11425.	11459.	11494.	11528.
5042	11563.	11597.	11632.	11667.	11701.	11736.	11771.	11806.	11841.	11876.
5043	11911.	11946.	11981.	12016.	12052.	12087.	12122.	12158.	12193.	12228.
5044	12264.	12300.	12335.	12371.	12407.	12442.	12478.	12514.	12550.	12586.
5045	12622.	12658.	12694.	12731.	12767.	12803.	12839.	12876.	12912.	12949.
5046	12985.	13022.	13058.	13095.	13132.	13169.	13206.	13242.	13279.	13316.
5047	13353.	13391.	13428.	13465.	13502.	13540.	13577.	13614.	13652.	13689.
5048	13727.	13765.	13802.	13840.	13878.	13916.	13954.	13992.	14030.	14068.
5049	14106.	14144.	14182.	14221.	14259.	14297.	14336.	14374.	14413.	14451.
5050	14490.	14529.	14567.	14606.	14645.	14684.	14723.	14762.	14801.	14840.
5051	14879.	14919.	14958.	14997.	15037.	15076.	15116.	15155.	15195.	15235.
5052	15274.	15314.	15354.	15394.	15434.	15474.	15514.	15554.	15594.	15634.
5053	15675.	15715.	15755.	15796.	15836.	15877.	15917.	15958.	15999.	16039.
5054	16080.	16121.	16162.	16203.	16244.	16285.	16326.	16367.	16409.	16450.
5055	16491.	16533.	16574.	16616.	16657.	16699.	16741.	16783.	16824.	16866.
5056	16908.	16950.	16992.	17034.	17077.	17119.	17161.	17203.	17246.	17288.
5057	17331.	17373.	17416.	17459.	17501.	17544.	17587.	17630.	17673.	17716.
5058	17759.	17802.	17845.	17889.	17932.	17975.	18019.	18062.	18106.	18149.
5059	18193.	18237.	18281.	18325.	18368.	18412.	18456.	18500.	18545.	18589.
5060	18633.	18677.	18722.	18766.	18811.	18855.	18900.	18945.	18989.	19034.
5061	19079.	19124.	19169.	19214.	19259.	19304.	19350.	19395.	19440.	19486.
5062	19531.	19577.	19622.	19668.	19714.	19760.	19806.	19852.	19898.	19944.
5063	19990.	20036.	20083.	20129.	20175.	20222.	20268.	20315.	20362.	20409.
5064	20456.	20502.	20549.	20596.	20644.	20691.	20738.	20785.	20833.	20880.
5065	20928.	20975.	21023.	21071.	21119.	21167.	21215.	21263.	21311.	21359.
5066	21407.	21455.	21504.	21552.	21601.	21649.	21698.	21747.	21795.	21844.
5067	21893.	21942.	21991.	22040.	22090.	22139.	22188.	22237.	22287.	22336.
5068	22386.	22436.	22485.	22535.	22585.	22635.	22685.	22735.	22785.	22835.
5069	22886.	22936.	22986.	23037.	23087.	23138.	23188.	23239.	23290.	23341.
5070	23392.	23443.	23494.	23545.	23596.	23648.	23699.	23750.	23802.	23853.
5071	23905.	23957.	24009.	24061.	24113.	24165.	24217.	24269.	24321.	24373.
5072	24426.	24478.	24531.	24583.	24636.	24689.	24742.	24795.	24848.	24901.
5073	24954.	25007.	25060.	25114.	25167.	25221.	25274.	25328.	25382.	25435.
5074	25489.	25543.	25597.	25651.	25705.	25760.	25814.	25868.	25923.	25977.

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ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
5075	26032.	26086.	26141.	26196.	26251.	26305.	26360.	26415.	26471.	26526.
5076	26581.	26636.	26692.	26747.	26803.	26858.	26914.	26970.	27025.	27081.
5077	27137.	27193.	27249.	27306.	27362.	27418.	27475.	27531.	27587.	27644.
5078	27701.	27757.	27814.	27871.	27928.	27985.	28042.	28099.	28157.	28214.
5079	28271.	28329.	28386.	28444.	28501.	28559.	28617.	28675.	28733.	28791.
5080	28849.	28907.	28965.	29024.	29082.	29140.	29199.	29258.	29316.	29375.
5081	29434.	29493.	29552.	29611.	29670.	29729.	29788.	29848.	29907.	29967.
5082	30026.	30086.	30145.	30205.	30265.	30325.	30385.	30445.	30505.	30565.
5083	30626.	30686.	30747.	30807.	30868.	30928.	30989.	31050.	31111.	31172.
5084	31233.	31294.	31355.	31417.	31478.	31539.	31601.	31662.	31724.	31786.
5085	31847.	31909.	31971.	32033.	32095.	32157.	32219.	32282.	32344.	32406.
5086	32469.	32531.	32594.	32656.	32719.	32782.	32845.	32908.	32971.	33034.
5087	33097.	33160.	33224.	33287.	33351.	33414.	33478.	33542.	33606.	33670.
5088	33734.	33798.	33862.	33926.	33990.	34055.	34119.	34183.	34248.	34313.
5089	34377.	34442.	34507.	34572.	34637.	34702.	34767.	34832.	34897.	34962.
5090	35028.	35093.	35159.	35224.	35290.	35356.	35421.	35487.	35553.	35619.
5091	35685.	35751.	35817.	35883.	35949.	36016.	36082.	36148.	36215.	36282.
5092	36348.	36415.	36481.	36548.	36615.	36682.	36749.	36816.	36883.	36950.
5093	37017.	37085.	37152.	37219.	37287.	37354.	37422.	37490.	37557.	37625.
5094	37693.	37761.	37829.	37897.	37965.	38033.	38101.	38170.	38238.	38306.
5095	38375.	38444.	38512.	38581.	38650.	38719.	38788.	38857.	38926.	38995.
5096	39064.	39134.	39203.	39272.	39342.	39411.	39481.	39551.	39621.	39690.
5097	39760.	39830.	39900.	39970.	40041.	40111.	40181.	40252.	40322.	40393.
5098	40463.	40534.	40604.	40675.	40746.	40817.	40888.	40959.	41030.	41101.
5099	41172.	41244.	41315.	41386.	41458.	41529.	41601.	41673.	41744.	41816.
5100	41888.	41960.	42032.	42104.	42176.	42248.	42320.	42392.	42465.	42537.
5101	42610.	42682.	42755.	42827.	42900.	42973.	43046.	43119.	43192.	43265.
5102	43338.	43411.	43484.	43558.	43631.	43705.	43778.	43852.	43925.	43999.
5103	44073.	44147.	44221.	44295.	44369.	44443.	44517.	44591.	44666.	44740.
5104	44814.	44889.	44964.	45038.	45113.	45188.	45263.	45338.	45413.	45488.
5105	45563.	45639.	45714.	45789.	45865.	45941.	46016.	46092.	46168.	46244.
5106	46320.	46396.	46473.	46549.	46625.	46702.	46778.	46855.	46932.	47008.
5107	47085.									