Publication No. WI–2009–2  
May 8, 2009

The Watershed Institute  
Division of Science and Environmental Policy  
California State University Monterey Bay  
http://watershed.csumb.edu  
100 Campus Center, Seaside, CA, 93955–8001  
831 582 4696 / 4431

Central Coast Watershed Studies  

Fall 2008 Stage–Volume Relationship for Los Padres Reservoir, Carmel River, California

Douglas Smith1  
Rikk Kvitek1  
Pat Iampietro1  
Ivano Aiello2  
Steven Quan1  
Emily Paddock1  
Charlie Endris2  
Krystle Gomez1

1Seafloor Mapping Lab, CSU Monterey Bay  
2Marine Geology Lab, Moss Landing Marine Laboratories

Author contact:  
douglas_smith@csumb.edu
This page deliberately left blank.
Executive Summary

Los Padres Reservoir is a surface water storage facility located in the headwaters of the Carmel River Watershed. A bathymetric and topographic survey was conducted on November 5, 2008 to capture a snapshot of the reservoir capacity. The survey comprised multi-beam sonar soundings below the water line and laser scanning above the water. We report reservoir capacity of 1786 acre-feet (af), and a surface area of 49.8 acres, at a water stage of 1040 ft. This 2008 capacity calculation is higher than the capacity estimate from a survey conducted in 1998. In the absence of dredging, reservoir capacity cannot increase through time. Given the high precision of the 2008 survey, we believe that the 1998 survey erroneously underestimated the true 1998 capacity, perhaps because lead-line technology under-samples the bathymetry.

This survey acts as a baseline condition from which to accurately measure future reservoir changes. Rapid siltation and delta growth are anticipated in the years following the “Basin–Complex” fire of summer 2008. We recommend performing annual repeat surveys following the 2008–09 storm season to capture the immediate and longer-term impacts of the Basin Complex Fire.

This work was funded by contracts between the Monterey Peninsula Water Management District and 1) the University Corporation of CSU Monterey Bay and 2) Moss Landing Marine Laboratories.

This report may be cited as:


Acknowledgements

- Larry Hampson Andy Bell and Thomas Christensen, Monterey Peninsula Water Management District
- California American Water Company
# Table of Contents

Executive Summary  ........................................................................................................... iii  
Acknowledgements  ........................................................................................................... iii  

Table of Contents  ...........................................................................................................  5  

1 Introduction ...........................................................................................................  7  
  1.1 Background .......................................................................................................  7  
  1.2 Basin Complex Fire and Debris–Flow Hazard ....................................................  9  

2 Methods ...........................................................................................................  11  
  2.1 Goals and Approach .....................................................................................  11  
  2.2 Positioning ....................................................................................................  12  
  2.3 Multibeam Bathymetry ..................................................................................  13  
  2.4 LiDAR ...........................................................................................................  14  
  2.5 Land-based Total Station ..............................................................................  15  
  2.6 Data Processing ............................................................................................  15  
  2.7 Vertical Adjustments ....................................................................................  16  
  2.8 Technology Comparison ...............................................................................  16  
  2.9 Horizontal and Vertical Precision and Accuracy .............................................  17  

3 Results .................................................................................................................  18  
  3.1 Digital Elevation Model of Los Padres Reservoir ...........................................  18  
  3.2 Reservoir Capacity in fall 2008 .......................................................................  20  
  3.3 Past Surveys ...................................................................................................  22  
    3.3.1 Historic Capacity Trends .......................................................................  22  
    3.3.2 Synthetic Lead–line Surveys ...................................................................  23  
    3.3.3 Spillway Elevation ..................................................................................  25  

4 References ...........................................................................................................  26  

5 APPENDIX A ..........................................................................................................  27  

6 APPENDIX B ..........................................................................................................  28
This page deliberately left blank.
1 Introduction

1.1 Background

Los Padres Reservoir stores surface water flowing from the upper watershed of the Carmel River in Monterey County, California (Fig. 1). A series of reservoir surveys has shown the volume of the reservoir gradually diminishing through sediment trapping (Figure 2). This report provides a fall 2008 volume estimate for the reservoir and a new volume-stage relationship.

The watershed above Los Padres Reservoir is approximately 28,700 acres (Fig. 1), and is underlain by highly erodible bedrock (Fig. 3). The watershed was burned during the summer 2008 Basin–Complex fire, leading to speculation that winter rains of 2008–2009 would lead to accelerated erosion and reservoir filling. The objectives of the 2008 survey are to:

- produce an accurate estimate of reservoir volume using high-precision bathymetry and terrestrial survey, and
- compare the present volume with past estimates in order to assess the general changes in volume.

Figure 1: Study area location.
Figure 2: Capacity of Los Padres reservoir from 1946 construction through 1998 survey. Sudden drop in capacity in 1978 is the result of the Marble–Cone Fire. Increased capacity in 1984 is from sediment removal. Data summary from Monterey Peninsula Water Management District.

Figure 3: Erosion potential of geologic substrate in the region of the Carmel River watershed. Erosion data from Rosenberg (2001).
1.2 Basin Complex Fire and Debris-Flow Hazard

Figure 4 and Table 1 show the burn severity distribution in the Basin Complex Fire in the land draining to the Los Padres Reservoir. Cannon et al., (in press) have found that the moderate-to-high burn severity areas generate the majority of debris flows during post-fire rains events; 30% of the watershed falls in that category.

Table 1: Burn Severity in the Los Padres Reservoir watershed (GIS data from USDA (2008))

<table>
<thead>
<tr>
<th>Burn Severity</th>
<th>Area (acres)</th>
<th>Watershed area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>10653</td>
<td>37%</td>
</tr>
<tr>
<td>High</td>
<td>3061</td>
<td>11%</td>
</tr>
<tr>
<td>Moderate + High</td>
<td>13700</td>
<td>48%</td>
</tr>
</tbody>
</table>

Figure 4: Distribution of Basin–Complex fire intensity in the watershed above Los Padres Reservoir. Red is high intensity; yellow is moderate intensity. Los Padres Reservoir is blue. Data from USDA.
Sediment erosion rates are typically elevated following fires. Debris flows are the greatest potential source of reservoir-filling sediment in the steep erodible sub-watersheds above Los Padres Reservoir. The elevated risk of slope failure and debris-flow generation diminishes in the first few years following a fire. Hecht (1981) found that stream channels above Los Padres Reservoir regained their original morphology within three years following the Marble Cone fire. Both debris-flow generation and stream recovery may have been amplified and accelerated by the heavy winter rains on the portion of the watershed burned in the Marble Cone fire.

Debris flow risk has been modeled in other parts of the country with reasonable success (Cannon et al. in press). Cannon (2008) modeled the debris flow probability and volume of over 850 sub-watersheds of the Basin Complex fire. The modeled triggering event was a 10-year, 3 hour duration storm delivering about 0.6 in/hr intensity. Cannon estimated both the % chance of debris flow generation and the approximate volume of the debris flow for each sub-watershed. A “Combined Relative Hazard Ranking” that uses both probability and volume provides a single number of relative risk for each basin. The numbers range from 0 to 9, with 9 representing the riskiest combination of flow probability and debris volume.

Cannon (personal communication, 2008) supplied model data in GIS format so that we could illustrate risks within sub-regions of the Basin Complex Fire perimeter. Table 2 and Figure 5 show the combined hazard index above the Los Padres Reservoir. 54% of the watershed has a ranking of 7 or above. The model figures might underestimate the true risk because the region is underlain by naturally weak substrate of the northern Santa Lucia Range (Fig. 3).

Increased soil loss and increased debris flow frequency can persist for up to three years following watershed fire events (Cannon 2008; Cannon et al., in press). We provide a baseline study from which to calculate the reservoir capacity reduction anticipated to occur in the years following the Basin–Complex fire.

Table 2: Debris Flow Risk in the Carmel River Watershed (GIS data from Cannon (2008); Risk method from Cannon et al. (in press)).

<table>
<thead>
<tr>
<th>Combined relative Hazard Ranking (Fig. 5)</th>
<th>Volume (m³)</th>
<th>% chance of event</th>
<th>Number of sub-basins</th>
<th>Area (acres)</th>
<th>Watershed area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1,001–10,000</td>
<td>&gt;80%</td>
<td>77</td>
<td>6610</td>
<td>14%</td>
</tr>
<tr>
<td>8</td>
<td>10,001 – 100,000</td>
<td>&gt;80%</td>
<td>26</td>
<td>18170</td>
<td>40%</td>
</tr>
<tr>
<td>Total area</td>
<td></td>
<td></td>
<td></td>
<td>24779</td>
<td>54%</td>
</tr>
</tbody>
</table>
Figure 5: “Combined Relative Hazard Ranking” index of debris–flow hazard in the watershed above Los Padres Reservoir. Yellow is an index of 7; red is index of 8. Los Padres Reservoir is blue. Debris flow hazard data from Cannon 2008).

2 Methods

2.1 Goals and Approach

The primary goal of our work is to produce an accurate estimate of the volume of the reservoir at various stages. We combined geospatial data from the following sources to produce a high-resolution bathymetric model of the reservoir.

1. Shore–based GPS station
2. Vessel–mounted high–frequency interferometric sidescan sonar bathymetry for subaqueous soundings
3. Vessel–mounted terrestrial LiDAR scanner for the portion of the reservoir above the water line
4. Tripod–based total station to fill in data gaps and establish vertical framework adjustments

Hydrographic and LiDAR data were collected on November 5, 2008 under clear skies with light wind. The data were cleaned and combined using standard hydrographic software (Caris Hips, Fledermaus, ArcGIS) to produce a “bare–earth” digital elevation model of the reservoir that extends several meters above the present spillway elevation.
Those data were augmented by shore-based scanning total station data described in a separate report from Moss Landing Marine Laboratories.

2.2 Positioning
The bench mark for the 2008 survey data is a large hex head bolt set in concrete with a small hole drilled off-center in its top. The small drill hole is the reference position for vertical and horizontal surveys. The benchmark is located near the boat ramp on the east side of the dam (Figs. 6 and 7).

Figure 6: General location of SFML benchmark (arrow), located below GPS antenna and positioning base station. See Figure 7 for benchmark detail.
The multi-hour, time-averaged GPS position of the benchmark is:
UTM WGS–84 Zone 10
Easting [meters] 619388.986
Northing [meters] 4027605.397

NAVD 88 (Computed using GEOID03)
Elevation [meters] 322.418

The L1/L2 static GPS data was collected at 1hz over a 7.3 h period with a Trimble NetR5 survey grade receiver and Zephyr GNSS Model 2 geodetic antenna (sn 55971.00). These data were processed using the National Geodetic Survey (NGS) Static Online Positioning User Service (OPS) at: http://www.ngs.noaa.gov/OPUS/. (See appendix B for OPUS solution.)

In practice, such measurements are repeatable to within 0.01 m.

2.3 Multibeam Bathymetry

A SwathPlus interferometric sidescan sonar bathymetry system was used to obtain soundings throughout the wetted part of the reservoir, as close as safe navigation would allow (Fig. 8). This system obtained bank to bank coverage of the entire wetted area except for a narrow band in front of the shallow delta at the extreme upper end where water depths of < 0.50 m restricted boat access. The sonar system was used to gather
millions of individual depth soundings of the reservoir. Each sounding was precisely located to geographic xyz coordinates using onboard GPS, a highly accurate attitude sensing system (Aplannix POS/MV 320v4), and post-processing using the base station on shore. Each sounding has a vertical precision of approximately 0.2 m (Fig. 9). These soundings were cleaned by hand in Fledermaus software to remove outliers and soundings associated with subaqueous snags and vegetation.

Figure 8: Photo from instrumented survey vessel to spillway crest.

The remaining high-quality soundings were averaged into a 1 m X 1 m grid in IVS Fledermaus for further geospatial analysis in ArcGIS. Each grid node elevation results from averaging a great number of nearby independent soundings, so the grid vertical precision is higher than the precision of individual soundings. The resulting grid represents the equivalent of 201,052 lead-line soundings, one sounding every 1 m, across the entire reservoir bottom.

2.4 LiDAR
A Reigl LMS-Z420i mobile laser scanning system was used to capture millions of individual laser returns from the subaerial part of the reservoir that was visible by boat. The system is designed to be used on a moving platform (such as a boat) via supplemental position (GPS) and attitude (IMU) sensors. The system is configured to achieve decimeter accuracy with sub-meter resolution at a 1 kilometer range. These data were merged with the bathymetry data following the same quality-control procedures that removed both spurious data and vegetation.

A detailed view of the merged LiDAR and sonar data shows that the two independent data sets match very well at the shoreline (Fig. 9), providing a high degree of confidence in geographic positioning and elevation soundings.
Figure 9: Screen grab from Fledermaus shows a vertical cross section through the raw soundings (blue) and subaerial laser returns (yellow) where they meet at the shoreline (approximately in center of image). Tick marks on vertical and horizontal axes are 1.0 m. The image illustrates the typical high data density within a small region of the reservoir. Vertical scatter of points represents precision of individual soundings (approximately 0.2 m). Averaging the data on a scale of 1 m produces a grid of well-defined elevation nodes throughout the reservoir.

2.5 Land-based Total Station
Moss Landing Marine Laboratories provided data collected by a robotic, automated Trimble VX Spatial Station based upon the SFML benchmark described above. Data from that system did not precisely align with the vessel-collected data, but several data holes were filled using carefully-selected points and point clouds.

2.6 Data Processing
Approximately 5 million individual xyz soundings from vessel-mounted and land-based systems were combined into one 1 m X 1 m grid file using the Fledermaus avggrid program. Remaining data gaps were filled using interpolation in the Fledermaus “DMagic” program. Interpolation was guided by the judicious addition of synthetic soundings. Textured and colored oblique images of the reservoir model were created in Fledermaus. A final ASCII ArcGIS elevation grid was exported from D–Magic for analysis in ArcGIS. The ASCII grid was converted to a floating point raster and projected to UTM WGS–84 zone 10 in ArcMap.
Contour maps and maps with regional context were created in ArcMap. Volume and surface area calculations were made at a variety of elevations using 3D analyst tools in ArcMap.

2.7 Vertical Adjustments
The elevations determined in the survey were vertically shifted to align with previous surveys of the reservoir. This vertical shift does not correspond to a simple geodetic conversion between NAVD–88 (GEIOD03) used in our survey and NAVD–1929, the putative datum for prior reservoir surveys. A simple conversion between datums would call for us to lower our survey elevations by 0.894 m (2.93 ft). However, the surveyed difference in elevations is 0.773 m (2.54 ft). The discrepancy indicates that either the previously used benchmarks, or the present survey is not true to its stated datum. We adjusted the digital elevation model by 2.54 ft to align with previous reservoir surveys.

Given the above vertical adjustment, and recent surveys of the edge of the spillway crest, a water stage of 1040.00 ft is approximately 0.22 ft above the crest of the spillway, and 1.1 ft above the bottom of the notch in the spillway (Fig. 10). Previous surveys may have made that same estimate. Alternatively, previous surveyors may have called the elevation of the spillway crest “1040 ft,” with the attendant low precision correctly implied by the lower number of significant digits. The “full” reservoir volume is significantly different at these different representative stages (1040.00, spillway crest, notch). We have provided reservoir capacity results for all three “full” stages.

![Figure 10: Schematic illustration of the three “full” elevations on Los Padres dam.](image)

2.8 Technology Comparison
Differences between historic volumes and the 2008 survey may arise from real differences, or differences in survey technology. Because we have digitized the entire reservoir, we have the luxury of sub-sampling the digital data in a simulation of lead-line survey technology. This work was accomplished by georeferencing the transect positions from the 1998 lead-line survey (Fig. 11) so that the 1998 transect positions
could guide a simulated lead–line survey through the 2008 data. A synthetic sounding was taken at the two shoreline positions of each transect and at intervals of approximately 60 to 75 ft along the transects. This sparse subsampling of bathymetry was used to generate a 3 m grid of elevations in ArcMap. Reservoir volume calculations were made using this grid. And the results were compared to the more accurate assessment using the entire data set.

Figure 11: 1998 sounding transect positions (Los Padres Silt Study, California American Water, 1999)

2.9 Horizontal and Vertical Precision and Accuracy

According to OPUS processing (Appendix B) the RMS error on base station positioning was 0.009 m. This result is in keeping with our past experience using multi-hour GPS averaging. The accuracy of the positioning is based upon several factors including the quality of the GEOID–03 conversion to NAVD 88 vertical reference.
3 Results

3.1 Digital Elevation Model of Los Padres Reservoir

This project includes several electronic files that can be used in further analysis and for creating a variety of terrain views (e.g., Figs. 12 through 15).

Figure 12: Fall 2008 colored hillshade of digital elevation model of Los Padres Reservoir filled to 985 ft. Rendering has 2X vertical exaggeration.

Figure 13: Hillshade of digital elevation model with water surface elevation of 965 ft (blue). Rendering has 2X vertical exaggeration with oblique southern perspective.
Figure 14: Topographic contours shown on hillshade of digital elevation model. Contour interval 10 ft, starting at 960 ft.

Digital elevation models can be used for reconnaissance inspection of dam–face integrity in reservoirs where draw–down does not expose the dam toe (Fig 15).
Figure 15: Detailed view of interior dam face and toe.

3.2 Reservoir Capacity in fall 2008

Reservoir volume and surface area calculations were made using the “surface volume” tool in ArcMap (Table 3; Fig. 16). These results provide an accurate base-line for measuring future change.
### Table 3: Capacity of Los Padres Reservoir

<table>
<thead>
<tr>
<th>Stage (ft)</th>
<th>Volume (acre-ft)</th>
<th>Area (acres)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>960</td>
<td>0</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>965</td>
<td>0</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>970</td>
<td>17</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>975</td>
<td>54</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>980</td>
<td>105</td>
<td>11.7</td>
<td></td>
</tr>
<tr>
<td>985</td>
<td>168</td>
<td>13.2</td>
<td></td>
</tr>
<tr>
<td>990</td>
<td>238</td>
<td>14.6</td>
<td></td>
</tr>
<tr>
<td>995</td>
<td>315</td>
<td>16.5</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>403</td>
<td>18.6</td>
<td></td>
</tr>
<tr>
<td>1005</td>
<td>501</td>
<td>20.6</td>
<td></td>
</tr>
<tr>
<td>1010</td>
<td>608</td>
<td>22.6</td>
<td></td>
</tr>
<tr>
<td>1015</td>
<td>734</td>
<td>30.2</td>
<td></td>
</tr>
<tr>
<td>1020</td>
<td>903</td>
<td>37.2</td>
<td></td>
</tr>
<tr>
<td>1025</td>
<td>1100</td>
<td>41.3</td>
<td></td>
</tr>
<tr>
<td>1030</td>
<td>1316</td>
<td>44.5</td>
<td></td>
</tr>
<tr>
<td>1035</td>
<td>1544</td>
<td>46.9</td>
<td></td>
</tr>
<tr>
<td>1038.90</td>
<td>1731</td>
<td>48.9</td>
<td>notch elevation</td>
</tr>
<tr>
<td>1039.78</td>
<td>1774</td>
<td>49.7</td>
<td>spillway elevation</td>
</tr>
<tr>
<td>1040.00</td>
<td>1786</td>
<td>49.8</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 16: Fall 2008 stage, area, and volume in Los Padres Reservoir**
3.3 Past Surveys

3.3.1 Historic Capacity Trends

The historic survey data for the Los Padres Reservoir includes the “as-built” estimate of initial volume in 1947, and five subsequent “lead-line” bathymetric surveys, with the most recent survey in 1998 (Table 4; Fig. 2). This project adds the most recent volume estimate using modern sonar and laser equipment (Table 3 and 4).

Table 4: Los Padres Reservoir capacity (10^4 ft^3). Historic data provided by Larry Hampson, 2008.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (acre-ft)</td>
<td>3070</td>
<td>2540</td>
<td>1950</td>
<td>2179a</td>
<td>1569b</td>
<td>1785</td>
</tr>
</tbody>
</table>

- Increase in capacity between 1978 and 1984 is by sediment removal.
- Discussion below suggests that data from the 1998 survey are suspect.

According to available data, Los Padres Reservoir lost approximately 610 acre-ft (44 af/yr) capacity between 1984 and 1998, years without major fire impacts (Fig. 2; Table 4). Based upon that historic data, we would anticipate approximately 440 acre-ft capacity loss, rather than the 216 acre-ft capacity gain between 1998 and 2008 (Table 4). Although the Kirk–Complex fire (1999) burned through a significant portion of the watershed above Los Padres Reservoir (primarily in the Miller Fork watershed), the burn intensity was low relative to both the Marble–Cone and Basin Complex fires. Furthermore, according to the observations of local resource managers, little or no fire impacts were realized between 1998 and the 2008 survey1, so we might anticipate lower than average capacity loss during that span. Nevertheless, given the typical monotonic trend for reservoirs to diminish in volume with time, the increase in volume indicated between 1998 and 2008 cannot be real. The reservoir was not dredged in the last decade, so the differences might be influenced by differences in technology or questionable surveys that led to underestimated capacity in 1998.

1 Don Lingenfelter, the dam tender for California American Water, stated that he observed little or no sediment deposition in Los Padres Reservoir after 1998 (interview with Larry Hampson, MPWMD, March 27, 2009). Similarly, Greg James, MPWMD Senior Hydrographer, noted that the channel in the vicinity of the MPWMD gaging station on the main stem above Los Padres Reservoir changed little during the same time period (interview with Larry Hampson, MPMWD, May 5, 2009).
3.3.2 Synthetic Lead-line Surveys

We synthesized lead-line sounding surveys to assess the possibility that lead-line surveying can underestimate reservoir volume estimates. We synthesized lead-sounding surveys by sub-sampling the 2008 high-resolution bathymetry (Fig. 17; Table 5). It is apparent that the lead-line subsampling overestimates depth (and therefore volume) in some areas and underestimates it in others (Fig. 17), but the net result is a loss of cross sectional area with fewer soundings.

![Figure 17: Cross section of 1998 transect line 25-36 (Fig. 11) plotted using 1 m spacing (small symbols) and 20 m spacing (larger symbols). See Table 5 for comparison of cross sectional area.](image)

<table>
<thead>
<tr>
<th>Sounding spacing (m)</th>
<th>Soundings used</th>
<th>Cross-sectional area (m²)</th>
<th>Cross-sectional area (ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>178</td>
<td>2115</td>
<td>22770</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>2071</td>
<td>22290</td>
</tr>
</tbody>
</table>
Figure 18 shows the site-specific elevation difference between surveys when the entire set of 1998 survey transects (Fig. 11) were used to resample the full 2008 bathymetric model at an average sounding spacing of 20 m.

![Figure 18: Elevation differences between full 2008 survey and synthetic lead-line survey through 2008 bathymetric data. Warm colors indicate regions where lead-line survey underestimated elevation (volume); cool colors are regions where lead-line survey overestimated elevation (volume); black dots are synthetic lead-line soundings aligned with 1998 transects (Fig. 11).](image)

The resulting total synthetic lead-line survey yielded an 1040.00 ft stage capacity of 1660 acre-ft, 126 acre-ft fewer than the high resolution 2008 survey (Table 3). It is clear that greater and lesser differences would result from using different sub-sampling strategies.

Finally, four reservoir-wide synthetic surveys were performed to assess the more general effect of sparse soundings. When the total number of soundings used in synthetic lead-line transects is reduced, the resulting 1040.00 ft stage capacity is reduced as well (Fig. 19). A sharp reduction in apparent capacity was found when there were fewer than approximately 280 soundings used. The paradoxical rise in reservoir capacity between 1998 and 2008 can be explained by a difference in technology if the 1998 survey employed fewer than 200 soundings (Fig. 19), or if the 1998 survey was
flawed for some other reason. The 2008 survey provides a new level of accuracy for future comparisons.

![Figure 19: Difference from fall 2008 capacity as a function of number of soundings used to survey the reservoir.](image)

3.3.3 Spillway Elevation

In past studies, “1040 ft” is the highest water surface elevation for which volume is computed. The spillway and water surface elevations from past surveys are referenced to a local benchmark presumed to be at an elevation of 1059.3 (APPENDIX A). Our assumed vertical datum for that elevation is National Geodetic Vertical Datum of 1929 (NGVD 29). A recent resurvey of the spillway, using the same reference benchmarks as the historic surveys, indicates that the actual spillway crest is lower than 1040.00 ft. The general spillway crest is approximately 1039.78 ft, and the bottom of a notch cut into the spillway is 1038.90 ft (Fig. 10). This discrepancy leaves at least two interpretations of the maximum volume reported in previous studies. Either the highest volumes are overestimates of the non-spilling volume of the reservoir, or the crest elevation was rounded to 1040 ft, with a lower implied precision. Each tenth of a foot stage difference, in the vicinity of 1040 ft, corresponds to a volume estimate difference of over 4.5 acre-ft. The stage difference between 1040.00 ft and the actual spillway crest corresponds to a capacity difference of 12 acre-ft. The stage difference between 1040.00 ft and the notch corresponds to capacity differences of 43 acre-ft.
4 References


Survey field notes of Larry Hampson (MPWMD) from March 27, 2009. BM Shack was used to shift the 2008 bathymetric survey to the reference frame of Los Padres Reservoir stage.
National Geodetic Survey On-line Positioning User Service solution report for the SFML benchmark used to survey the reservoir in 2008

- FILE: 4819K55871200811051640.08o 000465967
- NGS OPUS SOLUTION REPORT
- ========================
- All computed coordinate accuracies are listed as peak-to-peak values.
- For additional information: www.ngs.noaa.gov/OPUS/Using_OPUS.html#accuracy
- USER: rikk_kvitek@csumb.edu DATE: November 06, 2008
- RINEX FILE: 4819310q.08o TIME: 20:02:35 UTC
- SOFTWARE: page5 0810.20 master12.pl 081023 START: 2008/11/05 16:40:00
- EPHEMERIS: igr15043.eph [rapid] STOP: 2008/11/05 23:59:00
- NAV FILE: brdc3100.08n OBS USED: 16298 / 16345 : 100%
- ANT NAME: TRM55971.00 NONE # FIXED AMB: 46 / 51 : 90%
- ARP HEIGHT: 1.114 OVERALL RMS: 0.009(m)
- 
- X: -2699033.367(m) 0.015(m) -2699034.209(m) 0.015(m)
- Y: -4375426.494(m) 0.018(m) -4375424.986(m) 0.018(m)
- Z: 3762945.597(m) 0.021(m) 3762945.762(m) 0.021(m)
- LAT: 36 23 10.23945 0.023(m) 36 23 10.25996 0.023(m)
- E LON: 238 19 52.14169 0.019(m) 238 19 52.08118 0.019(m)
- W LON: 121 40 07.85831 0.019(m) 121 40 07.91882 0.019(m)
- EL HGT: 289.372(m) 0.008(m) 288.793(m) 0.008(m)
- ORTHO HGT: 322.418(m) 0.105(m) NAVD88 (Computed using GEOID03)
- 
- UTM COORDINATES STATE PLANE COORDINATES
- UTM (Zone 10) SPC (0404 CA 4)
- Northing (Y) [meters] 4027605.397 620151.628
- Easting (X) [meters] 619388.986 1760588.267
- Convergence [degrees] 0.78976463 -1.59220133
- Point Scale 0.99977562 0.99994946
- Combined Factor 0.99973021 0.99990405

6 APPENDIX B
US NATIONAL GRID DESIGNATOR: 10SFF1938927605(NAD 83)

BASE STATIONS USED

<table>
<thead>
<tr>
<th>PID</th>
<th>DESIGNATION</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>DISTANCE(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DH3876 P171 SANTALUCIACN2004 CORS ARP</td>
<td>N362907.865 W1214733.006</td>
<td>15638.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI7526 P210 ELKHRNSLGHCN2005 CORS ARP</td>
<td>N364858.073 W1214354.570</td>
<td>48045.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DH7214 P284 AVILARANCHCN2005 CORS ARP</td>
<td>N355559.715 W1205424.579</td>
<td>85018.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NEAREST NGS PUBLISHED CONTROL POINT

| GU3700 TULARCITOS | N362524.930 W1213931.424 | 4262.5 |

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.