The Bureau of Reclamation (Reclamation) surveyed Deadwood Reservoir in July 2002 to develop a topographic map and compute the present storage-elevation relationship (area-capacity tables). The data was used to generate current reservoir capacity since dam closure on November second of 1930. The underwater survey was conducted in July of 2002 near reservoir elevation 5,325 feet (project datum). The underwater survey used sonic depth recording equipment interfaced with a global positioning system (GPS) that gave continuous sounding positions throughout the underwater portions of the reservoir covered by the survey vessel. The above water survey was conducted on August 24, 2002 near reservoir elevation 5,299.6 feet. The above-water topography was determined by a GPS controlled LiDAR (light distance and ranging) method to developed reservoir contours from elevation 5,300 and above. The new topographic map of Deadwood Reservoir was developed from the combined 2002 underwater and above water-measured topography.

As of July 2002, at top of conservation water surface elevation (feet) 5,334.0, the surface area was 3,115 acres with a total capacity of 153,992 acre-feet.
Deadwood Reservoir

2002 Survey

by

Ronald L. Ferrari

Sedimentation and River Hydraulics Group
Water Resources Services
Technical Service Center
Denver, Colorado

July 2003
ACKNOWLEDGMENTS

The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics Group of the Technical Service Center (TSC) prepared and published this report. Ronald Ferrari and Sharon Nuanes of the TSC conducted the hydrographic survey. Horizons, Inc., under contract with the Pacific Northwest Regional Office, conducted the above water survey. Ronald Ferrari completed the data processing to generate the new topographic map and area-capacity tables. Sharon Nuanes of the TSC completed the final map development. Kent Collins of the TSC performed the technical peer review of this documentation.

Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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INTRODUCTION

Deadwood Dam and reservoir, features of the Boise Project, are located in Valley County about 25 miles southeast of the town of Cascade and 53 miles northeast of Boise, Idaho (fig. 1). The dam and reservoir are located on the Deadwood River that is a tributary of the south fork of the Payette River. Deadwood Reservoir is the primary storage facility for the Emmett Irrigation District, and in conjunction with Cascade Reservoir on the North Fork of the Payette River, provides irrigation water for lands in the Payette Division of the Boise Project. The dam and reservoir are operated and maintained by the Bureau of Reclamation’s Snake River Area Office West Unit - Black Canyon Dam Field Branch.

Deadwood Dam was completed in 1931 with closure on November 2, 1930. The dam is a concrete arch structure whose dimensions are (fig. 2):

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic height¹</td>
<td>137</td>
<td>feet²</td>
</tr>
<tr>
<td>Top width</td>
<td>9</td>
<td>feet</td>
</tr>
<tr>
<td>Crest of Dam elevation</td>
<td>5,340.0</td>
<td>feet</td>
</tr>
<tr>
<td>Structural height</td>
<td>165</td>
<td>feet</td>
</tr>
<tr>
<td>Crest length</td>
<td>749</td>
<td>feet</td>
</tr>
<tr>
<td>Parapet wall elevation</td>
<td>5,343.5</td>
<td>feet</td>
</tr>
</tbody>
</table>

An overflow spillway occupies 100 feet of the central portion of the dam and two outlets are provided near the bottom right of the spillway. The spillway is an uncontrolled overflow type with a crest elevation of 5,334.0 and capacity of 11,300 cfs (cubic feet per second) at reservoir water surface elevation 5,343.5 (top of parapet walls). The outlet works consist of a trashracked intake structure, two 66-inch inside diameter conduits through base of the dam and a valve house containing two 4.5 foot by 4.5 foot pressure emergency gates. Capacity of outlet works is 1,980 cfs at reservoir water surface elevation 5,334.0. A stilling basin is utilized by the spillway and outlet works.

The total drainage area above Deadwood Dam is 112 square miles. Deadwood Reservoir has an average width of 0.8 miles with a length of around 3.9 miles at reservoir elevation 5,334.0.

¹The definition of such terms as hydraulic height, structural height, and etc. may be found in manuals such as Reclamation’s Design of Small Dams and Guide for Preparation of Standing Operating Procedures for Dams and Reservoirs, or ASCE’s Nomenclature for Hydraulics.

²Elevation levels are shown in feet. All elevations shown in this report are based on the original project datum established by U.S. Bureau of Reclamation that was found by this study to be around 18.6 feet greater than the NAVD88.
Figure 1. - Deadwood Reservoir location map.
Space intentionally left blank due to security concerns
SUMMARY AND CONCLUSIONS

This Reclamation report presents the 2002 results of the survey of Deadwood Reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography
- compute area-capacity relationships

A GPS control and aerial collection survey was contracted by the Pacific Northwest Regional Office to establish the study area control and measure the above water portions of the reservoir area. The survey established horizontal and vertical control on existing Reclamation monuments located on the left (east) and right (west) abutments of the dam. The horizontal control was established in the Idaho west state plane coordinate zone of the North American Datum of 1983 (NAD83) and the vertical control was tied to the North American Vertical Datum of 1988 (NAVD88) and the Reclamation project datum. All elevations in this report are referenced to the Reclamation project or construction datum that was found to be around 18.6 feet greater than the NAVD88.

Due to the rapidly dropping reservoir water surface levels, the underwater survey was conducted in July of 2002 near reservoir water surface elevation 5,325 prior to the contracted GPS control survey. Prior to the underwater data collection, the hydrographic survey crew measured an absolute position on the Reclamation monument located on the west abutment of the dam. Using Real-time Kinematic (RTK) GPS, measurements were taken on the east monument, a temporary control point, and the reservoir water surface during the underwater survey. During post processing these measurements were shifted to match the horizontal and vertical control established by the GPS control survey. The bathymetric survey determined sounding locations throughout the reservoir using sonic depth recording equipment interfaced with RTK GPS. The bathymetric system continuously recorded depth and horizontal coordinates of the survey boat as it was navigated along grid lines covering Deadwood Reservoir. The positioning system provided information to allow the boat operator to maintain a course along these predetermined grid lines. Water surface elevations measured by the reservoir gauge (tied to the Reclamation vertical datum) and the RTK GPS were recorded during the time of collection and used to convert the sonic depth measurements to true reservoir bottom elevations.

The above water topography was measured on August 24 of 2002 near reservoir water surface elevation 5,299.6 by a contract aerial survey. The aerial survey was conducted using a LiDAR (Light Detection and Ranging) acquisition method that utilized GPS for control. The LiDAR instrument transmits light to measure the ground elevations below the aircraft. The airborne GPS data was processed as a kinematic survey and resulted in detailed x,y,z data sets and 2-foot reservoir topography from elevation 5300 and above (Horizon’s Inc.).

The 2002 Deadwood Reservoir topographic map is a combination of the 2002 aerial and underwater survey data. The 2002 reservoir surface areas at predetermined contour intervals were generated by a computer graphics program using the collected reservoir data. The 2002 area and capacity tables were produced by a computer program that used the measured contour
surface areas and a curve-fitting technique to compute the reservoir's area and capacity at prescribed elevation increments (Bureau of Reclamation, 1985).

Tables 1 and 2 contain summaries of the Deadwood Reservoir sedimentation and watershed characteristics for the 2002 survey. The 2002 survey determined that the reservoir has a total storage capacity of 153,992 acre-feet and a surface area of 3,115 acres at active conservation reservoir elevation 5,334.0.

RESERVOIR OPERATIONS

Deadwood Dam operates to provide regulation flows for the Black Canyon Dam powerplant and supply water for irrigation for the Payette Division and Emmett Irrigation District. The July 2002 area-capacity tables show 184,682 acre-feet of total storage at maximum water surface elevation 5,343.5. The 2002 survey measured a minimum bottom elevation of 5,195.0. The following values are from the July 2002 area-capacity tables:

- 30,690 acre-feet of surcharge between elevation 5,334.0 and 5,343.5.
- 153,992 acre-feet of conservation use between elevation 5,202.75 and 5,334.0.
- No measurable capacity below elevation 5,202.75.

The Deadwood Reservoir inflow and end-of-month stage records in table 1, for the operation period of water years 1931 through 2002, show the measured annual outflow and reservoir fluctuation since dam closure. These values were obtained from USGS and Reclamation records. The outflow data, that is regulated by the reservoir, was measured at the USGS gage located just downstream of the dam and is called “Deadwood River below Deadwood Reservoir near Lowman, Idaho.” Reclamation has monthly computed inflow data for all years of record, but for the purpose of this study time wasn’t taken to compute the annual values of all of this data. The outflow values don’t account for the annual runoff during initial filling of the reservoir and the years of total drawdown of the reservoir for repairs, but the measured outflow does provide an estimated total amount of runoff that has occurred since dam closure in November of 1930. Since initial filling, the extreme storage fluctuations of Deadwood Reservoir ranged from elevation 5,205 in 1951, 1952, 1973, and 1974 to the maximum-recorded elevation of 5,337.4 in 1974 and 1982. The elevation 5,205 measurements indicate total draining of the reservoir for repairs.

HYDROGRAPHIC SURVEY EQUIPMENT AND METHOD

The hydrographic survey equipment was mounted in the cabin of a 24-foot trihull aluminum vessel equipped with twin in-board motors (fig. 3). The hydrographic system contained on the survey vessel consisted of a GPS receiver with a built-in radio and an omnidirectional antenna, depth sounders, a helmsman display for navigation, computers, and hydrographic system software for collecting and processing the underwater data. An on-board generator supplied power to the equipment.
The shore equipment included a second GPS receiver with an external radio and an omnidirectional antenna. The GPS receiver and antenna were mounted on a survey tripod over a known datum point that had a clear line-of-sight to the survey boat over the vast majority of the reservoir. 12-volt batteries provided power for the shore unit.

The Sedimentation and River Hydraulics Group conducts their bathymetric surveys using Real-time Kinematic (RTK) GPS. The major benefit of RTK versus differential GPS (DGPS) is that precise heights can be measured in real time for monitoring water surface elevation changes. The basic outputs from a RTK receiver are precise 3D coordinates in latitude, longitude, and height with accuracies on the order of 2 centimeters horizontally and 3 centimeters vertically. The output was in the GPS datum of WGS-84 that the hydrographic collection software converted into state plane coordinates.

In 2001 the Sedimentation and River Hydraulics Group began utilizing an integrated multibeam hydrographic survey system. The system consists of a single transducer mounted on the center bow or forward portion of the boat. From the single transducer a fan array of narrow beams generate a detailed cross section of bottom geometry as the survey vessel passes over the areas to be mapped. The system transmits 80 separate 1-1/2 degree slant beams resulting in a 120-degree swath from the transducer. The 200 kHz high-resolution multibeam echosounder system measures the relative water
depth across the wide swath perpendicular to the vessel’s track. Figure 4 illuminates the swath of the sea floor that is about 3.5 times the water depth below the transducer.

The multibeam system is composed of several instruments that are all in constant communication with a central on-board notebook computer. The components include the RTK GPS for positioning; a motion reference unit to measure the heave, pitch, and roll of the survey vessel; a gyro to measure the yaw or vessel attitude; and a velocity meter to measure the speed of sound through the vertical profile of the reservoir water. With the proper calibration, the data processing software utilizes all the incoming information to provide an accurate detailed x,y,z data set of the lake bottom.

The Deadwood Reservoir bathymetric survey collection was conducted from July 11 through July 14 of 2002 between water surface elevation 5,324.1 and 5,325.2 (Reclamation project datum). The survey was run using the instrumentation described above where the survey system software continuously recorded reservoir depths and horizontal coordinates as the survey vessel moved across close-spaced grid lines covering the reservoir area. Most transects (grid lines) were run in a north or south direction of the reservoir where the multibeam swaths in the deeper portions of the reservoir overlapped. Even though the multibeam system could have provided full bottom coverage, time and budget didn’t allow for this to occur in the shallow portions of the reservoir. Detailed information along the face of the dam was collected with the multibeam collection system, but power surges during the time of collection at the dam along with positioning and depth-sounding anomalies affected the detail of the mapping along the face of the dam. The loss of this additional data didn’t have a significant impact on the area computations since it only occurred near the face of the dam.

The above water topography was measured on August 24 of 2002 near reservoir water surface elevation 5,299.6 by a contract aerial survey. The aerial survey was conducted using a LiDAR acquisition method that utilized GPS for control and the LiDAR instrument that transmits light to measure ground elevations below the aircraft. The methodology of the multibeam and LiDAR systems are very similar. The airborne GPS data was processed as a kinematic survey and
resulted in detailed x,y,z data sets and 2-foot reservoir topography from elevation 5300 and above. Figure 5 provides an orthophoto mosaic of the reservoir area covered by the LiDAR survey.

**Deadwood Reservoir Datums**

A GPS survey was contracted by the Pacific Northwest Regional Office to establish the study area control at Deadwood Dam on existing Reclamation monuments located on the west and east abutments of the reservoir. The horizontal control was established in the Idaho west state plane coordinate zone of NAD83. The vertical control was tied to the NAVD88 and the Reclamation project vertical datum. All elevations in this report are referenced to the Reclamation project or construction datum that was found to be around 18.6 feet greater than the NAVD88. Following are the results from the control survey.

<table>
<thead>
<tr>
<th>Name</th>
<th>Latitude (NAD83)</th>
<th>Longitude (NAD83)</th>
<th>Ellipsoid Height</th>
<th>Idaho West (North)</th>
<th>NAD83 (West)</th>
<th>NAVD88 Elevation</th>
<th>BOR* Elevation</th>
<th>BOR NAVD88 +</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>44°17'34.40889&quot;</td>
<td>115°38'47.92204&quot;</td>
<td>5273.86</td>
<td>957147.82</td>
<td>2651727.87</td>
<td>5322.00</td>
<td>5340.609</td>
<td>18.61</td>
</tr>
<tr>
<td>West</td>
<td>44°17'37.59099&quot;</td>
<td>115°38'41.51389&quot;</td>
<td>5273.95</td>
<td>957467.40</td>
<td>2652193.53</td>
<td>5322.06</td>
<td>5340.622</td>
<td>18.56</td>
</tr>
</tbody>
</table>

* The Reclamation elevations are from a previous level survey.

Due to the rapidly dropping reservoir water surface levels, the underwater survey was conducted prior to the contracted control survey. In order to tie all survey data together the hydrographic survey crew measured an absolute position on the Reclamation monument located on the dam’s west abutment. Using Real-time Kinematic (RTK) GPS, measurements were taken on the east monument and a temporary control point used for the GPS base station during the underwater survey. During post processing all the bathymetric measurements were shifted slightly to match the horizontal control established by the GPS control survey and vertical control established by a previous Reclamation level survey. The shift was determined to be (+) 2.35 feet to the north coordinates and (+) 0.97 feet to the west coordinates. All underwater measurements were tied to the Reclamation’s reservoir water surface gage readings recorded at the time of the underwater survey.

**RESERVOIR AREA AND CAPACITY**

**Topography Development**

Using ARC/INFO the topography of the reservoir was developed from the combined underwater and above water data (ESRI 1992). ARC/INFO is a software package for development and analysis of geographic information system (GIS) layers and development of interactive GIS applications. The underwater collected data was processed using the hydrographic system software that was also used for the onboard data collection. The analysis included applying all measurements such as vessel location and corrections for the roll, pitch, and yaw effects. The other corrections included applying the sound velocity of the reservoir water column and converting all depth data points to elevations using the measured water surface elevation at the
Figure 5 – Deadwood Reservoir LiDAR Coverage
time of collection. Due to the massive amount of data, the multibeam data was filtered by taking the measured maximum depth and location for each 5-foot cell or grid of the reservoir area surveyed. The resulting data set was in x,y,z format and contained over two million data points.

The contractor provided the above water LiDAR data in several formats consisting of AutoCAD drawing files and the x,y,z data sets used to generate the drawing contours. The x,y,z data sets were used for the final analysis due to the large size of the drawing files and since the reservoir surface areas needed to be computed for the entire reservoir area. The x,y,z data was labeled 3D- "edited surface" and represented the final bare earth LiDAR measurements. The resulting data set was in x,y,z format and contained nearly two million data points.

Using the APPEND option in ARC/INFO, the two data sets where merged resulting in a x,y,z data set of just over four million data points. Using ARCE, a clip of the 2002 Deadwood Reservoir data was developed such that interpolation was not allowed to occur outside of this boundary. Contours for the reservoir area inside this clip were computed from the combined 2002 data sets using the triangular irregular network (TIN) surface-modeling package within ARC/INFO. A TIN is a set of adjacent, non-overlapping triangles computed from irregularly spaced points with x,y coordinates and z values. The TIN method was 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 sample points are connected to their nearest neighbors to form triangles using all collected data. Elevation contours are then interpolated along the triangle elements. The linear interpolation option of the ARC/INFO TINCONTOUR command was used to interpolate contours from the Deadwood Reservoir TIN. The surface areas at 1-foot increments were also computed from the developed TIN from elevation 5,195.0 to 5,350.0. The contour topography at 2-foot intervals is presented on figures 6, 7, and 8.

Development of 2002 Contour Areas

The 2002 contour surface areas for Deadwood Reservoir were computed at 1-foot increments, from elevation 5,196.0 to 5,350.0, using the Deadwood Reservoir TIN discussed above. The 2002 survey measured a minimum reservoir bottom elevation of 5,195.0. These calculations were performed using the ARC/INFO VOLUME command. This command computes areas at user specified elevations directly from the TIN and takes into consideration all regions of equal elevation.

2002 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP85 (Bureau of Reclamation, 1985). Computed surface areas from the developed TIN, at 2-foot contour intervals, from reservoir elevation 5,196.0 to elevation 5,350.0 were used as the control parameters for computing the Deadwood Reservoir capacity. The program can compute an area and capacity at elevation increments 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 Deadwood Reservoir. The capacity equation is then used over the full range of intervals fitting within this allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from 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. Differentiating the capacity equations, which are of second order polynomial form, derives final area equations:

\[ y = a_1 + a_2x + a_3x^2 \]

where:
- \( y \) = capacity
- \( x \) = elevation above a reference base
- \( a_1 \) = intercept
- \( a_2 \) and \( a_3 \) = coefficients

Results of the 2002 Deadwood Reservoir area and capacity computations are listed in table 1 and columns 4 and 5 of table 2. On table 2, columns 2 and 3 list the original surface areas and capacities projected from the area and capacity curve dated 1935. A separate set of 2002 area and capacity tables has been published for the 0.01, 0.1 and 1-foot elevation increments (Bureau of Reclamation 2003). A description of the computations and coefficients output from the ACAP85 program is included with these tables. Both the original and 2002 area-capacity curves are plotted on figure 8. As of July 2002, at maximum reservoir water surface elevation 5,343.5, the surface area was 3,343 acres with a total capacity of 184,682 acre-feet.

**RESERVOIR ANALYSES**

Figure 8 is a plot of Deadwood Reservoir's original area and capacity data versus the 2002 measured area and capacity. The surface area curves illustrate the difference between the original survey of unknown origin and the very detailed 2002 survey of the Deadwood Reservoir area. The original surface areas and capacity values were projected from curves on a 1935 drawing labeled X-D-767 while the 2002 curves were developed from the 2002 survey results. The 2002 study assumes the difference between the two surveys is due to the detail of collection and not loss of surface area and resulting capacity due to sediment inflow. It is assumed the original survey was conducted by a plane table type survey prior to construction and clearing of the reservoir area where the detail of collection would have been affected by the forested terrain. The 2002 aerial survey was conducted near the Reclamation recorded gage reservoir elevation 5,299.4 which is over forty feet lower than the maximum reservoir water surface elevation of 5,343.5. This forty vertical feet of reservoir area is fairly clear of thick vegetation that would have impeded true ground measurements during the original survey. Another explanation could be a possible datum shift between the original and 2002 surveys. The 2002 underwater survey was processed utilizing the Reclamation gage measurements recorded at the time of the survey. Spot check of the x,y,z aerial data set found good elevation comparisons between the measured 2002 underwater data set and the Reclamation gage readings recorded at the time of aerial collection. Column 6 and 7 on table 2 list the differences between the two surveys with the
conclusion that the difference is due primarily to the variation in the levels of detail and accuracy between the two surveys.

REFERENCES


Environmental Systems Research Institute, Inc. (ESRI), 1992. *ARC Command References*.

Table 1. - Reservoir sediment data summary (page 1 of 3).
### Table 1. - Reservoir sediment data summary (page 2 of 3).
47. REMARKS AND REFERENCES

Top of parapet wall, elevation of 5,343.5, forms a continuous water barrier. All elevations are in feet and based on the original project datum established by Reclamation that were found by the 2002 study to be around 18.6 feet greater than the NAVD88.

Uncontrolled overflow spillway.


Calculated using mean annual runoff value of 167,200 AF, item 24, 11/30 through 7/02. (See remark #6). USGS discharges just downstream of dam by water year, from 11/30 through 7/02, at gage "Deadwood River Below Deadwood Reservoir, Near Lowman, ID." Provides total inflow information. Values affected by years of filling and years of total drawdown for dam construction (1951, 1952, 1973 & 1974).

Surface area & capacity at elevation 5,334.0 computed by ACAP program.


No computed sediment volumes due to unknown accuracy of 1930 surface area and capacity values.

Capacities computed by Reclamation's ACAP computer program.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE April 2003

Table 1. - Reservoir sediment data summary (page 3 of 3).
<table>
<thead>
<tr>
<th>Elevation (feet)</th>
<th>Original Survey (acres)</th>
<th>Original Capacity (acre-feet)</th>
<th>2002 Survey (acres)</th>
<th>2002 Capacity (acre-feet)</th>
<th>Volume Difference (acres)</th>
<th>Percent of Reservoir Survey Difference (acre-feet)</th>
<th>Percent of Reservoir Survey Difference Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,350.0</td>
<td>3,498</td>
<td>206,908</td>
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<td>5,345.0</td>
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<td>5,343.5</td>
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<td>184,682</td>
<td></td>
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<tr>
<td>5,340.0</td>
<td>3,260</td>
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<td>117,210</td>
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<td>29.8</td>
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<td>1,649</td>
<td>48,412</td>
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1. Elevation of reservoir water surface.
2. Original reservoir surface area projected from 1935 curve.
3. Original reservoir capacity projected from 1935 curve.
4. Reservoir surface area from 2002 survey.
5. Reservoir capacity computed from 2002 surface areas using ACAP.
6. Measured volume difference = column (3) - column (5).
7. Measured difference expressed in percentage of total 10,008 at elevation 5,334.0.
8. Depth of reservoir expressed in percentage of total_depth of 148.5 feet.

Table 2. - Summary of 2002 survey results
Figure 6. - Deadwood Reservoir topographic map.
Detailed topography developed by 2002 aerial and underwater data. Vertical datum based on original Project datum established by U.S. Bureau of Reclamation that is 18.6 feet greater than the North American Vertical Datum of 1988. Horizontal datum based on Idaho's State Plane Coordinate System, West Zone (NAD83).

Figure 7. - Deadwood Reservoir topographic map.
Detailed topography developed by 2002 aerial and underwater data.

Vertical datum based on original project datum established by U.S. Bureau of Reclamation that is 15.5 feet greater than the North American Vertical Datum of 1988

Horizontal datum based on Idaho's State Plane Coordinate System, West Zone 16N.
Figure 9. - 2002 area and capacity curves