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Memorandum

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From: Kyle Flynn, KF2 Consulting, PLCC

Copy: Kyle Cutting and Jeff Warren, U.S. Fish & Wildlife Service

Date: September 23, 2020

Subject: Upper Red Rock Lake and Shambow Pond Topographic Survey

This memo has been prepared to document the September 10 and 11, 2020 topographic survey of Upper Red Rock Lake (URRL) and Shambow Pond in support of the development of alternatives to improve Arctic grayling habitat in the Centennial Valley. Work was completed as part of Amendment # 2 to Montana Fish, Wildlife & Parks (FWP) contract # 33815A.

Bathymetric Survey in 2017

A bathymetry survey of URRL was completed on June 5 through 7, 2017 by the U.S. Fish and Wildlife Service (USFWS) Region 6 Water Resources Division as documented in *Red Rock Lakes Bathymetry and GPS Survey Project Summary & Meta Data* (Andrews, 2017). The survey consisted of an acoustic bathymetric survey using a Sontek Hydrosurveyor M9 tethered to a motorboat. Depths were acquired with the Hydrosurveyor and were corrected to elevation using a survey-grade Leica Global Positioning System (GPS) survey of lake elevation. The survey was completed using the North American Vertical Datum of 1988 (NAVD 88) using Geoid 12B. Surveyed heights were then adjusted to the local staff gage datum which is tied to Lower Lake. The Lower Lake Dam datum is within 0.2 ft of National Geodetic Vertical Datum of 1929 (NGVD29; Table 1). Lakebed elevations based on the Lower Lake datum are shown in Figure 1.

Table 1. Summary of 2017 field survey of URRL by USFWS.

Benchmark	Surveyed Elevation Lower Lake datum (ft)	Surveyed Elevation NAVD88 (ft) Geoid 12 B	Lower Lake to NAVD88 conversion (ft) [a]	Calculated Elevation NVGD29 (ft) [b]
Lower Lake WCS BM (south wall)	6611.99	6616.37	+ 4.38	6612.16
Upper Lake Campground Fee Box BM	6629.45	6633.90	+ 4.45	6629.69
Upper Lake Shoreside BM	6610.38	6614.83	+ 4.45	6610.62

[a] The correction between NAVD88 and the Lower Lake datum in the vicinity of URRL is +4.45 ft.
[b] NGVD 29 elevations are NAVD 88 surveyed elevations minus a fixed offset of 4.21 ft based on VERTCON separations between the two datums. WCS = Water Control Structure, BM = Benchmark

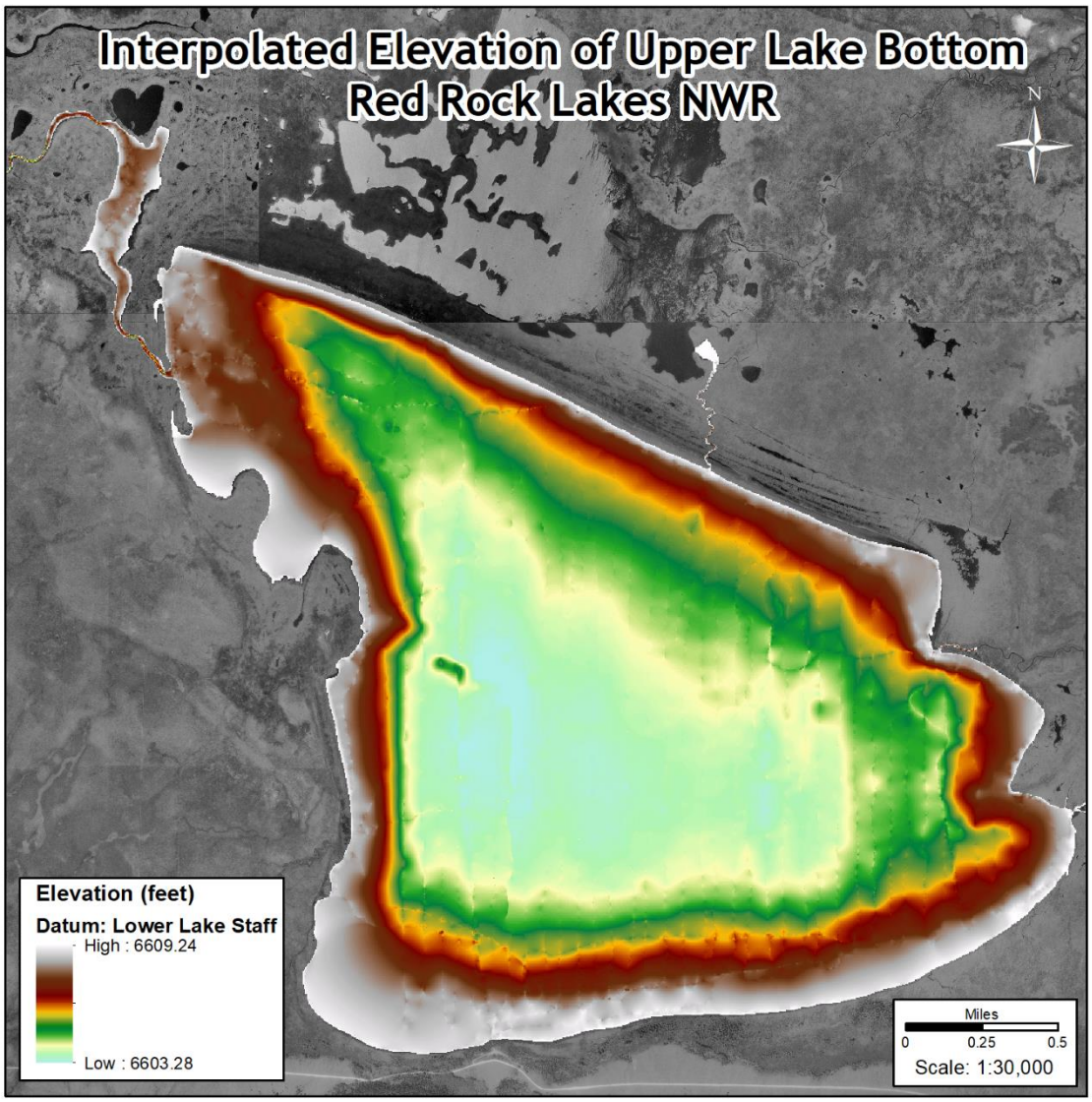

Figure 1. Interpolated elevation of the bottom of URRL (taken from Andrews, 2017), which approximates NGVD 29 elevations. Hydrosurveyor soundings were interpolated to a 5m x 5m grid using the nearest neighbor method.

Topographic and Bathymetric Survey in 2020

A topographic and bathymetric survey was completed in 2020 along the proposed pipeline alignment using a Leica GS14 GNSS RTK GPS system. The survey included portions of Shambow Pond, the proposed pipeline alignment, and parts of URRL, and was constrained by Shambow pond to the south, Shambow Creek to the east, Grayling Creek to the west and north, and URRL to the east (Sheet A-1). Several depth soundings were made in URRL to confirm agreement between the 2017 and 2020 survey. Corrections from the Online Positioning User Portal (OPUS) from the National Geodetic Survey (NGS) were used to correct the base station location and elevations based on nearby static GPS

receivers. The survey was processed in Montana State Plane NAD 1983 International feet, with Geoid 12B to calculate orthometric heights to match the prior survey. For bathymetric data, depth soundings were taken by fiberglass tape, which were subtracted from individually surveyed water surface elevations.

At the time of the 2020 survey, the Andrews (2017) report was not available to KF2 and thus benchmarks set during the 2017 survey were not discovered. However, a nearby National Geodetic Survey (NGS) vertical/horizontal control benchmark (PY0620) was used for the survey tie-in on September 11, 2020. The NGS published elevation and the field-surveyed elevation are listed in Table 2. The survey is within 0.01 ft of the published benchmark elevation and has a slightly larger horizontal position deviation.

Table 2. Summary of results of NGS benchmark tie-in for the 2020 survey.

Name	Northing NAD83 (ft)	Easting NAD83 (ft)	Height NAVD88 (ft) Geoid 12 B
PY0620 benchmark	133,106.81	1,380,717.80	6677.12
Measured	133,106.61	1,380,717.60	6677.11
Difference	0.2 ft	0.2 ft	0.01

Combining the 2017 and 2020 Surveys

The 2017 and 2020 survey data were tied together using the procedures described below. First, 2017 elevations were adjusted from Lower Lake datum back to NAVD88 using the +4.45 vertical correction noted in the footer of Table 1[1].Then, the elevation grid produced by USFWS from the 2017 bathymetry survey was resampled using bilinear interpolation to a 50 m grid and recontoured to remove noticeable shiptracks around the 5-beam acoustic returns and produce a less dense and more regular triangular irregular network (TIN). The procedure slightly modified elevations in the grid but produced an improved and smoother set of elevation contours (less busy) for development of the final surface.

Finally, a TIN surface was developed using the following inputs: (1) the 2020 ground survey data (mass points), (2) breaklines developed for the project based on linear features identified in the field (hard breaklines), (3) contours generated from the smoothed USFWS bathymetric grid (mass points), and (4) the lake perimeter based on the USFWS shoreline spatial file[2] (mass points). The TIN was developed in ArcMap Spatial Analyst, contoured, and then exported to a .dwg format.

In evaluating the results above, a deviation was identified between the two surveys. This was found by taking the difference between the original 5 m USFWS elevation grid (adjusted to NAVD88) and the bathymetric points (soundings and elevations) collected in 2020. The discontinuity was considerable and averaged 0.93 feet. The deviation was depth dependent, and included larger deviations at lower elevations (e.g., deeper depths), but also varied spatially with the smallest deviations occurring along the southern shoreline (Figure 2). Conditions during the 2020 bathymetric soundings were admittedly

[1] The was done using map algebra in ArcGIS Spatial Analyst. Example calculation is as follows: USFWS_Upper_Lake_Bathymetry (Lower Lake Datum) + 4.45 = USFWS_Upper_Lake_Bathymetry (NAVD88).
[2] The latter was set at the NAVD88 water surface elevation during the 2017 field survey (6613.75 feet) which was 0.71 feet higher than the lake elevation during the 2020 survey (6613.04 feet).

difficult (choppy water), but the perceived error in the elevations due to surface waves in 2020 are believed to be less than 0.1 feet based on the standard deviation of the surveyed water surface elevation at each point, which was ±0.05 feet (*n*=12) . As such, field conditions alone do not explain the difference between the two surveys.

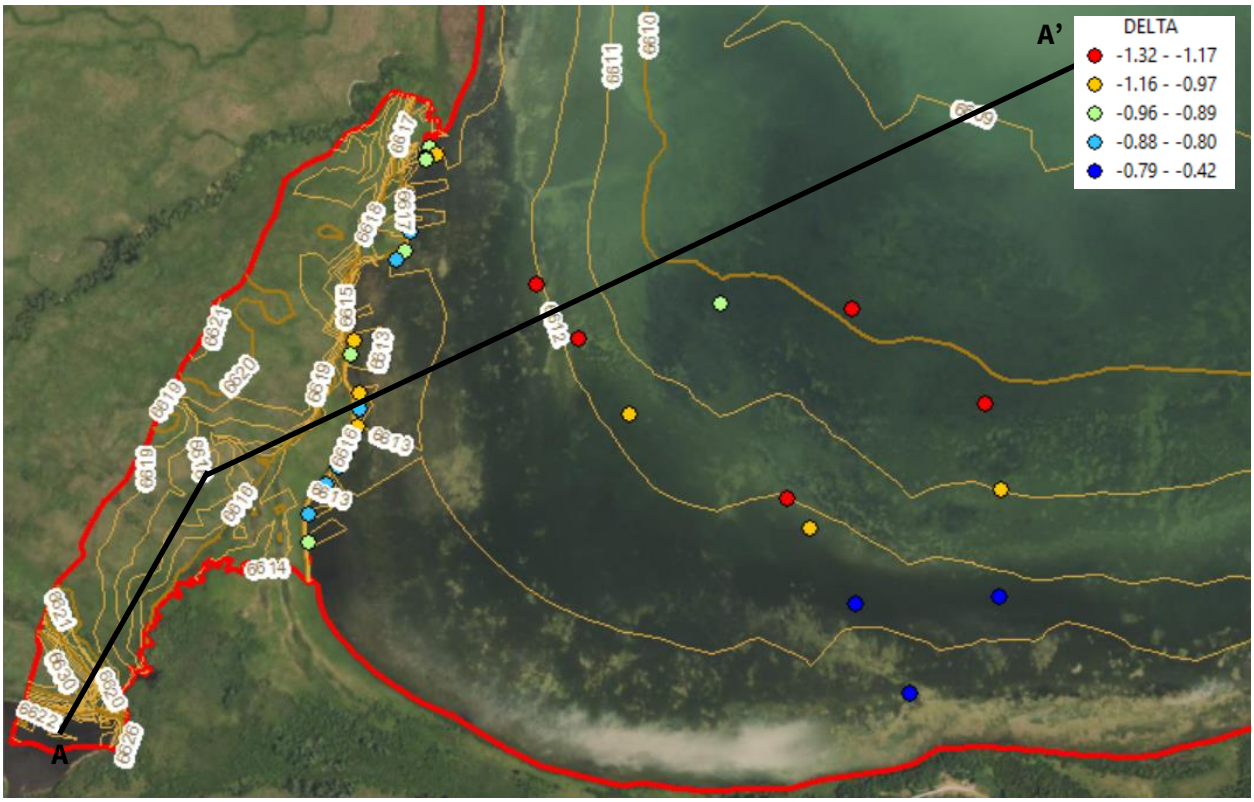

Figure 2. Deviations in NAVD88 lakebed elevations between the 2017 and 2020 surveys. The graduated color ramp of the points (blue to red) indicates the magnitude of the deviation between the two surveys

Given that both surveys were confirmed with NGS vertical control to within a few hundredths of a foot, elevation differences are not believed to be survey-related but rather are thought to be connected with the physical evolution of the lakebed through time, or possibly issues within the bathymetric survey methodology (e.g., acoustic returns from submerged aquatic vegetation). Evidence of erosional lake processes were identified in the ground survey (see cutline A to A' in Figure 2 and Figure 3) noting the lateral ice-ridge on the western shoreline which is a depositional feature with relief of up to 3 feet in some cases, recent activity in the form of unvegetated and unconsolidated ground, and presumably a nearby erosional source (e.g., the lakebed).

Although the underwater elevation differences in URRL are perplexing, they will have little influence on pipeline hydraulic calculations. Gravity flow is controlled by the water surface elevation difference between Shambow Pond and URRL (same survey), along with pipe diameter, length, and roughness (excluding minor friction losses). Thus, the discontinuity around the 6613-foot elevation contour was not remedied in any way. Should a pipeline design be finalized, a longitudinal survey of the design alignment should be completed at the time of construction staking, or in preparation for directional drilling, to confirm lakebed elevations prior to installation.

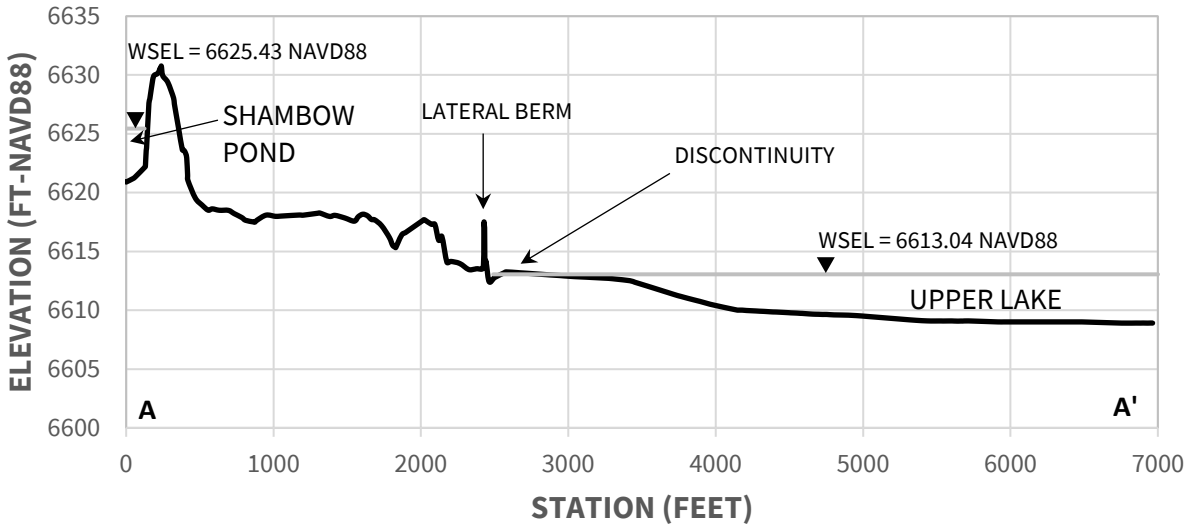

Figure 3. Cutline A to A' extending from Shambow Pond to the deeper basin of URLL (see Figure 2), noting the discontinuity between the two surveys.

References

Andrews, J., 2017. *Red Rock Lakes bathymetry and GPS survey: Project summary & meta data,* Lakewood, CO: U.S. Fish & Wildlife Service.

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Attachment(s): Sheet A-1 and Sheet A-2