

EVALUATION OF WATER QUALITY
AND RATE OF SEDIMENTATION OF BIGHORN LAKE

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Objectives

The managers of the Bighorn Canyon National Recreation Area have expressed concern about two aspects of water quality in Bighorn Lake, the rate of sediment accumulation in the upper ends of the lake, especially in the Horseshoe Bend region, and the excessive fertility that occurs generally in the upper end, although it sometimes extends throughout the total length of the lake. In the spring of 1980 a cooperative study was initiated which was designed to estimate the rate of sediment accumulation in the Horseshoe Bend area of Bighorn Lake since closure of the Yellowtail Dam in 1967. Studies were also initiated to evaluate the sources of aquatic plant nutrients, the factors limiting phytoplankton growth within the upper ends of Bighorn Lake, and the current degree of eutrophication-fertility of waters in this region of the waterbody. This report presents a summary of the results of the first eight months of these studies.

Methods and Results

The first year of this project was divided into three more or less distinct phases. Phase I consisted of conducting a critical review of existing water quality and potential water quality problems that are or could occur in Bighorn Lake. Phase II was concerned with assessing the amount of sediment accumulation in the Horseshoe Bend region of this lake, and Phase III focused on eutrophication-nutrient source studies. A brief summary of the activities in each of these areas is presented below.

Assessment of Water Quality Problems

As part of Phase I, discussions were held with Bighorn Canyon National Recreation Area rangers, water quality management specialists within several governmental agencies in both Wyoming and Montana, members of the staff of the Water and Power Resources Service (formerly the Bureau of Reclamation), and others about water quality problems in, and existing information on Bighorn Lake and its watershed. A detailed site visit into the accessible watershed of Bighorn Lake was made to identify potential nutrient sources - land use. All available reports, data, or other materials pertinent to water quality in Bighorn Lake were collected and reviewed. The final report for this project will present a detailed review of the literature and data from previous

studies. While it appears that there have been no previous studies or data gathered on rates of sediment accumulation in the upper reaches of Bighorn Lake, there have been a number of intensive studies on the eutrophication of this waterbody. A review of these findings is presented in the eutrophication section of this report. While there are a number of other water quality related problems that could be occurring in Bighorn Lake, based on land-use in the watershed, none of these appear at this time to be of sufficient potential magnitude or intensity to warrant spending the limited funds available on them.

Sedimentation in Horseshoe Bend Area of Bighorn Lake

Shortly after initiating this project, it was learned that the Bureau of Reclamation had, prior to closing the dam for Bighorn Lake, prepared a series of sediment range maps of the Bighorn River and its "flood plain" which would be inundated with the establishment of the reservoir. These range maps, showing the elevations of the land across various cross sections or transects across the river and flood plain, were referenced to benchmarks established using precise surveying techniques on both sides of the river above the full pool elevation of the projected impoundment. Copies of these sediment range maps were obtained; it was anticipated that these would be useful in determining sediment deposition in the reservoir since the closing of the dam.

In June, 1980, a field study team consisting of six people including Professors Lee and Jones, traveled to Bighorn Lake where they conducted a study to determine the current water depth - sediment contour at selected locations in the Horseshoe Bend region of the waterbody for comparison with elevations in the sediment range maps. The investigators' and their assistants' first task was to find the Bureau of Reclamation (now the Water and Power Resource Service) benchmarks in the Horseshoe Bend area. This was done with some difficulty since they were often located on relatively small ledges on the cliffs bordering the reservoir. By positioning staff members at both benchmarks for a particular transect and having several staff members in a boat on the reservoir, it was possible to determine through line-of-sight navigation and range finders, the location of the Bureau of Reclamation's transect and the boat's position along the transect. By measuring the water depth at known positions along each of the transects in the Horseshoe Bend area (Figure 1) using a metered line and weight, the current sediment contour was determined.

Figures 2 through 5 show the sediment accumulation at the Horseshoe Bend transects over the past 10 years, since closing of the dam. These figures illustrate the fact that in some areas of Horseshoe Bend as much as 40 feet of sediment have accumulated during this time, a rate which, if maintained, could have serious ramifications on the recreational use of the Horseshoe Bend area of Bighorn Lake. Figure 6 shows the sediment accumulation in the old river bed between sediment ranges 14 and 17 and indicates that the sediment appears to have deposited primarily in the bend area, with substantially less deposition as the reservoir narrows at sediment range 14. These results point to the importance of estab-

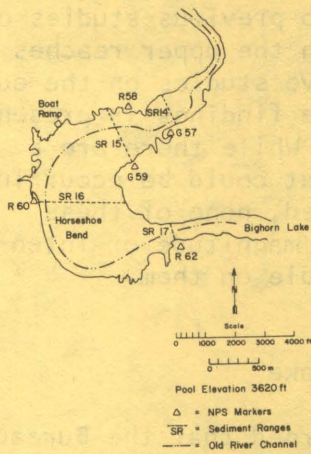


Figure 1. Horseshoe Bend area of Bighorn Lake

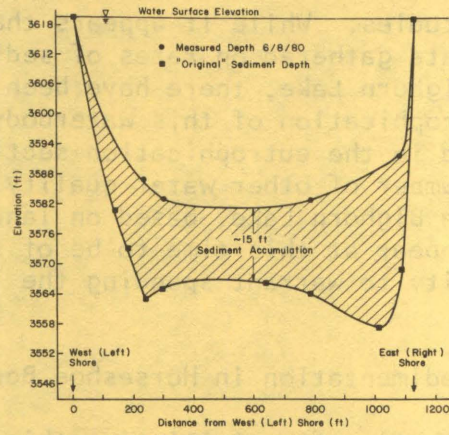


Figure 2. Sediment profiles at SR 14

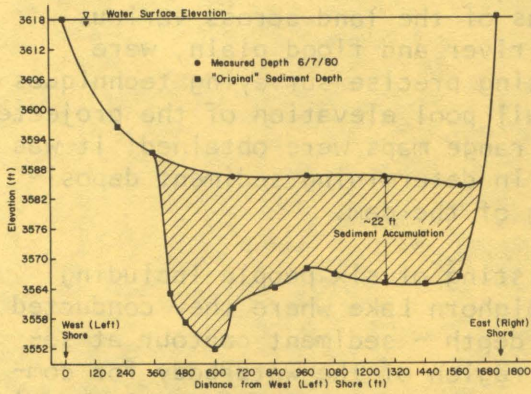


Figure 3. Sediment profiles at SR 15

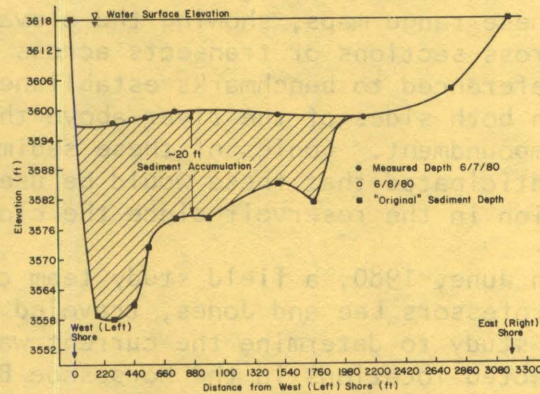


Figure 4. Sediment profiles at SR 16

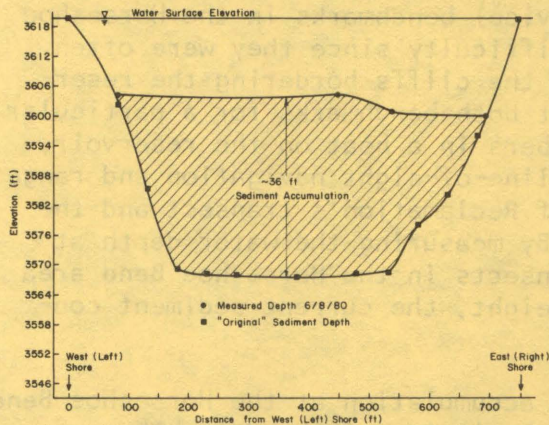


Figure 5. Sediment profiles at SR 17

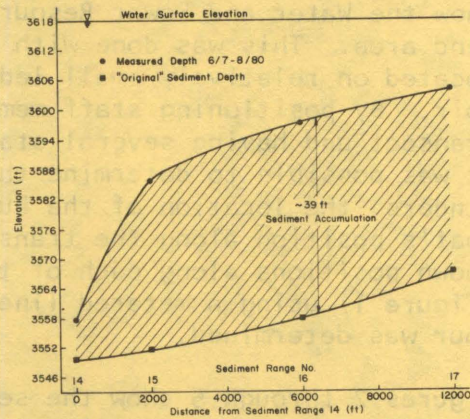


Figure 6. Sediment profile down old river channel

lishing a sediment depth monitoring program in which at periodic intervals the sediment depth is precisely measured using a dual frequency fathometer and precise navigation equipment.

Eutrophication

A water quality monitoring program in which samples of water from the two major tributaries (the Shoshone and Bighorn Rivers) just above the point at which they enter the lake, and from two different locations within the lake which receive extensive public use, was initiated in the summer of 1980. Through the cooperative efforts of the National Park Service staff it was possible to conduct a much more intensive monitoring program than would have been possible otherwise. The park rangers collected the samples, put them on ice, and shipped them by bus to Fort Collins for processing. The samples were received by the investigators on the same day as they were collected, and were placed under refrigeration; processing began the next day. As the result of this situation the integrity of the samples was maintained as well as could have been done if the samples were analyzed at the site, which was not possible because of the lack of facilities there.

The samples were analyzed for planktonic algal chlorophyll, various forms of phosphorus, nitrogen, and a variety of other chemical and physical characteristics. Table 1 presents the results of the chemical analyses completed thus far for the lake. Table 2 presents the results for the tributaries. At the time of preparation of this report the analyses of some of the chemical parameters for both the tributary and lake waters had not been completed. It was found that Bighorn Lake, as is well known to those who have visited it during late summer, is a highly eutrophic waterbody with planktonic algal chlorophyll concentrations of over 50 $\mu\text{g}/\text{l}$ in the Horseshoe Bend region. The results of the analyses are similar to those found by Soltero (1971) Soltero *et al.* (1973) and the US EPA (1977). Phosphorus was found to be the key element limiting peak planktonic algal growth in the summer in the Horseshoe Bend area and likely at Barry's Landing as well. Even though the Horseshoe Bend region of the lake is highly turbid, there is sufficient light penetration to enable the phytoplankton to utilize the available phosphorus to growth limiting concentrations.

As part of the June, 1980 intensive study of the lake, reconnaissance surveys were made of the lake's watershed along both of the major rivers. It was confirmed that the phosphorus added to this waterbody is derived primarily from diffuse sources, such as land runoff. Further work will be done in the second year of the study to define phosphorus sources and most importantly, to examine the origin of the phosphorus which is primarily responsible for the late summer (August) phytoplankton blooms which have the greatest deleterious effect on beneficial uses of the Horseshoe Bend part of the lake. While the overall phosphorus load to the waterbody may be uncontrollable, it is possible that the results of these studies could show that control of local sources such as phosphorus in the domestic wastewaters from the City of Lovell, could result

Table 1. Characteristics of Bighorn Lake at Horseshoe Bend and Barry's Landing

Date (mo-da-yr)	Temp (C°)	pH	specific conductance µmhos/cm at 20°C	Turbidity (NTU)	Secchi depth (cm)	Corrected Chlorophyll (µg/l)	Soluble Ortho P (mg P/l)	Total P (mg P/l)	Total NH ₃ (mg N/l) ³	NO ₃ ⁻ (mg N/l)	Alkalinity (mg/l as CaCO ₃)
<u>Horseshoe Bend</u>											
6-09-80	17.5	8.1	620	9.6	50	2	0.011	0.06	0.016	0.63	186
7-09-80	22.0	8.0	445	3.6	103	9	0.003	0.05	0.021	0.18	170
7-23-80	23.0	8.0	500	13	53	71	0.003	0.09	<0.01	0.21	155
8-06-80	23.0	7.9	-	-	70	10	0.060	0.24	0.097	0.15	
8-20-80	23.0	-	-	10	35	41	0.005				
9-03-80	18.0	8.2	673	7	35	31	0.003				
9-17-80	17.0	8.3	656	6	80	14	0.002				
10-16-80	12.0	7.7	686	17	30	11	0.006				
11-26-80	4.0	8.0	585	2.5	150	0.9	0.006				
<u>Barry's Landing</u>											
7-09-80	21.0	7.8	451	2.1	170	11	0.013	0.05	0.028	0.28	168
7-23-80	22.0	7.0	472	3.5	127	15	0.003	0.05	0.13	0.46	165
8-06-80	22.0	7.9	-	-	310	3	0.020	0.05	0.063	0.10	
8-20-80	22.0	-	-	-	280	16	0.012				
9-03-80	19.0	8.1	445	1	240	5	0.016				
9-17-80	18.5	8.1	540	1	330	1.5	0.019				
10-16-80	12.0	7.9	518	1	250	2.6	0.017				
11-26-80	10.0	7.7	656	1	315	1.1	0.014				

Dash (-) = no measurement made
Blank space = analysis not yet completed

Table 2. Characteristics of major tributaries to Bighorn Lake

Date (mo-da-yr)	Temp (C°)	pH	Specific conductance (µmhos/cm at 20 C)	Turbidity (NTU)	Soluble Ortho P (mg P/l)	Total P (mg P/l)	Total NH ₃ (mg N/l) ³	NO ₃ ⁻ (mg N/l)	Akalkinity (mg/l as CaCO ₃)
<u>Bighorn River</u>									
06-09-80	17.5	7.7	585	425	0.026	3	0.061	0.68	197
07-09-80	21.0	8.1	494	91	0.02	0.27	0.12	3.4	172
07-23-80	23.0	8.0	667	46	0.024	0.14	0.15	2.0	204
08-06-80	19.0	8.0	-	-	0.020	0.22	0.058	0.67	
08-20-80	-	7.8	675	330	0.031				
09-03-80	17.0	8.1	698	72	0.016				
09-17-80	12.5	8.1	605	6400	0.024				
10-16-80	6.0	8.1	686	32	0.001				
11-26-80	0.0	8.2	679	48	0.002				
<u>Shoshone River</u>									
06-09-80	17.0	7.2	838	95	0.020	0.30	0.018	0.68	224
07-09-80	17.0	7.2	439	63	0.057	0.24	0.018	0.62	159
07-23-80	17.0	8.1	652	55	0.041	0.23	0.045	1.4	209
08-06-80	16.0	7.8	-	10	0.050	0.28	0.051	1.0	
08-20-80	-	7.8	694	66	0.045				
09-03-80	14.0	8.1	765	46	0.028				
09-17-80	11.0	8.0	668	2400	0.034				
10-16-80	4.0	7.6	690	125	0.007				
11-26-80	-1.0	8.1	878	18	0.011				

Dash (-) = no measurement made
Blank Space = analysis not yet completed

in a considerable improvement in eutrophication-related water quality in the upper end of the reservoir which receives the most intensive recreational use.

At this time it is impossible to compute nutrient loads from the various sources since the USGS flow data for the gaging stations located near where the samples are taken are not yet available. These computations will be made using approaches discussed by Rast and Lee (1978) Lee et al. (1978), and Jones and Lee (1980) as soon as the USGS flow data are available. These results will be compared to the studies conducted in the mid 1970s by the U.S. Environmental Protection Agency as part of the National Eutrophication Survey of nutrient loads to Bighorn Lake.

Conclusions

It is concluded from the first year's results that very high sedimentation rates have occurred in Horseshoe Bend of Bighorn Lake, and that if these rates are representative of what will occur in the future, then the sediment accumulation could significantly impair future recreational uses of the upper ends of the reservoir. Bighorn Lake is highly eutrophic and derives its total phosphorus loads primarily from diffuse sources such as land runoff. Future work is needed and will be conducted to define year-to-year variations of sediment depth in the Horseshoe Bend region of Bighorn Lake and the role of point sources of phosphorus, such as domestic wastewater inputs from nearby communities on creating excessive planktonic algal growth in the upper parts of the reservoir.

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