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BIG HORN BASIN — CLARKS FORK Level II

Executive Summary

Prepared by:
ESA Geotechnical Consultants
in association with
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ARIX, A Professional Corporation

April, 1986

EXECUTIVE SUMMARY
BIG HORN BASIN - CLARKS FORK
LEVEL II STUDY

Submitted to:

State of Wyoming
Water Development Commission

Prepared by:

ESA Geotechnical Consultants
in association with:
Leonard Rice Consulting Water Engineers
and
ARIX, A Professional Corporation

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ESA Geotechnical Consultants

I. INTRODUCTION

The Wyoming Water Development Commission (WWDC) contracted with ESA Geotechnical Consultants (ESA) to perform Level II feasibility studies of development of Wyoming's share of runoff from the Clarks Fork Yellowstone River, as a part of the Big Horn Basin-Clarks Fork Master Plan. This study focuses on a potential major storage reservoir located in the lower Clarks Fork Basin of Wyoming at the mouth of the Clarks Fork Canyon. The general purpose of this study is to determine if it is technically feasible to develop Wyoming's share of the water at a reasonable cost, without encroaching into the environmentally sensitive upper watershed. It is the intent of this study to evaluate the major storage reservoir, and secondarily, to evaluate conceptual facilities and costs to distribute water to potential areas of use within the basin, and to transfer water to the Shoshone Basin to the south. Beneficial use of project water, other than hydropower generation, was not evaluated since most potential uses have not been defined and are left for later study.

The Clarks Fork Level II study was performed in three phases. Phase I studies were completed in January, 1985 with the acceptance by the WWDC of the Phase I: Interim Report on Geotechnical Analysis. The Phase I study concluded that no geotechnical "fatal flaws" existed at the site and that it is technically feasible to develop a major reservoir. The WWDC then authorized a Phase II study to provide a more complete and detailed evaluation of the project, especially with respect to project water yields and project facilities, all leading to more comprehensive cost estimates. The Phase II study emphasized maximum utilization of Clarks Fork water within Wyoming. However, the only specific demand identified was in-basin irrigation of Kimball and Chapman Benches near the proposed reservoir. All other reservoir yield was assumed to be exported to Shoshone Basin, without identification of specific end uses. Later, the scope of work was expanded to include a Phase III study. Two concepts (Alternatives A and B) emphasizing hydropower options were evaluated in this phase.

II. PURPOSE AND SCOPE

The primary purpose of the Phase I study was to analyse geotechnical conditions at the reservoir site and develop conceptual designs of the major dams required to form the reservoir. The critical issues that were addressed included reservoir seepage conditions, foundation strength at the

damsites, and availability of construction materials. A feasibility level field exploration and testing program was conducted to provide data for the analyses. The Phase I study was used as a basis for development of the more refined project designs developed in Phase II, and the conceptual evaluation of alternatives in Phase III.

The primary purpose of the Phase II and Phase III study was to determine the amount of water available for development and associated project costs. Although not a constraint in the final analysis, the maximum operational pool elevation was fixed at 4,500 feet so that the reservoir would not encroach significantly into the Clarks Fork Canyon. Accomplishment of these goals led to a series of major study tasks, starting with the development of detailed site topography and ending with estimated construction costs and the estimated cost of project water.

A major task of the Phase II study involved water resources analyses leading to determination of reservoir yields. This analysis included studies of the basin hydrology, water rights, Wyoming-Montana entitlement for the Clarks Fork under the Yellowstone Compact, and reservoir operation analyses. These studies utilized computer modeling techniques as a tool for data synthesis and analyses. Flood analyses were also conducted to develop design criteria for spillways and diversion requirements during construction.

The two major dams required to develop the reservoir were conceptualized during Phase I, with designs refined during Phase II. These refinements included adjustments in crest elevation to provide freeboard for design floods; slight adjustments in alignment to fit more accurate topography; selection of the best alternative at Lake Creek, and computation of more accurate embankment volumes. Conceptual designs of appurtenant structures, including power generating and pumping facilities, were also developed. Several concepts were investigated to export water to the Shoshone River Basin, and to deliver water to Chapman and Kimball Benches for irrigation of undeveloped in-basin lands.

Construction costs of all major Phase II project facilities were estimated, based on the conceptual designs. These construction costs, together with annual operation and maintenance costs, were then used to estimate the cost of project water. Both capital and amortized annual cost per acre-foot of reservoir yield were calculated.

In Phase III, two alternative projects using the same dam and reservoir configuration as Phase II were evaluated. These evaluations emphasized the hydropower aspects of each alternative, and included comparison with comparable aspects of the Phase II project. In Alternative A, the reservoir was operated only for hydropower generation from the reservoir yield released to Montana. Alternative B is an intermediate concept to the Phase II project and Alternative A. It involves delivery of project water to Kimball and Chapman Benches for in-basin irrigation, and export of a lesser quantity of water to Shoshone Basin than assumed for the Phase II project (65,000 acre-feet per year versus 372,000 acre-feet per year). The remaining reservoir yield released to Montana is used to generate hydropower, as in Alternative A. Project development costs of all three scenarios were evaluated and compared, with emphasis on the impact of hydropower development on project costs.

III. SUMMARY OF CONCLUSIONS

The conclusions contained herein result both from the Geotechnical Analysis of Phase I and the Project Analysis of Phase II and Phase III. The results of this study indicate that development of Wyoming's share of available water in the Clarks Fork Basin is technically feasible, although it would require a major design and construction effort to develop the project. Costs of development of project water remain somewhat unclear because of the unknowns involved in transferring most of the project yield to areas of beneficial use outside the basin. However, the costs related to reservoir development are clear within the normal data limitations of a Level II study.

The performance of the various analyses have led to the following summary of the more important conclusions reached during this study regarding the Phase II project:

1. Average annual runoff from the Clarks Fork Basin at the damsite is 622,000 acre-feet. Surplus water amounts to 584,700 acre-feet, of which Wyoming is entitled to 405,910 acre-feet annually.

2. The maximum size reservoir studied, with a storage capacity of 522,850 acre-feet, has a firm annual yield of 277,100 acre-feet and an average annual yield of 403,200 acre-feet when operated to maximize yields to Wyoming.
3. Sensitivity analyses indicate that optimum reservoir size is in the range of 350,000 to 522,850 acre-feet, using operating criteria for an intermediate yield scenario. This scenario is based on reservoir operations which might be implemented if the proposed project was built under the current legal and political conditions related to water use in Wyoming. The range of reservoir size reflects the yield criterion selected: the smaller reservoir is indicated to satisfy the firm and nine out of ten-year yields; the larger reservoir optimizes the median or eight out of ten-year yields.
4. Standard flood analyses indicate that the probable maximum flood (PMF) inflow to the reservoir would be 295,500 cubic feet per second (cfs). The 500-year flood inflow to the reservoir would be 14,400 cfs. These flood inflows were routed through the proposed reservoir to size the service and emergency spillways, and to establish required crest elevations for the dams. The 25-year flood, with an inflow of 11,600 cfs, was used as the criterion for diversion requirements during construction.
5. Reservoir seepage losses will be significant, but will not be large enough to seriously restrict reservoir development or operation. Substantial, but not extraordinary, seepage control measures will be required at both of the major dams.
6. Safe dams can be constructed across the Clarks Fork River and at both the recommended and alternate sites across the Lake Creek Valley. Data developed to date indicate that zoned earthfill designs are best suited to the foundation conditions and borrow availability. However, the recommended Lake Creek site may be suitable for a concrete gravity-type structure. More detailed information is required to determine if this is a feasible option. If a

concrete dam can be constructed cost-effectively, it would also provide potential for a more cost-effective overflow spillway design.

7. Construction materials for earthfill, rip rap, and concrete aggregate are available within or near the reservoir area in sufficient quantities and of adequate quality to construct the project.
8. Diversion of the river during a four-year construction period will require a 65 foot high cofferdam and a 21-foot diameter, cut-and-cover conduit. Near the end of construction, a 15-foot penstock will be installed in the conduit from a central gate chamber to a powerhouse/pumping plant at the downstream toe. A separate, 8-foot outlet pipe will be routed from the gate chamber alongside the 21-foot conduit.
9. The spillway configuration selected for conceptual design and costing uses a concrete service spillway across the right abutment of the Clarks Fork dam, capable of handling up to a 500-year flood. An unlined emergency spillway across the right abutment ridge is, in conjunction with the service spillway, capable of passing the PMF.
10. All water delivered to Shoshone Basin and Chapman and Kimball Benches will require pumping from the reservoir via pipeline. Constant year-round delivery to Shoshone Basin is much more cost-effective than seasonal delivery. The most direct pipeline route east to Alkali Creek is 10 miles long. A 102-inch pipeline capable of delivering a flow of 514 cfs is required. In the final analysis, the optimum delivery system will depend on how and where the water would be used. Thus, the delivery system selected for costing is only representative of what may be required.
11. The simplest delivery system to Chapman and Kimball Benches is a 78-inch pipeline, which would transmit water to relatively small staging reservoirs at the head of each bench. The pumps and pipeline would deliver a maximum flow of about 200 cfs.

12. Hydropower generation for the Phase II project was severely penalized because of the assumptions used that there would be no participation by Montana and that the project water yield to Wyoming would be maximized. These assumptions severely limit downstream releases available for power generation. Power generating facilities show only a break-even cost effectiveness, but they were left in the project to provide flexibility to realize possible future benefits.
13. Estimated 1985 construction costs for the Phase II project totaled \$340,000,000. This cost includes capital costs of the major structures and facilities; engineering, inspection, and construction management costs; and contingencies.
14. The Phase II project cost of reservoir development was allocated proportionally to the yield delivered to Kimball and Chapman Benches and to Shoshone Basin. This resulted in a 1985 capital cost per acre foot of \$1671 (at 3.5 percent interest during construction) for Kimball and Chapman Benches and \$823 per acre-foot for exported water. These costs amortized over 50 years at 3.5 percent real interest, and with operation and maintenance costs included, resulted in 1985 annual cost of \$151 per acre-foot for project water delivered to Chapman and Kimball Benches, and \$74 per acre-foot for water delivered to Shoshone Basin. Nearly one half of the annual cost per acre-foot is for purchased energy required for pumping.
15. The minimum feasible date by which the Phase II project could be put into service was estimated to be 1993. For purposes of comparison, the 1985 costs summarized previously were escalated to 1993. Construction costs in 1993 dollars are \$413,272,000. Capital cost per acre-foot for water delivered to Kimball and Chapman Benches is \$2340. Water exported to Shoshone Basin would cost \$1153 per acre-foot. The annual costs per acre-foot to the benches and Shoshone Basin are \$235 and \$116, respectively.

Important conclusions regarding the Alternative A and B projects developed as part of the Phase III study are as follows:

16. Alternative A, which represents development of a project to maximize hydropower generation at the Clarks Fork site, is technically feasible. Preliminary analyses indicate that installation of a single 17.5 MW turbine-generator is the optimum configuration. Major non-hydropower facilities are assumed the same as for the Phase II project. No pumping or distribution facilities are included in this project.
17. The 17.5 MW unit will generate marketable electrical energy valued at \$4,049,000 per year beginning in 1993. A pay-back analysis of just the hydropower facility demonstrates its economic feasibility, with a net annual benefit of \$2,069,000.
18. Construction costs (including interest during construction) for Alternative A in 1985 and 1993 dollars are \$257,475,000 and \$360,506,000 respectively. The resulting total annual costs are \$11,274,000 and \$15,787,000. Annual debt service on a 1993 datum (i.e., total annual cost less hydropower revenues) is \$11,738,000. Hydropower will pay back approximately 25 percent of the total annual cost.
19. Alternative B is similar to the Phase II project, except that constant export to Shoshone Basin is reduced from 372,000 acre-feet per year to 65,000 acre-feet per year. A single 17.5 MW unit was sized to generate power from the resulting larger downstream releases.
20. A pay-back analysis of just the hydropower component indicates a net annual benefit of \$2,259,000, thereby establishing the economic feasibility of including these facilities.
21. Reservoir yield in excess of deliveries to Kimball and Chapman Benches and export to Shoshone Basin generates approximately 60 percent of the total power required for pumping project water. The cost savings in 1993 dollars achieved with internal hydropower generation as compared to purchasing all required power is \$2,259,000 per year.

22. Construction costs (including interest during construction) for Alternative B in 1985 and 1993 dollars are \$350,889,000 and \$491,301,000, respectively. The resulting total annual costs are \$18,050,000 and \$25,907,000. The 1993 annual cost of \$25,907,000 includes the hydropower savings noted above, and thus represents the annual debt service on that datum.

A comparison of the Phase II project and Alternative A and B results in the following conclusions:

23. On the basis of both capital and total annual cost (on either a 1985 or 1993 datum), Alternative A is the least costly alternative. Total 1993 annual debt service shortfall is \$11,738,000 for Alternative A, compared to \$25,907,000 for Alternative B and \$53,492,000 for the Phase II Project.
24. A complete economic analysis, including consideration of benefits other than hydropower, was not within the scope of this study. Without these benefits, none of the projects can be shown to be economically feasible. Identification and quantification of other potential benefits and/or subsidies is necessary for all these projects to further assess their economic feasibility.

IV. AVAILABLE WATER RESOURCES

The results of the hydrology and water rights analysis were incorporated into the WIRSOS computer model data base. The model was calibrated and accepted as representing physical and legal conditions in the basin. There were approximately 8,000 acres irrigated in Wyoming, with an additional 20,000 acres which could be irrigated under current, valid water rights. The calibrated model run indicated that 622,000 acre-feet of water flows passed the proposed reservoir site in an average year. Of this total, 94 percent was available for storage. At the Wyoming state line, the average gage flow was 676,000 acre-feet per year.

WIRSOS was used to conduct reservoir operation studies to determine the project yield based on different combinations of operating criteria. The criteria for the operation studies were initially selected to produce

the maximum and minimum yields to Wyoming at a reservoir size of 522,850 acre-feet. The maximum yield model run results were used in the Phase II project hydraulic and hydropower analyses. In addition, a scenario applying intermediate yield criteria were suggested by the WWDC as representative of present day conditions.

The minimum yield to Wyoming scenario resulted in an average annual yield of nearly 290,000 acre-feet. The scenario with the criteria for maximum yield to Wyoming resulted in an average-year yield of approximately 403,000 acre-feet and a firm yield of 277,000 acre-feet. The use of the intermediate yield criteria resulted in an average yield of 324,500 acre-feet per year and a firm yield of 231,000 acre-feet.

Preliminary reservoir size sensitivity analyses were conducted using the intermediate yield criteria. The best reservoir size (based solely on a yield criterion) falls between 350,000 acre-feet and 522,850 acre-feet. This range reflects the importance placed on yield probability. Median and eight out of ten-year yields favor the larger size, while firm and nine out of ten-year yields favor the smaller size.

V. PROJECT DESCRIPTION

The proposed reservoir site is located about 26 miles north-northwest of Cody, Park County, Wyoming. The major elements of reservoir development and conceptual layouts of potential water distribution facilities are shown on Figure 1.

The project and alternatives studied herein have as their key element a reservoir with a maximum pool elevation of 4,500 feet, covering 4,900 acres, and with a storage capacity of 522,850 acre-feet. Retention of this reservoir would require two major earthfill dams. The main dam across the Clarks Fork River would be 235 feet high with a crest length of 7,320 feet, located in Sections 13 and 14, T56N, R103W. Closure of the reservoir would require a second earthfill dam 135 feet high with a crest length of 1,780 feet, across the Lake Creek Valley in Sections 3 and 36, T56N and T57N, R103W. Closure would also require a small earthfill saddle dam south of the main dam in Section 23, T56N, R130W.

Major appurtenant structures include a service spillway, an emergency spillway and a powerhouse/pumping plant. A combined outlet/diversion/penstock conduit will be constructed by cut and cover techniques at the base of the right abutment of the main dam.

A service spillway, sized to pass the 500-year flood, would be located across the right abutment of the main dam. It would be an ungated concrete-lined structure with a crest width of 165 feet at an elevation of 4,500 feet. The emergency spillway, sized to pass the probable maximum flood, would be located across the right abutment ridge south of the main dam. It would be an unlined cut with erosion controls across the ridge, and would have a crest elevation of 4,508 feet and a width of 3,000 feet.

The Phase II project would incorporate a combined hydroelectric power plant and pumping plant located near the downstream toe of the dam. The power plant would have a generating capacity of 15 megawatts. The pumping plant would consist of three pumps capable of pumping 514 cfs to Shoshone Basin and three smaller pumps capable of pumping a maximum of about 200 cfs to the head of Chapman and Kimball Benches. Distribution facilities include a 102-inch pipeline extending 10 miles east to Alkali Creek in the Shoshone Basin. Kimball and Chapman Benches are supplied by a 78-inch pipeline to the head of the benches, discharging into cut and fill staging reservoirs with capacities of 700 and 3,000 acre-feet, respectively. These distribution facilities are considered very preliminary in concept because specific end uses are unknown, except for irrigation of the two in-basin benches. Even the bench irrigation system could be significantly modified if the end use of the majority of the water transferred to the Shoshone Basin were known. As a result, the distribution facilities described in this report and used for costing should be considered representative, rather than optimal concepts.

Alternative A would include a hydroelectric plant with a generating capacity of 17.5 megawatts. Since this alternative was selected to optimize power generation, no project water distribution facilities are included. All reservoir yield is released to the Clarks Fork River below the dam and, with the exception of minor downstream diversions, flows to Montana.

The combined hydroelectric power plant and pumping plant for Alternative B would be similar in layout and design to that described above for the Phase II project. Facilities would be sized to accommodate the

differing demands. The in-basin distribution and irrigation system would be identical to that for the Phase II project. The only difference in the export pipeline to Shoshone Basin would be down-sizing to 54-inch diameter to accommodate the lower demand.

VI. COMPARISON OF ALTERNATIVES

A comparison of the Phase II project and Alternatives A and B is presented below, and preliminary conclusions are drawn. However, a complete evaluation requires that potential benefits be identified and quantified for all of the projects. This evaluation considers only comparisons on the cost side, except for Alternative A where external hydropower benefits have been quantified.

Table 1 presents a summary of the capital and total annual costs for all three projects, both in 1985 and 1993 dollars. It is apparent that Alternative A is the least costly project. However, even when revenues from sale of hydropower are considered, this alternative still requires an additional annual debt service of \$11,738,000 (see note 2 on Table 1). Thus, for this project to be considered economically feasible, one or more sources of additional revenue, and/or compensating indirect benefits, must be identified. These might include governmental subsidies or revenues from presently unidentified downstream users. As noted previously, the possibility of a trade with Montana of Clarks Fork water for water in some other Wyoming stream may offer the best potential. However, evaluation of this issue is beyond the scope of the present study.

Comparison of the Phase II project and Alternative B reveals that the lower export demand to Shoshone Basin (Alternative B) is less costly. This is due to the higher internal savings from hydropower generation, and the associated lower total energy cost for pumping. However, a more complete comparison must consider the value of the exported water in both projects, and the potential value of the large river releases in Alternative B.

TABLE 1
Comparison of Alternatives

Project	Capital Cost ⁽¹⁾		Total Annual Cost	
	1985	1993	1985	1993
Phase II	380,460,000	532,708,000	34,358,000	53,492,000
Alternative A	257,475,000	360,506,000	11,274,000	15,787,000 ⁽²⁾
Alternative B	350,889,000	491,301,000	18,050,000	25,907,000

(1) Includes interest during construction

(2) Net debt service = total annual cost - revenue from sale of hydropower
= 15,787,000 - 4,049,000
= \$11,738,000

