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# **Executive Summary**

## **Crook County Reservoirs and Water Management Study – Level I**



Submitted to:

**Wyoming Water Development Commission  
Cheyenne, Wyoming**

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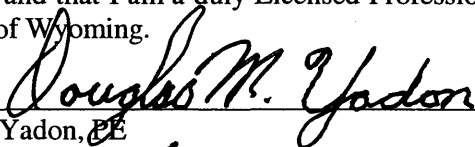
**February 23, 2006**

Crook County Reservoirs and Water Management Study – Level I

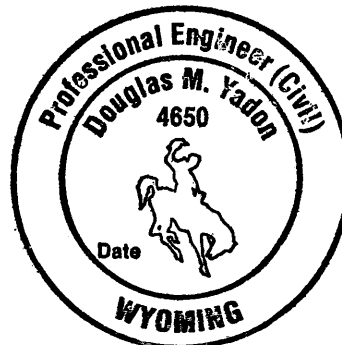
SEH No. A-WWDC00405.00

February 23, 2006

I hereby certify that this report was prepared by me or under my direct supervision, and that I am a duly Licensed Professional Engineer under the laws of the State of Wyoming.

  
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## Executive Summary

### Crook County Reservoirs and Water Management Study – Level I

Prepared for Wyoming Water Development Commission

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#### 1.0 Purpose and Scope

The primary purposes of the Crook County Reservoirs and Water Management - Level I study are to assess the current and potential future needs for water in the Belle Fourche River Basin below Keyhole Dam (and the Redwater Creek Basin) and evaluate alternative concepts/sites for new storage to meet some or all of those needs. The location of the study area is shown on Figure ES-1.

The scope of this study is fully responsive to the Scope of Services in Exhibit “A” of the Consultant Contract for Services. The study was performed in two major phases. Phase I involved the following primary tasks: assessment of the potential for enhanced conservation and water management in the study area; identification and quantification of existing and potential future water needs; and identification, characterization, and screening of alternative storage concepts/sites to meet the identified needs. Selected alternative storage concepts/sites identified in Phase I were then evaluated in more detail in Phase II, including preparation of conceptual designs and order-of-magnitude cost estimates. Phase II also included evaluation of permitting/environmental constraints and mitigation associated with the proposed alternatives, and performing economic analyses and assessing project financing options.

#### 2.0 Summary of Findings

The following subsections present the key findings of the Phase I and Phase II studies undertaken in this Level I study. More detail on any of the findings discussed here can be found in the corresponding named main sections in the Final Report. Note that the organization of this Executive Summary is modified somewhat from the Final Report where appropriate for clarity.

#### 2.1 System Efficiencies and Conservation Opportunities

**Conveyance and Diversion.** Diversions on the Belle Fourche River main stem are typically made by pumping adjacent to the ground to be irrigated, using the river as the primary conveyance of either direct flows or releases from storage in Keyhole Reservoir. Previous studies have approximated losses in the Belle Fourche River to the state line of water called from storage in Keyhole Reservoir at approximately 50 percent in dry conditions and 40 percent in a wet year.

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**Irrigation Practices.** It is estimated that on the order of 70 percent of the 13,900 currently irrigated acres in the study area are served by pressurized sprinklers. The remaining areas are served by gravity-flow.

**On-Farm Conservation and Water Management.** Appropriate and practical on-farm and water management practices are currently employed in the study area, and the ongoing trends indicate that further improvements can be anticipated over time. However, even more aggressive practices (including especially continued conversion to sprinkler irrigation) would not have a significant impact on current dry year shortages or allow significant new lands to come under irrigation.

## 2.2 Needs Analysis and Demand Projections

**Existing Irrigation Depletions.** The estimated current annual surface water depletion for irrigation in the study area is on the order of 15,000 acre-feet. This represents more than 95 percent of the estimated total depletion to irrigation with the balance coming from groundwater.

**Existing Irrigation Shortages.** A total of 7,038 acre-feet of dry-year (i.e., 2 out of 10 years) shortage is indicated by modeling (6,827 acre-feet in the main stem Belle Fourche River Basin and 211 acre-feet in the Redwater Creek Basin). Normal-year and wet-year shortages (all of which occur in the Belle Fourche Basin) are estimated at 1,675 acre-feet and 814 acre-feet, respectively. The general locations of the dry year shortages are shown in relation to existing and potentially irrigable lands on Figure ES-2, and are included in Table ES-1 relative to the study alternatives described later. Approximately 33 percent of the total dry-year shortages in the Belle Fourche Basin occur at the lower end of the study area, and almost 40 percent of the shortages occur high in the Inyan Kara Creek valley at the upper end of the study area.

**Future Irrigation Development.** A total of 7,128 acres in the Belle Fourche Basin below Keyhole Reservoir and 898 acres in the Redwater Basin of potential future irrigated lands have been identified by mapping of aerial photographs of the study area. Nearly 60 percent of the potentially irrigable acres in the Belle Fourche Basin occur in the main stem valley with the balance mostly in several major tributaries.

## 2.3 Hydrologic/Water Rights Analysis

**Available Flows.** Available normal-year annual flows are shown on Figure ES-2 for major tributaries of the Belle Fourche River at their confluence with the main stem and for Redwater Creek and selected tributaries. The total available annual flow for the Belle Fourche Basin in a normal year is approximately 73,000 acre-feet; normal annual available flow in the Redwater Basin is over 28,000 acre-feet. Note, however, that only 10 percent of these totals (about 7,300 and 2,800 acre-feet/year, respectively) are available to Wyoming under the terms of the Belle Fourche River Compact (Compact).

**Direct Flow Water Rights.** Although originally intended, it was not feasible within the scope of this Level I study to correlate water rights, irrigated lands and associated shortages to needs in the study area. Instead, shortages were estimated and allocated on a reach-by-reach and tributary basis. The shortage analysis focused on existing pre-Compact direct flow water rights that do not receive an adequate water supply.

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**Belle Fourche River Compact.** The Belle Fourche River Compact allocates flows that were unappropriated waters as of 1943 as ninety percent to South Dakota and 10 percent to Wyoming, except that allocations to Wyoming are exclusive of the use of these waters for domestic and stock purposes. The Compact also requires that any reservoir built solely to utilize the water allocated to Wyoming shall not exceed a capacity of 1,000 acre-feet. In accordance with direction from WWDC for the purposes of this Level I study, these key compact limitations were not imposed in developing the available flows and sizing of alternative reservoir capacities.

**Instream Flow.** There is a single instream flow right on Sand Creek above its confluence with Redwater Creek. Available flows in Redwater Creek above this confluence are significantly reduced, leading to consideration of sites only below the confluence in this Level I study.

## **2.4 Field Investigations**

Key geologic, environmental and land ownership conditions applicable to the study area as a whole and to the specific alternative sites recommended for advancement to Phase II of this study were identified and evaluated. Key geologic conditions at various locations in the study area include large landslide deposits, weak foundation materials (shales and bentonite layers), and highly soluble geologic units (gypsum). The environmental issue most likely to require mitigation for any new dam and reservoir site is impacts to riverine wetlands and riparian habitat. Further discussion of permitting and environmental issues at the selected alternative sites is presented in Section 2.7 below. The major landownership issues identified were at the Redwater Creek site designated as Alternative 5, involving multiple property owners, proximity to the Town of Beulah, and an existing Conservation Easement in a portion of the proposed reservoir area.

## **2.5 Storage Site Screening**

The storage site screening process involved three sequential steps of identification, evaluation and screening. The first step was to compile a map of all known existing and breached storage dams in the study area. These dams and reservoirs were then briefly evaluated in terms of their potential to serve any of the needs identified if enlarged. The second step involved identification of a “long list” of potentially favorable new dam sites on selected tributary drainages. Sites on the main stem of the Belle Fourche River were not considered due to anticipated very significant environmental and permitting challenges. During the third step in the process a refined set of potential target dam and reservoir sites was identified by additional site reconnaissance and further screening of the combined set of existing/breached and long-list sites considered in the first two steps. In some cases new sites were identified or sites relocated from the first two steps if/as appropriate. The final step in the screening process identified a total of eight potential dam and reservoir sites, representing five separate alternative storage concepts, as further discussed in Section 2.6.

## **2.6 Alternatives Analysis**

**Overview.** A total of five potential new storage “scenarios” (alternatives) have been identified and their locations are shown on Figure ES-3. Each scenario identifies one or two potential dam and reservoir sites that could address some portion of the overall needs identified in the study area. The particular sites and dam and reservoir

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sizes and configurations selected in this study provide a basis to assess overall technical, environmental/cultural and institutional issues and order of magnitude costs that would be associated with the particular alternative scenario.

A compilation of relevant needs and water supply information for each potential dam and reservoir site evaluated as part of the five storage alternatives (involving a total of eight dam and reservoir sites) is presented in Table ES-1. Comparison of columns ten or eleven (normal and dry year shortages) to column six (assumed annual yield) indicates how much of the existing downstream shortages a given alternative storage reservoir could serve. Similarly, comparison of column thirteen (potential additional annual irrigation need) with column six (assumed annual yield) indicates how much of the total potential new irrigated lands downstream of a given alternative reservoir site could be served (first accounting for any portion of the yield that is to be used for existing shortages). Given the cumulative amount and areal distribution of the existing shortages, it is clear that no single alternative can address all of the current needs in the study area. Similarly, bringing a significant portion of the potential new lands under irrigation would require consideration of more than one alternative site.

**Alternative 1 - Blacktail Creek (1A) and/or Lytle Creek (1B) Sites.** Alternatives 1A and 1B were selected for advancement to Phase II of this study as representative of the potential to construct moderate-size reservoirs located on tributaries with confluences with the Belle Fourche River that are as far downstream as practical (to result in lower conveyance losses as compared to serving needs/demands from release of Keyhole Reservoir storage), but still above the majority of current and potential future beneficiaries of their storage. Alternative 1B on Lytle Creek was selected as a 1,000 acre-foot option to comply with the Compact limitation discussed previously.

**Alternative 2 – Oak Creek (2A) and Pine Creek (2B) Sites.** Reservoirs would be constructed in both Pine Creek and Oak Creek at the downstream end of the study area with a minimum combined capacity to address the existing significant local dry year needs. A key consideration with this alternative (whether constructed with one or two reservoirs) is that the proposed local storage would only directly serve the needs of 2 of the 17 current CCID members.

**Alternative 3 – Miller Creek Site.** Alternative 3 was selected to examine the potential of developing a number of small, dispersed reservoirs to meet at least some significant portion of the overall downstream current needs and potentially some future irrigation needs. The Miller Creek site was identified as a surrogate to represent a typical small dam and reservoir site sized at 500 acre-feet. If feasible, some number (perhaps as many as 5 to 10) of these smaller reservoirs would be developed over time to meet one or some combination of the overall needs in the study area.

**Alternative 4 – Lower Inyan Kara Creek (4A) or Upper Inyan Kara Creek (4B) Site.** The primary concept for reservoir storage on lower Inyan Kara Creek is to maximize storage of available flows in the Belle Fourche Basin for later release to serve current shortages on the main stem, potential new irrigated acreage along the main stem, or some combination of these needs. Alternative 4B is a smaller dam and reservoir located higher on Inyan Kara Creek that would operate primarily to serve



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current dry-year shortages in the upper Inyan Kara basin by an exchange of direct flow diversions for release of storage from the Alternative 4B reservoir.

**Alternative 5 – Redwater Creek Site.** This alternative examined the practicality of storing in Wyoming as much as possible of the substantial available Redwater Basin flows in terms of dam and reservoir location and size, order-of-magnitude cost, and potential environmental and cultural resources issues. Given the location of this site just above the Wyoming – South Dakota state line, any future efforts on this concept would have to involve a cooperative effort by the two states.

## 2.7 Permitting/Environmental Constraints And Mitigation

**Permitting.** Environmental permits, agency approvals, and agency coordination activities that would likely be required for implementation of any of the various storage alternatives were identified and characterized. Typically the most significant environmental permit to be secured would be a Section 404 Dredge and Fill permit from the U.S. Army Corps of Engineers, Omaha District. Other permits or approvals that would or may be required include:

- Endangered Species Act (Section 7) Biological Assessment
- Fish and Wildlife Coordination Act requirements
- Laws and Regulations Addressing Cultural Resources (Section 106 consultation)
- Wyoming Board of Land Commissioners Rights of Way (on state lands)
- Wyoming State Engineer’s Office Surface Water Storage Permit
- Wyoming State Engineer’s Office Permit to Construct/Dam Safety Review
- Wyoming Department of Environmental Quality – National Pollution Discharge Elimination System (NPDES) permit and Section 401 Certification

**Environmental Constraints.** The key potential environmental constraints identified and evaluated at the alternative dam and reservoir sites are summarized as follows:

- *T&E Species* - The following Proposed, Threatened and Endangered (T&E) species have some potential to occur within one or more of the proposed project areas: black-footed ferret (*Mustela nigripes*), gray wolf (*Canis lupus*), Canada lynx (*Lynx Canadensis*), and the yellow-billed cuckoo (*Coccyzus americanus*).
- *Sensitive Plant Species* - Although there are 14 known sensitive plant species of concern located at the alternative reservoir sites, none of these species receive federal or state protection.
- *Big Game* - No significant impacts are anticipated to occur to big game seasonal ranges within or in the vicinity of any of the alternative sites.
- *Fisheries* - All of the alternative reservoir sites are located on tributaries that are considered intermittent streams and have the potential to contain viable fisheries resources. A portion of Redwater Creek in the vicinity of the Alternative 5 dam and reservoir site is classified as a Class III stream (described as “important trout waters – fisheries of regional importance”). In addition, a portion of Blacktail Creek in the vicinity of the Alternative 2A dam and reservoir site is classified as a Class IV stream (described as “low production trout waters – fisheries frequently of local importance, but generally incapable of sustaining substantial

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fishing pressure”). Impacts to the various streams and associated fishery resources will occur and should be considered during further environmental evaluation of any of the alternative reservoir sites.

- *Wetland Resources.* - The various locations identified as potential future dam and reservoir sites are all located on what are considered intermittent riverine systems with associated wetland/riparian habitat. The amount of wetlands potentially impacted is relatively low, ranging from an estimated 2 acres at Alternative 3 – Miller Creek to 17 acres at Alternative 2B – Pine Creek. Formal wetlands delineation would be necessary prior to construction at any of these sites to determine the level of impacts to wetlands located in the alternative project area and to identify and quantify necessary mitigation of those impacts.
- *Cultural Resources* - Based on class I cultural resource surveys of seven of the alternative dam and reservoir sites performed by the Office of the Wyoming State Archaeologist, it is apparent that historic and/or prehistoric sites are present at or in the general vicinity of at least five of the sites. Furthermore, the results of a class III cultural resource inventory previously conducted for Alternative 1B – Lytle Creek suggest that new cultural sites may well be found at or in the vicinity of all of the alternative dam and reservoir sites if the more detailed class III surveys are carried out at those sites.

**Mitigation.** Based on prior experience, mitigation may be required at any of the alternative dam and reservoir sites to address impacts to wetlands, riparian vegetation, stream channel habitat, fish and game resources, and possibly threatened or endangered species. Additional cultural and historic resource fieldwork would also need to be completed as the basis for developing a mitigation plan for those resources.

### **3.0 Project Configurations and Costs**

#### **3.1 Conceptual Designs And Cost Estimates**

**Flood Hydrology and Spillway Sizing.** All but one of the alternative dam and reservoir sites are preliminarily classified as either Class I or possibly Class II (designated as Class I/Class II) under Wyoming dam safety regulations. The Alternative 2B – Pine Creek dam is judged to classify as either Class II or Class III. The required IDF for both Class I and II dams is the Probable Maximum Flood (PMF), unless an incremental damage/loss of life analysis (IDA) demonstrates that a lesser IDF is applicable. The IDF for a Class III dam is the 100-year flood. This is especially significant to the conceptual design and estimated costs of most of the alternatives because the PMF peak flows in this region are very large and would require correspondingly very large spillway capacity.

In order to preliminarily assess the potential conservatism in assuming the default IDF as the PMF, an order-of-magnitude, simplified IDA was conducted for this study. The conclusion from the preliminary IDA is that it is likely that PMF spillways will be required for four of the sites, while smaller IDFs may be supportable at the other four sites. Given the potential that these latter four alternatives may be able to justify smaller spillways, it was decided to conceptually design and cost a smaller spillway for each. However, given the uncertainty at this level of study, it was further decided to also cost a full PMF spillway for Alternative 2A – Oak Creek, Alternative 3A – Miller Creek, and Alternative 4B – Upper Inyan Kara Creek.

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**Conceptual Design.** Two different dam and spillway types were considered at all but the Alternative 2B – Pine Creek site: a conventional zoned earthfill dam with an abutment spillway versus an RCC gravity dam with an overflow spillway section. In general, the anticipated geologic conditions at all of the alternative sites would strongly favor an earth dam given the generally weak to at best only moderately strong foundation rock. However, the topographic conditions at most of the sites together with the large IDF flows that will (or may) need to be accommodated favor a long, overflow-type spillway. This type of spillway is most economically achieved by incorporating a stair-stepped spillway section in the downstream face of a gravity dam (assumed as roller-compacted concrete (RCC) rather than conventional cast-in-place (CIP) concrete).

**Earth Dam/Abutment Spillway Concept.** The base design for the earth dam/abutment spillway concept includes a spillway constructed by excavation into the abutment of the dam, with the excavated material used (to the extent feasible) in construction of the earth dam in the valley section. The spillway is assumed to incorporate concrete or RCC in the crest and chute portions, and to be in natural cut in the entrance and tailrace channels. A low-level, cut-and-cover outlet works with gate control would be constructed at the base of one of the abutments. A zoned earthfill dam section is assumed that would incorporate an impervious core zone/core trench founded on competent foundation, internal filters and drains to control seepage and prevent internal erosion/piping, and upstream slope protection (either riprap or RCC/soil cement depending on material availability and cost). If needed, a grout curtain (or possibly a relief well system) would be installed to control seepage and pore pressures in the deeper foundation. Note that it may be feasible at many of the alternative sites to design a homogeneous versus a zoned embankment. The only real difference with the homogeneous design would be that the core and shell materials would be the same material. That material would be sufficiently impervious to act as the waterstop in the dam. All other features would be essentially the same.

**RCC Dam/Overtopping Spillway Concept.** This concept is based on the more detailed conceptual design of an RCC dam and overtopping spillway previously developed for the Alternative 1B - Lytle Creek site. In this concept, the overtopping spillway is built into the downstream face of an RCC gravity dam. The spillway is stair-stepped and a stilling basin is provided to dissipate the energy of the spillway flows prior to their release downstream. If necessary, a service spillway section can be constructed so that more frequent spills are contained within a small part of the spillway. A conventional concrete crest and sidewalls are included in the spillway design. The outlet is a pipe constructed within the RCC dam section with an operator and gate installed on the upstream face of the dam. The RCC dam cross-section is typical for a gravity dam, except that provision is made for a foundation mat to accommodate less than ideal but adequate foundation rock strengths. If sliding on a foundation layer that is not too deep below the mat were found possible, then consideration could be given to constructing a shear key of RCC to interrupt the weak zone. Note that if substantially deeper excavation, a significantly larger (i.e., longer in the upstream/downstream direction) foundation mat, and/or a shear key are required, this concept may prove infeasible.

**Alternative Designs.** There are substantial unavoidable uncertainties regarding the appropriate number, specific location and size of dam and reservoir to best meet some or all of the existing and potential future needs for this project. As a result, it

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was determined that preparation of detailed, site-specific conceptual layouts and designs for each alternative was premature and cost-inefficient. Instead, costs for the base designs described above were developed and then appropriately scaled and adjusted to arrive at the estimated costs for each alternative.

**Cost Estimates.** The conceptual-level estimated project costs for each of the Phase II alternatives are presented in Table ES-3. These estimates are in the contract-required WWDC format and are based on 2006 dollars. Where appropriate, the contract designated percentages were applied to derive the estimated cost for engineering during construction and contingency. Note that for a number of the alternatives, a cost was developed for both an earth dam/abutment spillway concept and an RCC/overtopping spillway concept. This was done in those cases where the preliminary incremental damages analysis (IDA) performed for this Level I study resulted in unavoidable uncertainty as to the size of the required inflow design flood (IDF).

### 3.2 Economic Analysis and Project Financing

The major potential benefits associated with the project alternatives are the delivery of additional water to area irrigators in the form of supplemental water in dry years or to bring new lands under irrigation. The economic benefits of supplemental irrigation water are measured by the marginal increase in farm income that would be generated by a given amount of additional water. Benefits from bringing new lands under irrigation are typically less due to the fixed costs of preparing the land and installing the new irrigation system, and because all of the costs of establishing, managing and harvesting the new crops must be deducted from the gross proceeds of those crops. Other potential project benefits include recreation and wildlife enhancement, the indirect economic benefits attributable to increased irrigated crop production, and the ability to more fully utilize Wyoming's water allotment under provisions of the Belle Fourche River Compact.

Table ES-4 presents a summary of the economic and financing evaluations of the project alternatives, including: total project cost for each alternative (and for both dam/spillway design concepts where appropriate); the estimated cost per acre-foot of storage; the maximum potential value of direct and indirect irrigation benefits; and the estimated sponsor's ability to pay as a percentage of total project cost. The direct and indirect benefits are in terms of lump sum present values. These benefits and the percentage ability to pay are based on the lower total project cost where two costs are given for an alternative. The ability to pay analysis assumed funding by WWDC based on 50-year loan at six percent interest. No estimates of benefits or ability to pay were derived for Alternative 5 - Redwater Creek due to the significant intra-state and Compact issues involved and the resulting uncertainty concerning potential project yield for Wyoming irrigators and the value of other potential benefits.

The estimated benefits summarized in Table ES-4 are substantially less than would be required to fund any of the alternatives under current WWDC guidelines for sponsored projects. Furthermore, the ability-to-pay results indicate a limited ability for project sponsors to repay estimated project costs without substantial state assistance in the form of a much higher than average grant or a state sponsored project.

**Table ES-1  
Supply and Needs Summary**

| Alternative Number | Stream                 | Reservoir Capacity (ac-ft) | Normal Year Available Flow (ac-ft/yr) | Wet Year Available Flow (ac-ft/yr) | Assumed Annual Reservoir Yield <sup>1</sup> (ac-ft) | Number of Acres Potentially Irrigated by Assumed Annual Reservoir Yield (acres) | Currently Irrigated Area Below Alternative Site <sup>2</sup> (acres) | Current Annual "Normal Year" Full Irrigation Supply Diversion Below Alternative Site <sup>3</sup> (acre-ft) | "Normal Year" Irrigation Shortage Below Alternative Site <sup>4</sup> (acre-ft) | "Dry Year" Irrigation Shortage Below Alternative Site <sup>4</sup> (acre-ft) | Potential New Irrigated Area Below Alternative Site (acres) | Potential Additional Annual "Normal Year" Irrigation Need Below Alternative Site (acre-ft) | Number of District Members Potentially Served by Direct Release | Number of District Members Potentially Served by Exchange Release |
|--------------------|------------------------|----------------------------|---------------------------------------|------------------------------------|---|---|--|---|---|--|---|--|---|---|
| 1A                 | Blacktail Creek        | 2,800                      | 2,315                                 | 2,802                              | 1,400   | 686   | 3,970  | 8,100   | 661   | 2,266  | 2,940   | 6,000  | 10  | n/a   |
| 1B                 | Lytle Creek            | 1,000                      | 1,964                                 | 2,671                              | 700   | 343   | 5,130  | 10,470  | 661   | 2,266  | 3,150   | 6,430  | 11  | n/a   |
| 2A                 | Oak Creek              | 3,100                      | 1,464                                 | 1,910                              | 1,600   | 541   | 30   | 90  | 182   | 625  | 230   | 680  | 1   | (TBD)   |
| 2B                 | Pine Creek             | 1,900                      | 1,167                                 | 1,523                              | 1,300   | 439   | 1,420  | 4,200   | 661   | 2,266  | 340   | 1,010  | 2   | (TBD)   |
| 3                  | Miller Creek           | 500                        | 1,483                                 | 2,035                              | 400   | 196   | 5,650  | 11,530  | 1,236   | 3,377  | 3,250   | 6,630  | 12  | n/a   |
| 4A                 | Lower Inyan Kara Creek | 12,600                     | 10,637                                | 14,590                             | 6,300   | 3,088   | 5,650  | 11,530  | 1,236   | 3,377  | <b>3,770</b>  | <b>7,690</b>   | 17  | n/a   |
| 4B                 | Upper Inyan Kara Creek | 6,400                      | 9,454                                 | 12,967                             | 3,200   | 1,569   | 5,650  | 11,530  | 1,236   | 3,377  | 3,960   | 8,080  | 17  | n/a   |
| 5                  | Redwater Creek         | 16,800                     | 28,382                                | 36,778                             | 8,400   | 4,118   | <b>13,860</b>  | <b>31,510</b>   | <b>1,675</b>  | <b>7,038</b>   | <b>8,150</b>  | <b>18,530</b>  | 0   | 18  |

<sup>1</sup> Reservoir yield is assumed as 70 percent of storage capacity for reservoirs of less than 2000 ac-ft and 50 percent of capacity for larger reservoirs.

<sup>2</sup> Total currently irrigated area that could be served by direct release (gravity flow) from given alternative.

<sup>3</sup> Assumed annual irrigation water requirement = 2.04 acre-feet/acre above "big bend" of Belle Fourche River and 2.96 acre-feet/acre below "big bend". Northeast River Basins model Full Supply Diversion = 27,369 acre-ft. Difference attributed to additional currently irrigated acres (Class I) which were not included in the NE Basins model, and to minor differences in calculating areas of irrigated lands.

<sup>4</sup> Wet and dry years are defined as each having a 20 percent and normal years a 60 percent chance of occurring any given year over a 30-year period. Normal and dry year shortages assume that: a) shortages from miscellaneous tributaries above the USGS gage at Node 66.04 all occur below Miller Creek confluence with the Belle Fourche River; b) shortages on Inyan Kara Creek all occur above Site 4B; and c) shortages on Cabin Creek are all above the confluence with the Belle Fourche River.

***Irrigated acreage shown for Alternative 5 on Redwater Creek equals total currently irrigated acres within study area (i.e., Belle Fourche River mainstem and tributaries and Redwater Creek and tributaries, both above the State Line.***

**Table ES-2  
Alternative Dams and Reservoirs Summary**

| Alternative Number | Stream                 | Location                              | Reservoir Capacity (ac-ft) | Reservoir Surface Area (ac) | Dam Height (ft) | Crest Length (ft) | Drainage Basin Area (mi <sup>2</sup> ) | Minimum Inflow Design Flood Peak Flow <sup>1</sup> (cfs) | Maximum Inflow Design Flood Peak Flow <sup>2</sup> (cfs) |
|--------------------|------------------------|---------------------------------------|----------------------------|-----------------------------|-----------------|-------------------|--|--|--|
| 1A                 | Blacktail Creek        | T54N, R64W, Sec. 30, SE 1/4 of NE 1/4 | 2,800                      | 133                         | 67              | 1,597             | 39                                     | 101,000  | 101,000  |
| 1B                 | Lytle Creek            | T53N, R65W, Sec. 16, SE 1/4 of NW 1/4 | 1,000                      | 60                          | 58              | 1,470             | 33                                     | 95,000   | 95,000   |
| 2A                 | Oak Creek              | T55N, R60W, Sec. 18, SW 1/4 of SE 1/4 | 3,100                      | 133                         | 65              | 1,912             | 41                                     | 1,000  | 102,000  |
| 2B                 | Pine Creek             | T55N, R61W, Sec. 4, NE 1/4 of NW 1/4  | 1,900                      | 103                         | 45              | 1,288             | 35                                     | 800  | 800  |
| 3                  | Miller Creek           | T52N, R65W, Sec. 8, SW 1/4 of NE 1/4  | 500                        | 34                          | 37              | 722               | 47                                     | 10,000   | 107,000  |
| 4A                 | Lower Inyan Kara Creek | T51N, R65W, Sec. 6, NW 1/4 of SE 1/4  | 12,600                     | 510                         | 70              | 2,414             | 337                                    | 203,000  | 203,000  |
| 4B                 | Upper Inyan Kara Creek | T50N, R65W, Sec. 11, NW 1/4 of SE 1/4 | 6,400                      | 324                         | 55              | 1,490             | 300                                    | 75,000   | 195,000  |
| 5                  | Redwater Creek         | T53N, R60W, Sec. 21, SE 1/4 of NW 1/4 | 16,800                     | 666                         | 75              | 2,316             | 474                                    | 227,000  | 227,000  |

<sup>1</sup> The minimum inflow design flood is based on a conceptual-level evaluation of potential downstream incremental loss of life and damages

<sup>2</sup> The maximum inflow design flood is the Probable Maximum Flood (PMF)

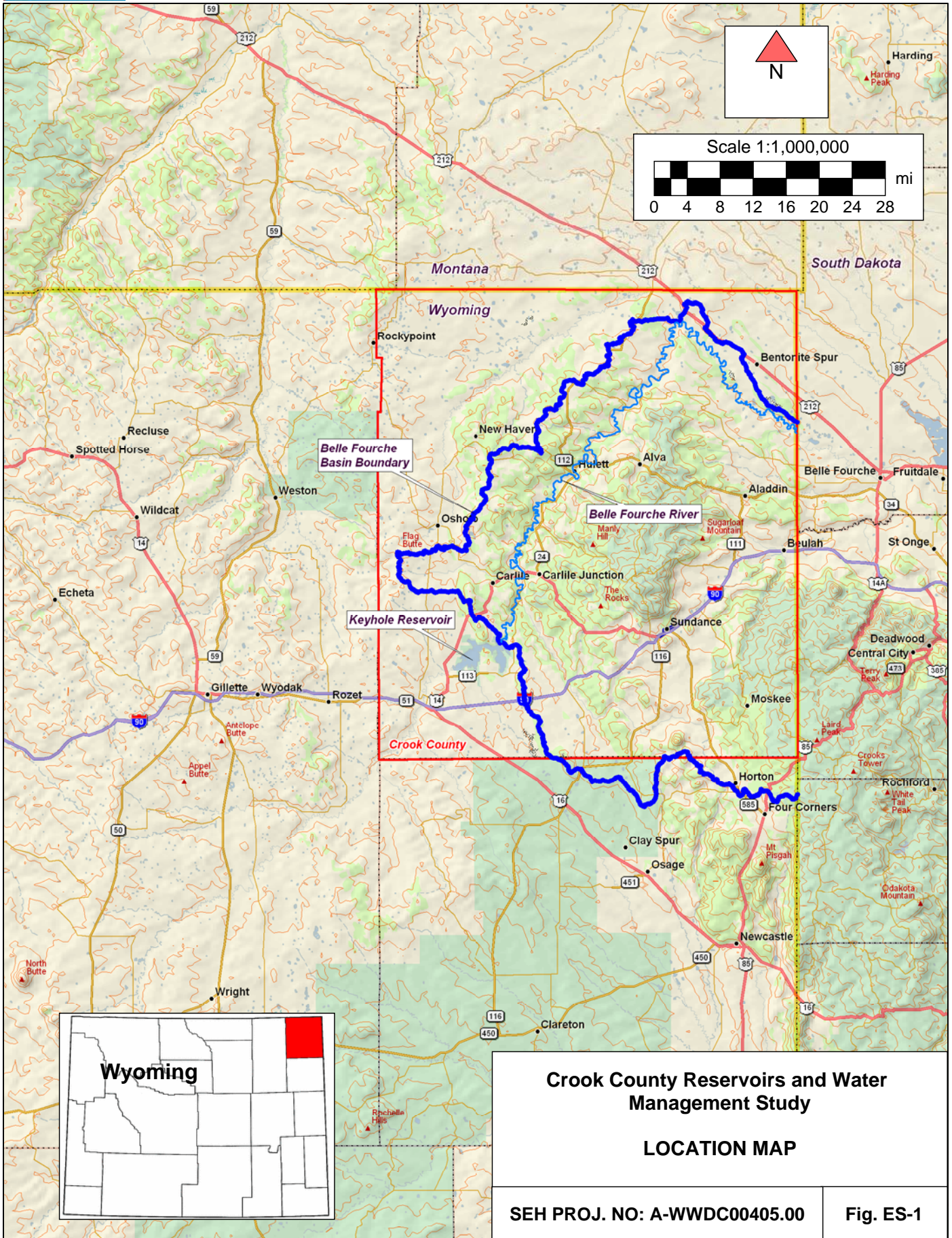
# Table ES-3 Detailed Alternative Cost Estimates

| Alternative 1A<br>Blacktail Creek Dam and Reservoir<br>RCC Dam and Overtopping Spillway<br>Cost Estimate Summary     |                     | Alternative 2A<br>Oak Creek Dam and Reservoir<br>RCC Dam and Overtopping Spillway (IDFmax)<br>Cost Estimate Summary     |                     | Alternative 2A<br>Oak Creek Dam and Reservoir<br>Earth Dam and Abutment Spillway (IDFmin)<br>Cost Estimate Summary                            |                     | Alternative 2B<br>Pine Creek Dam and Reservoir<br>Earth Dam and Abutment Spillway<br>Cost Estimate Summary                                   |                     | Alternative 3<br>Miller Creek Dam and Reservoir<br>RCC Dam and Overtopping Spillway (IDFmax)<br>Cost Estimate Summary |                     |
|--|---------------------|---|---------------------|---|---------------------|--|---------------------|---|---------------------|
| Preparation of Final Designs and Specifications  | \$1,500,000         | Preparation of Final Designs and Specifications   | \$2,200,000         | Preparation of Final Designs and Specifications   | \$1,300,000         | Preparation of Final Designs and Specifications  | \$1,000,000         | Preparation of Final Designs and Specifications   | \$700,000           |
| Permitting and Mitigation  | \$500,000           | Permitting and Mitigation   | \$500,000           | Permitting and Mitigation   | \$500,000           | Permitting and Mitigation  | \$400,000           | Permitting and Mitigation   | \$300,000           |
| Legal Fees   | \$20,000            | Legal Fees  | \$20,000            | Legal Fees  | \$20,000            | Legal Fees   | \$20,000            | Legal Fees  | \$10,000            |
| Acquisition of Access and Rights of Way  | \$700,000           | Acquisition of Access and Rights of Way   | \$400,000           | Acquisition of Access and Rights of Way   | \$400,000           | Acquisition of Access and Rights of Way  | \$300,000           | Acquisition of Access and Rights of Way   | \$100,000           |
| Cost of Project Components   |                     | Cost of Project Components  |                     | Cost of Project Components  |                     | Cost of Project Components   |                     | Cost of Project Components  |                     |
| Mobilization   | \$600,000           | Mobilization  | \$700,000           | Mobilization  | \$400,000           | Mobilization   | \$300,000           | Mobilization  | \$300,000           |
| Dam  | \$6,700,000         | Dam   | \$7,500,000         | Dam   | \$4,100,000         | Dam  | \$2,400,000         | Dam   | \$1,100,000         |
| Spillway   | \$2,800,000         | Spillway  | \$2,800,000         | Spillway  | \$1,000,000         | Spillway   | \$900,000           | Spillway  | \$2,300,000         |
| Outlet Works   | \$400,000           | Outlet Works  | \$400,000           | Outlet Works  | \$800,000           | Outlet Works   | \$500,000           | Outlet Works  | \$200,000           |
| Other  | \$700,000           | Other   | \$500,000           | Other   | \$400,000           | Other  | \$400,000           | Other   | \$300,000           |
| Construction Cost Subtotal #1  | \$11,900,000        | Construction Cost Subtotal #1   | \$12,300,000        | Construction Cost Subtotal #1   | \$7,100,000         | Construction Cost Subtotal #1  | \$4,800,000         | Construction Cost Subtotal #1   | \$4,300,000         |
| Engineering Costs = CCS#1 x 10%  | \$1,200,000         | Engineering Costs = CCS#1 x 10%   | \$1,200,000         | Engineering Costs = CCS#1 x 10%   | \$700,000           | Engineering Costs = CCS#1 x 10%  | \$500,000           | Engineering Costs = CCS#1 x 10%   | \$400,000           |
| Subtotal #2  | \$13,100,000        | Subtotal #2   | \$13,500,000        | Subtotal #2   | \$7,800,000         | Subtotal #2  | \$5,300,000         | Subtotal #2   | \$4,700,000         |
| Contingency = Subtotal #2 x 15%  | \$2,000,000         | Contingency = Subtotal #2 x 15%   | \$2,000,000         | Contingency = Subtotal #2 x 15%   | \$1,200,000         | Contingency = Subtotal #2 x 15%  | \$800,000           | Contingency = Subtotal #2 x 15%   | \$700,000           |
| <b>Construction Cost Total</b>   | <b>\$15,100,000</b> | <b>Construction Cost Total</b>  | <b>\$15,500,000</b> | <b>Construction Cost Total</b>  | <b>\$9,000,000</b>  | <b>Construction Cost Total</b>   | <b>\$6,100,000</b>  | <b>Construction Cost Total</b>  | <b>\$5,400,000</b>  |
| <b>Project Cost Total</b>  | <b>\$17,100,000</b> | <b>Project Cost Total</b>   | <b>\$18,200,000</b> | <b>Project Cost Total</b>   | <b>\$10,800,000</b> | <b>Project Cost Total</b>  | <b>\$7,500,000</b>  | <b>Project Cost Total</b>   | <b>\$6,400,000</b>  |
|  |                     |   |                     |   |                     |  |                     |   |                     |
| Alternative 3<br>Miller Creek Dam and Reservoir<br>Earth Dam and Abutment Spillway (IDFmin)<br>Cost Estimate Summary |                     | Alternative 4A<br>Lower Inyan Kara Creek Dam and Reservoir<br>RCC Dam and Overtopping Spillway<br>Cost Estimate Summary |                     | Alternative 4B<br>Upper Inyan Kara Creek Dam and Reservoir<br>RCC Dam and Overtopping Spillway (IDF <sub>max</sub> )<br>Cost Estimate Summary |                     | Alternative 4B<br>Upper Inyan Kara Creek Dam and Reservoir<br>Earth Dam and Abutment Spillway (IDF <sub>min</sub> )<br>Cost Estimate Summary |                     | Alternative 5<br>Redwater Creek Dam and Reservoir<br>RCC Dam and Overtopping Spillway<br>Cost Estimate Summary        |                     |
| Preparation of Final Designs and Specifications  | \$600,000           | Preparation of Final Designs and Specifications   | \$2,600,000         | Preparation of Final Designs and Specifications   | \$1,900,000         | Preparation of Final Designs and Specifications  | \$1,900,000         | Preparation of Final Designs and Specifications   | \$2,900,000         |
| Permitting and Mitigation  | \$300,000           | Permitting and Mitigation   | \$900,000           | Permitting and Mitigation   | \$500,000           | Permitting and Mitigation  | \$500,000           | Permitting and Mitigation   | \$1,000,000         |
| Legal Fees   | \$10,000            | Legal Fees  | \$40,000            | Legal Fees  | \$20,000            | Legal Fees   | \$20,000            | Legal Fees  | \$40,000            |
| Acquisition of Access and Rights of Way  | \$100,000           | Acquisition of Access and Rights of Way   | \$1,400,000         | Acquisition of Access and Rights of Way   | \$600,000           | Acquisition of Access and Rights of Way  | \$600,000           | Acquisition of Access and Rights of Way   | \$1,300,000         |
| Cost of Project Components   |                     | Cost of Project Components  |                     | Cost of Project Components  |                     | Cost of Project Components   |                     | Cost of Project Components  |                     |
| Mobilization   | \$200,000           | Mobilization  | \$1,000,000         | Mobilization  | \$600,000           | Mobilization   | \$600,000           | Mobilization  | \$1,100,000         |
| Dam  | \$1,100,000         | Dam   | \$11,200,000        | Dam   | \$4,500,000         | Dam  | \$4,500,000         | Dam   | \$12,400,000        |
| Spillway   | \$1,400,000         | Spillway  | \$4,800,000         | Spillway  | \$4,300,000         | Spillway   | \$4,300,000         | Spillway  | \$5,000,000         |
| Outlet Works   | \$300,000           | Outlet Works  | \$800,000           | Outlet Works  | \$500,000           | Outlet Works   | \$500,000           | Outlet Works  | \$1,000,000         |
| Other  | \$200,000           | Other   | \$1,200,000         | Other   | \$600,000           | Other  | \$600,000           | Other   | \$1,300,000         |
| Construction Cost Subtotal #1  | \$3,300,000         | Construction Cost Subtotal #1   | \$20,400,000        | Construction Cost Subtotal #1   | \$11,100,000        | Construction Cost Subtotal #1  | \$11,100,000        | Construction Cost Subtotal #1   | \$22,100,000        |
| Engineering Costs = CCS#1 x 10%  | \$300,000           | Engineering Costs = CCS#1 x 10%   | \$2,000,000         | Engineering Costs = CCS#1 x 10%   | \$1,100,000         | Engineering Costs = CCS#1 x 10%  | \$1,100,000         | Engineering Costs = CCS#1 x 10%   | \$2,200,000         |
| Subtotal #2  | \$3,600,000         | Subtotal #2   | \$22,400,000        | Subtotal #2   | \$12,200,000        | Subtotal #2  | \$12,200,000        | Subtotal #2   | \$24,300,000        |
| Contingency = Subtotal #2 x 15%  | \$500,000           | Contingency = Subtotal #2 x 15%   | \$3,400,000         | Contingency = Subtotal #2 x 15%   | \$1,800,000         | Contingency = Subtotal #2 x 15%  | \$1,800,000         | Contingency = Subtotal #2 x 15%   | \$3,600,000         |
| <b>Construction Cost Total</b>   | <b>\$4,100,000</b>  | <b>Construction Cost Total</b>  | <b>\$25,800,000</b> | <b>Construction Cost Total</b>  | <b>\$14,000,000</b> | <b>Construction Cost Total</b>   | <b>\$14,000,000</b> | <b>Construction Cost Total</b>  | <b>\$27,900,000</b> |
| <b>Project Cost Total</b>  | <b>\$5,000,000</b>  | <b>Project Cost Total</b>   | <b>\$29,300,000</b> | <b>Project Cost Total</b>   | <b>\$16,400,000</b> | <b>Project Cost Total</b>  | <b>\$16,400,000</b> | <b>Project Cost Total</b>   | <b>\$31,800,000</b> |

**Table ES-4**  
**Economic Analysis and Project Financing Summary**

| Alternative Number | Stream                 | Estimated Order of Magnitude Costs   |                               |   |                               | Economic and Financing Analysis                                    |                                     |
|--------------------|------------------------|--------------------------------------|-------------------------------|---|-------------------------------|--|-------------------------------------|
|                    |                        | Earthfill Dam                        |                               | RCC Dam                                 |                               | Maximum Potential Value of Direct and Indirect Irrigation Benefits | Sponsor's Percentage Ability to Pay |
|                    |                        | IDF <sub>min</sub> Abutment Spillway | Cost per Acre Foot of Storage | IDF <sub>max</sub> Overtopping Spillway | Cost per Acre Foot of Storage |  |                                     |
| Project Cost       | Project Cost           | Project Cost                         | Project Cost                  | Project Cost                            | Project Cost                  | Project Cost   |                                     |
| 1A                 | Blacktail Creek        | n/a                                  | n/a                           | \$17,100,000                            | \$6,100                       | \$2,738,400  | 0.8%                                |
| 1B                 | Lytle Creek            | n/a                                  | n/a                           | \$11,900,000                            | \$11,900                      | \$2,170,560  | 1.0%                                |
| 2A                 | Oak Creek              | \$10,800,000                         | \$3,500                       | \$18,200,000                            | \$5,900                       | \$2,540,160  | 1.8%                                |
| 2B                 | Pine Creek             | \$7,500,000                          | \$3,900                       | n/a                                     | n/a                           | \$2,657,760  | 1.8%                                |
| 3                  | Miller Creek           | \$5,000,000                          | \$10,000                      | \$6,400,000                             | \$12,800                      | \$1,293,600  | 1.4%                                |
| 4A                 | Lower Inyan Kara Creek | n/a                                  | n/a                           | \$29,300,000                            | \$2,300                       | \$15,640,800   | 3.1%                                |
| 4B                 | Upper Inyan Kara Creek | \$13,300,000                         | \$2,100                       | \$16,400,000                            | \$2,600                       | \$5,587,680  | 2.2%                                |
| 5                  | Redwater Creek         | n/a                                  | n/a                           | \$31,800,000                            | \$1,900                       | n/a  | n/a                                 |



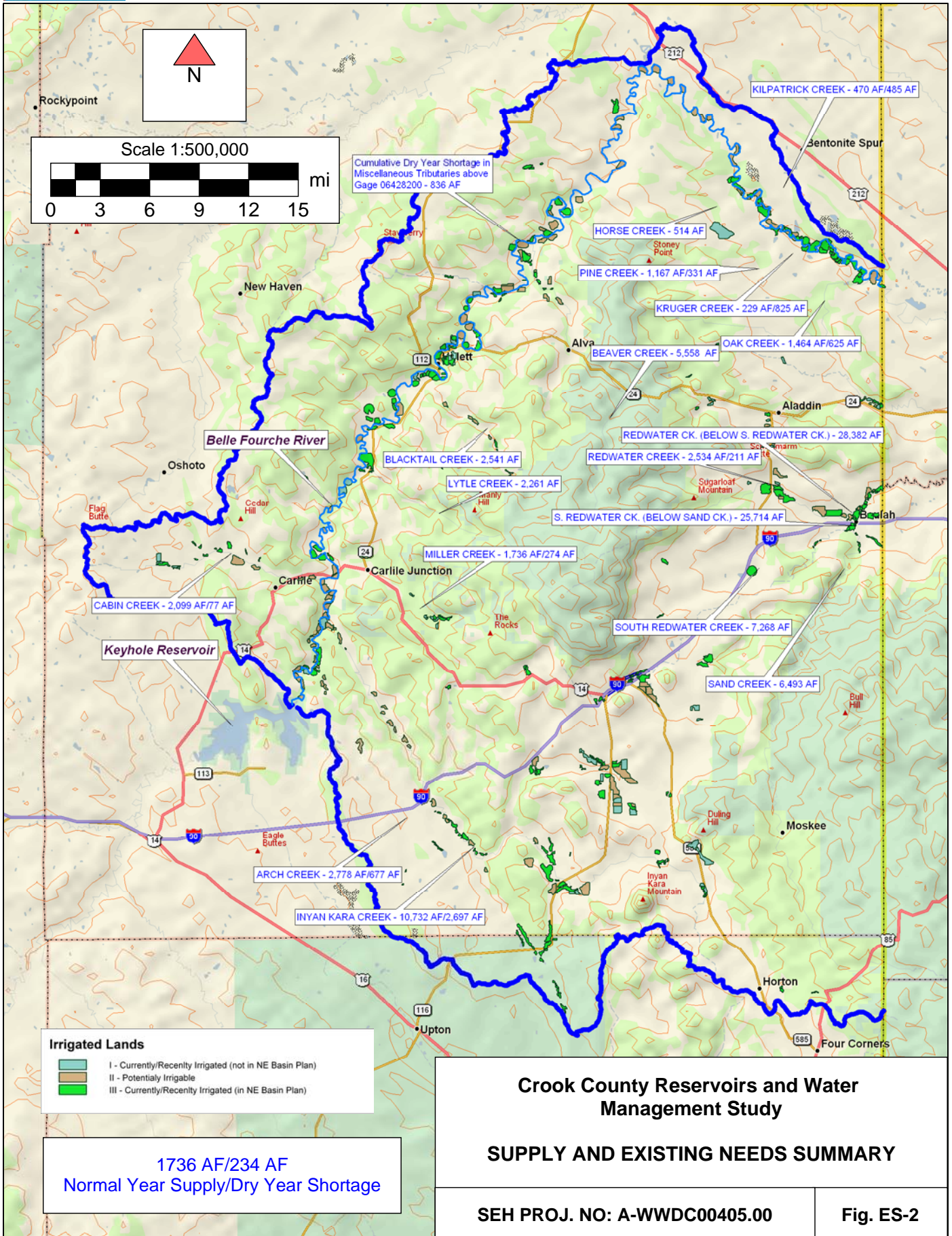


**Crook County Reservoirs and Water Management Study**

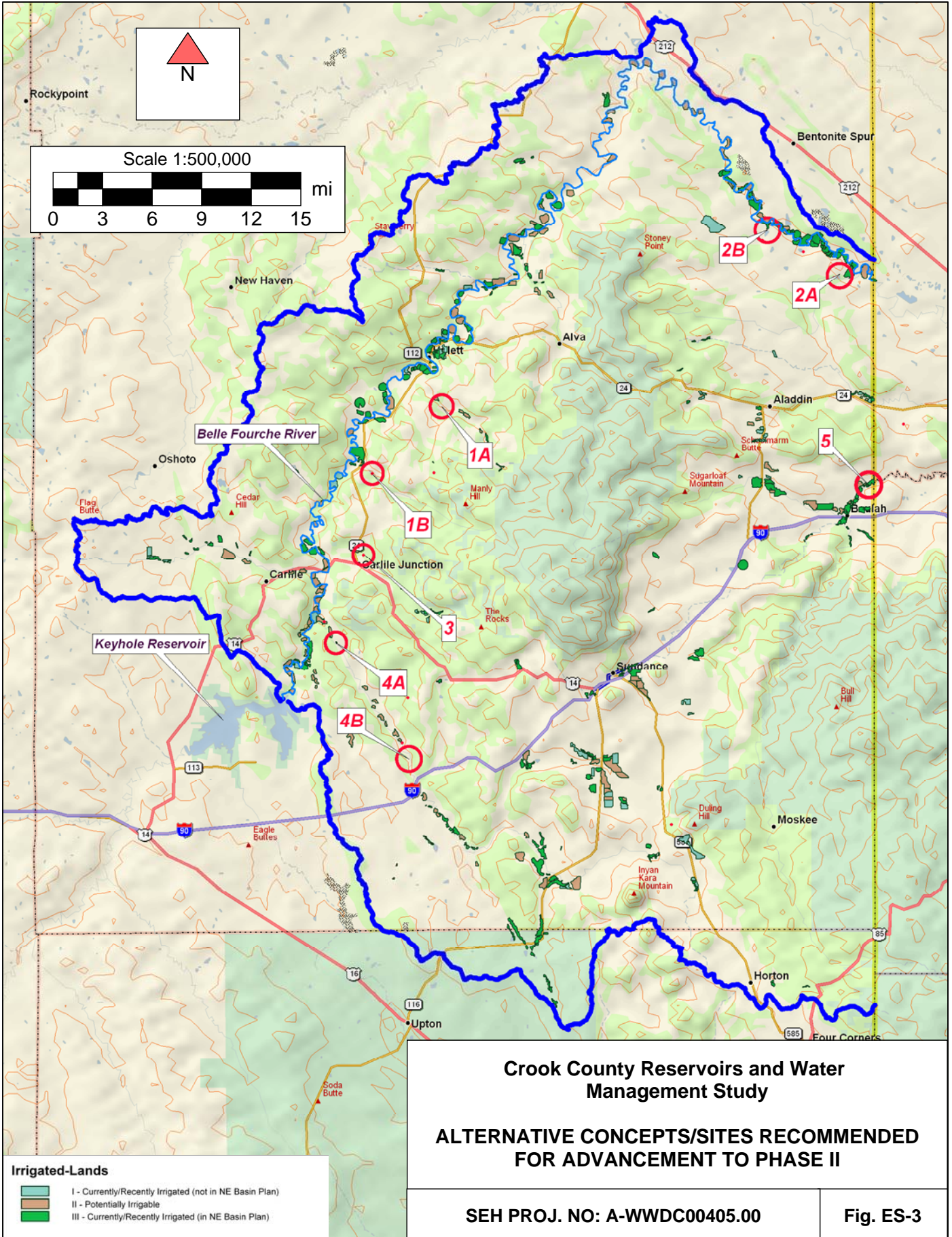
**LOCATION MAP**

|                              |           |
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