PHASE 2 COORDINATED FACILITIES WATER AVAILABILITY STUDY FOR THE ENDANGERED FISHES OF THE UPPER COLORADO RIVER

FINAL REPORT

September 2003

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EXECUTIVE SUMMARY

The purpose of this report is to summarize the results of a reconnaissance level investigation of 19 alternatives to supply 20,000 acre-feet of water to the head of the 15-Mile Reach to help recover four species of endangered fish in the Colorado River in Colorado pursuant to the Programmatic Biological Opinion (PBO) for the 15-Mile Reach. This investigation is in response to the findings, conclusions and recommendations of the Phase 1 report for this project, *Phase 1 Coordinated Facilities Water Availability Study for the Endangered Fishes of the Upper Colorado River* (Colorado Water Conservation Board, September 2000). These 19 alternatives include:

1. **Expanded Coordinated Reservoir Operations**
   - Alternative 1a: Green Mountain Reservoir reduced winter power operations.
   - Alternative 1a: Green Mountain Reservoir conjunctive pool operations.
   - Alternative 1a: Preemptive release and water carried over in Green Mountain Reservoir.
   - Alternative 1b: Ruedi Reservoir modified operations.
   - Alternative 1d: Modify Colorado-Big Thompson (CBT) west slope facilities operations.
   - Alternative 1e: Denver Water system modified operations.
   - Alternative 1f: Bypass diversions to storage.
   - Alternative 1g: Reduce constraints on Coordinated Reservoir Operations Program (CROPS).

2. **Efficiencies of Conveyance and Distribution Facilities**
   - Alternatives 3d and 3e investigated as components of 1a: Re-analysis of Grand Valley Project (GVP) and analysis of Grand Valley Irrigation Company (GVIC) water management for additional efficiency as a component of Alternative 1a, Green Mountain Reservoir operations.

3. **New Storage Projects**
   - Alternatives 4f, 4g, 4k, 4n, and 4o: New tributary storage facilities below Shoshone Power Plant.
   - Alternative 4m: New mainstem storage facility.

4. **Power Plant Operations and Scheduling**
   - Alternative 5a: East slope power operations and scheduling, investigated as a component of Alternative 1d: CBT west slope facilities operations.
   - Alternative 5b: Shoshone Power Plant.

5. Other Alternatives

- Alternative 6a: Insurance Pool.

The methodology used in the analyses, together with the results and conclusions from this investigation are summarized in this report. Detailed analysis methodology, results and conclusions are presented in a series of eleven Technical Memoranda that are included in the Appendices.

GENERAL RESULTS, CONCLUSIONS AND RECOMMENDATIONS

The findings, conclusions and recommendations listed below concerning feasibility of the alternatives are the result of using a monthly hydrology model called StateMod and the C1 Data Set as agreed to by the Executive Committee at the start of the study process. It was realized that perspectives and model analysis might differ from the perspectives and model analysis of some Executive Committee members and the water conservancy districts, water suppliers and water users who may be affected by these alternatives.

In reality, reservoir operators will not preemptively release water from their reservoir(s) unless one of two conditions exists: 1) the operator, based upon real time snow pack and runoff knowledge, determines that it is highly likely the reservoir will fill and spill or 2) the operator has access to an "insurance pool" of water in case a preemptive release results in the loss of water to the reservoir. The first condition is basically what occurs in the CROPS and cannot be counted as a new alternative. The second condition is the most promising alternative for meeting the 20,000 acre-foot goal through use of existing reservoirs. While these conclusions are somewhat different than a reader might deduct by solely reading the study, the study participants agreed that it was important, in furtherance of the commitments in the PBO, to list the following study results for documentation purposes:

1. Supplying 20,000 acre-feet to the 15-Mile Reach was not required every year. It was necessary to supply the 20,000 acre-feet in only six years (1975, 1978, 1979, 1980, 1985 and 1986) and possibly 1982 and 1991 for a total of eight years out of the 17 years during the 1975-91 study period.

2. Supplying the 20,000 acre-feet was not required during the very dry years of the study period. For example, releases were not required in 1977 or 1981. Further analysis indicates that supplying the 20,000 acre-feet would not have been required in 2001 and 2002. It is also important to recognize that there is a fundamental difference between what a monthly hydrology model calculates is possible and what reservoir operators will actually agree to do after dry years. For example, no reservoir operator would allow non-required reservoir releases in years following dry years - like 1978 or 1982 - until it was demonstrated that the reservoir would fill, regardless of the fact that the model indicates this type of release could be accomplished. The difference in the projected availability of releases and the reality of available releases is because the model has "perfect knowledge" on when the reservoir would refill - reservoir operators do not. Because the model indicates that supplying the 20,000 acre-feet in dry years is not required, it provides reservoir operators some comfort that firm yield would not be impacted.

3. Based on the results of sensitivity analysis, it appears that it should be possible to make the CROPS bypasses and the 20,000 acre-feet release and have only limited effects on junior water rights.

4. Results of sensitivity analysis indicate that if an alternative is feasible under the current conditions of the C1 Data Set, it is likely to remain feasible under future flow conditions in which there would be up to approximately 120,000 acre-feet of additional depletions.

5. Sensitivity analysis on estimated CROPS bypasses, reduced Grand Valley Project demands, Palisade Pipeline bypasses and the Shoshone Power Plant maintenance schedule indicates continued feasibility of the alternatives investigated in the Technical Memoranda**.** Sensitivity analyses involving these parameters indicate there would be little effect on availability of Green Mountain Reservoir storage for making the 20,000 acre-feet release from CROPS bypasses, reduced Grand Valley Project demands, Palisade Pipeline bypass flows and the Shoshone Power Plant maintenance schedule. Including CROPS bypasses, however, would not always leave sufficient release capacity through the Green Mountain Reservoir turbines to make the 1,000 cfs Coordinated Facilities Operation Study (CFOPS) release during the 10-day peak flow. This lack of sufficient release capacity at Green Mountain Reservoir would necessitate allocating responsibility for making a portion of the 20,000 acre-feet CFOPS release to other reservoirs. The opportunity for Green Mountain Reservoir to function as an insurance pool in these situations and payback the other reservoirs could also be considered.

6. An analysis was made of the effect on Colorado River flows at the head of the 15-Mile Reach to determine if making the 20,000 acre-feet release generally during June would reduce flows during other months. Results of this analysis indicate that the maximum average monthly reduction occurred during July and reduced flows in that month by 1,048 acre-feet (295,601 acre-feet to 294,553 acre-feet).

Throughout the investigation, it was noticed that the exchanges and substitutions among Dillon, Williams Fork, and Wolford Mountain Reservoirs using the C1 Data Set in StateMod differed from the simulations by Denver Water using their daily PACSIM model. In order to address this issue, the Colorado Water Conservation Board (CWCB) modified StateMod and a fifth revision was made to the C1 Data Set. A comparison of the base runs with the C1 Data Set (fourth revision) and the modified StateMod and C1 Data Set (fifth revision) was made to determine if these changes were sufficient to necessitate redoing the previous work with the modified StateMod and C1 Data Set (fifth revision). A comparison of these two base runs indicated that a difference remained, which was increased storage in Dillon Reservoir and decreased storage in Williams Fork Reservoir. In order to further check the need for rerunning previous simulation runs with the modified StateMod and C1 Data Set (fifth revision), simulation runs for two alternatives were made: (1) Green Mountain Reservoir making the 20,000 acre-feet release and replacing this release using its refill priority and (2) the "Share the Pain" with responsibility for making the 20,000 acre-feet release divided equally among Granby, Green Mountain and Williams Fork Reservoirs. Results of these additional simulation runs did not differ significantly enough to change original conclusions presented in the Technical Memoranda concerning these alternatives. However, comparing simulations by Denver Water using its daily PACSIM model with StateMod showed differences in accounting for exchanges and substitutions into and out of

Dillon, Williams Fork and Wolford Mountain Reservoirs. These differences would overstate the availability of water for release from these reservoirs for meeting the 20,000 acre-foot goal. Rather than continue to investigate and debate the need for further refinements to the model, it was determined that time would be better spent working on what could be done to meet the 20,000 acre-foot goal.

FEASIBILITY OF EXPANDED CROPS ALTERNATIVES

From an engineering and economic perspective, the following alternatives could supply the 20,000 acre-feet to the 15-Mile Reach when required during the study period, at reasonable costs:

- Alternative 1a: Green Mountain Reservoir reduced winter power operations.
- Alternative 1a: Green Mountain Reservoir conjunctive pool operations.
- Alternative 1a: Preemptive release and water carried over in Green Mountain Reservoir.
- Alternative 1d: Modify CBT West Slope Facilities Operations.
- Alternative 1e: Denver Water system modified operations.
- Alternative 1f: Bypass diversions to storage.
- Alternative 1g: Reduce constraints on CROPS.

The StateMod model calculated that the effects of supplying the 20,000 acre-feet on reservoir storage, reservoir yield, reservoir operations, hydropower generation, water deliveries, channel constraints, and the Check Case Settlement would vary among these alternatives. These effects are briefly summarized in this report and presented in detail in the Technical Memoranda. The results discussed below and in the Technical Memoranda assume that the StateMod model accurately simulated reservoir operations in this study. Some study participants have questioned that assumption. However, the study participants agreed the studies were sufficient for their purpose and to document the results of the study in order to move on to discussing what can realistically be accomplished to meet the 20,000 acre-foot goal.

The study showed that the above alternatives were generally able to replace the 20,000 acre-feet release/bypass by diverting to storage under the reservoirs' refill rights. This replacement was generally done within a period of several months. In some cases (e.g. Granby Reservoir) the replacement was not completed for several years. In the case of Granby Reservoir, replacement of the 20,000 acre-feet release/bypass to the 15-Mile Reach was probably delayed because of limited availability of storable inflow in those years when releases were made. In general, however, replacement of the 20,000 acre-feet by diverting to storage under the reservoirs' refill rights proved to be more efficient, effective, and less costly, than some of the measures incorporated into the above alternatives for providing sources of replacement water for the 20,000 acre-feet release/bypass.

Because of this, replacement of the 20,000 acre-feet should be done by diverting to storage under the reservoirs' refill rights rather than utilizing some of the specific strategies included in the above alternatives for replacement. One issue that will have to be addressed is that most existing refill rights

are not decreed for this new use. Therefore, most of the reservoirs would require new junior refill rights for this new use.

The only Expanded CROPS alternative that the study showed was not feasible in its proposed form was Alternative 1b, Ruedi Reservoir Operations, which was not able to make the full 20,000 acre-feet release/bypass because of: (1) downstream channel constraints and (2) limited physical water availability which prevented the replacement of the 20,000 acre-feet in Ruedi Reservoir under the reservoir's refill right. For these reasons, the consultant team recommends that Ruedi Reservoir's contribution to the 20,000 acre-feet release/bypass be limited to 7,000 acre-feet or less.

The "Share the Pain" consists of Alternatives 1f and 1g. The "Share the Pain" attempts to minimize the risk to individual facilities by placing responsibility on as many facilities as possible for supplying some portion of the 20,000 acre-feet to the 15-Mile Reach. Analysis of this alternative indicates that the 20,000 acre-feet can generally be replaced in the various facilities by diverting to storage under the reservoirs' refill rights or a new refill right. The "Share the Pain" may also be necessary because of the limited release capacity at some of the reservoirs. For example, Green Mountain Reservoir was restricted from making both the estimated CROPS bypasses and the 20,000 acre-feet release in one of the eight years of the study period in which the 20,000 acre-feet release would be required.

Technical Memorandum No. 7 (Appendix H) utilized both a proportionate release among nine reservoirs, and an equal release among three reservoirs to model the "Share the Pain". A Modified "Share the Pain" was developed in which responsibility for supplying the 20,000 acre-feet release was shared among Green Mountain, Granby, Ruedi, Williams Fork and Wolford Mountain Reservoirs. Under this Modified "Share the Pain", as much of the 20,000 acre-feet was released from Green Mountain Reservoir as possible without releasing flows through the turbine bypass and releasing the remainder of the 20,000 acre-feet from other reservoirs.

FEASIBILITY OF EFFICIENCIES OF CONVEYANCE AND DISTRIBUTION FACILITIES ALTERNATIVES

Alternatives 3d, Re-analysis of Grand Valley Water Management Alternatives, and 3e, Analysis of GVIC Water Management, were analyzed as components of Alternative 1a, Green Mountain Reservoir Operations. This analysis focused on: (1) making the 20,000 acre-feet release to the 15-Mile Reach from Green Mountain Reservoir and (2) the potential for replacing this 20,000 acre-feet in Green Mountain Reservoir by accruing "savings" to the Historic Users Pool (HUP) through increased GVP and GVIC efficiency.

Analysis of this alternative indicated that diverting to storage under the Green Mountain refill priority was a more efficient way to replace the 20,000 acre-feet supplied to the 15-Mile Reach than attempting to make this replacement with reduced demand for releases from the Green Mountain HUP. Furthermore, based on the analysis using StateMod and the C1 Data Set, there was limited reduced demand on the HUP as a result of increased GVP efficiency. Therefore, it appears that this alternative would be a more efficient and effective source of supply for making releases to the 15-Mile Reach during the late summer and early fall than for releases during the spring peak flows.

FEASIBILITY OF NEW TRIBUTARY STORAGE PROJECTS BELOW SHOSHONE

The alternatives for building new tributary storage (Alternatives 4f, 4g, 4k, 4n and 4o) are all costly, due primarily to the limited physical supplies of water available from the tributaries and the need to depend on pumping from the mainstem Colorado River to supply water to most of these proposed reservoirs. However these new reservoir sites should be considered further if the reliability and frequency to provide the 20,000 acre-feet of water from existing reservoirs is not sufficient to meet the Programs needs. This alternative should also be considered in coordination with other possible reservoir storage projects that water users need to provide the 10,825 acre-feet of late summer and fall base flow releases for the Program. The economy of scale of building a new reservoir to provide both the 10,825 acre-feet and the 20,000 acre-feet could make a new tributary reservoir more attractive.

FEASIBILITY OF NEW MAINSTEM STORAGE PROJECT

An additional engineering and economic feasibility investigation of the mainstem Webster Hill site was completed in Technical Memorandum No. 4a (See Appendix E). The cost of reservoir storage at this site for making the 20,000 acre-feet release to the 15-Mile Reach would be partially offset by the generation of hydropower. Net capital costs per acre-foot of yield from the Webster Hill Reservoir would range from $29 to $134/acre-foot of yield per year depending on the assumed value of hydropower produced at the site. Results from this additional investigation further indicate that this site would likely be feasible if: (1) the necessary right-of-way can be obtained at reasonable cost and (2) the U.S. Fish and Wildlife Service (Service) would approve construction of a reservoir at the Webster Hill site, which would be located in the upper end of the currently designated critical habitat.

The Webster Hill Reservoir would produce a firm yield of 20,000 to 40,000 acre-feet per year. It is important to emphasize that the 20,000 acre-feet release would be available from Webster Hill Reservoir even in dry years when this release would not be required. Therefore, the Webster Hill Reservoir alternative would produce yield with a greater reliability than is required. It makes sense as a next step to analyze the economy of scale of building Webster Hill Reservoir to provide both the 10,825 acre-feet committed by the water users and the 20,000 acre-feet that is the subject of this study.

FEASIBILITY OF POWER PLANT OPERATIONS AND SCHEDULING ALTERNATIVES

Alternative 5a, East Slope Power Operations and Scheduling, was investigated as one component of Alternative 1d, CBT West Slope Facilities Operations. This alternative primarily consisted of: (1) delaying winter deliveries through the Adams Tunnel, (2) using these delayed winter deliveries to replace the release/bypass of the 20,000 acre-feet from Granby Reservoir to the 15-Mile Reach and (3) replacing the delayed deliveries to east slope reservoirs by diversions to storage in these reservoirs under the east slope priorities.

Alternative 5a was not modeled because:

- This alternative cannot be fully investigated using StateMod and the C1 Data Set. StateMod and the C1 Data Set only cover the Colorado River basin in Colorado and

do not presently extend to east slope facilities and systems. Specifically, StateMod and the C1 Data Set cannot be used to determine the quantity of deliveries through the Adams Tunnel that could be replaced through use of Northern Colorado Water Conservancy District's (NCWCD) east slope water rights.

- The Bureau of Reclamation in its October 12, 2001 letter to the Colorado River Water Conservation District (River District) concludes that it is not feasible for a number of reasons to delay winter and early spring deliveries of west slope water to the east slope via the Adams Tunnel in order to keep east slope reservoir storage relatively low.

Alternative 1d was found to be an apparently feasible alternative for supplying the 20,000 acre-feet from Granby Reservoir without the possible source of replacement water resulting from Alternative 5a. It should be noted, however, that at certain elevations, the release rate from Granby is not sufficient to release 1,008 cfs (20,000 acre-feet over 10 days) (Don Carlson, NCWCD's March 5, 2003 comment letter on Draft Phase 2 Report). For Granby to participate in releases, a maximum amount should be identified because of outlet capacity restrictions.

Alternative 5b, Shoshone Power Plant, focused on general, not selective, removal of the Shoshone Power Plant priority call. Analysis of this alternative indicated that general removal of this priority call would result in an increase in stored water in those reservoirs, which could supply the 20,000 acre-feet to the 15-Mile Reach; thereby reducing the risk of lower storage and/or lower reservoir yields accruing to those reservoirs. Elimination of the Shoshone priority call decreased the value of Shoshone power production by an average of approximately $116,000 per year. Therefore, it appears that Alternative 5b could be an efficient and effective component of Alternative 6a, Insurance Pool, discussed below. Further sensitivity analysis of this alternative was completed to determine the effects of removing the Shoshone priority call on November through April Colorado River flows at the head of the 15-Mile Reach. Results of this analysis indicate that the average monthly reduction in flows at the head of the 15-Mile Reach was approximately 6 cfs.

FEASIBILITY OF OTHER ALTERNATIVES

Alternative 6a, Insurance Pool, would establish an insurance pool to reduce the risk of lower storage and yields to individual facilities providing all or a portion of the 20,000 acre-feet to the 15-Mile Reach. Two possibilities for establishing an insurance pool were considered and investigated:

- Increasing the number of facilities providing a portion of the 20,000 acre-feet to the 15-Mile reach spreads the risk among a larger number of facilities. Allocating responsibility for the 20,000 acre-feet release among several reservoirs is necessary because of limited release capacity in Green Mountain Reservoir, which prohibits Green Mountain Reservoir from making both the CROPS bypass and the 20,000 acre-feet release in six of the eight years of the study period in which the 20,000 acre-feet release would be required.
- Removing the Shoshone priority call in those years in which the 20,000 acre-feet would be supplied to the 15-Mile Reach provides replacement water for storage in those facilities supplying the 20,000 acre-feet release.

Either of these possibilities, or a combination of the two, might provide the basis for an effective insurance pool.

A third, and perhaps the most promising insurance pool concept, was identified late in the comment process for the study. The insurance pool could be provided by the Service's Environmental Pools: first from Ruedi Reservoir, and second from Wolford Mountain Reservoir. Each year, the Service would determine whether peak flow augmentation in the spring or low flow augmentation in the fall was the best use of water from the Environmental Pools. If the Service decided on or about May 1st of the year that peak flow augmentation was the best use of a portion or all of water from the Environmental Pools, the Service would designate up to 20,000 acre-feet of the water as the insurance pool for preemptive releases from existing reservoirs to augment peak flows in the spring. That way, operators of existing reservoirs would have virtually no risk to yield from their reservoirs if they preemptively released water from those reservoirs. By way of example, if Denver Water released 10,000 acre-feet from Williams Fork Reservoir for peak flow augmentation and the runoff was not sufficient to refill Williams Fork Reservoir, a 10,000 acre-foot exchange or substitution would occur from Ruedi or Wolford Mountain Reservoirs to make up for the lost water to Williams Fork Reservoir. However, if Williams Fork Reservoir did fill after a preemptive release, the Service could use that 10,000 acre-foot insurance pool for low flow augmentation later in the fall.

EXECUTIVE COMMITTEE RECOMMENDATION

The Executive Committee of the Coordinated Facilities Operation Study (CFOPS) recommends the following two alternatives for spring peak-flow augmentation to benefit endangered fishes in the 15-mile reach of the Colorado River.

Recommendation 1: Maximize Coordinated Reservoir Operations (CROPS) - As documented in the 1997 CFOPS report, the CROPS process was developed by a group of cooperating agencies over a number of years. Its purpose is to bypass storable inflows at participating reservoirs, in a way that does not impact a reservoirs' yield, to increase the magnitude of the peak flow through the 15-mile reach in years when the predicted peak flow at the Cameo gauge is greater than 12,900 cfs, but not likely to exceed 26,600 cfs or otherwise cause flooding concerns. CROPS were first implemented in 1997, and the process has demonstrated success in 1997, 1998, and 1999. This process should be continued as the primary means of augmenting the spring peak in the 15-mile reach, and efforts should be made to encourage increased participation in the process.

Recommendation 2: Augment the spring peak by using up to 20,000 acre-feet of stored water in addition to CROPS - The Service and Upper Colorado River Basin Recovery Program (Recovery Program) may determine that in certain years additional peak-flow augmentation would be desirable above and beyond what can be accomplished through CROPS. Under this scenario, up to 20,000 acre-feet of stored water would be released from existing reservoirs for that purpose in addition to CROPS. The amount of water released from storage in those years would depend on the size of an insurance pool of water that would be designated by the Service on or about May 5, from existing Environmental Pools in Ruedi, Green Mountain, Wolford Mountain, and Williams Fork reservoirs (which are now used solely for summer/fall base-flow augmentation). In any given year, the insurance pool would ensure that releases of stored water from the specified reservoir(s) for peak-flow augmentation would not jeopardize that (or those) reservoir's water supply yield. If the specified reservoir(s) re-fills and the insurance pool water is not used to offset reservoir shortages, then all Environmental Pool water would be available for base-flow augmentation. The Environmental Pool will only be reduced to the extent of a shortage in the filling of the specified reservoir(s) caused by the

peak flow release. The ability to implement this recommendation depends on successfully addressing the institutional issues and uncertainties discussed in the report. The effectiveness of CFOPS for peak flow enhancement and its impact on the Service's Environmental Pool, its operation in coordination with CROPS, and all institutional issues will be assessed and reported annually.

Reservoir Storage: In addition to the two recommendations above, the CFOPS study identified a mainstem reservoir alternative at Webster Hill, just downstream from the City of Rifle, that could have multiple benefits and provide greater certainty of instream flow augmentation to benefit the endangered fishes. Although new storage to provide water for only the 20,000 acre-feet peak-flow augmentation was found to be expensive in the CFOPS study, a multi-purpose storage project, possibly including run-of-the-river hydropower and other water supply and recreation functions, may be much more cost effective and provide added benefits for endangered fish and their habitat as well. At some point in the future the water users may conduct an independent feasibility study of options for a multi-purpose reservoir to provide water for both 20,000 acre-feet of peak-flow augmentation and 10,825 acre-feet for base-flow augmentation. The feasibility study would be funded outside the Recovery Program and address a set of environmental questions and criteria provided by the Service, which would include among other things measures of direct adverse impacts to endangered fish and their habitat. Upon completion of the feasibility study, the Recovery Program would consider whether or not to participate in the proposed multi-purpose project. If the Program wished to participate in the proposed multi-purpose reservoir project, further negotiations would be required to determine the level and means of Program participation.

POLITICAL AND INSTITUTIONAL ISSUES ASSOCIATED WITH IMPLEMENTATION OF THE EXECUTIVE COMMITTEE RECOMMENDATIONS

Executive Committee Recommendation No. 1, Maximize CROPS, is an expansion of the existing CROPS program, no new issues associated with this alternative were identified that would hinder the expansion of this program.

There are, however, several potential issues associated with implementation of Executive Committee Recommendation No. 2. Some of the reservoirs, e.g. Ruedi and Green Mountain, operate under federal authorizing legislation and operating criteria. Other reservoirs, e.g. Wolford Mountain and Williams Fork, operate pursuant to federal and local permits or licenses, such as federal rights of way or local 1041 permits. These authorities define purposes and prescribe limitations on the use and operation of these facilities. Additionally, all of the reservoirs operate under state water right decrees that define the purposes for which water may be stored and released. Before further considering implementation of the Executive Committee recommendation, the implementing agencies should undertake a joint analysis of the legal issues associated with this recommendation. For example, implementing the recommendation may require amending authorizing legislation, operating criteria, permits, or licenses, or may require changes of water rights or new water rights decrees, or may require new or amended contracts. Additionally, implementation of the recommendation may entail compliance processes with the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA). These issues may apply both for using each of the reservoirs that would make releases for augmenting the spring peak by using up to 20,000 acre-feet of stored water in addition to CROPS, and for providing an insurance pool to release stored water for replacement purposes to other reservoirs.

CHAPTER 1

INTRODUCTION AND PURPOSE

1.1 PURPOSE

The purpose of this investigation is to summarize the results of a feasibility investigation of 19 alternatives to supply 20,000 acre-feet of water to the head of the 15-Mile Reach for purposes of recovering four species of endangered fish in the Colorado River in Colorado. This investigation is in response to the findings, conclusions and of recommendations of the Phase 1 report for this project, *Phase 1 Coordinated Facilities Water Availability Study for the Endangered Fishes of the Upper Colorado River* (Colorado Water Conservation Board, September 2000). These 19 alternatives include:

1. Expanded Coordinated Reservoir Operations

- Alternative 1a: Green Mountain Reservoir reduced winter power operations.
- Alternative 1a: Green Mountain Reservoir conjunctive pool operations.
- Alternative 1a: Preemptive release and water carried over in Green Mountain Reservoir.
- Alternative 1b: Ruedi Reservoir modified operations.
- Alternative 1d: Modify Colorado-Big Thompson (CBT) west slope facilities operations.
- Alternative 1e: Denver Water system modified operations.
- Alternative 1f: Bypass diversions to storage.
- Alternative 1g: Reduce constraints on Coordinated Reservoir Operations (CROPS).

2. Efficiencies of Conveyance and Distribution Facilities

- Alternatives 3d and 3e investigated as components of 1a: Re-analysis of Grand Valley Project (GVP) and analysis of Grand Valley Irrigation Company (GVIC) water management for additional efficiency as a component of Alternative 1a, Green Mountain Reservoir operations.

3. New Storage Projects

- Alternatives 4f, 4g, 4k, 4n, and 4o: New tributary storage facilities below Shoshone Power Plant.
- Alternative 4m: New mainstem storage facility.

4. Power Plant Operations and Scheduling

- Alternative 5a: East slope power operations and scheduling, investigated as a component of Alternative 1d: CBT west slope facilities operations.

- Alternative 5b: Shoshone Power Plant.

5. Other Alternatives

- Alternative 6a: Insurance Pool.

The methodology used in the analyses, together with the results and conclusions from this investigation, are summarized in this report. Detailed analysis methodology, results and conclusions are presented in a series of twelve Technical Memoranda that are included in Appendices A through L. Executive Committee comments regarding the draft Phase 2 Report study findings are included in Appendix M.

1.2 GENERAL

Providing 20,000 acre-feet of supplemental water is an identified element of the *Final Programmatic Biological Opinion* (PBO) (U.S. Fish and Wildlife Service, December 20, 1999). The PBO specifies actions designed to offset the impacts of all water depletions that have historically occurred, and a specified level of depletions (up to 120,000 acre-feet) that will occur in the future, upstream from the lower terminus of the 15-Mile Reach. Persons or entities with projects upstream from the 15-Mile Reach requiring a federal permit or federal action that would invoke the jurisdiction of the U. S. Fish and Wildlife Service (Service) under §7 of the Endangered Species Act (a "federal nexus"), may rely on actions identified in the PBO as a Reasonable and Prudent Alternative (RPA) to avoid jeopardy to, or adverse modification of critical habitat for, the four Colorado River fish species listed under the Act.

The PBO identifies the 15-Mile Reach as important for the survival and recovery of the listed species. The PBO also identifies providing adequate flows in the 15-Mile Reach, in combination with other recovery actions, as important to achieving recovery of the listed species. In particular, with regard to this report, the Service has identified enhancement of spring peak flows in the 15-Mile Reach as assisting in habitat formation and maintenance. The Service identified target peak flows in the 15-Mile Reach of 12,900 to 26,600 cfs as important to mobilize gravel/cobble substrate. Management activities to enhance spring peak flows are expected to result in an increased frequency of years in which flows exceed 12,900 cfs. The Service has also identified enhancement of flows in the late irrigation season (July through October) as important because flows in the 15-Mile Reach are significantly reduced by agricultural operations in the Grand Valley.

One of the management elements identified in the PBO is the subject of this report. The PBO states:

> *"The intent is to provide additional water up to approximately 20,000 acre-feet per year of water for spring peak flow enhancement, without diminishing project yield or causing project sponsors to incur significant costs. When additional water of approximately 20,000 acre-feet is available, it will provide 1,009 cfs per day for a 10 day period."* (U.S. Fish and Wildlife Service, 1999, p. 11)

In preparing this report, the consultant team has worked closely with, and incorporated input from, an Executive Committee representing a broad set of interests participating in the Upper Colorado River Basin Recovery Program (Recovery Program). The Executive Committee consists of the following: (1) one representative from the Colorado Water Conservation Board (CWCB) who serves as the Executive Committee's primary point of contact with the consultant team and who chairs the

Committee; (2) one representative from the U.S. Bureau of Reclamation (Reclamation); (3) one representative from the Service; (4) two representatives from the water user community (one east slope and one west slope); and (5) one representative from the environmental community. The Executive Committee has sought advice and input from a Steering Committee, which consists of a broader array of interests in the Recovery Program. The consultant team and the CWCB made drafts of this report available to the Executive Committee and any other interested person. In addition, the consultant team and the CWCB held two public meetings, in Glenwood Springs and Denver, to seek input into the study. Finally, members of the consultant team conducted numerous one-on-one interviews with various interests to verify assumptions and information, critique alternatives, and seek new alternatives.

1.3 BACKGROUND

The Service and the Recovery Program have been working on a number of initiatives to secure water to augment spring flows to the 15-Mile Reach. The Coordinated Reservoir Operations program (CROPS) was implemented as a coordinated interagency effort to provide discretionary bypasses of inflow at major reservoirs in the basin to coincide with the natural spring peak. Augmentation of the peak under CROPS can occur during slightly below average, average, and above average hydrologic conditions.

The second initiative is the Coordinated Management of Colorado Water Division 5 Facilities pursuant to the PBO, which is the subject of this report. This initiative is intended to assess water management facilities and operations that can be further managed to benefit fish habitat primarily in the spring and secondarily in the late summer and fall. The intent of the initiative is for project sponsors to secure a firm water supply for project purposes, and to utilize any flexibility that may concurrently exist to provide water for enhancement of the spring peak (U.S. Fish and Wildlife Service, December 20, 1999). The amount of water available, benefits, physical and legal constraints, and recommended options will be determined through this analysis and presented to the Recovery Program.

The following discussion of the sources and amounts of water presently available for recovery of the endangered fishes under the Recovery Implementation Program Recovery Action Plan (RIPRAP) is presented in order to indicate the relationship of the 20,000 acre-feet to the other components of the Recovery Program.

1.3.1 Late Summer and Fall Base Flow Period Augmentation

The RIPRAP will provide for late summer and fall base flow period augmentation from a number of sources (U.S. Fish and Wildlife Service, April 1, 1999).

- 581 cfs instream flow right decreed to the CWCB (September 2, 1997 decree date) for the 15-Mile Reach during July, August and September. This decree protects the Orchard Mesa Irrigation District (OMID) hydraulic pump return flows and the Grand Valley Power Plant return flows from being diverted out of the 15-Mile Reach.

- 300 cfs instream flow right decreed to the CWCB for water accretions accruing to the 15-Mile Reach during July, August and September. This right provides further protection to water reaching the 15-Mile Reach from future diversions.
- 5,000 acre-feet per year of stored water is made available from Ruedi Reservoir by Reclamation in consultation with the Service and the CWCB when needed by the fish pursuant to the Ruedi Reservoir Round II Water Sales Biological Opinion.
- An additional 5,000 acre-feet in 4 out of 5 years is made available from either Ruedi Reservoir of Green Mountain Reservoir by the Bureau of Reclamation via modified reservoir operations in consultation with the Service and CWCB when needed by the fish. Protection of this 5,000 acre-feet and the 5,000 acre-feet above is accomplished pursuant to the terms of an agreement between Reclamation, CWCB and the Service which provides for the contract delivery and protection of the water to and through the 15-Mile Reach.
- An additional 10,825 acre-feet per year from Ruedi Reservoir delivered to the 15-Mile Reach under the terms of a short and/or long term lease(s) through the year 2012. In the past, Reclamation had provided 21,650 acre-feet of water annually from the unsold regulatory capacity as referred to in the Ruedi Reservoir Round II Water Sales Amended Biological Opinion (January 6, 1999). This 21,650 acre-feet annual commitment, contained in the Ruedi Reservoir Biological Opinion, will be replaced by the long-term lease of 10,825 acre-feet from Ruedi Reservoir and a 10,825 acre-feet interim/permanent commitment divided equally between other facilities serving east slope and west slope water users. All of this water is presently used for augmenting flows during the late summer and early fall periods and not for spring peak augmentation.
- Initially, the 10,825 acre-feet, which is the responsibility of the east and west slope water users to supply, will be provided on an interim basis for a period up to 10 years or until permanent contracts are signed for delivery as needed by the fish, whichever occurs first. Colorado's water users will determine which facilities will provide the water and will execute necessary agreements. Until the permanent source(s) of this water are determined, two 10-year Agreements for the Interim Provision of Water to the 15-Mile Reach of the Colorado River have been entered into: (1) with the Colorado River Water Conservation District (River District), (Colorado River Water Conservation District and Colorado Water Conservation Board, 2000), and (2) with Denver Water (Denver Water and Colorado Water Conservation Board, 2000).

  Both agreements involve the CWCB and the Service on behalf of themselves and other water users. Under the agreement with the River District, the River District will release 5,412.5 acre-feet of water per year. The primary source of water will be Wolford Mountain Reservoir (West Slope Pool) and unused Ruedi, Round I and Round II contracted water.

  Under the Denver Water agreement, Denver Water will release 5,412.5 acre-feet per year. Denver Water's primary source of water will be Williams Fork Reservoir (subject to drought provisions). Denver Water may also use Wolford Mountain Reservoir (Denver Water's Pool, subject to drought provisions), Dillon Reservoir, and Homestake Reservoir.

The interim agreements take 5,412.5 acre-feet from Williams Fork Reservoir and 5,412.5 acre-feet from Wolford Mountain Reservoir with options to go to Ruedi Reservoir under certain conditions.

- 6,000 acre-feet of reservoir storage space in Wolford Mountain Reservoir to benefit endangered fish habitat pursuant to the Wolford Mountain Reservoir Biological Opinion. Protection of releases of this water is accomplished pursuant to the terms of the Wolford Mountain Reservoir Biological Opinion and an agreement among the River District, CWCB and the Service.
- Up to an estimated 28,400 acre-feet of water on an average annual basis resulting from construction of improved water management features for the Grand Valley Water Management Project. This project consists of adding seven new check structures to the canal system, automation of the checks and other structures, construction of the 1,000-foot Palisade Pipeline and the construction of the Highline Lake Pumping Station. Much of this water will exist and be managed as surplus Historic User Pool (HUP) water in Green Mountain Reservoir.
- Legal protections for delivery of surplus HUP water and water made available by the Grand Valley Water Management Plan will be accomplished in two phases.

    1. Protect water up to the capacity of the Grand Valley Power Plant pursuant to the Orchard Mesa Check Settlement. This water is protected by a contract agreement, which will ensure its delivery to the Orchard Mesa Power Plant and the head of the 15-Mile Reach after release from Green Mountain Reservoir.
    2. Additional legal mechanisms to protect surplus HUP water in excess of paragraph (1) above will be developed and will be available for enhancement of flows in the 15-Mile Reach as a result of the Grand Valley Water Management Project. In order to work within the confines of State of Colorado water law, a municipal recreation contract with the City of Grand Junction, City of Fruita and Town of Palisade has been entered into. This contract would protect releases of surplus water from the Green Mountain HUP in excess of the capacity of the Orchard Mesa Power Plant to and through the 15-Mile Reach for municipal recreational purposes.

1.3.2 Spring Peak Enhancement

CROPS is a voluntary program that coordinates operations and bypasses of water from various water facilities to enhance flows to the 15-Mile Reach during the peak spring runoff period. The Recovery Program implemented CROPS in 1997 and augmented spring peak flows by approximately 2,000 cfs in that year; in 1998, CROPS added approximately 2,400 cfs to the peak and in 1999 an estimated 2,500 cfs was added to the peak (Smith and Wilson, 1999). No CROPS activities were conducted in 2000 and 2001 due to low snow pack and concerns about reservoir storage, although a peak in the range of 13,500 cfs did occur in 2000 because of rapid snow melt.

CHAPTER 2

GROUND RULES, ASSUMPTIONS AND ANALYSIS PROCEDURES

2.1 INTRODUCTION

The Executive Committee and the consultant team established ground rules in Phase 1 under which the feasibility investigation of alternatives for supplying an average of 20,000 acre-feet of water in those years when the forecast spring peak flows are between 12,900 cfs and 26,600 cfs would proceed. The Executive Committee and the team also identified assumptions that are necessary to facilitate the study. The purpose of this section is to detail the ground rules and assumptions that have been made for this investigation and to provide explanation and justification for them. The frequency and certainty with which the 20,000 acre-feet will be made available is detailed in the Flow Targets section below.

2.2 GROUND RULES

2.2.1 Administration

Recommended alternatives from this investigation do not need to include recommendations for a mechanism for administration or legal protection of water released or otherwise supplied during the spring peak to the head of the 15-Mile Reach. This is because there is unappropriated water available during the spring peak in years when flows at the head of the 15-Mile Reach are in the range of 12,900 to 26,600 cfs. From an administrative standpoint, the river is under "free river" conditions, and therefore administration of flows past intervening water rights is currently unnecessary. As specified in the PBO, any new depletion during this period of the year may be covered under the PBO. For the same reason, the conversion of water rights to instream flows in order to protect and convey flows to the head of the 15-Mile Reach during the spring peak will not be considered further.

With regard to the secondary study purpose of providing flows in the late irrigation season, potential administrative mechanisms will need to be identified to protect the water to and through the 15-Mile Reach because the river is generally on call during that time of the year.

During Phase 1, the issue of how bypassed diversions to storage would be administered has been discussed. Several alternatives for administration exist:

- Bypassed diversions to storage would be credited toward a "paper fill" of the reservoir and the reservoir would attempt to achieve a subsequent physical fill using a junior refill right. This is essentially the administration agreed to by the SWAT team and used to decree the Clinton Gulch, Green Mountain and Dillon refills.
- Bypassed diversions to storage would not be credited toward a paper fill under an administrative policy such that bypasses are regulatory in nature and the reservoir would attempt to fill later under its own priority.

- Bypassed diversions to storage would not be administered toward a paper fill of the reservoir, but would be administered in Division 5 only, and under the PBO, as a voluntary bypass that would not count against the fill of the reservoir.

These matters were discussed with the State Engineer (James Lochhead personal communication with Hal Simpson, February 15, 2000) with the following outcome:

- These three potential administration policies could be further analyzed and included in modeling studies. The effect of change in administration and using a junior refill right could be modeled by assigning a junior priority date to the particular facility one day junior to the applicable storage right. The facility will then continue its fill under that right after the primary storage right has been accounted as "full." The sensitivity analysis will be made by comparing this operation to a model run without the assigned junior priority.
- The various alternatives that involve bypassing diversions to storage could also be modeled with the alternative policies detailed above to determine the effects of the alternative policies on other water rights and facility operations. Where possible, the costs associated with these effects could be estimated.
- The results of these investigations and modeling studies could then be considered further by the State Engineer in developing the administration policy that will be used for bypassed diversions.

This matter of how bypassed diversions to storage will be administered has not been resolved in Phase 2. Full resolution of these matters is outside the scope of Phase 2 of the Coordinated Facilities Operations Study.

2.2.2 No Restrictions on Alternatives Investigated

In the Phase 1 investigation, consideration of all alternatives was permitted; no alternatives were summarily eliminated from investigation solely because of stakeholder opposition.

The focus of the alternatives is primarily on the re-operation of water management and storage facilities located within the Upper Colorado River Basin, the inter-related hydropower operations of east and west slope facilities, and the construction of new facilities, in order to determine the feasibility of obtaining water for the endangered fishes from these sources in accordance with the original scope of work for this investigation (Colorado Water Conservation Board, October 2, 1998). Improved conveyance facilities and efficiencies were considered with respect to canals, but actual on-farm practices were not considered as an alternative to be investigated by this study.

2.2.3 Evaluation and Screening Criteria

Participants in this Phase 1 investigation indicated the importance of three criteria for evaluating and screening alternatives:

- Reduction in existing projects' yields is not to occur,
- Existing projects' operations and maintenance costs should not be increased, and
- Existing projects operational flexibility, and/or reliability are not to be affected.

Analysis has been completed in Phase 2 to help quantify these evaluation criteria for the alternatives to supply the average annual 20,000 acre-feet.

2.2.3.1 Impact on Existing Projects' Yields. The term "yield" is used in this investigation to indicate the historic yield of a project under historic hydrologic conditions and does not refer to the decreed yield of the project's water right. In Phase 2 of this investigation, extensive analysis has been completed to determine the effect, if any, of implementing the alternatives described in this report on existing projects' yields and storage. These effects were determined by comparing hydrologic model simulations with and without the proposed alternatives.

2.2.3.2 Effect on Existing Projects' Operations and Maintenance Costs. Analysis of effects of alternatives on existing projects' operations and maintenance costs has been completed as part of this investigation in those situations where operations and maintenance costs could be affected.

2.2.3.3 Effect on Existing Projects Operational Flexibility or Reliability. Analysis of effects of alternatives on existing project operational flexibility or reliability has been completed as part of this investigation in those situations where operational flexibility or reliability could be affected.

2.2.4 RIPRAP Alternatives

The feasibility of expanding or modifying certain of the RIPRAP alternatives as listed in the PBO and the Recovery Implementation Program (U.S. Fish and Wildlife Service, December 20, 1999) was considered and these alternatives were investigated. Yield available from a specific modification and/or expansion of the RIPRAP alternatives is counted toward meeting the 20,000 acre-feet target if (1) this yield was in addition to the yield of the original RIPRAP alternative and (2) the modified/expanded alternative would not diminish the yield of the original RIPRAP alternative.

2.2.5 Incentives for Participation

Participation in actions identified in the PBO is voluntary. The PBO examined both existing and future depletions on the Colorado River and its tributaries upstream of the confluence of the Gunnison River associated with Federal, State, and private projects which rely on, or will rely on, the Recovery Action Plan (RAP). The Service believes that these RAP items are sufficient to avoid the likelihood of jeopardy and/or adverse modification of critical habitat from: (1) depletions occurring as of September 30, 1995 from existing individual projects, and (2) future depletions up to 120,000 acre-feet/year. Individual Section 7 consultation will still be required on specific Federal

actions, pursuant to the Endangered Species Act, to determine if they fit under the umbrella of the PBO. Federal Projects which deplete water above the 15-Mile Reach are exempt from further consultation on their depletion impacts. The following criteria must be met at the time of individual project consultation to rely on the Recovery Program and be considered under the umbrella of the PBO:

1. A Recovery Agreement must be signed prior to the issuance of a final biological opinion for an individual project.
2. A fee will be submitted as described in the PBO for new project depletions greater than 100 acre-feet/year. The fee is adjusted each year for inflation. The 2003 fee is $15.68 per acre-foot.
3. The Service will include individual incidental take statements in biological opinions for projects covered by the PBO.
4. Re-initiation stipulations will be included in all biological opinions for individual consultations under the umbrella of the PBO.
5. The Service will request that discretionary Federal control be retained for all consultations under the PBO.

Future consultations that meet the criteria would avoid the likelihood of jeopardy and/or adverse modification of critical habitat from depletion impacts. Projects that do not meet the criteria are not covered by the PBO, and therefore will require consultation outside of the Recovery Program.

Participation in the measures identified in the PBO, and in the implementation of the alternatives identified pursuant to this study to provide an annual average 20,000 acre-feet, will be strictly voluntary.

This report identifies specific facilities or property owned by public agencies and private parties. Direct communication has not in all instances occurred with those parties, particularly with regard to the preliminary identification of alternatives. Therefore, identification of alternatives is not intended to, and does not, indicate agreement to participate by the person or entity involved in the implementation of any alternative. In order for any alternative to be implemented, the affected parties must agree to implement that alternative. Specific issues and concerns with regard to participation have been identified in this report, and the report makes some recommendations concerning potential incentives for parties to participate in the implementation of identified alternatives.

Review of present policy indicates that a lack of incentives exist for entities who are not currently contemplating some action with a federal nexus. Consideration perhaps should be given to developing incentives for participation in the Recovery Program by those entities currently not proposing an action with a federal nexus. The consultant team in this report makes suggestions in this regard.

2.3 ASSUMPTIONS AND ANALYSIS PROCEDURES

2.3.1 Model

Evaluation and analysis of the various alternatives was performed using StateMod, the State of Colorado's Stream Simulation Model by determining the effects of the various alternatives on the nine major reservoirs in the Upper Colorado River Basin (see Table 1). StateMod was originally developed for the Colorado River Decision Support System (CRDSS) and is a monthly water allocation and accounting model with flexibility to become a daily model. It can be used to make comparative analyses for assessing various water management policies and practices utilized in the administration of a river basin. The model's operation is governed by basin hydrology, water rights associated with diversion and storage structures, and the operating rules used for the diversion and storage structures. StateMod uses four types of water rights: direct flow rights, instream flow rights, reservoir storage rights, and operational rights. Water rights are sorted by priority and river administration is simulated using the Prior Appropriation Doctrine.

StateMod was selected for this analysis for several reasons. It can be operated on a monthly time step that allows for fast execution and a reasonable volume of output to be analyzed. The simulations on a monthly time step will generally be adequate for assessing the impacts of potential changes to water management policies within the basin. In those cases where the impacts need to be examined at shorter time intervals, StateMod can be set up to run on a daily time step. Input to the daily version of the model can be daily data for stream flow, diversion demands, and reservoir targets, or a set of values for distributing the monthly data.

Routing of reservoir releases (lag times, etc.) is not included in either the monthly or daily model because: (1) StateMod is primarily a planning model; (2) the additional detail required to properly implement reservoir releases with a travel time component is not justified because the system would have to include some kind of forecasting to know a reservoir release is required before a reservoir demand occurs; and (3) the volume of water associated with a potential under-release that occurs by ignoring travel time before a reservoir demand is known is offset by the potential over-release that occurs after the demand is satisfied.

2.3.2 Baseline Hydrology: C1 Data Set

2.3.2.1 C1 Data Set. The PBO employs the hydrology from the C1 Data Set developed for the PBO for investigative purposes. In the C1 Data Set, irrigation demands are calculated from average irrigation efficiencies for the study period, 1975-1991. Irrigation efficiencies were calculated for CRDSS based on historic data for the Colorado River Basin in Colorado (Moore, 1999). The C1 Data Set also includes "backcasting" of 1995 water year demands throughout the entire study period for selected major structures. Average annual depletions for these existing demands are used for every year. Depletions from demands that were in place for only a portion of the 1975-1991 period were included in the C1 Data Set for the entire study period. Depletions from new demands such as Ruedi Reservoir Round 1 and 2 water sales are also included. [See Appendix F of the Final PBO (U.S. Fish and Wildlife Service, December 20, 1999) for a listing of all projects included in the backcast 1995 demand levels.]

The Service requested that the baseline hydrology should be the C1 Data Set hydrology with the existing flow-related RIPRAP projects included and the Category 2 (i.e., future) depletions excluded (Maddux, February 2, 1999 and clarification from Bob Muth to Leo Eisel, May 5, 1999). Communication with CWCB concerning the baseline hydrology indicated that this data set (C1 Data Set hydrology with RIPRAP flow related projects and without the 60,000 acre-feet or 120,000 acre-feet of future projects) was available for the Phase 2 investigation. This data set also included provision for the Green Mountain Reservoir Historic User's Pool (HUP) surplus. HUP surplus is that water which is determined to be in excess of the HUP beneficiaries needs and can be released for authorized purposes. The determination is an ongoing process during the irrigation season and surpluses are typically not available or released until late summer.

The baseline hydrology initially used for analysis purposes in Phase 2 is the 1975 through 1991 monthly flow data used in the C1 Data Set. It was originally thought that the C1 Data Set as received from the State included the RIPRAP projects as listed in the PBO and did not include the 60,000 acre-feet or 120,000 acre-feet per year of estimated depletions from new projects. Subsequent to the initial use of the C1 Data Set in the Technical Memoranda, it was determined that not all the operation rules necessary for including the RIPRAP projects were implemented (i.e. "turned on") in the version of StateMod and the C1 Data Set received from the State. As discussed in Sections 2.3.2.2 and 2.3.3, the necessary operational rules were turned on in C1 Data Set Fourth Revision to include the RIPRAP projects.

2.3.2.2 Modifications. Modifications to the original C1 Data Set as supplied by the State were necessary in order to carry out the Phase 2 analysis of the alternatives. These modifications included:

- The original C1 Data Set scenario as supplied by the State was modified by adding full reservoir targets in Green Mountain Reservoir for the months of September and October. This prevented discretionary hydropower releases until after the irrigation season but did allow releases to HUP beneficiaries, including the USA power plant. In addition, monthly demands of 20,000 acre-feet were added to diversion ID #952001 corresponding to the projected 20,000 acre-feet releases to enhance the spring runoff in the 15-Mile Reach in 1975, 1978, 1979, 1980, 1982, 1985, 1986 and 1991. Finally, any water rights were eliminated from that diversion to prevent the right from simply taking credit for water in the stream when available.
- Based on conversations with the Bureau of Reclamation, all Green Mountain Reservoir water in storage on April 1st of each year is credited to the CBT replacement pool and any remaining water is credited to the sub-pools of the 100,000 acre-feet power pool in order of priority; the Silt pool, the HUP and the Contract pool. An operational rule was added to the C1 Data Set to reflect this action in the C1 Data Set First Revision.
- The original C1 Data Set included adjudicated refill rights, as well as a free river refill right (priority number 99999.99) to allow any reservoir with available storage to store water under free river conditions, as is normal practice. Although Ruedi Reservoir has an adjudicated refill right, it was incorrectly given a priority number of 99999.99 in the C1 Data Set. The correct priority number of 47869 was used in the C1 Data Set Second Revision.

As the Phase 2 investigation progressed it was necessary to make further modifications to the C1 Data Set. The modifications are summarized in Table 2 and are further described in Appendix N. These modifications primarily involve:

- Including the reduced demands for diversion resulting from the Grand Valley Project.
- Including the maintenance periods for the Shoshone Hydropower Plant.
- Turning on the correct operating rules in StateMod to model the reduced U.S.A. Grand Valley Power Plant summer priority call.
- Turning on the correct operating rules in StateMod to model the HUP operation in accordance with the Orchard Mesa Check Settlement.
- Implementing the correct operations of fish pools in Ruedi, Williams Fork and Wolford Mountain Reservoirs.
- Turning on correct operating rules to meet USFWS and CWCB 15-Mile Reach instream flow demands.

As a result of these modifications, there are five successive C1 Data Sets:

- C1 Data Set: Data Set originally received from CWCB.
- C1 Data Set (First Revision): Used in Technical Memoranda 1 through 4.
- C1 Data Set (Second Revision): Used in Technical Memoranda 5 through 11 and for sensitivity analysis in October 2001 Draft Phase 2 Report.
- C1 Data Set (Third Revision): Used in February 2002 Draft Phase 2 Report analysis and sensitivity analysis.
- C1 Data Set (Fourth Revision): Used in March 2002 Draft Phase 2 Report analysis and sensitivity analysis.

For each data set revision after the first, StateMod runs were made to compare results obtained with the revised data set with results from the previous data set in order to determine if results had changed sufficiently to affect conclusions which were based on StateMod runs made with previous data sets. As a result of these comparisons of StateMod results, the consultant team concluded that: (1) the effects of the revised data sets were not sufficiently significant to warrant re-running all of the previous work with the revised data set and (2) conclusions based on StateMod runs using previous C1 Data Sets were valid.

Data Set revisions are further discussed in Table 2 and Appendix N.

Throughout the investigation, it was noticed that the exchanges and substitutions among Dillon, Williams Fork, and Wolford Mountain Reservoirs using the C1 Data Set in StateMod differed from the simulations by Denver Water using their daily PACSIM model. In order to address this issue, the Colorado Water Conservation Board (CWCB) modified StateMod and a fifth revision was made to the C1 Data Set. A comparison of the base runs with the C1 Data Set (fourth revision) and the modified StateMod and C1 Data Set (fifth revision) was made to determine if these changes were sufficient to necessitate redoing the previous work with the modified StateMod and C1 Data Set (fifth revision). A comparison of these two base runs indicated that a difference remained, which was increased storage

in Dillon Reservoir and decreased storage in Williams Fork Reservoir. In order to further check the need for rerunning previous simulation runs with the modified StateMod and C1 Data Set (fifth revision), simulation runs for two alternatives were made: (1) Green Mountain Reservoir making the 20,000 acre-feet release and replacing this release using its refill priority and (2) the "Share the Pain" with responsibility for making the 20,000 acre-feet release divided equally among Granby, Green Mountain and Williams Fork Reservoirs. Results of these additional simulation runs did not differ significantly enough to change original conclusions presented in the Technical Memoranda concerning these alternatives (see Chapter 3). However, comparing simulations by Denver Water using its daily PACSIM model with StateMod showed differences in accounting for exchanges and substitutions into and out of Dillon, Williams Fork and Wolford Mountain Reservoirs. These differences would overstate the availability of water for release from these reservoirs for meeting the 20,000 acre-foot goal (see Appendix O). Rather than continue to investigate and debate the need for further refinements to the model, it was determined that time would be better spent working on what could be done to meet the 20,000 acre-foot goal.

2.3.3 RIPRAP

For purposes of determining the feasibility of each alternative for contributing toward the 20,000 acre-feet, the Final PBO specified the baseline conditions of the StateMod C1 Data Set were to include the RIPRAP projects (see Appendix D of USFWS, December 22, 1999). The StateMod C1 Data Set as originally received from the State at initiation of the Phase 2 investigation did not have the following components of RIPRAP adequately incorporated into the C1 Data Set:

- 5,000 acre-feet per year from Ruedi Reservoir,
- An additional 5,000 acre-feet in 4 out of 5 years from Ruedi Reservoir or Green Mountain Reservoir,
- 10,825 acre-feet per year from Ruedi Reservoir under long-term lease,
- 10,825 acre-feet per year on a permanent basis divided equally between east slope and west slope water users. At the present time, this requirement is being met on an interim basis by Williams Fork and Wolford Mountain Reservoirs. A permanent, long term solution will have to be established in the future (see section 1.3.1). This permanent solution may not involve the same components as the interim measures.
- Up to 6,000 acre-feet per year from Wolford Mountain Reservoir, and
- Up to 28,400 acre-feet per year of water resulting from construction of improved water management features for the Grand Valley Water Management Project.

Implementation of necessary revisions to incorporate the RIPRAP projects into the C1 Data Set resulted in the C1 Data Set Fourth Revision (see Table 2).

2.3.4 CROPS

CROPS is a voluntary program, the participation in which is determined on a yearly basis. Individual participation in CROPS is dependent on conditions that are present each year, including snowpack, forecasted streamflows, and reservoir storage levels, among others. CFOPS is perceived to be a firmer

commitment, once made, as part of the Biological Opinion. CFOPS will likely be expected to operate each year that flow in the stream in the 15-Mile Reach is within the target range during the spring run-off. There is no guarantee that CROPS will actually provide water every year.

As indicated above in the Assumptions and Analysis Procedures section, the Phase 1 report indicated that CROPS would not be initially included in the baseline hydrology to be used in Phase 2, but appropriate sensitivity analysis could subsequently be completed to determine if CROPS would affect the feasibility of specific alternatives to produce the 20,000 acre-feet release. This is the procedure used in Phase 2. The CROPS releases/bypasses investigated in Phase 2 are detailed in Table 3.

2.3.5 Future Depletions

The Phase 1 report directed that: (1) sensitivity analysis will be used in a similar fashion with respect to the 120,000 acre-feet per year of future depletions, and (2) at the conclusion of investigating each of the alternatives in Phase 2, the alternative will be subjected to necessary and appropriate sensitivity analysis to determine if feasibility of the alternative is affected by including the 120,000 acre-feet per year of future depletions in the baseline hydrology.

The procedures followed in Phase 2 and the assumptions used for the sensitivity analysis include:

1. Increased average annual diversions from Dillon Reservoir via the Roberts Tunnel of approximately 50,000 acre-feet per year based on a monthly demand schedule for the study period provided by Denver Water (October 2, 2001 personal communication from Steve Schmitzer to Bruce Rindahl).

2. An average of 12,000 acre-feet per year of additional depletions at the Adams Tunnel node during April, May, June and July.

3. An average of approximately 1,000 acre-feet per year taken at Denver Water's existing points of diversion under Denver's Water existing priorities in the Fraser River system and conveyed via the Moffat Tunnel.

4. An average of 20,000 acre-feet per year of additional depletions to the Eagle River from April 15-July 15 at the Homestake Reservoir node.

5. 14,000 acre-feet per year, on a consistent basis throughout the year, of additional depletions at a node on the Colorado River immediately downstream from the confluence with the Roaring Fork. This water would be diverted under a 1960 priority.

6. 14,000 acre-feet per year, on a consistent basis throughout the year, of additional depletions at the node at the head of the 15-Mile Reach. This water would be diverted under a 1960 priority.

The sum of the above listed average annual additional depletions is approximately 111,000 acre-feet per year. Note that the estimated future depletions from each entity were in total 9,000 acre-feet less than the original estimate of 120,000 acre-feet.

2.3.6 Flow Targets

As indicated in: (1) a memo from the Service (Maddux, February 2, 1999), (2) the RIPRAP action plan (April 1, 1999), and (3) the Final PBO (U.S. Fish and Wildlife Service, December 20, 1999, pg. 11), the Service is first and foremost interested in augmenting the peak of the spring runoff hydrograph with an additional 20,000 acre-feet of water on average based on the years which the flow triggers at the Cameo gage are realized. The Service's priority is to increase spring peak flows when the peak runoff is expected to be in the range of 12,900 to 26,600 cfs at the head of the 15-Mile Reach or approximately 15,000 to 29,000 cfs at the Cameo USGS gage (Coordinated Reservoir Operations Group, 1999 and personal communication from George Smith to Leo Eisel and Sue Uppendahl, January 2000). The upper limit, 26,600 cfs, is based to some extent on downstream flooding considerations and is not totally habitat based. The Service has the objective of increasing the frequency of occurrence of flows greater than 12,900 cfs. The Service has identified target flows in the 15-Mile Reach in the range of 12,900 to 26,600 cfs because flows of this magnitude have been shown to mobilize gravel cobble substrate (U.S. Fish and Wildlife Service, December 20, 1999). The Service is not interested in increasing the peak when the actual peak or augmented peak is likely to be less than 12,900 cfs or greater than 26,600 cfs. The Service would like to see as much as possible of the average 20,000 acre-feet made available during the 7 to 10 day period surrounding the peak spring discharge.

The Service has indicated that the 20,000 acre-feet will be determined as an average volume in those years when the triggers at the Cameo gage are realized. (Smith and Muth, July 1999). In years when flows in the Colorado River at the top of the 15-Mile Reach are less than 12,900 cfs or greater than 26,600 cfs, no water will be provided. For those years when the flow is between 12,900 and 26,600 cfs, an average of 20,000 acre-feet will be provided, i.e., in some years more than 20,000 acre-feet will be provided, and in some years less.

With some alternatives it may be possible to carry over unused water to the next year for purposes of meeting the average 20,000 acre-feet target in that year.

If some portion of the average 20,000 acre-feet remains after augmentation of the spring peak discharge and this water can not be carried over for use in the succeeding spring, this water may be used for augmenting low flows during the July 15 through October 31 period. Augmentation of low flows in late summer and fall is second priority to augmenting the spring peak discharge during the 7 to 10 day spring peak period.

The following characterize the low flow target:

- During the July 15 through October 31 period, the goal will be to maintain minimum flows at the head of the 15-Mile Reach as specified by the Service (U.S. Fish and Wildlife Service, May 1995).
- During years of above average precipitation (i.e., precipitation greater than the 50th percentile), efforts would be made to maintain flows at or around 1,630 cfs.
- During years of low precipitation (i.e., precipitation less than the 50th percentile), efforts would be made to maintain flows at or greater than 1,240 cfs.
- During drought years (the lowest 20th percentile), efforts would be made to maintain flows at or greater than 810 cfs.

The Service has indicated the following priorities concerning when diversions to storage would be made (Smith and Muth, July 1999):

1. Winter,
2. Descending limb of the spring runoff hydrograph, and
3. Ascending limb of the spring runoff hydrograph.

The Service has indicated that: (1) the source of water for the 10,825 acre-feet interim/permanent commitment during the late summer and early fall will be according to the contracts recently entered into (Colorado River Conservation District and Colorado Water Conservation Board, 2000 and Denver Water and Colorado Water Conservation Board, 2000), and (2) these sources of supply are independent from sources of supply which will be used for the 20,000 acre-feet commitment to be used for augmenting spring peak flows.

2.3.7 Scoring

An acre-foot of water released or otherwise made available will be counted or credited as meeting the target flows when:

1. The flow at the head of the 15-Mile Reach is between 12,900 and 26,600 cfs;
2. The acre-foot of water would not have been available at that point in time under baseline conditions without the program and projects to provide the average 20,000 acre-feet; and
3. The acre-foot is made available during the 10-day period surrounding the peak spring flow; or
4. The acre-foot was not used in the spring, the acre-foot cannot be carried over in storage until the next spring, and the acre-foot is used to augment low flows during the July to October period.

In order to be scored as having been available, water will be scored at the source of delivery, not at the 15-Mile Reach.

Throughout this report, the term, "average 20,000 acre-feet " will be used to indicate the target for this program. It must be emphasized that this is an average of 20,000 acre-feet added to the spring hydrograph peak in those years in which the forecast flow at the head of the 15-Mile Reach is between 12,900 and 29,600 cfs. The calculation to determine the average delivery will be based on those years in which the peak flow is expected to be between 12,900 and 26,600 cfs.

2.3.8 Piscatorial Purposes

A water right decreed for piscatorial purposes may be required for implementation of several of the alternatives analyzed in this report. It may be necessary, therefore, to obtain a junior water right for piscatorial purposes in order to implement those alternatives where there is no existing water right for

piscatorial purposes. The necessity and frequency of obtaining such a junior water right must be determined before implementing any of the alternatives.

2.3.9 Electric Power Purchase and Sales Prices

Electric power purchase and sales prices were obtained from the Western Area Power Administration (WAPA) for estimating the value of power generation foregone at Green Mountain Reservoir as a result of the alternative investigated in this report and the Technical Memoranda (personal communication from John Gierard, WAPA, to Leo Eisel and Bruce Rindahl, January 23, 2001). The sales prices were used in evaluating foregone power generation at both Shoshone and Green Mountain Power Plants. The Executive Committee requested at the April 6, 2001 meeting that the consultant submit the power rate schedules employed in the analysis to WAPA and to Excel Energy for comment concerning the appropriateness of these rate schedules for use in the analysis and specifically concerning the cost of replacement power. At the time of publication of this report, the consultant had not received a response to the May 2001 request to WAPA and Excel Energy concerning this matter.

2.3.10 Hydropower Maintenance Schedules

The normal maintenance procedure for Green Mountain Reservoir is two outages (one for each unit) of 4-5 weeks each. Typically one of the outages is in January and the other in March. The units are not normally worked on at the same time thus maintaining capacity to deliver water through at least one unit.

Ruedi Reservoir hydropower facilities are generally maintained during a period of approximately two weeks sometime during the year. There is no set schedule for when these two weeks will occur during the year (personal communication with Phillip Harris, High Country Engineering, September 12, 2001).

A typical maintenance schedule for Shoshone Power Plant will have Unit A out for January and Unit B out for February. The C1 Data Set scenario, however, assumes that power generation facilities are always available at full capacity and does not acknowledge these periods of downtime for maintenance.

In the analysis herein, the total kilowatt-hours of power generation were calculated for the C1 Data Setline scenario and compared to the calculated total kilowatt-hours generated with the alternative scenario. Therefore, the two scenarios were affected equally by the C1 Data Set data set's lack of simulation of the hydropower maintenance periods.

Maintenance schedules for hydropower generation facilities at Green Mountain and Ruedi Reservoirs and the Shoshone Power Plant were not incorporated into StateMod and the C1 Data Set because hydropower generation is not specifically modeled by StateMod for Green Mountain and Ruedi Reservoirs. Hydropower generation is, however, specifically modeled for the Shoshone Power Plant in StateMod. Consequently, the maintenance schedule for the Shoshone Power Plant was included in the C1 Data Set Third Revision and subsequent revisions.

It should be noted that impacts to other hydropower generation facilities (e.g. Williams Fork, Dillon, East Portal) were not analyzed during the course of this study.

2.3.11 Municipal Recreation Agreement

The June 19, 2001 Municipal Recreation Agreement Between the United States, the Town of Palisade, the City of Grand Junction, and the City of Fruita allows for a release of HUP Surplus water to be made from Green Mountain Reservoir for municipal recreational purposes if:

- HUP Surplus water is not needed to generate power at the Grand Valley Power Plant;
- Target flows for recovery of the endangered fishes in the 15-Mile Reach, as specified in USFWS (May 1995, p. 65), are not being met; and
- Sufficient HUP Surplus water exists to make the release.

Releases of Green Mountain Reservoir HUP water for municipal recreational purposes generally begin in approximately mid-August and can continue into the fall.

StateMod and the C1 Data Set, C1 Data Set First Revision and the C1 Data Set Second Revision do not model releases of HUP Surplus water under the Municipal Recreational Agreement. The C1 Data Set Third Revision (and subsequent revisions), however, do permit release of Surplus HUP water under the Municipal Recreation Agreement (see Table 2).

2.3.12 Green Mountain Reservoir Accounting and Administration

The Accounting Principles for Green Mountain Reservoir (Revised Draft, April 21, 1994) include three categories of reservoir fill:

- Physical Fill. "A physical fill of Green Mountain Reservoir (GMR) is achieved when the actual water surface reaches an elevation of 7,950.0 feet. The contents of GMR at 7,950 feet are 153,639 acre-feet. This includes 40,845 acre-feet of storage capacity at elevation 7,870 feet, designated the minimum power pool, and 112,794 acre-feet of active conservation capacity. The minimum power pool consists of 6,860 acre-feet of dead storage at elevation 7,800 feet and 33,985 acre-feet of inactive storage. The power plant generating units cannot generate electrical energy if the water surface of the reservoir falls below elevation 7,870 feet. Water can be released through the river outlet when the contents of GMR are below elevation 7,870 feet and above elevation 7,800 feet."
- Division 5 Fill. "The sum of the (a) water actually stored in GMR since the initiation of storage (between April 1 and May 15 of each year), (b) releases of inflow since the initiation of storage (between April 1 and May 15 of each year) to replace depletions of Senate Document No. 80 beneficiaries, including contractors, who are subject to any "call" on the Colorado River by an appropriator junior to August 1, 1935 greater than 60 cfs (amount that satisfies operating criteria provisions including downstream rights on the Blue River senior to August 1, 1935), (c) releases of inflow greater than (b) that bypass the power plant, (d) depletions caused by Senate Document No. 80

beneficiaries, including contractors, whose rights are junior to August 1, 1935) and located upstream of GMR, and (e) contents of GMR, exclusive of non-project and junior "refill" right water held in the reservoir, upon the initiation by Reclamation of storage (between April 1 and May 15 of each year). The Colorado River Water Division No. 5 "fill" is achieved when the sum equals 154,645 acre-feet."

- Blue River Decree Fill. "The sum of the (a) water actually stored in GMR since the initiation of storage (between April 1 and May 15 of each year), (b) releases of all inflow since the initiation of storage (between April 1 and May 15 of each year) greater than 60 cfs (amount that satisfies operating criteria provisions including downstream rights on the Blue River senior to August 1, 1935), (c) depletions caused by Senate Doc. No. 80 beneficiaries, including contractors, whose rights are junior to August 1, 1935 and located upstream of GMR, and (d) contents of GMR, exclusive of non-project water held in the reservoir, upon the initiation by Reclamation of Storage (between April 1 and May 15 of each year) pursuant to the Blue River Decree. The Blue River Decree "fill" is achieved when the sum equals 154,645 acre-feet."

The 20,000 acre-feet release to the 15-Mile Reach would count against the first fill right of a reservoir because under Water Division 5 policy, the allowable fill under a first fill right cannot exceed the difference between a reservoir's Start of Fill Date storage and the maximum decreed storage amount under the first fill right (personal communication with Alan Martellaro, July 2001). StateMod and the C1 Data Set count the 20,000 acre-feet release against the reservoir's first fill right. This policy does not apply to a refill right where water can be diverted under a reservoir's refill priority up to the decreed amount of the refill right. StateMod and the C1 Data Set correctly handle this situation.

Power generation effected by the direct flow power right is not debited against the "paper fill" of Green Mountain Reservoir by the Division 5 Engineer. StateMod and the C1 Data Set are currently not modeling this situation accordingly; StateMod and the C1 Data Set are debiting such power releases made under the direct flow power right against Green Mountain Reservoir's first fill right.

Power releases made under the direct flow power right are debited in the accounting against the "Blue River Fill" specified in the Blue River Decrees which define the obligations of Denver Water and Colorado Springs in relationship to Green Mountain Reservoir. Based on the results of the analysis using the C1 Data Set (Fourth Revision) and prior revisions, however, StateMod and the C1 Data Set were not correctly modeling the exchanges and substitutions among Williams Fork Reservoir, Wolford Mountain Reservoir and Dillon Reservoir. Consequently, it was uncertain whether the fill obligations of Dillon Reservoir in relationship to Green Mountain Reservoir under the Blue River Decree were being handled correctly in StateMod and the C1data sets. The Revised StateMod and C1 Data Set (Fifth Revision) attempted to correct this problem. However, comparing simulations by Denver Water using its daily PACSIM model with StateMod showed differences in accounting for exchanges and substitutions into and out of Dillon, Williams Fork and Wolford Mountain Reservoirs. These differences would overstate the availability of water for release from these reservoirs for meeting the 20,000 acre-foot goal. Rather than continue to investigate and debate the need for further refinements to the model, it was determined that time would be better spent working on what could be done to meet the 20,000 acre-foot goal.

2.3.13 Modeling the Orchard Mesa Check Case Settlement - Reduced USA Grand Valley Power Plant Summer Call and HUP Pool Operation.

An operational rule is available in StateMod and the C1 Data Set set for releasing Surplus HUP Water to the USA Power Plant according to the Orchard Mesa Check Case Stipulation and Agreement in Water Division No. 5 Case No. 91CW247. This operational rule was turned off in the C1 Data Set received from the State for purposes of this study. The Ground Rules specified using the C1 Data Set set in the condition received from CWCB. Consequently all of the analysis completed for Technical Memoranda 1 – 11 used the C1 Data Set data set in which this operational rule remained turned off.

The necessary operational rule to model the Orchard Mesa Check Case Settlement was turned on in the C1 Data Set Fourth Revision (see Table 2 and Appendix N).

2.3.14 Comparison of Runs

The difficulty of comparing the output from several model runs on a side-by-side basis was overcome by the design and implementation of several Excel spreadsheets. These spreadsheets allowed a detailed comparison of any two runs through the use of pull-down menus to facilitate selection of any storage reservoir, water diversion, or operational rule desired. In addition the spreadsheets permitted the user to view both raw data and graphs of any parameter computed by StateMod, including, but not limited to, end-of-month (EOM) storage, total release, diversions by priority, shortages and individual accounts. These spreadsheets with all of the modeled results are included in Appendix P.

2.3.15 Procedures to Estimate Outlet Works Capacities

It was necessary to estimate the available release capacity for CFOPS releases in order to ensure that the StateMod runs did not assume infinite release capacity available for CROPS, CFOPS and normal operating releases. Available release capacities were estimated using the following procedures.

- Monthly releases for Wolford Mountain Reservoir, Williams Fork Reservoir, Granby Reservoir and Green Mountain Reservoir were obtained from the C1 Data Set Fourth Revision. Maximum release capacities from these reservoirs were obtained from the Colorado River Water Conservation District for Wolford Mountain Reservoir, from Denver Water for Williams Fork Reservoir and from the U.S. Bureau of Reclamation for Green Mountain Reservoir and Granby Reservoir. The estimated CROPS releases are presented in Table 3.
- Available release capacity was estimated by:

  Available Release Capacity = Max. Release Cap. - C1 Data Set Fourth Revision Release - estimated CROPS Bypass.
- The principal limiting factor for releases from Ruedi Reservoir is downstream channel capacity. Maximum channel capacity on the Frying Pan River near Basalt is 1,100 cfs (see Technical Memorandum No. 5 – Appendix F). For Ruedi Reservoir, available release capacity was estimated by:

Available Release Capacity = Max. Channel Cap. - C1 Data Set Fourth Revision Release - estimated CROPS Bypass.

The determinations of outlet capacity are presented in Tables 5 through 10 for Green Mountain, Ruedi, Williams Fork, Wolford Mountain and Granby Reservoirs respectively. Table 10 presents total available release capacity during the 10-day peak period from the five reservoirs for the study period. Table 11 presents potential CFOPS releases for the Modified "Share the Pain" alternative for the 10-day peak and Table 12 presents potential total CFOPS and CROPS release for the Modified "Share the Pain" alternative for the 10-day peak.

2.3.16 Sensitivity Analysis Procedures Concerning Potential Shortages to Junior Water Rights

The effects of making CFOPS and CROPS releases/bypasses on water rights with junior priorities was estimated by the following:

Shortages to Juniors = (Diversion by Structure X in Month M in C1 Data Set Fourth Revision) - (Diversion by Structure X in Month M in C1 Data Set Fourth Revision with CFOPS releases and CROPS releases/bypasses).

2.3.17 Sensitivity Analysis Procedures Concerning Effects of General Removal of Shoshone Priority Call on Winter Colorado River Flows

The following procedure was employed to calculate the effect of removing the Shoshone priority call on winter (November through April) Colorado River flows upstream of Shoshone and at the head of the 15-Mile Reach:

- The C1 Data Set Fourth Revision monthly flows were obtained for the study period from the C1 Data Set for the node at the head of the 15-Mile Reach and immediately upstream of Shoshone.
- The flows for the same nodes and with removal of the Shoshone priority call were calculated for the C1 Data Set Fourth Revision using the same procedure as detailed in Technical Memorandum No. 9 (See Appendix J).

  Flow change = (C1 Data Set Fourth Revision) - (flow with removal of Shoshone call calculated using procedures from Technical Memorandum No. 9).

2.3.18 Homestake Reservoir

Analysis in Technical Memorandum No. 7 (Appendix H) originally suggested that StateMod and the C1 Data Set were not adequately characterizing Homestake Reservoir. In subsequent analysis, this apparent problem was determined to result from the operating policy for Homestake Reservoir contained in the C1 Data Set. Contact with Colorado Springs Utilities resulted in confirmation that the operating policy for Homestake Reservoir contained in the C1 Data Set is the Colorado Springs

Utilities' preferred operating policy for Homestake Reservoir. This operating policy essentially precludes participation in CROPS and CFOPS by Colorado Springs Utilities.

2.3.19 Granby Reservoir

Concern was expressed by the Executive Committee during the review of the Technical Memoranda that StateMod and the C1 Data Set were allowing releases to be made from Granby Reservoir's dead storage pool. This was investigated with the determination that releases were being made by StateMod and the C1 Data Set only from the CBT pool and not from Granby Reservoir's dead storage pool.

CHAPTER 3

RESULTS

3.1 INTRODUCTION

The technical investigation of the alternatives was reported as it was completed in a series of Technical Memoranda which are attached to this report as Appendices A through L. These Technical Memoranda were published in draft as the investigation of each alternative was completed, reviewed by the Executive Committee and revised accordingly. After technical analysis of the alternatives was completed, sensitivity analysis of the alternatives was carried out as originally directed: (1) in the Ground Rules and Assumptions in the Phase 1 report and (2) by the Executive Committee at the December 18, 2001 meeting. The results of this sensitivity analysis are included in the main body of this report.

A summary of study results is presented in Table 15 with more detailed description below.

3.2 SUMMARY OF RESULTS REPORTED IN TECHNICAL MEMORANDA NOS. 1-11

3.2.1 General

Model results and data sets used in the course of this investigation are contained in Appendix P.

A summary of the investigation of the 19 alternatives for supplying the 20,000 acre-feet release to the 15-Mile Reach is presented in Table 15. Table 15, however, contains only a brief summary and the interested reader is directed to Technical Memoranda Nos. 1 through 11 (see Appendices A-L) for details.

Important overall results include:

1. Supplying the 20,000 acre-feet to the 15-Mile Reach was not required every year. It was necessary to supply the 20,000 acre-feet in only six, and possibly eight, years of the 17 years for the 1975-91 study period.

2. Supplying the 20,000 acre-feet was not required during the very dry years of the study period. For example, releases were not required in 1977 or 1981. Further analysis indicates that supplying the 20,000 acre-feet would not have been required in 2001 and 2002.

3. Not having to supply the 20,000 acre-feet in dry years indicates that the 20,000 acre-feet does not have to be supplied from firm yield. Instead, the 20,000 acre-feet can be supplied from sources in a manner that minimizes or eliminates effects on reservoir firm yields.

Brief descriptions of the feasibility of each alternative are presented in the sections below.

3.2.2 Alternative 1a: Green Mountain Reservoir Reduced Winter Power Operations

This alternative was investigated in Technical Memorandum No. 1 (see Appendix A) and found to be feasible from engineering and economic perspectives. Since completion of Technical Memorandum No.1, it has been determined that those alternatives, such as Reduced Winter Power Operations at Green Mountain Reservoir, which would "save" water for later release to the 15-Mile Reach were not as efficient as simply allowing Green Mountain Reservoir to replace the 20,000 acre-feet bypass/release to the 15-Mile Reach by diverting water to storage under the Green Mountain Reservoir refill right.

Based on the analysis of this alternative in Technical Memorandum No. 1, there would be little, if any, effect from implementation of this alternative on:

- Storage in west slope reservoirs,
- Deliveries through the Adams, Roberts, Boustead and Busk-Ivanhoe Tunnels.

Hydropower revenues would be reduced at Green Mountain Reservoir by an annual average of $36,000 per year and $174,000 per year at the Shoshone power plant. These decreases in hydropower revenue would be reduced by eliminating the delayed winter releases from Green Mountain Reservoir and depending on replacement of the 20,000 acre-feet release using Green Mountain Reservoir's refill right.

It would be feasible to supply the 20,000 acre-feet to the 15-Mile Reach at a rate of approximately 1,000 cfs over a 10-day period during the eight years of the study period when it could be required. This release/bypass could be made through existing Green Mountain Reservoir release/bypass facilities. It would be feasible to supply the 20,000 acre-feet per year to the 15-Mile Reach without violating downstream channel flow constraints on the Blue and/or Colorado Rivers.

3.2.3 Alternative 1a: Green Mountain Reservoir Conjunctive Pool Operations

This alternative involved supplying the 20,000 acre-feet from Green Mountain Reservoir and replacing the 20,000 acre-feet from either the HUP pool or the CBT pool depending on which pool had greater water availability. Modeling results (see Technical Memorandum No. 3 in Appendix C) indicate:

- This alternative was feasible from engineering and economic perspectives.
- The conjunctive pool operation was not necessary because Green Mountain Reservoir replaced the 20,000 acre-feet by diverting to storage under its refill priority.
- Because the 20,000 acre-feet release was replaced in the HUP during the eight years of the study period in which the release was made, there would have been no disruption to releases from Green Mountain under the Check Settlement.
- Storage in other west slope reservoirs and deliveries by the Adams, Roberts, Boustead and Busk-Ivanhoe Tunnels were generally unaffected by this alternative.

It would be feasible to supply the 20,000 acre-feet to the 15-Mile Reach at a rate of approximately 1,000 cfs over a 10-day period during the eight years of the study period when it could be required. This release/bypass could be made through existing Green Mountain Reservoir release facilities. It would be feasible to supply the 20,000 acre-feet per year to the 15-Mile Reach without violating downstream channel flow constraints on the Blue and/or Colorado Rivers.

Hydropower production at Green Mountain Reservoir was increased by an average of $10,085 per year while hydropower production at Ruedi Reservoir, Shoshone Power Plant and the Orchard Mesa Power Plant were unaffected.

3.2.4 Alternative 1b: Modify Ruedi Reservoir Operations

This alternative attempted to make the 20,000 acre-feet release to the 15-Mile Reach from Ruedi Reservoir and replace this release by diverting to storage under the Ruedi Reservoir refill right (See Technical Memorandum No. 5, Appendix F).

The 1,100 cfs channel constraint on the Frying Pan River near Basalt precludes releasing the full 20,000 acre-feet over a 10-day period at an average release rate of 1,000 cfs. Making the full 20,000 acre-feet release is further complicated by the inadequate physical availability of inflow to Ruedi Reservoir that can be diverted to storage under the 1981 Ruedi Reservoir refill right to replace the 20,000 acre-feet release.

Calculations and sensitivity analysis were performed which indicated that Ruedi Reservoir could supply approximately 7,000 acre-feet out of the total 20,000 acre-feet to the 15-Mile Reach without: (1) violating downstream channel constraints and (2) reducing storage in Ruedi Reservoir. Supplying 7,000 acre-feet from Ruedi Reservoir is not expected to reduce storage in other west slope reservoirs or to reduce deliveries through the Adams, Roberts, Boustead or Busk-Ivanhoe Tunnels. Average annual hydropower revenues from Ruedi would be reduced approximately $4,000 to $18,000 per year by this alternative. No reduction of hydropower revenues at Green Mountain Reservoir, Shoshone Power Plant or Orchard Mesa Power Plant is anticipated from this alternative.

These results indicate that this alternative is not feasible for supplying the full 20,000 acre-feet but should be further considered for supplying approximately 7,000 acre-feet toward the 20,000 acre-feet target.

3.2.5 Alternative 1e: Denver Water System Operations

Analysis of this alternative is presented in Technical Memorandum No. 11 (see Appendix L) and focuses on the feasibility of making the 20,000 acre-feet release from Williams Fork Reservoir. The consultant team, with approval from Denver Water, chose to model this alternative using Williams Fork Reservoir because: (1) its purpose is to act as a supply of augmentation water for Dillon, and (2) its location is further downstream than Dillon. The analysis was completed using StateMod with the C1 Data Set. Because the C1 Data Set only includes the Colorado River basin, major components of the Denver Water system located on the east slope are not included. Because of this, the initial results from StateMod were provided to Denver Water for further analysis using Denver Water's own models, data sets and computation procedures.

Results of this analysis include:

- Alternative 1e, Expanded Coordinated Reservoir Operations, Denver Water Systems Operations, was able to make the 20,000 acre-feet release to the 15-Mile Reach in each of the eight years when the release could have been required.
- Effects on west slope facilities from Alternative 1e are limited to Williams Fork Reservoir storage, which does not fill in 1975, 1980, 1982, and has a 19,000 acre-feet deficit in 1978 after making the 20,000 acre-feet release. These results underscore the need for an insurance pool to reduce the risk of impacting yield to a reservoir after making all or a portion of the 20,000 acre-feet release.

3.2.6 Alternatives 1f and 1g: Bypass Diversions to Storage and Reduce Constraints on CROPS

The analysis of Alternatives 1f and 1g is presented in Technical Memorandum No. 7 (see Appendix H). Alternative 1f, Bypass Diversions to Storage, originally included all participating facilities ceasing diversion to in-basin storage, transmountain diversion and/or direct flow diversions during the 10-day period surrounding the estimated spring peak flow. This was subsequently modified in the Phase 1 Final Report (Colorado Water Conservation Board, September 2000) to include cessation of diversions to in-basin storage. Consequently, investigation of this alternative includes bypassing diversion to storage in the following reservoirs:

- Dillon
- Granby
- Green Mountain
- Homestake
- Ruedi
- Williams Fork
- Willow Creek
- Wolford Mountain
- Vega

For the investigation of Alternative 1g, Reduce Constraints on CROPS, the following modifications of CROPS constraints were considered.

- Alternative 1g recommended having additional projects participate in the CROPS program on a consistent basis; consequently a scenario was developed to have more reservoirs participate in providing the 20,000 acre-feet release (i.e. "Share the Pain"). The listed reservoirs above were assumed to participate in CROPS on a consistent basis.
- In order to provide flows toward the 20,000 acre-feet target, the participating reservoirs could make releases from storage and/or bypass diversion to storage during the 10-day period surrounding the spring peak flow period.

To investigate Alternatives 1f and 1g, a portion of the 20,000 acre-feet target was assigned to each of the reservoirs listed above and assumed to be participating in the CROPS program. For purposes of this analysis, the portion of the 20,000 acre-feet assigned to each reservoir was specified in three ways:

1. Proportionate share based on reservoir inflow. Each reservoir's bypass/release responsibility was based on the annual average annual inflow to that reservoir divided by the total annual average inflow to the nine reservoirs multiplied by 20,000 acre-feet.
2. Equal division among three reservoirs. Responsibility for bypassing inflows or making a release was divided equally among Granby, Green Mountain and Williams Fork Reservoirs (i.e. 6,667 acre-feet for each reservoir).
3. Total release from Granby Reservoir. For comparison purposes, all 20,000 acre-feet were assigned to Granby Reservoir.

Results of the analysis indicate that it would be possible to release the 20,000 acre-feet to the 15-Mile Reach in the eight years in which the release could be required under all three release scenarios. There were no, or limited effects, on reservoir storage for all the reservoirs for the proportionate share and the equal division rules. There was greater reduction in storage in Granby Reservoir when it was solely responsible for the 20,000 acre-feet release, likely due to lack of storable inflows in those years when the releases were made. It should be noted, however, that at certain elevations, the release rate from Granby is not sufficient to release 1,008 cfs (20,000 acre-feet over 10 days) (Don Carlson, NCWCD's March 5, 2003 comment letter on Draft Phase 2 Report). For Granby to participate in releases, a maximum amount should be identified because of outlet capacity restrictions.

Small reductions in hydropower generation were experienced at Green Mountain Reservoir Power Plant ($5-6,000/year average) and Ruedi Reservoir ($800/year average) and a small increase in power generation at Shoshone Power Plant ($3-7,000/year average). Minimal effects were experienced on Adams, Roberts, Boustead and Busk-Ivanhoe Tunnel deliveries from these alternatives.

3.2.7 Alternatives 1a, 3d and 3e: Green Mountain Reservoir Pre-emptive Release, Water Carried Over and Developing Additional Yield from GVP and GVIC through Increased Efficiency

This alternative focused on: (1) making the 20,000 acre-feet release to the 15-Mile Reach from Green Mountain Reservoir and (2) the potential for replacing this 20,000 acre-feet in Green Mountain Reservoir by accruing "savings" to the HUP through increased GVP and GVIC efficiency (See Technical Memorandum No. 2, Appendix B). Analysis of this alternative resulted in the following findings:

- Increased efficiencies in GVP and GVIC would produce "savings" in the form of reduced HUP demand generally in the dry years when it was not needed for making the 20,000 acre-feet release to the 15-Mile Reach. The savings would not be available until August through October, by which time Green Mountain Reservoir would have replaced the May-June 20,000 acre-feet release to the 15-Mile Reach by diverting to storage under Green Mountain Reservoir's refill right. Furthermore, the estimated quantities of "savings" in the form of reduced HUP demand available in those years when the release was made were relatively small.
- Green Mountain Reservoir refilled under its own refill priority and "savings" from other sources were not required to replace the 20,000 acre-feet release.

Therefore, this alternative was found not to be necessary for making the 20,000 acre-feet release to the 15-Mile Reach during spring peak flows and was not modeled. It is important to point out, however, that there is likely to be additional flow available in the 15-Mile Reach during the late summer and early fall as a result of greater GVP efficiency and these increased flows will benefit the endangered fish during this period.

3.2.8 Alternatives 4f, 4g, 4k, 4m, 4n and 4o: New Storage Facilities Below Shoshone

Results of investigating these alternatives are presented in Technical Memorandum No. 4 (see Appendix D). This investigation focuses on the following potential reservoir sites:

- Alternative 4f: Roan Creek Reservoir,
- Alternative 4g: Mt. Logan Reservoir,
- Alternative 4k: Dry Hollow Reservoir,
- Alternative 4m: Mainstem Colorado River Reservoir (Webster Hill Site),
- Alternative 4n: Parachute Creek Reservoir, and
- Alternative 4o: Starky Gulch Reservoir.

Opinions of probable cost indicated that storing water in the tributary sites and releasing to the 15-Mile Reach would be relatively costly because of the limited yield for storage available from the tributary flows and the resulting high cost of pumping from the mainstem to many of these reservoirs. Because of the substantial flows available for storage at the mainstem site (Alternative 4m), this site appeared potentially feasible.

An additional engineering and economic feasibility investigation of the mainstem Webster Hill site was completed in Technical Memorandum 4a (See Appendix E). The cost of reservoir storage at this site for making the 20,000 acre-feet release to the 15-Mile Reach would be partially offset by the generation of hydropower. Net capital costs per acre-foot of yield from the Webster Hill Reservoir would range from $29 to $134/acre-foot of yield per year depending on the assumed value of hydropower produced at the site. Results from this additional investigation further indicate that this site would likely be feasible if: (1) the necessary right-of-way can be obtained at reasonable cost and (2) the U.S. Fish and Wildlife Service would approve construction of a reservoir at the Webster Hill site, which would be located in the upper end of the currently designated critical habitat.

The Webster Hill Reservoir could release 20,000 to 40,000 acre-feet per year for the endangered fish in the required years at a location relatively close to the 15-mile reach. It is important to emphasize that the 20,000 acre-feet release would be available from Webster Hill Reservoir even in dry years when this release would not be required. Therefore, the Webster Hill Reservoir alternative would produce yield with a greater reliability than is required, and could potentially provide both the 10,825 acre-feet (RIPRAP) and the 20,000 acre-feet which is the subject of this study.

3.2.9 Alternatives 1d and 5a: CBT West Slope Facilities Operations and East Slope Power Operations and Scheduling

Investigation of Alternative 1d, CBT West Slope Facilities Operation, indicates that Granby Reservoir had sufficient available stored water to make the 20,000 acre-feet release for all eight years during the 1974-91 study period when the release could have been required (see Technical Memorandum No. 8 in Appendix I). The primary effect on Granby Reservoir storage from making the 20,000 acre-feet release during eight years of the 1974-91 study period was to reduce annual average storage in Granby Reservoir by approximately 16,000 acre-feet for the period 1979-1982. Granby Reservoir does not replace the 20,000 acre-feet release as rapidly as Green Mountain Reservoir, due to limited availability of storable inflows in these years. Alternative 1d, however, is sufficiently feasible to warrant continued consideration as a source of supply for all or a portion of the 20,000 acre-feet supply to the 15-Mile Reach. It should be noted, however, that at certain elevations, the release rate from Granby is not sufficient to release 1,008 cfs (20,000 acre-feet over 10 days) (Don Carlson, NCWCD's March 5, 2003 comment letter on Draft Phase 2 Report). For Granby to participate in releases, a maximum amount should be identified because of outlet capacity restrictions.

Alternative 5a, East Slope Power Operations and Scheduling, was investigated as one component of Alternative 1d, CBT West Slope Facilities Operations. This alternative primarily consists of: (1) delaying winter deliveries through the Adams Tunnel, (2) using these delayed winter deliveries to replace the release/bypass of the 20,000 acre-feet from Granby Reservoir to the 15-Mile Reach and (3) replacing the delayed deliveries to east slope reservoirs by diversions to storage in these reservoirs under the east slope priorities.

Alternative 5a was not modeled because:

- This alternative cannot be fully investigated using StateMod and the C1 Data Set because StateMod and the C1 Data Set only cover the Colorado River basin in Colorado and do not extend to east slope facilities and systems. Specifically, StateMod and the C1 Data Set cannot be used to determine the quantity of deliveries through the Adams Tunnel that could be replaced through use of NCWCD's east slope water rights.
- The Bureau of Reclamation in its October 12, 2001 letter to the Colorado River Water Conservation District concludes that it is not feasible for a number of reasons to delay winter and early spring deliveries of west slope water to the east slope via the Adams Tunnel in order to keep east slope reservoir storage relatively low.

Alternative 1d, as reported above, was found to be a feasible alternative for supplying the 20,000 acre-feet from Granby Reservoir without the possible source of replacement water resulting from Alternative 5a.

3.2.10 Alternative 5b: Shoshone Power Plant Operations

This alternative focused on general removal of the Shoshone Power Plant priority call. Under this alternative, Excel Energy would be paid for those power revenues foregone as a result of not issuing a priority call. The available flows would then be available for diversion by any in priority water right.

Results of technical analysis of this alternative are reported in Technical Memorandum No. 9 in Appendix J. Analysis of this alternative indicated general removal of this priority call would result in an increase in stored water in those reservoirs which could supply the 20,000 acre-feet to the 15-Mile Reach thereby reducing the risk of lower storage and/or lower reservoir yields accruing to those facilities. For example, the average monthly increase in Green Mountain Reservoir storage with removal of the Shoshone priority call is estimated to be 5,162 acre-feet for the 17-year study period.

This increase in reservoir storage resulting from removing the Shoshone priority call may not occur in Granby Reservoir because Granby Reservoir diverts all possible inflows to storage under Granby Reservoir's own priorities or by exchange from Green Mountain Reservoir.

Elimination of the Shoshone priority call decreased the value of Shoshone power production by an average of approximately $116,000 per year. Therefore, it appears that Alternative 5b could be an efficient and effective component of the Alternative 6a, Insurance Pool, discussed below. An analysis of effects of this alternative on winter flows in the Colorado River at the head of the 15-Mile Reach and immediately downstream from Shoshone is presented in the sensitivity analysis section below.

3.2.11 Alternative 6a: Insurance Pool

Establishing an insurance pool could be done to reduce the risk of lower storage and yields to individual participants providing all or a portion of the 20,000 acre-feet to the 15-Mile Reach (See Technical memorandum No. 10, Appendix K). Two possibilities for establishing an insurance pool were considered and investigated:

- Increasing the number of facilities providing a portion of the 20,000 acre-feet to the 15-Mile reach, thereby spreading the risk among a larger number of facilities. Allocating responsibility for the 20,000 acre-feet release among several reservoirs is necessary because of limited release capacity in Green Mountain Reservoir, which prohibits Green Mountain Reservoir from making both the CROPS bypass and the 20,000 acre-feet release in six of the eight years of the study period in which the 20,000 acre-feet release would be required.
- Removing the Shoshone priority call in those years in which the 20,000 acre-feet would be supplied to the 15-Mile Reach, thereby providing additional storage and yield to those facilities supplying the 20,000 acre-feet to the 15-Mile Reach.

The first possibility was investigated in Technical Memorandum No. 7 (See Appendix H) where it was found feasible to supply the 20,000 acre-feet to the 15-Mile Reach from multiple reservoirs, thereby spreading the risk among a larger number of participants. Establishing an insurance pool in one or more reservoirs will serve the purpose of lowering the risk of reduced storage and yield in those reservoirs responsible for making the 20,000 acre-feet release to the 15-Mile Reach.

In a similar fashion, general removal of the Shoshone priority call in those years in which the 20,000 acre-feet was supplied to the 15-Mile Reach also appears to be a feasible way to reduce the risk of lower storage and/or yield to individual structures as a result of supplying a portion of the 20,000 acre-feet (See Technical Memorandum No. 9).

A third, and perhaps the most promising insurance pool concept, was identified late in the comment process for the study. The insurance pool could be provided by the Service's Environmental Pools: first from Ruedi Reservoir and second from Wolford Mountain Reservoir. Each year, the Service would determine whether peak flow augmentation in the spring or low flow augmentation in the fall was the best use of water from the Environmental Pools. If the Service decided on or about May 1st of the year that peak flow augmentation was the best use of a portion or all of water from the Environmental Pools, the Service would designate up to 20,000 acre-feet of the water as the insurance pool for preemptive releases from existing reservoirs to augment peak flows in the spring. That way, operators of existing reservoirs would have virtually no risk to yield from their reservoirs if they preemptively released water from those reservoirs. By way of example, if Denver Water released 10,000 acre-feet from Williams Fork Reservoir for peak flow augmentation and the runoff was not sufficient to refill Williams Fork Reservoir, a 10,000 acre-foot exchange or substitution would occur from Ruedi or Wolford Mountain Reservoirs to make up for the lost water to Williams Fork Reservoir. However, if Williams Fork Reservoir did fill after a preemptive release, the Service could use that 10,000 acre-foot insurance pool for low flow augmentation later in the fall.

3.3 ANALYSIS OF RESULTS OBTAINED FROM REVISED STATEMOD AND C1 DATA SET (FIFTH REVISION)

3.3.1 Comparison of C1 Data Set (Fourth Revision) with Revised StateMod and C1 Data Set (Fifth Revision)

Figures 1 through 9 present a comparison of storage in nine reservoirs (Dillon, Granby, Green Mountain, Homestake, Ruedi, Vega, Williams Fork, Willow Creek and Wolford Mountain) for: (1) the C1 Data Set (Fourth Revision) with (2) the Revised StateMod and C1 Data Set (Fifth Revision). As discussed above and in Table 2, the C1 Data Set (Fourth Revision) includes:

- HUP storage to CBT Pool on April 1.
- Correct Ruedi Reservoir refill priority date.
- Adjusted Shoshone maintenance schedule.
- Meeting the RIPRAP flow, release and bypass targets.
- Shoshone hydropower facility maintenance schedule.
- Palisade Pipeline bypass flows and reduced demands for diversion from the Grand Valley Project.

Revised StateMod and C1 Data Set (Fifth Revision) has all of the above together with revisions of StateMod to more accurately model the exchanges and substitutions among Dillon, Williams Fork and Wolford Mountain Reservoirs. Review of Figures 1 (Dillon Reservoir), 7 (Williams Fork Reservoir) and 9 (Wolford Mountain Reservoir) indicates that the Revised StateMod is more correctly modeling the exchanges and substitutions among Dillon, Williams Fork and Wolford Mountain Reservoirs. Results in Figure 5 (Ruedi Reservoir) indicate that the correction of StateMod to more adequately model the exchanges and substitutions has resulted in more use of Ruedi Reservoir to meet the RIPRAP flow, release and bypass targets.

3.3.2 Green Mountain Reservoir Makes 20, 000 Acre-Feet Release

The effects of Green Mountain Reservoir making the total 20,000 acre-feet release are presented in Figures 10 through 18. In general, these figures show minimal effects on any of the reservoirs from making the 20,000 acre-feet release from Green Mountain Reservoir.

The effects on Green Mountain Reservoir storage from making the 20,000 acre-feet release are presented in Figure 12 which shows only minimal effects on storage. Effects on Green Mountain Reservoir storage are minimal because:

- The 20,000 acre-feet release is only required in wet years, and
- Green Mountain Reservoir is able to replace this release under its junior refill right.

In the situation where the 20,000 acre-feet release would be required in a year immediately after a drought period (e.g. 1978 required a release after the 1977 drought), Green Mountain Reservoir did not replace this released storage until the following spring (1979) when Green Mountain was able to fill under its first fill right (see Figure 12).

Figure 14 shows an interesting effect on Ruedi Reservoir storage in 1982-83. The Green Mountain Reservoir Release of 20,000 acre-feet in 1982 potentially reduced low flow augmentation capability under the HUP surplus rules resulting in an increased draw on Ruedi Reservoir.

3.3.3 "Share the Pain" Alternative

The "Share the Pain" alternative is a modification of Alternatives 1f and 1g in which responsibility for making the 20,000 acre-feet release is equally divided among Granby, Green Mountain and Williams Fork Reservoirs with each reservoir making a 6,667 acre-feet release.

The effects of the "Share the Pain" alternative are presented in Figures 19 through 27. Results for Granby Reservoir (Figure 20), Green Mountain Reservoir (Figure 21) and Williams Fork Reservoir (Figure 24) indicate that in the situation in which a drought year is followed by a year in which a release is required (e.g. the 1977 drought followed by 1978 in which a release was required), it may take the reservoirs from which the release was made a year or longer to replace the release. For the 1977- 1978 period:

- Granby Reservoir did not replace the 6,667 acre-feet release made in June 1978 until spring 1983 when a wet year occurred (Figure 20).
- Green Mountain Reservoir was able to replace the 6,667 acre-feet release in June 1978 in 1978 using its refill right.
- Williams Fork Reservoir was able to replace the 6,667 acre-feet release in June 1978 by the following spring of 1979.

It should be noted that while lower levels were carried over in those years after the 20,000 acre-feet release, the analyses never showed a reduction in deliveries or yield.

3.4 SENSITIVITY ANALYSIS

3.4.1 Revised StateMod and C1 Data Set (Fifth Revision) with 111,000 Acre-Feet of Additional Future Depletions

The results of adding 111,000 acre-feet of future depletions to the Revised StateMod and C1 Data Set are presented in Figures 28-36. Analysis of these results indicates that the effects of these additional depletions are most apparent in Dillon Reservoir storage (Figure 28). Reduced storage levels are also apparent in some years in Granby Reservoir (Figure 29) and Green Mountain Reservoir (Figure 30). The anomaly in 1982-83 for Ruedi Reservoir (Figure 32) potentially results from the need for additional low flow augmentation from Ruedi Reservoir necessary to achieve the Service's minimum flow targets due to reduced HUP surplus in Green Mountain Reservoir.

In 1977-78 and 1981-82, results for Williams Fork Reservoir (Figure 34) indicate greater storage in Williams Fork Reservoir with the 111,000 acre-feet of future demands. These results occur because of reduced exchange potential between Williams Fork and Dillon Reservoir as a result of the increased future depletions which results in greater storage in Williams Fork Reservoir.

Effects on Wolford Mountain Reservoir storage (see Figure 36) from the 111,000 acre-feet of future depletions occurs because in certain years Wolford Mountain Reservoir will make releases to supplement releases of Surplus HUP water from Green Mountain Reservoir to the 15-Mile Reach.

3.4.2 Revised StateMod and C1 Data Set (Fifth Revision) with 111,000 Acre-Feet of Additional Future Depletions and Green Mountain Reservoir Making the Total 20,000 Acre-Feet Release

As indicated above, this alternative is very similar to the Green Mountain Reservoir operations alternatives presented in Technical Memoranda Nos. 1, 2, and 3 (see Appendices A, B and C), except that Green Mountain Reservoir uses its refill right to replace the 20,000 acre-feet release and no attempt is made to replace the release by, for example, delaying hydropower releases or reducing demands on the HUP pool.

Results for this alternative are presented in Figures 37-45 and indicate the feasibility of making the 20,000 acre-feet release from Green Mountain Reservoir with the additional 111,000 acre-feet of future depletions.

As expected, the only reservoir affected by this alternative is Green Mountain Reservoir (Figure 39). In some years Green Mountain Reservoir would not be able to replace the 20,000 acre-feet release immediately. For example, consider the 1977-79 period when a release made in June 1978 would not be fully replaced until the following spring of 1979.

3.4.3 Revised StateMod and C1 Data Set (Fifth Revision) with 111,000 Acre-Feet of Additional Future Depletions and "Share the Pain" Alternative

This alternative is equivalent to the equal allocation of responsibility for making the 20,000 acre-feet release alternative that was analyzed in Technical Memorandum No. 7 (see Appendix H). Under this alternative, responsibility for supplying the 20,000 acre-feet was equally divided among Granby, Green Mountain and Williams Fork Reservoirs with each reservoir making a 6,667 acre-feet release.

Analysis results for this alternative are presented in Figures 46-54. These results indicate that it would still be feasible to provide the 20,000 acre-feet to the 15-Mile Reach in the eight years of the study period when the release could be required with the additional 111,000 acre-feet of future demands.

The effects on storage in Granby Reservoir are presented in Figure 47. In some years Granby Reservoir would not be able to replace the 6,667 acre-feet release immediately. For example, consider the 1977-79 period when a release made in June 1978 would not be fully replaced until the spring of 1983. Green Mountain Reservoir (Figure 48) was able to replace the 6,667 acre-foot release in the same year in which it was made.

There were multi-year delays in replacing the 6,667 acre-feet releases from Williams Fork Reservoir (Figure 52). For example, consider the 1977-79 period when a release made in June 1978 would not be fully replaced until the spring of 1980.

3.4.4 Outlet Works Limitations

Calculations were completed to determine if sufficient outlet capacity was available in Green Mountain Reservoir to permit both the CROPS bypass and the 20,000 acre-feet CFOPS release during the 10-day period surrounding the spring hydrograph peak. These results (see Tables 5-12 and Technical Memoranda Nos. 1, 2 and 3 in Appendices A, B and C) indicate that:

- It would not be possible to make the CROPS bypass and the 20,000 acre-feet release from Green Mountain Reservoir in six of the eight years (1975, 1980, 1982, 1985, 1986 and 1991) without making releases through the turbine bypass and over the spillway at the same time.
- It would not have been possible to make only the CROPS bypass in three of the eight years (1980,1985 and 1986) without making releases through the turbine bypass and over the spillway at the same time.
- There would be sufficient water stored in Green Mountain Reservoir to make both the CROPS bypass and the 20,000 acre-feet CFOPS release during the 10-day period during those eight years in which the release could be required. However, turbine and spillway capacities limit this release. Therefore, the full 20,000 AF release could not be made from Green Mountain Reservoir in 1985.
- Tables 5, 6, 7 and 8 indicate there is available release capacity in Ruedi, Williams Fork, Wolford and Granby Reservoirs for making a portion of the 20,000 acre-feet release in most years.

Therefore, a modified form of the "Share the Pain" alternative (see Technical Memorandum No. 7 in Appendix H) was developed to overcome Green Mountain Reservoir's limited release capacity and allow for both the CROPS bypasses and the 20,000 acre-feet release to be made. This modified "Share the Pain" alternative is discussed below.

3.4.5 Modified "Share the Pain" Alternative with CROPS

The CROPS bypasses/releases are discussed in Section 2.3.4 and presented in Table 3. Investigating the feasibility of making both the CROPS bypasses/releases and the CFOPS bypasses/releases with StateMod with a monthly time step is difficult because CROPS will generally only change the timing of a diversion to storage by a few weeks and the effect of this change in timing is difficult to demonstrate with a monthly time step model.

A Modified "Share the Pain" alternative was investigated that would allow for making the CROPS release/bypass as well as the 20,000 acre-feet release in those years in which the 20,000 acre-feet release was required while avoiding increased use of the turbine bypass. In the Modified "Share the Pain" alternative, the major portion of the 20,000 acre-feet release is made from Green Mountain Reservoir, with the remainder from Ruedi, Wolford Mountain, Williams Fork and Granby Reservoirs as detailed in Table 11. Results of making both the CROPS bypasses/releases and Modified "Share the Pain" releases are presented in Figures 55-63. Results presented in these figures show:

- It was feasible to make the 20,000 acre-feet release according to the Table 11 Modified "Share the Pain" alternative and make the CROPS bypasses/releases in all eight years in which the 20,000 acre-feet release was required.
- The effects on reservoir storage from the CROPS bypasses/releases and the Modified "Share the Pain" alternative were mainly to delay filling of the reservoirs, but with relatively minimal impact on total storage.

It should be noted that the allocation of the 20,000 acre-feet release to the reservoirs listed in table 11 is based on historical data. Under real-time operations it would be problematic to determine this allocation, which underscores the need for an insurance pool.

3.4.6 Shortage to Junior Water Rights

The results of analysis to quantify the shortages in diversions by junior water rights resulting from release of the 20,000 acre-feet and the CROPS bypasses are presented in Table 4. Results presented in this table indicate that for the 487 structures contained in the C1 Data Set, only 13 experienced a decrease in diversion as a result of the CROPS bypasses and the 20,000 acre-feet release over the 17-year study period. There were only 47 occasions of decreased diversions out of a potential 99,348 occasions (487 structures x 17 years x 12 months/year = 99,348). Furthermore, the average decrease in diversions as a result of the CROPS bypasses and the 20,000 acre-feet release on these 47 occasions was estimated to be approximately 127 acre-feet (see Table 3). Furthermore, many of the diversion decreases in one month were balanced by an increase in other months because the overall average diversion for the 29 structures which experienced changes increased by 9 acre-feet per month.

The consultant team concludes on the basis of these results that the effects on junior water rights from the CROPS bypasses and the 20,000 acre-feet release from Green Mountain Reservoir are relatively minimal. These results, however, must be reviewed by the Executive Committee to determine the acceptability, or unacceptability, of these effects on junior water rights.

3.4.7 Effects of Removal of Shoshone Priority Call on Winter Flows

The effects on winter (November through April) Colorado River flows at the head of the 15-Mile Reach from removing the Shoshone priority call (every year, every month) were investigated and the results are presented in Table 13. Results in Table 13 indicate:

- The average winter monthly flow immediately upstream from Shoshone would be reduced by approximately 5 cfs by removing the Shoshone priority call. The maximum average monthly decrease is approximately 35 cfs in February.
- The average winter flow at the head of the 15-Mile Reach would be reduced by approximately 6 cfs. The maximum average monthly decrease is 35 cfs in February.

These results must be reviewed by the Executive Committee to determine if these decreases are sufficiently significant to constitute a fatal flaw to further consideration of this alternative.

3.4.8 Effects of "Share the Pain" Alternative with 111,000 Acre-Feet of Additional Future Depletions on Colorado River Flows

The estimated effects on Colorado River flows at the head of the 15-Mile Reach from the "Share the Pain" alternative (6,667 acre-feet releases from Granby, Green Mountain and Williams Fork Reservoirs) are presented in Table 14 which indicate:

- The average monthly flow at the head of the 15-Mile Reach (184,658 acre-feet) was increased an average of 64 acre-feet by the "Share the Pain" alternative making the 20,000 acre-feet release per year.
- The maximum average monthly flow reduction was 1,048 acre-feet in July. This represents a reduction from 295,601 acre-feet to 294,553 acre-feet.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

The following conclusions are based on:

- Results detailed in Technical Memoranda 1-11,
- Results of additional simulation studies completed using the revised StateMod with the C1 Data Set (Fifth Revision), and
- Sensitivity analysis.

Subsequent to completion of the Technical Memoranda, sensitivity analyses were developed to analyze the effects of the following on the feasibility of making the 20,000 acre-feet release:

- 111,000 acre-feet of future additional depletions.
- CROPS bypasses/releases.
- Inclusion of the Shoshone Power Plant maintenance schedule, Palisade Pipeline bypass flows, reduced Grand Valley Project demands and outlet works limitations.

Subsequent to completion of the Technical Memoranda and much of the sensitivity analysis, the C1 Data Set and StateMod were modified to more correctly model the exchanges and substitutions among Dillon, Williams Fork and Wolford Mountain reservoirs.

From the standpoint of the consultant team, the results of this sensitivity analysis, revisions to the C1 Data Set and the modification of StateMod did not change the original conclusions based on the Technical Memoranda except where specifically indicated below.

4.2 CONCLUSIONS AND RECOMMENDATIONS

The findings, conclusions and recommendations listed below concerning feasibility of the alternatives are those of the consultant team. These are based on our perspectives of economic and engineering feasibility. It is realized that these perspectives may differ from those of the Executive Committee and the water conservancy districts, water suppliers and water users who may be affected by these alternatives. Therefore, the Executive Committee, together with other potentially affected water suppliers, water users and water conservancy districts, must review the effects of these alternatives on reservoir storage, reservoir yield, reservoir operations, hydropower generation, tunnel deliveries, channel constraints, and the Check Case Settlement. This review must take into account engineering, economic, institutional and legal concerns specific to the water conservancy districts, municipalities, clients and users to determine the feasibility and acceptability of the specific alternatives.

The following summarizes the conclusions and recommendations from the Phase 2 Report.

1. **20,000 Acre-Feet Not Required Every Year.** Supplying the 20,000 acre-feet to the 15-Mile Reach would not have been required every year; it would have been necessary to supply the 20,000 acre-feet in only six, and possibly eight, years of the 17 years for the 1975-91 study period.

2. **20,000 Acre-Feet Not Required in Dry Years.** Supplying the 20,000 acre-feet would not have been required during the very dry years of the study period. For example, releases would not have been required in 1977 or 1981. Further analysis indicates that supplying the 20,000 acre-feet would not have been required in 2001 or 2002.

3. **Firm Yield Not Required for 20,000 Acre-Feet Release.** Not having to supply the 20,000 acre-feet in dry years indicates that the 20,000 acre-feet does not have to be supplied from firm yield. Instead, the 20,000 acre-feet can be supplied from sources in a manner that minimizes or eliminates effects on reservoir firm yields.

4. **20,000 Acre-feet Can Be Replaced Under Refill Priorities.** Several alternatives were designed to provide a source of replacement water for the 20,000 acre-feet release to the 15-Mile Reach:

   - Alternative 1a, Green Mountain Reservoir, Reduced Winter Power Operations.
   - Alternative 1a, Expanded Coordinated Reservoir Operations of Green Mountain Reservoir, Including Green Mountain Reservoir Pre-emptive Release and Release of Water Carried Over in Green Mountain Reservoir.
   - Alternative 1a, Expanded Coordinated Reservoir Operations of Green Mountain Reservoir, Conjunctive Pool Operations.

   These alternatives turned out to be less efficient than those alternatives that relied on reservoir refill priorities to replace the 20,000 acre-feet release to the 15-Mile Reach. The consultant team has concluded that the various strategies employed in the above alternatives to replace the 20,000 acre-feet are not necessary and that relying on the reservoir refill priorities is more efficient and effective. For all three of the above alternatives, relying on diversion to storage under Green Mountain Reservoir's refill priority would have replaced the 20,000 acre-feet supplied to the 15-Mile Reach.

   Analysis of the Conjunctive Pool Operation alternative indicated that it was possible to replace the 20,000 acre-feet release from Green Mountain Reservoir in the eight years of the study period in which it was made. Therefore, these results indicate that there should be no effect on releases from the HUP.

In general, the effects on storage and yield for west slope reservoirs from supplying the 20,000 acre-feet varied somewhat among the alternatives. From the consultant team's perspective of economic and engineering feasibility, however, these effects on storage and yield do not appear to constitute fatal flaws and one, or a combination of these alternatives could be an effective and efficient supply of the 20,000 acre-feet for the 15-Mile Reach.

5. **Other Feasible Expanded CROPS Alternatives.** The following alternatives could be expected to be feasible sources for all or part of the 20,000 acre-feet by relying on their refill priorities to replace the 20,000 acre-feet supplied to the 15-Mile Reach:

   - Alternative 1b, Expanded Coordinated Reservoir Operations of Ruedi Reservoir.
   - Alternative 1d, Modify CBT West Slope Facilities Operations.
   - Alternative 1e, Expanded Coordinated Reservoir Operations, Denver Water Systems Operations.
   - Alternative 1f, Bypass Diversions to Storage.
   - Alternative 1g, Reduce Constraints on CROPS.

   The Phase 1 Report directed that Alternative 1d be investigated with Alternative 5a, East Slope Power Operations and Scheduling. Alternative 5a, however, was never modeled because StateMod and the C1 Data Set only model the Colorado River Basin. Alternative 1d, however, can provide the 20,000 acre-feet bypass/release without the source of replacement for the 20,000 acre-feet bypass/release that might be available from Alternative 5a.

6. **Increased GVP and GVIC Efficiency Better for Late Summer Supply.** Alternative 3d, Re-analysis of Grand Valley Project (GVP) and Alternative 3e, Analysis of Grand Valley Irrigation Company (GVIC) Water Management, were originally designed to replace the 20,000 acre-feet bypass/release from savings produced to the HUP in Green Mountain Reservoir as a result of increased efficiency in the GVP and possible increased efficiency by the GVIC. As discussed above, analysis of these alternatives indicated that diverting to storage under the Green Mountain Reservoir refill priority was a more efficient way to replace the 20,000 acre-feet supplied to the 15-Mile Reach. Furthermore, based on the analysis using StateMod and the C1 Data Set, there was limited reduced demand on the HUP as a result of increased GVP efficiency. It appears that the reduced late summer and early fall diversions resulting from the increased GVP efficiency could be an important source of water supply for increasing low flows for the endangered species in the 15-Mile Reach during the later summer and/or early fall.

7. **Channel Constraints Affect Ruedi Reservoir Alternative.** The only alternative to be affected by downstream channel constraints in the original analysis completed in the Technical Memoranda and consequently unable to release 1,000 cfs over a 10-day period was Alternative 1b, Expanded Coordinated Reservoir Operations of Ruedi Reservoir. Limited physical availability also made it difficult for Ruedi Reservoir to replace releases to the 15-Mile Reach by diverting to storage under its refill priority. Therefore, it is suggested that Ruedi Reservoir's contribution to the 15-Mile Reach be limited to approximately 7,000 acre-feet or less.

8. **Inadequate Reservoir Release/Channel Capacity to Release 20,000 Acre-Feet and CROPS Bypass from Only One Reservoir.** Sensitivity analysis completed after the Technical Memoranda indicates there is adequate stored water in Green Mountain Reservoir to make the 20,000 acre-feet release together with the estimated CROPS bypasses for this reservoir, but that there is insufficient outlet capacity, without using the turbine bypass, for both the CROPS bypasses and the 20,000 acre-feet releases in one of the eight years (1985) in which the 20,000 acre-feet release would be required and the CROPS bypasses would be made. These results indicate the need for sharing responsibility for making the 20,000 acre-feet release among several reservoirs. Under such an arrangement, Green Mountain Reservoir could serve as the Insurance Pool by replacing by exchange those portions of the 20,000 acre-feet release made by other reservoirs if necessary.

9. **Green Mountain Reservoir Supply Creates Least Disruption.** From economic and engineering perspectives, releasing the full 20,000 acre-feet from Green Mountain Reservoir has the least disruption overall to expected yields and operations of all the reservoirs and power generation facilities, including Green Mountain Reservoir. Under this alternative, the 20,000 acre-feet bypass/release would be replaced by diversions to storage in Green Mountain Reservoir under the Green Mountain Reservoir refill priority. This alternative, however, places all the responsibility, and risk, on only Green Mountain Reservoir. Furthermore, as noted above, it will probably not be possible for Green Mountain Reservoir to physically make the 20,000 acre-feet release and do the estimated CROPS bypass for Green Mountain Reservoir without using the turbine bypass. Therefore, consideration should be given to sharing responsibility for the 20,000 acre-feet release among several reservoirs and possibly using Green Mountain Reservoir as the Insurance Pool for replacing releases from storage in other reservoirs toward the 20,000 acre-feet release by exchange.

10. **Modified "Share the Pain" Alternative Produced Least Effects on Reservoir Storage.** From engineering and economic perspectives, some version of the "Share the Pain" Alternatives (i.e., Alternative 1f, Bypass Diversions to Storage and Alternative 1g, Reduce Constraints on CROPS) would appear to be the most acceptable because this alternative minimizes the risk of reduced yield and storage to individual participating facilities, while providing the 20,000 acre-feet to the 15-Mile Reach and allowing the CROPS bypasses/releases to be made. As noted previously, sharing responsibility for making the 20,000 acre-feet release among several reservoirs may be desirable because of the insufficient release capacity in Green Mountain Reservoir to make both the estimated CROPS bypasses and the 20,000 acre-feet release without using the turbine bypass.

A Modified "Share the Pain" alternative was developed in which responsibility for supplying the 20,000 acre-feet was shared by Green Mountain, Ruedi, Wolford Mountain, Williams Fork and Green Mountain Reservoirs with most of the 20,000 acre-feet supplied by Green Mountain Reservoir while avoiding use of the Green Mountain Reservoir Power Plant turbine bypass and the remainder of the 20,000 acre-feet supplied by the other reservoirs. In the opinion of the consultant team, this Modified "Share the Pain" alternative was able to supply the 20,000 acre-feet in those years in which it would be required and produced the least effects on reservoir storage of any of the alternatives investigated while permitting both the CROPS bypasses/releases and the 20,000 acre-feet release to be made.

11. **New Tributary Storage Is Too Expensive.** The alternatives for building new tributary storage (Alternatives 4f, 4g, 4k, 4n and 4o) are all costly, due primarily to the limited physical supplies of water available from the tributaries and the need to depend on pumping from the Colorado River to supply most of these proposed reservoirs.

12. **Webster Hill Reservoir Site May Be Feasible Source of Water.** An additional engineering and economic feasibility investigation of the mainstem Webster Hill site was completed in Technical Memorandum No. 4a (See Appendix E). The cost of reservoir storage at this site for making the 20,000 acre-feet release to the 15-Mile Reach would be partially offset by the generation of hydropower. Remaining estimated capital costs per acre-foot of yield from the Webster Hill Reservoir after netting out the estimated power revenue would range from $29 to $134/acre-foot of yield per year depending on the assumed value of hydropower produced at the site. Results from this additional investigation further indicate that this site would likely be feasible if: (1) the necessary right-of-way can be obtained at reasonable cost and (2) the U.S. Fish and Wildlife Service would approve construction of a reservoir at the Webster Hill site.

    The Webster Hill Reservoir would produce a firm yield of 20,000 to 40,000 acre-feet per year. It is important to emphasize that the 20,000 acre-feet release would be available from Webster Hill Reservoir even in dry years when this release would not be required. Therefore, the Webster Hill Reservoir alternative would produce yield with a greater reliability than is necessary for supplying the 20,000 acre-feet to the 15-Mile Reach, which is not required in very dry years.

13. **East Slope Power Operations and Scheduling Were Not Modeled.** Alternative 5a, East Slope Power Operations and Scheduling, was investigated as one component of Alternative 1d, CBT West Slope Facilities Operations. Alternative 5a consists of: (1) delaying winter deliveries through the Adams Tunnel, (2) using these delayed winter deliveries to replace the release/bypass of the 20,000 acre-feet from Granby Reservoir to the 15-Mile Reach and (3) replacing the delayed deliveries to east slope reservoirs by diversions to storage in these reservoirs under the east slope priorities.

    Alternative 5a was not modeled because:

    - This alternative cannot be fully investigated using StateMod and the C1 Data Set because StateMod and the C1 Data Set only cover the Colorado River basin in Colorado and do not extend to east slope facilities and systems.

Specifically, StateMod and the C1 Data Set cannot be used to determine the quantity of deliveries through the Adams Tunnel that could be replaced through use of NCWCD's east slope water rights.

- The Bureau of Reclamation in its October 12, 2001 letter to the Colorado River Water Conservation District concludes that it is not feasible for a number of reasons to delay winter and early spring deliveries of west slope water to the east slope via the Adams Tunnel in order to keep east slope reservoir storage relatively low.

14. **Shoshone Power Plant Could Be Component of Insurance Pool.** Alternative 5b, Shoshone Power Plant, focused on general, not selective, removal of the Shoshone Power Plant priority call. Analysis of this alternative indicated that general removal of this priority call would result in an increase in stored water in those reservoirs which could supply the 20,000 acre-feet to the 15-Mile Reach, thereby reducing the risk of lower storage and/or lower reservoir yields accruing to those facilities. Elimination of the Shoshone priority call decreased the value of Shoshone power production by an average of approximately $116,000 per year. Further sensitivity analysis of the effect on November through April Colorado River flows at the head of the 15-Mile Reach from removing the Shoshone priority call indicated the average monthly reduced flow would be approximately 6 cfs. Further review of these sensitivity analysis results should be completed in order to determine if these reduced winter flows at the head of the 15-Mile Reach are sufficiently significant to discourage further consideration of this alternative.

15. **Insurance Pool Alternative Appears Feasible.** The Insurance Pool Alternative (Alternative 6a) appears feasible. This alternative could likely best be implemented by: (1) spreading responsibility among two or more reservoirs in those years in which the 20,000 acre-feet release would be necessary, (2) non-selective removal of the Shoshone priority call in years during which it was deemed necessary to reduce the effects on yield and storage for those structures supplying the 20,000 acre-feet release to the 15-Mile Reach, or (3) designation of a portion of the Service's existing Environmental Pools in Ruedi Reservoir and/or Wolford Mountain Reservoir to serve as the insurance pool in a given year (to be determined by the Service).

16. **Sensitivity Analysis Concerning 111,000 Acre-Feet of Future Demand Indicates Continued Feasibility of Alternatives.** Results of the sensitivity analysis indicate that those alternatives which appear to be feasible for supplying all or part of the 20,000 acre-feet to the 15-Mile Reach under conditions of the C1 Data Set can be expected to remain feasible in the future with an approximately 111,000 additional acre-feet of future depletions per year

17. **Sensitivity Analysis Concerning CROPS, Reduced Grand Valley Project Demands, Palisade Pipeline Return Flows, Shoshone Power Plant Maintenance Schedule and Outlet Works Limitations Indicates Continued Feasibility of Alternatives.** Sensitivity analyses involving these parameters indicates there would be little effect on availability of Green Mountain Reservoir storage for making the 20,000 acre-feet release from including CROPS bypasses, reduced Grand Valley Project demands, Palisade Pipeline bypass flows and the Shoshone Power Plant maintenance schedule. Including CROPS bypasses/releases, however, would not always leave sufficient release capacity through the Green Mountain Reservoir turbines to make the 1,000 cfs CFOPS release. This lack of sufficient release capacity at Green Mountain Reservoir will necessitate allocating responsibility for making a portion of the 20,000 acre-feet CFOPS release to other reservoirs. The opportunity for Green Mountain Reservoir to function as an insurance pool in these situations and payback the other reservoirs could also be considered.

18. **Effects on Junior Water Rights.** The results of analysis to quantify the shortages in diversions by junior water rights resulting from release of the 20,000 acre-feet and the CROPS bypasses indicate that for the 487 structures contained in the C1 Data Set, only 13 experienced a decrease in diversion as a result of the CROPS bypasses and the 20,000 acre-feet release over the 17-year study period, with an average increase in supply of 9 acre-feet per month, when a difference in shortage was noted.

19. **Effects on Colorado River Flows in 15-Mile Reach.** An analysis was made of the effect on Colorado River flows at the head of the 15-Mile Reach to determine if making the 20,000 acre-feet release (during June generally) would reduce flows during other months. Results of this analysis indicate that the maximum average monthly reduction occurred during July and reduced flows in that month by 1,048 acre-feet (295,601 acre-feet to 294,553 acre-feet).

20. **In General, StateMod and the C1 Data Set Performed Well in the Analysis of the Alternatives.** In the course of the investigation, however, the C1 Data Set was revised four time to correct for deficiencies including: transferring HUP storage to the Green Mountain Reservoir CBT pool on April 1, correcting the Ruedi Reservoir refill priority date, reducing the Grand Valley Project demand to account for increased efficiency of that project, incorporating the Shoshone Power Plant maintenance schedule into the C1 Data Set, and incorporating RIPRAP releases into the C1 Data Set. After each of these revisions, simulation runs were completed to compare the results from the revised C1 Data Sets to determine the necessity of redoing the previous work with a consistent data set. For each of the four revisions, the corrections and/or changes to the C1 Data Set did not produce sufficiently different simulation study results to change conclusions concerning the feasibility of alternatives.

21. **Revised StateMod and C1 Data Set Fifth Revision.** Throughout the investigation, it was noticed that the exchanges and substitutions among Dillon, Williams Fork, and Wolford Mountain Reservoirs using the C1 Data Set in StateMod differed from the simulations by Denver Water using their daily PACSIM model. In order to address this issue, the CWCB modified StateMod and a fifth revision was made to the C1 Data Set. A comparison of the base runs with the C1 Data Set (fourth revision) and the modified StateMod and C1 Data Set (fifth revision) was made to determine if these changes were sufficient to necessitate redoing the previous work with the modified StateMod and C1 Data Set (fifth revision). A comparison of these two base runs indicated that a difference remained, which was increased storage in Dillon Reservoir and decreased storage in Williams Fork Reservoir. In order to further check the need for re-running previous simulation runs with the modified StateMod and C1 Data Set (fifth revision), simulation runs for two alternatives were made: (1) Green Mountain Reservoir making the 20,000 acre-feet release and replacing this release using its refill priority and (2) the "Share the Pain" with responsibility for making the 20,000 acre-feet release divided equally among Granby, Green Mountain and Williams Fork Reservoirs. Results of these additional simulation runs did not differ significantly enough to change original conclusions presented in the Technical Memoranda concerning these alternatives. However, comparing simulations by Denver Water using its daily PACSIM model with StateMod showed differences in accounting for exchanges and substitutions into and out of Dillon, Williams Fork and Wolford Mountain Reservoirs. These differences would overstate the availability of water for release from these reservoirs for meeting the 20,000 acre-foot goal. Rather than continue to investigate and debate the need for further refinements to the model, it was determined that time would be better spent working on what could be done to meet the 20,000 acre-foot goal.

22. **Study Period is Satisfactory.** The consultant team believes that the study period of 1975-91 employed in the modeling and analysis produced satisfactory results. It should not be necessary to include more extreme periods of hydrologic data in the analysis, e.g., the 1950's, because the 20,000 acre-feet bypass/release would not be required for the 15-Mile reach during those extraordinarily dry years. Consequently, little would be gained by including these data in the analyses.

23. **Monthly Time Step is Satisfactory.** The consultant team similarly believes that the monthly time step used in the modeling and analysis is sufficient for purposes of this study and that the effort and cost of going to a daily time step could not be justified.

4.3 EXECUTIVE COMMITTEE RECOMMENDATION

The Executive Committee of the Coordinated Facilities Operation Study (CFOPS) developed the following recommendation after completion of the CFOPS Study and Draft Report (January 2003). This recommendation includes the following two alternatives for spring peak-flow augmentation to benefit endangered fishes in the 15-mile reach of the Colorado River.

Recommendation 1: Maximize Coordinated Reservoir Operations (CROPS) - As documented in the 1997 CFOPS report, the CROPS process was developed by a group of cooperating agencies over a number of years. Its purpose is to bypass storable inflows at participating reservoirs, in a way that does not impact a reservoirs' yield, to increase the magnitude of the peak flow through the 15-mile reach in years when the predicted peak flow at the Cameo gauge is greater than 12,900 cfs, but not likely to exceed 26,600 cfs or otherwise cause flooding concerns. CROPS were first implemented in 1997, and the process has demonstrated success in 1997, 1998, and 1999. This process should be continued as the primary means of augmenting the spring peak in the 15-mile reach, and efforts should be made to encourage increased participation in the process.

Recommendation 2: Augment the spring peak by using up to 20,000 acre-feet of stored water in addition to CROPS - The Service and Upper Colorado River Basin Recovery Program (Recovery Program) may determine that in certain years additional peak-flow augmentation would be desirable above and beyond what can be accomplished through CROPS. Under this scenario, up to 20,000 acre-feet of stored water would be released from existing reservoirs for that purpose in addition to CROPS. The amount of water released from storage in those years would depend on the size of an insurance pool of water that would be designated by the Service on or about May 5, from existing Environmental Pools in Ruedi, Green Mountain, Wolford Mountain, and Williams Fork reservoirs (which are now used solely for summer/fall base-flow augmentation). In any given year, the insurance pool would ensure that releases of stored water from the specified reservoir(s) for peak-flow augmentation would not jeopardize that (or those) reservoir's water supply yield. If the specified reservoir(s) re-fills and the insurance pool water is not used to offset reservoir shortages, then all Environmental Pool water would be available for base-flow augmentation. The Environmental Pool will only be reduced to the extent of a shortage in the filling of the specified reservoir(s) caused by the peak flow release. The ability to implement this recommendation depends on successfully addressing the institutional issues and uncertainties discussed in the report. The effectiveness of CFOPS for peak flow enhancement and its impact on the Service's Environmental Pool, its operation in coordination with CROPS, and all institutional issues will be assessed and reported annually.

Reservoir Storage: In addition to the two recommendations above, the CFOPS study identified a mainstem reservoir alternative at Webster Hill, just downstream from the City of Rifle, that could have multiple benefits and provide greater certainty of instream flow augmentation to benefit the endangered fishes. Although new storage to provide water for only the 20,000 acre-feet peak-flow augmentation was found to be expensive in the CFOPS study, a multi-purpose storage project, possibly including run-of-the-river hydropower and other water supply and recreation functions, may be much more cost effective and provide added benefits for endangered fish and their habitat as well. At some point in the future the water users may conduct an independent feasibility study of options for a multi-purpose reservoir to provide water for both 20,000 acre-feet of peak-flow augmentation and 10,825 acre-feet for base-flow augmentation. The feasibility study would be funded outside the Recovery Program and address a set of environmental questions and criteria provided by the Service, which would include among other things measures of direct adverse impacts to endangered fish and

their habitat. Upon completion of the feasibility study, the Recovery Program would consider whether or not to participate in the proposed multi-purpose project. If the Program wished to participate in the proposed multi-purpose reservoir project, further negotiations would be required to determine the level and means of Program participation.

CHAPTER 5

REFERENCES

Colorado Water Conservation Board, September 2000, *Phase 1 Coordinated Facilities Water Availability Study for the Endangered Fishes of the Upper Colorado River.*

Coordinated Reservoir Operations Group (Colorado Water Conservation Board, Lead), 1999, *Reservoir Bypasses for Endangered Fish: Draft Report on the 1997 Upper Colorado River Implementation Program,* Colorado Water Conservation Board, Denver, Colorado.

Maddux, Henry, February 2, 1999, Memo to Randy Seaholm, Response to January 22, 1999 letter from Randy Seaholm to Henry Maddux**.**

Moore, Andrew, July 19, 1999, Personal Communication to Leo Eisel.

Smith, George and Muth, Robert, July 1999 Memo to Leo Eisel: Comments on Draft Phase 1 Coordinated Facilities Water Availability Study Report.

U.S. Fish and Wildlife Service, May 1995, *Relationships Between Flow and Rare Fish Habitat in the 15-Mile Reach of the Upper Colorado River, Final Report.*

U.S. Fish and Wildlife Service, April 1, 1999, *Section 7 Cons*ultation, *Sufficient Progress, and Historic Projects Agreement and Recovery Action Plan (RIPRAP)*: *Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin,* Region 6, Denver, Colorado.

U.S. Fish and Wildlife Service, December 20, 1999, *Final Programmatic Biological Opinion for Bureau of Reclamation's Operations and Depletions, Other Depletions, and Funding and Implementation of Recovery Program Actions and Water Depletions in the Upper Colorado River Above the Confluence with the Gunnison River December 1999 (PDF) 380 KB.*

Table 1. Water Rights Summary

Structure	Water Right	Decreed Amount	Administration Number	Appropriation Date	Adjudication Date
Ruedi Reservoir	First Fill - absolute	102,373 AF	39291.00000	1957-07-29	1958-06-20
	Refill - absolute	101,280 AF	47869.00000	1981-01-22	1981-12-31
	Power - absolute	600 cfs	45950.00000	1975-10-22	1975-12-31
Granby Reservoir	First Fill - absolute	543,758 AF	31258.00000	1935-08-01	1955-10-12
	Refill[1]	543,758 AF	99999.99999	n/a	n/a
Green Mountain Reservoir	First Fill - absolute	154,645 AF	31258.00000	1925-08-01	1955-10-12
	Refill - absolute	6,316 AF	31258.00000	1925-08-01	1955-10-12
	Power - absolute	1,726 cfs	31258.00000	1935-08-01	1955-10-12
Dillon Reservoir	First Fill - absolute	252,678 AF	35238.00000	1946-06-24	1952-03-10
	Refill[1]	252,678 AF	49500.00000	n/a	n/a
	Out-of-Priority[1]	252,678 AF	31257.99999	n/a	n/a
Homestake Reservoir	First Fill - absolute	43,505 AF	38753.37520	1952-09-22	1958-07-23
	First Fill - conditional	83,339 AF	38753.37520	1952-09-22	1958-07-23
Williams Fork Reservoir	First Fill - absolute	93,637 AF	31359.00000	1935-11-10	1937-11-05
	Refill - absolute	93,637 AF	39095.38998	1956-10-09	1972-05-30
Willow Creek Reservoir	First Fill - absolute	10,553 AF	31258.00000	1935-08-01	1955-10-12
Wolford Mountain Reservoir	First Fill - absolute	32,986 AF	48196.00000	1981-12-15	1981-12-31
	Refill - conditional	27,007 AF	50386.00000	1987-12-14	1987-12-31
	Refill - conditional	6,000 AF	52976.00000	1995-01-16	1995-12-31
Vega Reservoir	First fill- absolute	33,500 AF	37486.00000	1952-08-19	1959-07-21
Shoshone Power Plant	Power - absolute	1,250 cfs	20427.18999	1902-01-07	1907-12-09
	Power - absolute	158 cfs	33023.28989	1929-05-15	1956-02-07
Boustead Tunnel	Absolute	900 cfs	39291.00000	1952-10-24	1958-06-20
	Absolute	63 cfs	48577.39291	1982-12-31	1983-12-31
	Conditional	37 cfs	48577.39291	1982-12-31	1983-12-31
Busk-Ivanhoe Tunnel	Absolute	150 cfs	39291.00000	1957-07-29	1958-16-20
	Absolute	30 cfs	39291.00000	1957-07-29	1958-16-20

Source: C1 data set for StateMod

[1]Not found in HydroBase

TABLE 2
SUMMARY OF C1 DATA SET REVISIONS

Revision	HUP Storage to CBT Pool on April 1	Correct Ruedi Res. Refill Priority Date	Reduced GVP Demands, Adj. Shoshone Maint. Sched.	RIPRAP	Correct Exchanges and Substitutions	Comments
C1 Data Set						This is form received from CWCB
C1 Data Set (First Revision)	Yes	No	No	No	No	Used in Tech. Memos 1-4
C1 Data Set (Second Revision)	Yes	Yes	No	No	No	Used in Tech. Memos 5-11 and October 2001Draft Phase 2 Report Sensitivity Analysis
C1 Data Set (Third Revision)	Yes	Yes	Yes	No	No	Used in February 2002 Draft Phase 2 Report Analysis and Sensitivity Analysis.
C1 Data Set (Fourth Revision)	Yes	Yes	Yes	Yes	No	Used in March 2002 Draft Phase 2 Report Analysis and Sensitivity Analysis
Revised StateMod and C1 Data Set (Fifth Revision)	Yes	Yes	Yes	Yes	Yes	Used in Final September 2003 Phase 2 Report Analysis and Sensitivity Analysis

Table 3. Estimated CROPS Bypasses (Acre-feet)

Year	Granby	Dillon	Green Mt.	Wms Fork	Homestake	Wolford	Ruedi	Vega	Willow Creek
1975	0	9200	11700	5000	0	4000	3932	0	0
1978	0	0	0	0	0	0	6088	0	0
1979	0	18000	0	0	0	4000	6838	0	300
1980	0	0	9200	9000	0	2250	0	0	0
1982	0	13000	9800	0	0	4000	3395	0	0
1985	200	1200	11500	10000	0	2250	5442	0	700
1986	5000	0	2000	6000	0	2750	6144	0	800
1991	0	0	8300	0	0	2750	3680	0	0

Note: Estimated CROP bypasses (modeled as releases) were obtained from:

- Bureau of Reclamation: Granby Reservoir, Green Mountain Reservoir, Ruedi Reservoir, Vega Reservoir and Willow Creek Reservoir
- Denver Water: Dillon Reservoir, Williams Fork Reservoir
- Colorado Springs Utilities: Homestake Reservoir
- Colorado River Water Conservation District: Wolford Mountain Reservoir

Table 4. Summary of Shortages to Junior Water Right Priorities

Structure ID	Year	Month	Difference in Shortages (AF)
510958	1979	NOV	-17
514655	1981	AUG	320
510941	1981	JUL	49
51_ADC_006	1980	AUG	-290
51_ADC_006	1982	JUL	-92
512038	1980	AUG	-244
512038	1980	SEP	-34
512038	1980	OCT	-11
512038	1980	NOV	-4
512038	1980	DEC	-1
512038	1981	AUG	3
512038	1981	SEP	2
512038	1981	OCT	2
512038	1981	NOV	1
512038	1981	DEC	1
512038	1982	JAN	1
512038	1982	FEB	1
512038	1982	MAR	1
512038	1983	JAN	1
512038	1983	FEB	1
512037	1981	DEC	1
512037	1982	JAN	1
512037	1982	MAR	1
510893	1982	JUL	-4
360841	1980	AUG	235
360841	1982	JUL	-494
362045	1979	MAY	148
362045	1981	JUL	-24
362046	1979	MAY	2600
362046	1981	JUL	-24
362047	1981	JUL	-24
530783	1982	JUL	-93
370583	1982	JUL	-22
530584	1975	OCT	-2
530584	1975	NOV	-2
530584	1975	DEC	-2
530584	1976	MAR	-2
530584	1978	AUG	724
530584	1978	NOV	-316
530584	1978	DEC	-315
530584	1979	MAR	-315
530584	1979	APR	1
530584	1980	SEP	-34
530584	1980	OCT	-10
530584	1980	NOV	-98
530584	1980	DEC	-96
530584	1981	MAR	-95
530584	1981	AUG	3
530584	1981	SEP	2

Table 4. Summary of Shortages to Junior Water Right Priorities

Structure ID	Year	Month	Difference in Shortages (AF)
530584	1981	OCT	1
530584	1981	NOV	-3
530584	1981	DEC	-4
530584	1982	MAR	-8
530584	1982	DEC	1
380720	1980	JUN	437
381121	1982	JUL	-86
380715	1980	JUN	542
380715	1982	JUL	-57
380757	1980	JUN	426
382041	1980	SEP	5
382041	1980	NOV	3
382041	1980	DEC	2
382041	1981	JAN	2
382041	1981	FEB	1
382041	1981	MAR	1
380968	1982	JUL	-243
380618	1982	JUL	-588
380712	1980	JUN	515
380712	1982	JUL	-589
380970	1982	JUL	-25
381018	1982	JUL	-625
381066	1982	JUL	-6
390825	1982	JUL	-28
390672	1982	JUL	-121
392010	1982	AUG	-1
390612	1982	JUL	-111
450743	1982	JUL	-290
392004	1979	DEC	114
		TOTAL	**699**
		OVERALL AVERAGE	**9.0**
		AVERAGE OF NEGATIVE DIFFERENCES	**-126.7**

Notes:

1. Shortage = (monthly demand for a separate structure from C1 Data Set Fourth Revision) - (monthly diversion for a specific structure from C1 Data Set Fourth Revision)
2. Differences in shortages are calculated between C1 Baseline (including reduced GVP demands and Shoshone maintenance) and 20,000 AF release from Green Mountain Reservoir (including CROP releases). A negative difference in shortages means there was less water diverted by the specific structure with the 20,000 AF release and CROP as compared to the C1 Baseline.

Table 5. Available Release Capacity Calculations for Green Mountain Reservoir

Year	Month	Spillway Capacity[1] (cfs)	C1 Baseline Release[2] (AF/month)	C1 Baseline Release (cfs)	CROPS Bypass[3] during 10-day Peak (AF)	CROPS Bypass during 10-day Peak (cfs)	Available Capacity during 10-day Peak (cfs)	Available Capacity during 10-day peak (AF)
1975	June	1500	10,362	173	11,700	585	2,242	44,846
1978	June	1500	16,329	272	0	0	2,728	54,557
1979	May	0	5,289	88	0	0	1,412	28,237
1980	June	1500	91,596	1,527	9,200	460	1,013	20,268
1982	June	1500	5,970	100	9,800	490	2,411	48,210
1985	June	1500	100,470	1,675	11,500	575	751	15,010
1986	June	1500	103,802	1,730	2,000	100	1,170	23,399
1991	June	1500	29,383	490	8,300	415	2,095	41,906

[1]A Green Mountain Reservoir Power Plant capacity of 1500 cfs was used for purposes of this investigation. In addition, a turbine bypass (approximately 1600 cfs capacity) can be used to make releases from Green Mountain Reservoir. Use of the turbine bypass, however, results in lost power generation and is avoided if possible. An additional 1500 cfs over the spillway is available if storage exceeds 111,000 AF. The Bureau of Reclamation avoids using the spillway and the turbine bypass at the same time. Therefore, the available capacity during the 10-day peak is calculated based on the 1500 cfs Power Plant Capacity and the 1500 cfs spillway capacity.

[2]This is the amount of reservoir release from the C1 Data Set without CROPS.

[3]CROPS Bypasses were modeled as releases in the same month as the inflow.

Table 6. Available Release Capacity Calculations for Ruedi Reservoir

Year	Month	Estimated Average Flow during 10-day Peak (AF/month)	Estimated Average Flow during 10-day Peak (cfs)	CROPS Bypass[1] during 10-day Peak (AF)	CROPS Bypass during 10-day Peak (cfs)	Available Capacity during 10-day Peak[2] (cfs)	Available Capacity during 10-day peak (AF)
1975	June	15,553	259	3,932	197	644	12,884
1978	June	16,533	276	6,088	304	520	10,401
1979	May	6,764	113	6,838	342	645	12,907
1980	June	12,388	206	0	0	894	17,871
1982	June	14,650	244	3,395	170	686	13,722
1985	June	19,914	332	5,442	272	496	9,920
1986	June	20,321	339	6,144	307	454	9,082
1991	June	9,514	159	3,680	184	757	15,149

[1]CROPS Bypasses were modeled as releases in the same month as the inflow.

[2]Limiting downstream channel capacity near Basalt is 1100 cfs. Turbine Capacity is 260 cfs in practice with 1000 cfs turbine bypass capacity.

Table 7. Available Release Capacity Calculations for Wolford Mountain Reservoir

Year	Month	C1 Baseline Release[1] (AF/month)	C1 Baseline Release (cfs)	CROPS Bypass[2] during 10-day Peak (AF)	CROPS Bypass during 10-day Peak (cfs)	Available Capacity during 10-day Peak[3] (cfs)	Available Capacity during 10-day peak (AF)
1975	June	12,353	206	4,000	200	-6	-118
1978	June	31,394	523	0	0	-123	-2,465
1979	May	19,821	330	4,000	200	-130	-2,607
1980	June	19,099	318	2,250	113	-31	-616
1982	June	32,394	540	4,000	200	-340	-6,798
1985	June	16,864	281	2,250	113	6	129
1986	June	21,621	360	2,750	138	-98	-1,957
1991	June	22,099	368	2,750	138	-106	-2,116

[1]This is the amount of reservoir release from the C1 Data Set without CROPS.

[2]CROPS Bypasses were modeled as releases in the same month as the inflow.

[3]Limiting release capacity for Wolford Mountain Reservoir is 400 cfs.

Table 8. Available Release Capacity Calculations for Williams Fork Reservoir

Year	Month	C1 Baseline Release[1] (AF/month)	C1 Baseline Release (cfs)	CROPS Bypass[2] during 10-day Peak (AF)	CROPS Bypass during 10-day Peak (cfs)	Available Capacity during 10-day Peak[3] (cfs)	Available Capacity during 10-day peak (AF)
1975	June	893	15	5,000	250	270	5,402
1978	June	969	16	0	0	519	10,377
1979	May	922	15	0	0	520	10,393
1980	June	8,533	142	9,000	450	-57	-1,144
1982	June	4,042	67	0	0	468	9,353
1985	June	34,442	574	10,000	500	-539	-10,781
1986	June	31,100	518	6,000	300	-283	-5,667
1991	June	18,306	305	0	0	230	4,598

[1]This is the amount of reservoir release from the C1 Data Set without CROPS.

[2]CROPS Bypasses were modeled as releases in the same month as the inflow.

[3]Limiting release capacity for Williams Fork Reservoir is 535 cfs.

Table 9. Available Release Capacity Calculations for Granby Reservoir

Year	Month	C1 Baseline Release[1] (AF/month)	C1 Baseline Release (cfs)	CROPS Bypass[2] during 10-day Peak (AF)	CROPS Bypass during 10-day Peak (cfs)	Available Capacity during 10-day Peak[3] (cfs)	Available Capacity during 10-day peak (AF)
1975	June	7,465	124	0	0	336	6,712
1978	June	4,908	82	0	0	378	7,564
1979	May	4,750	79	0	0	381	7,617
1980	June	5,036	84	0	0	376	7,521
1982	June	4,868	81	0	0	379	7,577
1985	June	30,963	516	200	10	-66	-1,321
1986	June	5,030	84	5,000	250	126	2,523
1991	June	4,776	80	0	0	380	7,608

[1]This is the amount of reservoir release from the C1 Data Set without CROPS.

[2]CROPS Bypasses were modeled as releases in the same month as the inflow.

[3]Limiting release capacity for Granby Reservoir is 460 cfs.

Table 10. Total available capacity during 10-day peak from all 5 reservoirs for period of study

Year	Green Mountain	Ruedi	Wolford	Williams Fork	Granby	Available Capacity (AF)
1975	44,846	12,884	0	5,402	6,712	69,844
1978	54,557	10,401	0	10,377	7,564	82,899
1979	28,237	12,907	0	10,393	7,617	59,154
1980	20,268	17,871	0	0	7,521	45,660
1982	48,210	13,722	0	9,353	7,577	78,862
1985	15,010	9,920	129	0	0	25,059
1986	23,399	9,082	0	0	2,523	35,005
1991	41,906	15,149	0	4,598	7,608	69,260

Table 11. Potential CFOPS Release for Modified Share the Pain Alternative for 10-day Peak

Year	Green Mountain	Ruedi	Wolford	Williams Fork	Granby	Total Release (AF)
1975	14,000	2,000	0	2,000	2,000	20,000
1978	14,000	2,000	0	2,000	2,000	20,000
1979	14,000	2,000	0	2,000	2,000	20,000
1980	16,000	2,000	0	0	2,000	20,000
1982	14,000	2,000	0	2,000	2,000	20,000
1985	17,871	2,000	129	0	0	20,000
1986	16,000	2,000	0	0	2,000	20,000
1991	14,000	2,000	0	2,000	2,000	20,000

Table 12. Potential Total CFOPS and CROPS Bypass/Release for Modified Share the Pain Alternative for 10-day Peak

Year	Green Mountain	Ruedi	Wolford	Williams Fork	Granby	Total Release (AF)
1975	25,700	5,932	4,000	7,000	2,000	44,632
1978	14,000	8,088	0	2,000	2,000	26,088
1979	14,000	8,838	4,000	2,000	2,000	30,838
1980	25,200	2,000	2,250	9,000	2,000	40,450
1982	23,800	5,395	4,000	2,000	2,000	37,195
1985	29,371	7,442	2,379	10,000	200	49,392
1986	18,000	8,144	2,750	6,000	7,000	41,894
1991	22,300	5,680	2,750	2,000	2,000	34,730

Table 13. Effects on Winter Colorado River Flows from Removal of the Shoshone Priority Call

Winter Month	C1 Baseline Flow upstream of Shoshone (cfs)	Flow Change with Removal of the Shoshone Call Upstream of Shoshone (cfs)	C1 Baseline Flow at Head of 15-Mile Reach (cfs)	Flow Change with Removal of the Shoshone Call at Head of 15-Mile Reach (cfs)
Nov-74	1112.31	-52.27	1661.23	-52.27
Dec-74	1040.91	-51.57	1779.70	-51.57
Jan-75	1008.40	-54.65	1650.57	-48.87
Feb-75	984.44	-59.33	1536.57	-59.33
Mar-75	1029.98	-17.27	1952.00	-17.27
Apr-75	1252.21	115.08	2026.21	109.98
Nov-75	1337.51	-6.62	2264.51	-6.62
Dec-75	1207.79	-35.69	2101.94	-35.69
Jan-76	1153.15	-26.13	2050.69	-26.14
Feb-76	1188.79	-23.69	2094.60	-23.69
Mar-76	1290.08	15.49	2348.79	15.49
Apr-76	1391.21	46.78	1438.37	46.78
Nov-76	1005.00	-54.73	1780.79	-54.71
Dec-76	832.44	-58.38	1650.91	-58.37
Jan-77	793.79	-58.48	1573.47	-58.48
Feb-77	795.12	-59.26	1510.54	-59.26
Mar-77	839.60	-35.25	1515.30	-35.25
Apr-77	1252.21	281.62	689.02	281.62
Nov-77	771.90	0.07	1223.22	13.82
Dec-77	782.12	-17.29	1493.64	-4.73
Jan-78	744.71	-29.70	1288.75	-17.90
Feb-78	640.76	-18.55	1114.38	-7.53
Mar-78	867.73	35.69	1512.29	46.16
Apr-78	1410.49	0.00	1616.52	-96.43
Nov-78	1073.16	-70.89	1327.14	-85.13
Dec-78	899.55	-69.63	1604.36	-75.49
Jan-79	832.86	-69.75	1436.31	-72.85
Feb-79	839.33	-69.43	1415.02	-71.21
Mar-79	1035.94	-27.04	1914.98	-28.18
Apr-79	1379.01	114.48	1835.86	113.62
Nov-79	1180.93	-8.20	2173.89	-12.32
Dec-79	1144.53	-8.43	2015.98	-10.64
Jan-80	1130.34	-11.23	1941.80	-12.41
Feb-80	1045.52	-11.58	2001.72	-12.31
Mar-80	1068.35	23.03	2132.07	22.49
Apr-80	1252.21	34.81	1864.78	34.44
Nov-80	1064.75	-70.27	1577.56	-67.79
Dec-80	1003.27	-55.39	1656.06	-53.91
Jan-81	868.13	-52.47	1460.29	-51.48
Feb-81	785.67	-67.96	1290.94	-67.26
Mar-81	842.41	-49.46	1348.13	-49.04
Apr-81	1252.21	292.76	594.55	293.01
Nov-81	871.23	-165.07	1112.56	-160.69
Dec-81	771.25	-170.64	1446.84	-167.58
Jan-82	744.83	-169.87	1501.78	-167.73
Feb-82	656.18	-173.72	1241.38	-172.14

Table 13. Effects on Winter Colorado River Flows from Removal of the Shoshone Priority Call

Winter Month	C1 Baseline Flow upstream of Shoshone (cfs)	Flow Change with Removal of the Shoshone Call Upstream of Shoshone (cfs)	C1 Baseline Flow at Head of 15-Mile Reach (cfs)	Flow Change with Removal of the Shoshone Call at Head of 15-Mile Reach (cfs)
Mar-82	854.71	-151.82	1583.25	-149.73
Apr-82	1252.21	134.97	1367.76	135.77
Nov-82	1351.50	-18.22	2703.50	-17.90
Dec-82	1151.43	-28.59	2208.42	-29.16
Jan-83	1087.34	-30.64	2033.10	-30.47
Feb-83	1016.85	-25.08	1871.38	-24.97
Mar-83	1150.30	169.07	2229.85	169.18
Apr-83	1183.08	257.41	1961.01	257.47
Nov-83	1410.49	0.00	2569.73	-15.07
Dec-83	1457.51	2.42	2588.77	2.42
Jan-84	1268.82	21.01	2294.87	21.01
Feb-84	1245.00	10.20	2391.89	10.20
Mar-84	1203.27	41.75	2630.79	41.75
Apr-84	1341.68	64.55	2734.34	64.53
Nov-84	1410.49	0.00	3230.62	0.74
Dec-84	1446.55	68.67	3067.32	68.67
Jan-85	1361.36	27.15	2563.06	27.15
Feb-85	1290.03	22.63	2317.93	22.64
Mar-85	1457.51	0.00	2901.08	2.29
Apr-85	1410.49	0.00	5929.66	-6.89
Nov-85	1410.49	0.00	2895.00	3.32
Dec-85	1457.51	0.00	2551.57	0.00
Jan-86	1441.94	18.43	2526.08	18.42
Feb-86	1316.46	0.00	2679.98	-4.95
Mar-86	1457.51	0.00	3251.78	0.61
Apr-86	1410.49	0.00	5432.41	-46.20
Nov-86	1410.49	0.00	3135.64	-0.91
Dec-86	1326.36	8.40	2670.24	8.38
Jan-87	1162.59	13.43	2266.53	13.45
Feb-87	1127.17	14.48	2235.12	14.46
Mar-87	1304.19	65.98	2617.31	65.98
Apr-87	1410.49	0.00	2648.43	-11.35
Nov-87	1331.53	18.64	2283.32	18.65
Dec-87	1160.03	-36.21	2034.46	-36.21
Jan-88	1179.38	-25.02	1852.21	-25.03
Feb-88	1082.14	-25.57	1749.85	-25.59
Mar-88	1210.39	89.18	2141.06	89.18
Apr-88	1410.49	0.00	1915.77	-0.88
Nov-88	1018.69	-50.25	1475.91	-50.25
Dec-88	958.96	-50.35	1623.62	-50.37
Jan-89	999.39	-49.78	1590.79	-49.76
Feb-89	875.57	-50.52	1492.34	-50.52
Mar-89	1285.27	55.27	1991.11	55.27
Apr-89	1410.49	0.00	1523.05	-27.47
Nov-89	1027.56	0.49	1323.48	3.70
Dec-89	1042.21	-4.34	1626.63	-1.11

Table 13. Effects on Winter Colorado River Flows from Removal of the Shoshone Priority Call

Winter Month	C1 Baseline Flow upstream of Shoshone (cfs)	Flow Change with Removal of the Shoshone Call Upstream of Shoshone (cfs)	C1 Baseline Flow at Head of 15-Mile Reach (cfs)	Flow Change with Removal of the Shoshone Call at Head of 15-Mile Reach (cfs)
Jan-90	974.76	-4.73	1443.18	-1.48
Feb-90	834.48	-5.19	1455.76	-1.94
Mar-90	1053.16	39.04	1572.22	42.31
Apr-90	1410.49	0.00	686.35	0.00
Nov-90	1018.00	-50.61	1625.08	-50.61
Dec-90	907.96	-52.29	1269.76	-52.29
Jan-91	836.78	-54.95	1385.86	-54.93
Feb-91	782.41	-55.44	1286.25	-55.44
Mar-91	877.58	-29.98	1646.23	-30.00
Apr-91	1252.21	189.93	1508.11	189.93
Overall Monthly Average	**1117.65**	**-4.77**	**1954.50**	**-6.16**
Monthly Averages				
November	***1165.06***	***-31.05***	***2021.36***	***-31.41***
December	***1093.55***	***-32.90***	***1964.13***	***-32.21***
January	***1034.62***	***-32.79***	***1815.26***	***-31.62***
February	***970.94***	***-35.18***	***1746.21***	***-34.64***
March	***1107.53***	***13.16***	***2075.78***	***14.19***
April	***1334.21***	***90.14***	***2104.25***	***78.70***
Maximum Increase				
November	***n/a***	***18.64***	***n/a***	***18.65***
December	***n/a***	***68.67***	***n/a***	***68.67***
January	***n/a***	***27.15***	***n/a***	***27.15***
February	***n/a***	***22.63***	***n/a***	***22.64***
March	***n/a***	***169.07***	***n/a***	***168.18***
April	***n/a***	***292.76***	***n/a***	***293.01***
Maximum Decrease				
November	***n/a***	***-165.07***	***n/a***	***-160.69***
December	***n/a***	***-170.64***	***n/a***	***-167.58***
January	***n/a***	***-169.87***	***n/a***	***-167.73***
February	***n/a***	***-173.72***	***n/a***	***-172.14***
March	***n/a***	***-151.82***	***n/a***	***-149.73***
April	***n/a***	***0***	***n/a***	***-96.43***

Table 14. Effects on Colorado River Flows at Head of 15-mile Reach From Share the Pain Alternative with 111,000 AF of Future Demands

	Revised Statemod and C1 Data Set (Fifth Revision) and 111,000 AF Demand	Revised Statemod and C1 Data Set (Fifth Revision) with Share the Pain Alternative and 111,000 AF Demand	Difference (Column 2 - Column 1)
Date	**Flow (AF)**	**Flow (AF)**	**Flow (AF)**
Oct-74	74990	74990	0
Nov-74	92787	92787	0
Dec-74	99424	99424	0
Jan-75	91080	91080	0
Feb-75	84684	84684	0
Mar-75	110162	110162	0
Apr-75	121776	121776	0
May-75	299250	299250	0
Jun-75	679136	692037	12901
Jul-75	472509	463246	-9263
Aug-75	101393	101393	0
Sep-75	71191	69737	-1454
Oct-75	67683	67683	0
Nov-75	118938	118887	-51
Dec-75	110189	110139	-50
Jan-76	107377	107328	-49
Feb-76	109359	109310	-49
Mar-76	122765	122716	-49
Apr-76	87389	87389	0
May-76	309355	309355	0
Jun-76	334425	334425	0
Jul-76	136545	136544	-1
Aug-76	60459	60459	0
Sep-76	61800	61800	0
Oct-76	56071	56071	0
Nov-76	93170	93170	0
Dec-76	86160	86160	0
Jan-77	81323	81323	0
Feb-77	77162	77162	0
Mar-77	77413	77413	0
Apr-77	40754	40754	0
May-77	61132	61132	0
Jun-77	56358	56358	0
Jul-77	35511	35510	-1
Aug-77	182	182	0
Sep-77	5408	5408	0
Oct-77	46926	46926	0
Nov-77	67810	67810	0
Dec-77	84388	84388	0
Jan-78	71520	71520	0
Feb-78	61216	61216	0
Mar-78	87545	87545	0
Apr-78	92963	92962	-1
May-78	315046	315046	0
Jun-78	751265	760175	8910
Jul-78	255241	255238	-3
Aug-78	33873	32733	-1140
Sep-78	26571	26572	1
Oct-78	12203	12203	0

Table 14. Effects on Colorado River Flows at Head of 15-mile Reach From Share the Pain Alternative with 111,000 AF of Future Demands

	Revised Statemod and C1 Data Set (Fifth Revision) and 111,000 AF Demand	Revised Statemod and C1 Data Set (Fifth Revision) with Share the Pain Alternative and 111,000 AF Demand	Difference (Column 2 - Column 1)
Date	**Flow (AF)**	**Flow (AF)**	**Flow (AF)**
Nov-78	63849	63979	130
Dec-78	81060	81190	130
Jan-79	70094	70225	131
Feb-79	69127	69257	130
Mar-79	101174	101304	130
Apr-79	106288	106288	0
May-79	553480	564115	10635
Jun-79	832759	829790	-2969
Jul-79	331360	331360	0
Aug-79	101393	101393	0
Sep-79	23820	18027	-5793
Oct-79	14036	14197	161
Nov-79	114388	113184	-1204
Dec-79	106272	105211	-1061
Jan-80	102086	101255	-831
Feb-80	106131	105289	-842
Mar-80	112081	111544	-537
Apr-80	116096	115692	-404
May-80	521636	521629	-7
Jun-80	762067	763152	1085
Jul-80	286212	286193	-19
Aug-80	47330	47330	0
Sep-80	24495	24495	0
Oct-80	50973	50973	0
Nov-80	82218	82234	16
Dec-80	87181	87181	0
Jan-81	76223	76222	-1
Feb-81	65825	65825	0
Mar-81	73176	73176	0
Apr-81	31539	31539	0
May-81	125956	125956	0
Jun-81	212899	212899	0
Jul-81	69611	69611	0
Aug-81	3296	3296	0
Sep-81	30055	30055	0
Oct-81	96049	96049	0
Nov-81	59423	59422	-1
Dec-81	78654	78654	0
Jan-82	80739	80739	0
Feb-82	65553	65553	0
Mar-82	91641	91641	0
Apr-82	79325	79325	0
May-82	330945	330945	0
Jun-82	626968	636584	9616
Jul-82	330860	324463	-6397
Aug-82	72421	72689	268
Sep-82	98160	98160	0
Oct-82	120116	120116	0
Nov-82	148680	148350	-330

Table 14. Effects on Colorado River Flows at Head of 15-mile Reach From Share the Pain Alternative with 111,000 AF of Future Demands

	Revised Statemod and C1 Data Set (Fifth Revision) and 111,000 AF Demand	Revised Statemod and C1 Data Set (Fifth Revision) with Share the Pain Alternative and 111,000 AF Demand	Difference (Column 2 - Column 1)
Date	**Flow (AF)**	**Flow (AF)**	**Flow (AF)**
Dec-82	119695	119366	-329
Jan-83	108985	108656	-329
Feb-83	99948	99618	-330
Mar-83	119382	119101	-281
Apr-83	111610	111610	0
May-83	450783	450783	0
Jun-83	1498501	1499016	515
Jul-83	873240	873238	-2
Aug-83	286613	286613	0
Sep-83	98160	98160	0
Oct-83	85707	84313	-1394
Nov-83	140940	140940	0
Dec-83	145764	145116	-648
Jan-84	123492	122844	-648
Feb-84	129582	128928	-654
Mar-84	142106	141547	-559
Apr-84	152121	152121	0
May-84	1169297	1169086	-211
Jun-84	1614053	1611790	-2263
Jul-84	844307	844310	3
Aug-84	309989	309988	-1
Sep-84	151438	151438	0
Oct-84	237210	237209	-1
Nov-84	190495	190494	-1
Dec-84	180851	180850	-1
Jan-85	152447	152447	0
Feb-85	137834	137834	0
Mar-85	171541	171541	0
Apr-85	345108	345108	0
May-85	970512	970511	-1
Jun-85	978191	978191	0
Jul-85	384484	384483	-1
Aug-85	72102	72029	-73
Sep-85	91574	92438	864
Oct-85	172123	172123	0
Nov-85	161363	161205	-158
Dec-85	144273	144114	-159
Jan-86	139357	139198	-159
Feb-86	147867	147708	-159
Mar-86	182001	181843	-158
Apr-86	315571	315571	0
May-86	661757	661757	0
Jun-86	985700	987337	1637
Jul-86	435276	435276	0
Aug-86	101393	101393	0
Sep-86	124075	124075	0
Oct-86	136835	136835	0
Nov-86	184053	184054	1
Dec-86	156164	156164	0

Table 14. Effects on Colorado River Flows at Head of 15-mile Reach From Share the Pain Alternative with 111,000 AF of Future Demands

	Revised Statemod and C1 Data Set (Fifth Revision) and 111,000 AF Demand	Revised Statemod and C1 Data Set (Fifth Revision) with Share the Pain Alternative and 111,000 AF Demand	Difference (Column 2 - Column 1)
Date	**Flow (AF)**	**Flow (AF)**	**Flow (AF)**
Jan-87	132603	132603	0
Feb-87	130896	130896	0
Mar-87	151930	151930	0
Apr-87	155311	155311	0
May-87	449281	449281	0
Jun-87	316943	316943	0
Jul-87	148367	148367	0
Aug-87	77413	77413	0
Sep-87	31567	31567	0
Oct-87	25119	25119	0
Nov-87	113049	113049	0
Dec-87	101393	101393	0
Jan-88	91674	91674	0
Feb-88	84999	84999	0
Mar-88	109140	109140	0
Apr-88	106959	106959	0
May-88	255730	255730	0
Jun-88	385677	385677	0
Jul-88	85681	85681	0
Aug-88	26831	26831	0
Sep-88	39581	39581	0
Oct-88	3635	3635	0
Nov-88	75004	75004	0
Dec-88	84448	84448	0
Jan-89	82885	82885	0
Feb-89	77400	77400	0
Mar-89	108375	108375	0
Apr-89	90095	90095	0
May-89	221452	221452	0
Jun-89	224614	224614	0
Jul-89	92063	92063	0
Aug-89	50973	50973	0
Sep-89	24116	24116	0
Oct-89	15290	15290	0
Nov-89	60645	60645	0
Dec-89	77921	77921	0
Jan-90	67126	67126	0
Feb-90	68541	68541	0
Mar-90	78138	78138	0
Apr-90	42855	42855	0
May-90	82410	82410	0
Jun-90	282735	282735	0
Jul-90	92170	92170	0
Aug-90	14771	14771	0
Sep-90	13926	13926	0
Oct-90	73661	73661	0
Nov-90	88093	88093	0
Dec-90	64303	64303	0
Jan-91	71980	71980	0

Table 14. Effects on Colorado River Flows at Head of 15-mile Reach From Share the Pain Alternative with 111,000 AF of Future Demands

	Revised Statemod and C1 Data Set (Fifth Revision) and 111,000 AF Demand	Revised Statemod and C1 Data Set (Fifth Revision) with Share the Pain Alternative and 111,000 AF Demand	Difference (Column 2 - Column 1)
Date	**Flow (AF)**	**Flow (AF)**	**Flow (AF)**
Feb-91	65816	65816	0
Mar-91	93234	93234	0
Apr-91	87840	87840	0
May-91	263428	263428	0
Jun-91	483772	492701	8929
Jul-91	151783	149645	-2138
Aug-91	44138	44135	-3
Sep-91	57052	57050	-2
		Monthly Averages	
January	97117	97006	-111
February	93055	92943	-112
March	113636	113550	-86
April	122565	122541	-24
May	414203	414816	613
June	648592	650848	2257
July	295601	294553	-1048
August	82622	82566	-56
September	57235	56859	-376
October	75802	75729	-73
November	109112	109018	-94
December	106361	106237	-125
Average	***184658***	***184722***	***64***

TABLE 15. Summary of Alternatives

PHASE 1 ALTERNATIVE NO.	TECHNICAL MEMORANDUM NO.	ALTERNATIVE NAME	ALTERNATIVE DESCRIPTION	SOURCE OF WATER	ABILITY OF ALT. TO MAKE 20,000 AF RELEASE	EFFECT ON DILLON RESERVOIR	EFFECT ON GRANBY RESERVOIR	EFFECT ON GREEN MOUNTAIN RESERVOIR	EFFECT ON HOMESTAKE RESERVOIR	EFFECT ON RUEDI RESERVOIR	EFFECT ON WILLIAMS FORK RESERVOIR	EFFECT ON WILLOW CREEK RESERVOIR	EFFECT ON WOLFORD MTN. RESERVOIR	EFFECT ON VEGA RESERVOIR	EFFECT ON HYDRO-POWER: GR. MTN. RES	EFFECT ON HYDRO-POWER: RUEDI RES	EFFECT ON HYDRO-POWER: SHOSHONE	EFFECT ON HYDRO-POWER: ORCHARD MESA	EFFECT ON ADAMS TUNNEL DELIVERIES	EFFECT ON ROBERTS TUNNEL DELIVERIES1	EFFECT ON BOUSTEAD TUNNEL DELIVERIES	EFF. ON BUSK-IVANHOE TUNNEL DELIVERIES	CHANNEL CAPACITY EFFECTS	EFFECTS ON CHECK CASE SETTLEMENT
EXPANDED COORDINATED RESERVOIR OPERATIONS																								
1a	No. 1	Green Mt. Reservoir Operations	Reduced Winter Power Operations	Green Mountain Reservoir	Feasible	Unaffected	Unaffected	Unaffected	Unaffected	Unaffected	Unaffected	Unaffected	Generally unaffected, increase in storage in 1977, 1981 and 1982	Unaffected	Reduced revenue avg $36,000/year	None anticipated	Reduced revenue avg $174,000/year	Unaffected	None anticipated	None anticipated	None Anticipated	None Anticipated	Unaffected	None Anticipated
1a	No. 3	Green Mt. Reservoir Operations	Conjunctive Pool Operations	Green Mountain Reservoir	Feasible	Unaffected	Unaffected	Unaffected	Unaffected	Unaffected	Unaffected	Unaffected	Generally unaffected, decrease in storage in 1982	Unaffected	Increased by $10,085/year average	Unaffected	Unaffected	Unaffected	Unaffected	None anticipated	Unaffected	Unaffected	Unaffected	Unaffected
1b	No. 5	Ruedi Reservior Operations	Modify Ruedi Reservoir operations	Ruedi Reservoir	20,000 AF not feasible due to channel constraints, half and full channel capacity release feasible	None Anticipated	None Anticipated	None Anticipated	None Anticipated	Full channel release: deficit in 1978, 1980, 1991, avg of 2,073 AF; Half channel release: deficit in 1980, 1991, avg of 351 AF	None Anticipated	None Anticipated	None Anticipated	None Anticipated	None Anticipated	Full channel release: reduced avg $18,200/year; Half channel release: increased avg $4,150/year	None Anticipated	Unaffected	None anticipated	None anticipated	Generally unaffected, short in May 1979	Unaffected	Release restricted by Frying Pan channel capacity, modeling based on capacity	None Anticipated
1e	No. 11	Denver Water Systems Operations	Modify Denver Water System Operations	Williams Fork Reservoir	Feasible	Unaffected	None Anticipated	Unaffected	None Anticipated	Unaffected	Did not fill in 1975, 1980, 1982 - storage matched baseline at end of irrigation season; 19,000 AF deficit in 1978 - did not refill till following summer	None Anticipated	None Anticipated	None Anticipated	Increased revenue $800/year	Increased revenue $3,100/year	Reduced revenue $15,000/year	Unaffected	None anticipated	None anticipated	None Anticipated	None Anticipated	None Anticipated	None Anticipated
1f, 1g	No. 7 (Modified "Share the Pain" discussed in Final Phase 2 Report)	1f - Bypass Diversions to Storage; 1g - Reduce Constraints on CROP	1f - Bypass diversions during 10-day peak; 1g - Eliminate or reduce CROPS constraints	Proportional Allocation: All 9 Reservoirs; Equal Allocation: Granby, Green Mtn., Williams Fork; Granby: 20,000 AF from Granby; Modified "Share the Pain": Green Mtn, Ruedi, Wolford, Williams Fork and Granby	Feasible	Proportional: Unaffected; Equal: Unaffected; Granby: Unaffected	Proportional: Generally unaffected, slight deficit in 1979-1982; Equal: same as above; Granby: reduced average annual by 16,000 AF; Modified "Share the Pain": generally unaffected	Proportional: Unaffected; Equal: Unaffected; Granby: Unaffected; Modified "Share the Pain": generally unaffected	Proportional: Significantly reduced storage, modeling is suspect; Equal: Unaffected; Granby: Unaffected; Modified "Share the Pain": generally unaffected	Proportional: Unaffected; Equal: Unaffected; Granby: Unaffected; Modified "Share the Pain": generally unaffected	Proportional: Unaffected; Equal: Deficit in 1978; Granby: Unaffected; Modified "Share the Pain": generally unaffected	Proportional: temporary storage deficit in 1975, 1978, 1982, 1991; Equal: Unaffected; Granby: Unaffected; Modified "Share the Pain": generally unaffected	Proportional: Temporary deficit in 1978, 1982, 1991; Equal: Unaffected; Granby: Unaffected; Modified "Share the Pain": generally unaffected	Proportional: Unaffected; Equal: Unaffected; Granby: Unaffected; Modified "Share the Pain": generally unaffected	Proportional: Reduced avg $5,500/year; Equal: Reduced avg $5,900/year: Granby Unaffected	Proportional: Reduced avg $800/year; Equal: Unaffected; Granby: Unaffected	Proportional: Increased avg $3,700/year; Equal: Reduced avg $6,900/year; Granby: Unaffected	Proportional: Unaffected; Equal: Unaffected; Granby: Unaffected	Proportional: Unaffected; Equal: Unaffected; Granby: Unaffected	None anticipated	Proportional: Generally unaffected, short in Oct 1977 & May 1979; Equal: Unaffected; Granby: Unaffected	Proportional: Unaffected; Equal: Unaffected; Granby: Unaffected	Proportional: Unaffected; Equal: Unaffected; Granby: Unaffected	Proportional: None anticipated; Equal: None Anticipated; Granby: Unaffected
EFFICIENCIES OF CONVEYANCE AND DISTRIBUTION FACILITIES																								
3d, 3e, 1a	No. 2	1a - Green Mountain Reservoir Operations; 3d - Reanalysis of Grand Valley Water Management Alternatives; 3e - Analysis of GVIC Water Management	1a - Preemptive Release and Release of Water Carried Over in Gr. Mtn. Res; 3d & 3e - Develop additional yield from GVP & GVIC through increased efficiency	Green Mountain Reservoir	Feasible. Release replaced from refill right and not from savings to HUP	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled
NEW STORAGE PROJECTS																								
4f, 4g, 4k, 4m, 4n, 4o	No. 4	New Storage Facilities Below Shoshone	Feasibility of various reservoir sites for source of 20,000 AF release	Various alternative reservoir sites	Not Feasible	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled
4m	No. 4a	New storage Facility at Webster Hill Site, Mainstem Colorado River	Feasibility of reservoir site at Webster Hill site downstream from Rifle	Webster Hill Reservoir	Feasible	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled
POWER PLANT OPERATIONS AND SCHEDULING																								
5a, 1d	No. 8	5a - East Slope Power Operations and Scheduling; 1d - CBT West Slope Facilities Operations	5a - Investigate changes in E. Slope power operations and scheduling; 1d - Modify CBT West Slope Facilities Operations	Granby Reservoir	Not modeled because StateMod and C1 dataset are exclusive to Colorado Basin; feasibility based on results from Tech Memo 7	Unaffected, See Tech Memo No. 7	Reduced avg annual by 16,000 AF, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, modeling is suspect, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	Unaffected, See Tech Memo No. 7	None anticipated	See Tech Memo No. 7	See Tech Memo No. 7	See Tech Memo No. 7	None Anticpated
5b	No. 9	Shoshone Power Plant	Removal of senior priority call and making 20,000 AF release	Dillon, Granby, Green Mtn., Williams Fork and Wolford Mtn. Reservoirs	Feasible	Temporary deficit in 1977-1978, 1981-1982, avg storage increase of 2,703 AF/month	Deficit in 1980-1983, avg storage increase of 2,445 AF/month	Avg storage increase of 5,109/month	Removal of call increased monthly storage by 11,471 AF, modeling is suspect	None Anticipated	Avg storage increase 4,902 AF/month	Average storage decrease 61 AF/month	Temporary deficit in 1975, 1978, 1991; avg storage increase 1,439 AF/month	Unaffected	Increased annual avg $71,000/year	None anticipated	Reduced by annual avg $116,000/year	Unaffected	None anticipated	None anticipated	None Anticipated	None Anticipated	Unaffected	None Anticpated
OTHER ALTERNATIVES																								
6a	No. 10	Insurance Pool	Potential for using an insurance pool to spread the risk.	Various sources	Feasible	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled	Not modeled

1Effects on Roberts Tunnel Deliveries was not explicitly modeled, but assumed to be minimal when the effects on Dillon Reservoir were minimal

TABLE 15. Summary of Alternatives

PHASE 1 ALTERNATIVE NO.	TECHNICAL MEMORANDUM NO.	ALTERNATIVE NAME	CAPITAL COST / AF OF YIELD	SENSITIVITY ANALYSIS: FEASIBLE TO MAKE 20,000 AF RELEASE	SENSITIVITY ANALYSIS: EFFECTS ON OTHER STRUCTURES	SENSITIVITY ANALYSIS RESULTS: COMMENTS	ADMINISTRATION CONSIDERATIONS	LEGAL CONSIDERATIONS
EXPANDED COORDINATED RESERVOIR OPERATIONS								
1a	No. 1	Green Mt. Reservoir Operations	Minimal	N/A	N/A	N/A	Concern over how to administer releases to 15-Mile Reach. Possibly in late summer and early fall. Forbearance agreements may be necessary	Blue River Decree, Sen Doc 80 and Green Mtn. Res Operating Principles; Uncertainty of authority of the USBR to release for piscatorial purposes
1a	No. 3	Green Mt. Reservoir Operations	Minimal	Feasible	All other structures unaffected	These results provide further evidence of the feasibility of a 20,000 AF pre-emptive release from GMR for the fish	Concern over how to administer releases to 15-Mile Reach. Possibly in late summer and early fall. Forbearance agreements may be necessary	Blue River Decree, Sen Doc 80 and Green Mtn. Res Operating Principles; Uncertainty of authority of the USBR to release for piscatorial purposes
1b	No. 5	Ruedi Reservior Operations	Minimal	N/A	N/A	N/A	Concern over how to administer releases to 15-Mile Reach	Uncertainty of authority of the USBR to release for piscatorial purposes
1e	No. 11	Denver Water Systems Operations	Minimal	Feasible to release 6,667 AF from Williams Fork Reservoir	All other structures unaffected	N/A	Concern over how to administer releases to 15-Mile Reach. Could require administration for late summer and fall delivery to the fish	Would depend on source of efficiencies in Denver System
1f, 1g	No. 7 (Modified "Share the Pain" discussed in Final Phase 2 Report)	1f - Bypass Diversions to Storage; 1g - Reduce Constraints on CROP	Minimal	Temporary deficits in storage for GMR, Granby and Williams Fork. Granby: 1979-1984, GMR: 1978, 1983, 1984, Williams Fork: 1975, 1978-79, 1982, 1991. Temporary deficits were reduced by Modified "Share the Pain"	Minimal effects in Dillon and Wolford Mtn., All other reservoirs unaffected	These results provide further evidence of the feasibility of an equal allocation release (6,667 AF) from Granby, GMR and Williams Fork towards the 20,000 AF release for the fish. Modified "Share the Pain" allows for making CROP bypass and CFOPS releases at same time.	Concern over how to administer releases to 15-Mile Reach, including counting bypassed water towards reservoir fill	Blue River Decree, Sen Doc 80, Fry-Ark Authorizing Stat. Proj. Operating Principles; Uncertainty of authority of the USBR to release for piscatorial purposes
EFFICIENCIES OF CONVEYANCE AND DISTRIBUTION FACILITIES								
3d, 3e, 1a	No. 2	1a - Green Mountain Reservoir Operations; 3d - Reanalysis of Grand Valley Water Management Alternatives; 3e - Analysis of GVIC Water Management	Minimal	N/A	N/A	N/A	Check Settlement/Reservoir Admin; Concern over how to administer releases to 15-Mile Reach	Requires agreements with GVIC; Uncertainty of authority of the USBR to release for piscatorial purposes
NEW STORAGE PROJECTS								
4f, 4g, 4k, 4m, 4n, 4o	No. 4	New Storage Facilities Below Shoshone	Roan Creek: $553/AF of yield/year; Dry Creek: $533/AF of yield/year	N/A	N/A	N/A	Concern over how to administer releases to 15-Mile Reach	
4m	No. 4a	New storage Facility at Webster Hill Site, Mainstem Colorado River	$26 - $134/AF of yield/year	N/A	N/A	N/A	Concern over how to administer releases to 15-Mile Reach	Located in critical habitat
POWER PLANT OPERATIONS AND SCHEDULING								
5a, 1d	No. 8	5a - East Slope Power Operations and Scheduling; 1d - CBT West Slope Facilities Operations	Minimal	N/A	N/A	N/A	Sen Doc 80, Water Rights decrees for C-BT facilities; Concern over how to administer releases to 15-Mile Reach	Sen Doc 80, Blue River Decree, Project Operating Policies; Uncertainty of authority of the USBR to release for piscatorial purposes
5b	No. 9	Shoshone Power Plant	Minimal	N/A	N/A	N/A	Selective subordination issues; Concern over how to administer releases to 15-Mile Reach	Uncertainty of authority of the USBR to release for piscatorial purposes
OTHER ALTERNATIVES								
6a	No. 10	Insurance Pool	Minimal	N/A	N/A	N/A	May be necessary depending on source of mitigation water and where it is required; Concern over how to administer releases to 15-Mile Reach	Deepends on location of insurance pool and where mitigation water is needed; Uncertainty of authority of the USBR to release for piscatorial purposes

1Effects on Roberts Tunnel Deliveries was not explicitly modeled, but assume