DRAFT

ELKHEAD DAM/RESERVOIR
FISH SEPARATION
PRELIMINARY DESIGN REPORT

Prepared for

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Elkhead Fish Report.doc

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

General

The overall summary of this report is presented in the following sections as conclusions and recommendations.

Conclusions

1. Fish management of some type will likely be required as part of the dam rehabilitation or storage enlargement of Elkhead Dam/Reservoir. Such management will be to keep non-native sport fish in the reservoir from moving downstream and competing with endangered fish in the Yampa River.

2. Fish management will likely take the form of physical fish separation devices and reservoir management at the dam to prevent escapement, or eradication of fish from the reservoir.

3. It is technically feasible to install fish separation in conjunction with a dam rehabilitation or a storage enlargement project, thereby preserving a reservoir fishery while protecting endangered fish in the Yampa River.

4. Alternative 1 and Alternative 2 for the rehabilitation option cost approximately $900,000 and $ 910,000 respectively.

5. Alternative 1 for the enlargement option is the same cost as for the rehabilitation option and Alternative 2 for the enlargement option is approximately 26% higher than the rehabilitation due to the need to screen a larger outlet structure.

Recommendations

Based upon this report and its conclusions, it is recommended that the City of Craig:

1. Accept the report as a basis for further action on the fish separation issue at Elkhead Dam/Reservoir.

2. Adopt Alternative 1 as the basis for fish separation for the prospective dam rehabilitation project.

3. Adopt Alternative 2 as the basis for fish separation for the prospective enlargement project (15’ dam raise). This is primarily because the primary outlet is being reconstructed with a larger flow capacity providing the opportunity to fit it with cylinder screens for greater exclusion reliability. Provide this information to the entity, which will be responsible for the enlarged project.

4. In recommending a net as the key element of both alternatives, a low initial cost, short life structure is being proposed. This seems especially prudent in view of the unknowns associated with the actual escapement from Elkhead Reservoir and the extent to which this

presents a threat to endangered fish. It is very hard to recommend the construction of a high capital cost, long life structure when the cost and benefit per fish excluded is unknown (as it is now), or is very high. At this site, alternative structures to nets are physically obtrusive in addition to being expensive. Improvements in the knowledge of the fish and separation technology will continue to be refined enabling us to place separation devices in the future where they can provide a documented, meaningful benefit at a reasonable cost and to modify those we build now to be more effective, if needed. A low initial cost solution allows the flexibility of economically adding a supplementary separation device if the initial device fails to achieve the expected results and avoids spending a lot of limited funds up front to correct a problem which may actually be much less severe than currently assumed.

5. Should either Alternative 1 or 2 not be desired, adopt an interim or permanent policy of periodic eradication of fish from the reservoir using a fish toxicant such as rotenone to eliminate this source of competing species. This will have associated obvious public relations ramifications that will have to be proactively addressed.

6. Complete the "on hold" dam rehabilitation preliminary design project and related fish separation component as the basis for conclusion of the "Acquisition Agreement" between the City and the DOW.

7. Postpone proceeding with final design of the dam rehabilitation option until definite action is taken on the enlargement project.

8. Implementation of Alternative 2, which will involve significant structural modifications to the dam for either the rehabilitation or enlargement options should include designed in provisions for the addition of a secondary or replacement barrier in the event that initial results of the separation project do not meet expectations. Such a barrier could be an electrical barrier or experimental high velocity net in the service spillway apron approach, and/or finer mesh cylinder screens on the primary outlet.

9. Translocation of northern pipe or stocking of any fish species except trout should not be further considered until the effective means and responsibility for managing the separation of these species of fish is decided upon and the costs of such measures agreed to by the respective entities. To allow translocation or stocking would certainly require separation measures to be constructed; eliminating other options (such as fish eradication, a delay in constructing separation measures while further study occurs, etc.) from consideration.

10. Simultaneously with the adoption of either Alternative 1 or Alternative 2, pursue identification of an entity to finance the capital cost of the separation measures and the respective operations and maintenance costs.

Continue to study the characteristics of the Elkhead Reservoir native/non-native related fish interactions, especially as might be affected by the separation program suggested herein.

Background

General

Elkhead Dam creates a 13,700 acre-foot reservoir on Elkhead Creek approximately three miles upstream of its confluence with the Yampa River in northeast Colorado. The dam and reservoir were constructed by and are owned by the State of Colorado, acting through its Division of Wildlife (DOW). A need to rehabilitate the dam has been identified and a separate proposal has been made to combine a dam raise with the rehabilitation. The Yampa River contains populations of three endangered fish whose well being is a major issue which must be addressed before rehabilitation or new construction on the dam occurs. The immediately following sections of this report and Appendix A will describe the project history and the endangered fish issue. This will set the stage for addressing the implementation of project improvements while making appropriate provisions for the protection/recovery of the endangered fish.

A Condensed Project History

Elkhead Dam/Reservoir was constructed in 1974 as a cooperative undertaking of the DOW and the Yampa Participants as a multiple purpose reservoir. DOW owns and has operation and maintenance responsibility for the project. In 1979 the National DAM Safety Program (USACOE 1980) determined that the dam had a hydraulically inadequate spillway. Several enlargement/rehabilitation studies were conducted between 1979 and 1990. Until March of 1999 solving the inadequate spillway issue had been an integral part of the many subsequent studies. During the interim this issue had neither been resolved nor enforcement action taken to achieve compliance with the inadequate spillway issue. In 1985 plans and specifications were prepared for a dam raise and auxiliary spillway construction; these documents were submitted for approval to the Colorado Office of the State Engineer (SEO). It was at about this time that a Colorado Water Conservation Board (CWCB) loan request was made, presumably to assist with the construction of the 1985 project under review. We have not been able to ascertain what the results of the SEO review process are (nor have we ever found copies of the plans and specifications which were submitted for review), and the designed project never proceeded to construction for an unknown reason.

In 1990 the City of Craig (City) entered an agreement (Transfer Agreement) with the DOW to acquire the dam and reservoir in five years. The Transfer Agreement was accompanied by a supplemental agreement between the City, DOW, and the Yampa participants, which describes the responsibility of each party as is related to the ownership transfer. The agreements are quite complex. The required conditions for ownership transfer were not met within the original five years. The agreements were extended for another five years, and that extension expired in August 2000. A second extension of three years continues the Transfer Agreement until August 2003.

Between 1990 and 1993 a study known as the “Yampa River Basin Alternatives Feasibility Study” (Hydrosphere 1993) was conducted for the Colorado Endangered Fish Recovery Program by the Colorado River Water Conservation District (CRWCD) and the CWCB. The study was performed by Hydrosphere Resource Consultants and personnel now employed by Ayres

Associates. The study examined current and projected future water needs in the basin and evaluated a number of sites for development of water storage. It concluded that expansion of Elkhead Reservoir and Stagecoach Reservoir are the short term and long term storage options, respectively.

In 1995 the "Yampa River Basin Recommended Alternative Detailed Feasibility Study" (Hydrosphere 1995) was completed by the same Hydrosphere team. The objectives of this study were to follow up on the recommendations of the previous study, specifically the enlargement of Elkhead Reservoir. Following the 1995 feasibility study, Ayres Associates completed a detailed, inflow design flood (IDF) hydrology study (Ayres 1997) of Elkhead Dam/Reservoir for CRWCD in preparation for addressing the enlargement, the inadequate spillway, and other rehabilitation issues. This hydrology study was completed and filed with the State Engineer in April 1997. A subsequent decision was made not to pursue enlargement of Elkhead. This left the inadequate spillway issue and other rehabilitation needs unresolved.

A rehabilitation project was still needed since the spillway enlargement and other defined improvements would not now be accomplished as part of an "enlargement" project. The storage enlargement based hydrology report (100% PMP based IDF) (Ayres 1997) was therefore withdrawn from consideration in 1997 and replaced with a "non-storage enlargement" dam rehabilitation hydrology report (75% PMP based IDF) (Ayres 1999). In order to objectively revisit the non-storage enlargement options, Ayres completed "Elkhead Dam/Reservoir Projects Updating" (Ayres 1998). That report updates concepts and costs of previous relevant studies on a comparable basis to allow the City, DOW and the Yampa Participants to each revisit the Transfer Agreement to confirm its continued validity (or to set the stage for mutually acceptable modifications) and to consider which of the several previously studied options best describes the "non-storage enlargement" dam rehabilitation. In March 1999 the "non-storage enlargement" dam rehabilitation hydrology report was approved by the SEO. Since that report documented that the current spillway was hydraulically adequate, the largest cost of the dam rehabilitation (the spillway enlargement) was eliminated. This enabled the City to decide to proceed with preliminary design of the fifth option (rehabilitation) described in the updating report (Ayres 1998). The City, with the knowledge and cooperation of the Yampa Participants then authorized Ayres Associates to proceed with the subject rehabilitation preliminary design in order to accomplish the following objectives:

1. Establish a firm basis for the accomplishment of the rehabilitation described in the Transfer Agreement and as necessary for the City to take over the dam/reservoir in good operating condition free of any short term rehabilitation needs.
2. More clearly define the precise scope of rehabilitation.
3. Provide a preliminary construction cost estimate to replace earlier versions which had either a different scope of work, were outdated, or were done on a comparative versus absolute basis.
4. Establish a basis for City Council review of the Transfer Agreement with respect to its closure, continuation, or termination.

Several months after the draft preliminary design report (Ayres 2000) request was submitted, a renewed proposal to enlarge Elkhead was made by local water development interest. The

preliminary design report remains incomplete while the new enlargement proposal is under investigation.

Endangered Fish

A very unique ecological condition is both impacted by and impacts Elkhead Dam/Reservoir. Elkhead Creek is tributary to the Yampa River. The Yampa River and its major tributaries are experiencing a general evolution of native fish being replaced by non-native (primarily sport) fish. In addition, the Yampa river contains the pike minnow, humpback chub, and the razorback sucker fish which are identified as "endangered" and protected by the United States Endangered Species Act (ESA) of 1973 (Public Law 93-205). For a summary of the ESA and its application to this project refer to Appendix A. As such, most of the Yampa River, including the reach downstream of the confluence of Elkhead Creek is designated as critical habitat. These Federal designations carry along with them a limitation on acts which could restrict recovery of these fish (Section 7) and the intentional or accidental take of these fish (Section 9). Activation of either of these sections could initiate close Federal and State intervention/oversight of even seemingly straightforward dam rehabilitation construction related activity and their involvement would certainly occur in the case of a reservoir enlargement.

The "Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin" is a recovery program which was established to assist the recovery of native species, particularly those threatened or endangered, in their native habitat. Certain non-native fish species (some of which are sport fish) have been identified as competitors with these endangered fish and it has been established that the control of non-native fish populations are a necessary part of the recovery program. In particular, it is thought that chronic escapement of non-native fish from off-channel impoundments is associated with mortality or competition that may limit recruitment of endangered fish. The following sections of the Recovery Action Plan for the Colorado River mainstream and Yampa/Little Snake Rivers describe this specifically:

III. Reduce negative impacts of non-native fish and sport fish management activities (non-native and sport fish management)
III.A.2. Identify and implement viable control measures
III.A. (c). Implement and evaluate the effectiveness of viable active control measures
III.B. Reduce negative impacts to endangered fish from sport fish management activities
III.B2. Evaluate control options and implement control of non-native fish escapement from Elkhead Reservoir.

In order to achieve the objective of preventing escapement while providing recreational fisheries opportunities, the "Procedures for Stocking Non-native Fish Species in the Upper Colorado River Basin" (U.S.D.I 1996) was developed. That document describes among other things, the basic guidelines for separating non-native and endangered fish.

Elkhead Reservoir has been managed for sport fishing (it is widely believed to have been the original source of the now large population of northern pike in the Yampa River) and related recreational activities. Since it has been decided that this recreational resource is valuable to the public and should be maintained, there is a corresponding need to prevent the non-native fish

from escaping this reservoir into the Yampa River which is occupied by the endangered species. Actually implementing measures to prevent such escapement can be voluntary or could be mandated by regulatory entities. While there is no current requirement to implement fish separation measures at Elkhead, a dam rehabilitation or enlargement project might trigger one, adding significantly to the project cost. Accordingly, an effort was undertaken to evaluate both management and physical means for separating fish at this location.

The need for fish separation was first acknowledged in the "Yampa River Basin, Recommended Alternative" report (Hydrosphere, 1995), but at that time little was known about the specifics of what this fish separation might entail. The concepts and costs presented in that report were simply a "place holder" or an acknowledgment that a need for fish separation was expected. The subsequent "Upper Colorado River Basin Implementation Program Feasibility Evaluation of Non-native Fish Control Structures," report (Miller, 1997) completed by Miller Ecological and Ayres Associates describes the feasibility of implementing fish separation in general and specifically at Elkhead Dam/Reservoir. The Miller report described several different prototype fish separation facilities for Elkhead Dam/Reservoir. The design criteria have changed somewhat since that report was published and the resulting changes to the fish separation facilities have not been reevaluated. The concept of screening to "current industry practice" which consisted of a 6.35-mm net protecting the service spillway and a 2.38-mm cylinder screen system protecting the primary outlet for flow events up to a 100-year frequency is the closest option described in that report to the facility characteristics which would meet current standards. The updated minimum construction cost of that facility is approximately $1 million.

The Recovery Program has been active in studying these complex fish competition and species recovery issues and have undertaken several "experimental" constructed projects (levee removals and a fish net at Highline Reservoir, for example). Physical fish separation as a part of this program is still a developing area as is the general implementation of separation requirements on other problematic public and private facilities. As such the Recovery Program has not formalized specific separation criteria nor officially identified projects where separation will be required. As the criteria and locations become formally established there will probably be a shift from Recovery Program funding (as is currently occurring) of selected "experimental" separation projects to a separate funding program for implementing larger numbers of constructed projects.

As part of the rehabilitation preliminary design (Ayres 2000) we have kept in mind the possibility of the need to implement fish separation measures as identified in the Miller report (1997) at Elkhead Reservoir, but have not included any measures in the scope of work. They are not included as they are too expensive to accomplish without assistance, were not mentioned in the Transfer Agreement, and they are not institutionally required at this time. The larger project involving rehabilitation and enlargement which is just now getting underway, would certainly involve an institutional requirement for fish separation.

Fish Separation at Elkhead Dam/Reservoir

Setting the Stage

Considering the attention this project has received, its prospective funding, its location within endangered species designated critical habitat, the prospective need for a project EA or EIS, and/or the prospective need for a 404 permit, it is safe to conclude that either a dam rehabilitation or enlargement will have to include some form of fish control or separation facilities. Since fish separation facilities are still experimental, since Elkhead Dam/Reservoir has distinctive physical characteristics which differ from Highline Dam/Reservoir (where a separation net exists) and since new information is available to update the Miller report (1997), it was decided that a conceptual /preliminary design was needed to fully address the fish separation issue at Elkhead Dam/Reservoir. In addition, the nature and cost of such a facility is important to both the current and prospective owners of either a rehabilitated or an enlarged Elkhead Dam/Reservoir.

It is important to note that the reservoir is not currently managed or in recent years been managed for non-native fish which potentially compete with the endangered fish. That is no non-native fish stocking other than trout has occurred. There is a small population of warm water fish both in the reservoir and downstream. This is likely a remnant population from historical stocking, reproduction and/or unauthorized private stocking. It has not been established if the current non-native fish population is at a significant enough strength (size and population) to jeopardize downstream endangered fish via escapement from Elkhead. There is pressure to renew the practice of active management of Elkhead Reservoir for warm water fish including the translocation of northern pike removed from the Yampa River to Elkhead Reservoir. This could not be done without initiating fish control or separation measures at the reservoir. There is no current proposal to routinely eradicate sport fish from Elkhead Reservoir in order to avoid the need for fish separation devices altogether, and evaluation of such a proposal is not part of the current scope of work.

Sport/Endangered Fish Separation Guidelines and Standards

The first effort to further define what was meant by reducing the impact of and controlling non-native fish as mentioned in the Recovery Action Plan was the aforementioned Miller report (1997). The emphasis of that report was separating sport and endangered fish to help keep their conflict from worsening and to hopefully initiate endangered fish recovery while at the same time preserving and enhancing a sport fishery. Other means of reducing the impact and control exist of course, however they are not the subject of this report. The report addressed separation means in general and applied them to Highline and Elkhead projects in Colorado as experimental prototype applications. The report addressed three basic separation criteria:

Frequency - The period of years on the average for which separation measures should be functionally effective without structural failure or exceeding the design capacity

Size - The minimum dimension of a potentially competing biological unit (passive or active) which should remain separate.

Reliability – The success of the separation in terms of the percent of the size of the biological units able to pass the separation barrier of those available to pass.

The recovery program and ad-hoc advisory committee initially ideally decided on 100-year frequency, 0.5-mm size and 100% reliability. These criteria were found to be marginally feasible and cost prohibitive. A more practical state-of-the-art (current industry standard) criteria of 100-year frequency, 2.38-mm and 90%(min) reliability was also presented in the report. This report set the stage for developing more precise technical criteria for reducing the impact of and controlling non-native fish by separation. Similar standards of separation also appeared in U.S. Fish and Wildlife Service Publications (U.S.D.I. 1998) which mentions 50-year frequency, (U.S.D.I. 1996) which mentions a 50-year frequency, and a CDOW publication (CDOW 1998) which describes a 50-year frequency and 2.38-mm screening. None of the institutional references, which we are aware of, describe reliability as a criteria.

Some precedent for fish separation of this nature was established with the recent extensive study and resulting fish separation barrier which was constructed at Highline Dam/Reservoir, a Colorado River Basin off-stream site near Grand Junction, Colorado. A narrative describing this project is located in Appendix B.

At the initiation of the subject project an advisory committee was formed with the intent of following a similar pre-design process as was conducted for the Highline fish separation project. An initial meeting of that group was held on December 7, 2000 at which time the following major issues were discussed:

- Fish separation design criteria (frequency, size, and reliability) for Elkhead considering the previously described institutional criteria and the experience at Highline
- The characteristics of Elkhead which are uniquely different than Highline and how this might impact selection of design criteria and screening options including:
    1. Routine primary outlet and service spillway discharges
    2. Much larger 50-year frequency flow to screen
    3. The possible translocation of northern pike into Elkhead Reservoir
    4. Different physical characteristics
    5. Acceptability of incidental killing of game fish
    6. Current technology of fish nets (minimum size limitation)
    7. Need to separately screen the dam's primary outlet
    8. Provisions for separation should reservoir enlargement be pursued
    9. The period of the year and total time during which opportunity for escapement exists
    10. Higher altitude location and deeper water at Elkhead
- The need to evaluate life cycle costing without respect to who the responsible entity is.

The primary result of that meeting (refer to meeting summary in Appendix C) was that a state-of-the-art size net by itself plus reservoir management can meet the exclusion criteria and that a net provides a reasonably affordable solution to fish separation. The basis for that conclusion was the monitoring work DOW has completed at Highline which indicates an acceptable separation reliability and the general concurrence with this conclusion of those in attendance at the

December 7th meeting. It was also agreed that no further design concept issues needed to be addressed by the group; that is, the evaluation could be completed and draft report prepared.

Application of Guidelines and Standards

Fish separation criteria as applied to this project is summarized by category as follows:

Frequency – The 50- year flood frequency will be used. At Elkhead this is a snowmelt dominated event and a peak diurnal flow rate of 2,000 cfs is applicable to either the rehabilitation or enlargement project. For the enlarged project more of this flow will be going through the primary outlet as it will be enlarged to meet SEO drawdown criteria.

Size – The previously mentioned 2.38-mm spacing criteria will be applied to the primary element intended to separate fish. In the instance where the primary outlet is separately screened with a 2.38-mm spacing, the secondary device (net) in front of the service spillway will have larger 6.35-mm spacing as at Highline Dam/Reservoir and for consistency with the Miller (1997) report.

Reliability – An adopted reliability of 70% based on the Highline Dam/Reservoir results and the theoretic reliability of a net will be applied to Elkhead Dam/Reservoir.

Configuration of Alternatives

General

On the basis of the December meeting and follow-up thereafter, the following alternatives were decided upon for further analysis and presentation in the report:

- Alternative 1 – Net only (2.38-mm, the smallest feasible net size)
- Alternative 2 – Net (6.35-mm) and separate cylinder screen (2.38-mm)
- Alternatives not evaluated in detail
- Alternative variations

Construction costs and life cycle costing on an annual cost basis is presented for Alternatives 1 and 2.

Our experience with the Highline Reservoir net has given us information on how to improve a net barrier. Some of that knowledge which will be incorporated into a similar net at Elkhead Reservoir includes:

- Deployment of surface skirt on the down gradient side of the net in order to maintain skirt and main net buoy line float separation.

- Mount shoreline connections of net in areas where it will not become weighted by mobile shoreline material.

- Use of stiffeners between the main float line and top skirt float line

- Construction of a net with more exact dimensions and/or a wider top skirt to minimize net deflection and submergence under spillway flow conditions.

- Closure of gaps along float lines.

- Provide removeability of floats so net can be dropped to the bottom.

Spacing measurements for screens and nets can be confusing. Manufacturers of nets use a stretch dimension (the dimension from center of webbing to center of webbing of opposite corners on a rectangular grid when the net is pulled, fully closing the opening), the clear horizontal spacing on a screen, the center to center gross horizontal spacing on a screen or the net, or gross, equivalent circular opening. Unless otherwise specified herein, spacing measurements given represent the clear horizontal dimension that a fish must squeeze through to pass the net. This is consistent with the size criteria definition previously described in design criteria.

Description of Alternatives

Alternative 1 – Net Only – Rehabilitation Project

The alternative of a net only is consistent with the design criteria previously described, is reasonably economical and is the expressed preference of the advisory committee. The net can screen both the service spillway and the primary outlet structure as a single installation. In addition, net manufacturing refinements now permit openings as small as (2.38-mm) without significant loss of net strength, although development of such size nets is still subject to ongoing technological refinement.

Elements considered for the installation of a net can be broken into two primary construction focuses: anchor construction, and net fabrication and installation. Anchor construction can be considered as the construction of the net foundation. This requires a full survey along the precise net alignment for anchor placement along the floor of the reservoir. Anchor buoys are included for easily locating the anchors during the installation and replacement of the net. In addition to floor anchors, side dam slope net apron/footings provide the primary support for keeping the net in place. The net fabrication and installation also includes a center net support, additional stiffners and refinements to the net to insure that the top of the net does not bow in the direction of water flow pulling the net buoys below the water surface and allow fish passage. Boater and public safety require above water buoys and fencing around the anchor/footings. The design for placement of the net has been based upon a 2.38-mm Spectra-Dyneema Rashel Knottless (Redden Nets) weaved net sized for a velocity of 0.3 fps with 60% open area and 50% clogged.

At this velocity the net would be placed approximately 190 feet from the service spillway with an area of 21,500 ft^2 and 620 foot top length.

Alternative 2 – Net and Cylinder Screens – Rehabilitation Project

The alternative of a 6.35-mm net protecting both the service spillway and the primary outlet and a 2.38-mm cylinder screen on the primary outlet was selected as the alternative closest to that described in the Miller (1997) report.

The primary physical components of this alternative is the same as Alternative 1. However, because the net weave is larger two additional components, the primary outlet cylinder screens and the Starr Ditch screen, have been added to increase the system's reliability. Although the net weave is 6.35-mm for Alternative 2 versus the 2.38-mm in Alternative 1 the physical construction components, design velocity with % open and clogged areas, area, and surface length of the net are the same. The construction cost decreases because of the change in net fabrication. The physical components of the primary outlet screens are the manifold structure and the pneumatic backwash system. Five cylinder screens are needed for a 170 cfs discharge through the 36 in. diameter primary outlet pipe. These 2.38-mm screens are 4 feet in diameter and 8 feet long and would be mounted onto a 40 foot long concrete manifold structure. The screens would need to be cleaned by a manufacturer designed pneumatic backwash system. The Starr Ditch has a discharge of 10 cfs and assumed velocity of 0.4 fps. The screen requirements are 3- 4 foot x 4 foot, 2.38-mm screen panels with a concrete frame structure mounted around the outlet gate.

Enlargement Project

Both alternatives were evaluated for their suitability as part of an enlargement project. After evaluation of the physical differences between the two types of projects we were pleased to be able to conclude that the material differences are quite minor. No conceptual changes were needed for the fish separation measures which would be necessary for an enlargement project. Those differences and the extent that they require any special considerations are listed as follows:

- An enlarged primary outlet structure will be necessary – this will result in additional primary outlet cylinder screens with approximately twice the flow capacity
- An enlarged service spillway or auxiliary/emergency spillway will be needed to meet inflow design flood criteria – except for possible minor net geometry changes there will be no impact as the net has a 50-year frequency design criteria
- Greater water head will exist over the primary outlet – this does not have any significant impact and has a small impact on the pneumatic backwash for the cylinder screens
- Greater reservoir depth – this will require minor geometry and anchoring changes for a net but no area change as the design flow rate will remain essentially unchanged
- An enlargement project will be subject to much closer institutional scrutiny – EIS related issues may result in stricter or new criteria which is different than that

described herein for the rehabilitation design; the impact of this can not be evaluated at this time

Alternatives Not Evaluated in Detail

Fish Graters or Comminutors

As an option to using inlet screens to prevent entry of fish into the primary outlet structure, a device can be fitted to the outlet end of the pipe to cause fatal trauma to any fish which pass through the primary outlet structure. Fatal trauma is incidentally a result of fish passing through turbines, valves and energy dissipaters on outlet structures, but not a predictable level of reliability. Experimental stationary grates specifically intended to shred any object down to 1 in. in size and mechanical grates down to ¼ in. in size have been used to cause fatal trauma but are not effective on egg or larval life forms which are smaller. These grates or comminutors cause a head (and discharge) loss, but have surprisingly suffered few debris obstruction problems. Known applications have been for flows much less than expected at Elkhead.

Intentionally indiscriminately killing fish is viewed as being unacceptable at this location for philosophic, political and cruelty reasons. In addition, handling remnant fish parts creates an increased operation and maintenance responsibility, an esthetically unacceptable condition, a potential organic nuisance/health hazard and a sensitive political/institutional public relations challenge. These reasons in addition to the flow range limit and the probable high escapement rate for small life forms eliminated this measure from further consideration.

Enlarged Primary Outlet

An additional possibility which has been mentioned for fish separation at Elkhead is reducing the frequency of discharge though the service spillway or the primary outlet sufficiently so that only one would have to be screened. Since the primary outlet has and will continue to have routine discharges for various reasons it will have to be screened. Since the primary outlet will have to be replaced with enlarged capacity to meet the requirements of the Colorado State Engineer (SEO) if the reservoir is enlarged, we evaluated the apparent feasibility of it being enlarged enough to be able to pass the 50-year flood. We also looked at the 10-year flood to see if it was reasonable to consider making a request for a change in the fish separation frequency criteria if the primary outlet could economically be enlarged to pass this more frequent event.

The current primary outlet pipe is 36 in. diameter and can handle approximately 170 cfs with the water level at the 50-year routed flood elevation. The enlarged primary outlet serving a raised dam will probably be 48 in. diameter and handle approximately 345 cfs with the water level at the 50-year routed flood elevation. The 50-year routed flood flow is approximately 2000 cfs for either the existing or enlarged dam scenarios. This flow is about ten times the maximum flow that would otherwise be used to size the primary outlet. This would require approximately a 10 foot diameter outlet pipe which is prohibitively large and expensive, especially since a service spillway is still necessary anyway. Since floods more frequent than the 100-year event are controlled by snowmelt events and the snowmelt flow-frequency curve is very flat, the 10-year

flood is approximately 1500 cfs. This number is also very large and would require approximately a 9 foot diameter outlet pipe, which is still prohibitively large and expensive.

Drum Screens

Drum Screens have been used with a good level of success (85% reliability) for fish separation and are quite economical. They are best applied to controlled flow, limited head and warm season operation such as for irrigation ditches. They could potentially be placed in either the spillway approach area or in the stream channel downstream of the dam (where they would screen flow from both the service spillway and the primary outlet). Unfortunately, Elkhead must be able to screen flow year-round including occasionally under floating ice, debris and sub-freezing conditions. Elkhead must also be able to handle flows from 16 cfs to 2000 cfs with a corresponding head range fluctuation. At 2,000 cfs flow is in the floodplain fringe as well as the channel, creating potentially extensive flow control issues for any structure downstream. In addition, drum out-of-roundness and perimeter seals limit the passage effectiveness to ¼ in. (6.35-mm) square openings on an 11/32 in. (9.00-mm) pattern effective opening.

Fixed plate screens could be used in the same locations as drum screens but they require continuous cleaning in addition to the other limitations of drum screens. Downstream screens require fish handling. Both types of screens in the spillway approach area present an unacceptable potential obstruction to flood flow.

It was therefore concluded that for the criteria we are working with screens of this type are not suitable for use at this location as a primary separation device.

Because of the interest expressed in drum screens by fishery professionals associated with the project we felt it would be appropriate to take the analysis one step further and include some conceptual cost information. Drum screens situated in the left downstream floodplain fringe would cost approximately $5.5M or approximately 6 times the cost of a net alone. A Coanda style screen in the upstream service spillway approach area would cost approximately $4.0M or approximately 4.5 times the cost of a net alone.

Higher Velocity Net

The use of a smaller overall size net, which protects only the service spillway, was investigated. This type of net is potentially physically feasible at Elkhead. This shallower depth, more tightly strung, more frequently anchored and higher buoyancy net would be designed to tolerate higher velocities (up to 2 ft/sec) in a smaller flow area. It is expected that net deflection, net submergence and net strength will be particularly significant issues for such an installation. In addition, frequent net cleaning would have to be practiced to avoid a head differential at the net and to avoid higher clogging related stresses on the net.

Such a net would be experimental, as little data is available for this type of installation. Model or prototype testing should precede actual installation.

Alternative Variations

General

A variety of suggestions for fish passage/separation were brought up by the advisory committee for further consideration. Where these ideas could not be incorporated into the alternatives they are more fully described in the following narrative.

Net Variable Size Mesh Opening

To reduce overall net size, increase the percent open mesh area and reduce the net clogging characteristic we evaluated the idea of constructing a net with a transitioning or two tier opening size. This net would have large (25-mm square) openings in the bottom half of the net to exclude the larger fish expected to reside at greater depths transitioning to small size (6.35-mm or 2.38-mm square) openings at the surface to exclude the more shallow dwelling sac-fry size fish. This type of net can be constructed with some savings in cost in comparison with a conventional single size opening net. Unfortunately, the extent of escapement from the reservoir via the primary outlet and service spillway respectively is unknown so the value of such a variable opening net is unknown.

Electrical Barrier

To eliminate the potential flow obstruction of a net in the spillway entrance area an electrical barrier which would repel fish trying to enter or terminate fish which pass was further evaluated. Electrical barriers can be configured to repel fish in a spillway approach very effectively (>80% success). Unfortunately, weak or injured fish, passive life forms or stunned fish will pass the barrier. Since a minimum of 3 minutes of electrical field contact time is required to reliably cause fatal trauma, an electrical barrier cannot be relied upon for this purpose at this location. Fish will also pass the barrier during power failures or when it is otherwise out of operation. An alternate application of an electrical barrier which involves shocking, floating, collecting and moving stunned fish back to the reservoir is also possible, but this requires fish handling as an additional operation and maintenance cost.

Combination Systems

While reliability is apparently not a definitively explained criteria for separation, composite or combination systems can be used to achieve a target reliability greater than one device alone can achieve. For instance, a net with 75% reliability can be combined with an electrical barrier with 85% reliability to limit service spillway escapement to over 95% reliability ($0.75x + 0.85 (x-0.75x)=0.96x$)

Making provisions for the addition of a second barrier (should the first fail to live up to expectations or should greater reliability become necessary) is a way to continue with experimental separation systems while more experience is gained or until more information on escapement is available and still have the opportunity for making reliability improvements. A double system for instance, can also cover periods of time when one system is not functional or

when a different system is more effective during different conditions (e.g. time of the year or fish life stages), thereby achieving greater reliability.

Alternatives Cost Evaluation

General

The fish separation issue is a part of either the dam rehabilitation project, for which preliminary design is underway, or a storage enlargement/dam raise project which is in the conceptual engineering stage. The fish separation provisions are divided into the previously mentioned construction focuses and primary physical components of each alternative and assumes they are part of a larger overall project. Cost assumptions, not included items, line item cost estimates and "annual cost" comparative information are all presented in this section of the report.

Assumptions

The costs presented herein reflect the following assumptions:

- The Engineering News Record Construction Cost Index (ENR-CCI) of 6286 of April 2001 was used as the basis for the cost estimate
- Totaled items include a 20% contingency allowance (this accounts for unknowns in site conditions, minor changes in components and unit price uncertainty)
- Totaled items include a 10% unlisted items allowance (this accounts for items which individually account for less than 5% of the construction cost and all small items combined together; this includes the components of construction which are so small in price or quantity that they aren't considered a major component for construction)
- Dam rehabilitation items are accomplished at same time for maximum economy. Current cost estimate reflects only additional costs to accommodate fish separation measures.
- Dam raise items are accomplished at same time for maximum economy. Current cost estimate reflects only additional costs to accommodate fish separation measures.
- Maintenance barge is shared with two other projects (1/3 capital cost in estimate)
- On an annual cost basis, each line item cost has an approximated life cycle which requires eventual replacement. The number of life cycles were estimated for a 50-year period and their 2001 price connected to an annual cost value at a 7% interest rate. Inflation was not considered. These prices are not absolute and are only comparisons between alternatives.
- The average annual operation and maintenance cost and are estimated based on the basis of 2001 costs, for each of the elements needed to operate the respective separation device.
- No secondary or duplicate separation devices (such as an electrical barrier) are included in the cost estimate.
- The dam raise design and construction cost should include the physical provisions necessary to accommodate a second or duplicate separation device.
- Table numbers may not add up exactly as standard U.S.B.R. significant digit numerical rounding rules have been applied.

Items Not Included

To clarify costs stated herein is to state factors which may effect total project cost, but which are not included herein at this time:

- Inflation (forward pricing not used)
- Land or right-of-way cost
- Increase in storage
- Horizontal or vertical grade adjustments or rehabilitation improvements to the County road outside of the dam limits-assumed to be a County responsibility
- Environmental mitigation
- City staff, time, and resources (for example, to dewater the reservoir to the outlet structure level)
- Easements and costs associated with downstream land and powerline use

Construction Cost Estimates – Rehabilitation Project

Alternative 1 – Net (2.38-mm) Only – Rehabilitation Project

Anchor Construction		
Anchor installation, survey and buoys		$58,200
Dam slope net apron/footings		$59,000
Mobilization, demobilization and restoration		$10,000
	Subtotal	**$130,000**

Net Fabrication/Installation		
Net Fabrication		$488,000
Net Installation		$5,300
Safety and Four Sided Buoys		$13,300
Reinforced Center Support		$6,000
Stiffners (b/w main and top skirt) and other net refinements		$12,000
Fencing		$3,200
Mobilization, demobilization and restoration		$30,000
	Subtotal	**$560,000**

Unlisted items	$69,000
Contingency items	**$**138,000
Construction Cost Total	**$900,000**

	Annual Cost
Construction	$160,000
O&M	$120,000
Total Annual	$280,000

Alternative 2 – Net (6.35-mm) and Cylinder Screens – Rehabilitation Project

Anchor Construction		
Anchor installation, survey and buoys		$58,200
Dam slope net apron/footings		$59,000
Mobilization, demobilization and restoration		$10,000
	Subtotal	**$130,000**

Net Fabrication/Installation		
Net Fabrication		$318,000
Net Installation		$5,300
Safety and Four Sided Buoys		$13,300
Reinforced Center Support		$6,000
Stiffners (b/w main and top skirt) and other net refinements		$12,000
Fencing		$3,200
Mobilization, demobilization and restoration		$20,000
	Subtotal	**$380,000**

Cylinder Screen Fabrication/Installation		
Cylinder Screen Fabrication		$69,000
Screen Manifold Structure		$83,000
Pneumatic Backwash System		$5,000
Mobilization, demobilization and restoration		$10,000
	Subtotal	**$170,000**

Starr Ditch Screen Fabrication/Installation		
Screen Fabrication		$12,500
Screen Frame		$2,000
Mobilization, demobilization and restoration		$1,000
	Subtotal	**$15,500**

Unlisted items	$70,000
Contingency items	$140,000
Construction Cost Total	**$910,000**

	Annual Cost
Construction	$140,000
O&M	$125,000
Total Annual	$265,000

Enlargement Project

Separate line item construction cost estimates and an annual cost estimate were not prepared for fish separation facilities for an enlargement project. This is because the facilities are very similar to those for a rehabilitation project and detailed cost evaluation of an enlargement project was not part of the original scope of work. We did conceptually evaluate how fish separation construction costs might be impacted by being part of an enlargement project.

The nets which appear in both alternatives would have some geometry changes to maintain the same flow area but these would be minor, probably resulting in a <10% total cost increase. The primary outlet screens will be higher in cost due to the greater discharge created by the increase in the diameter of the primary outlet pipe (36 in. to 48 in.). The screens will be the same size as in Alternative 2, but the number of screens will increase and will require a larger manifold structure. In addition, since these alternatives have not been studied in detail, a 5% higher contingency allowance would be applicable.

The probable higher cost of Alternative 1 could be reflected by a 5% higher contingency or a total construction cost of approximately $950,000. The probable higher cost of Alternative 2 could be reflected by a 26% higher cylinder screen cost and 5% higher contingency or a total construction cost of approximately $1,250,000.

Management Issues

Reservoir Management Practices

Implementing Elkhead Reservoir management practices which can help prevent non-native fish escapement is part of the fish separation plan and should include:

- Regulate reservoir levels during periods the service spillway does not have to be spilling to 1 foot (min) below the spillway sill in order to prevent wind tide or wave splash spills and to provide for a small amount of reservoir flow attenuation for minor rainfall events

- Reduce the frequency of surface spills and the escapement of small life forms by passing as much flow though the primary outlet as possible, especially during the post spawn period for warm water fish (May 1 through end of spring snowmelt runoff).

- Drawdown reservoir more during the late summer through early spring period to make use of outlet capacity when it would be flowing at less than maximum capacity and to allow storing some spring runoff in reservoir that otherwise would flow over the spillway.

- Coordinate Elkhead Reservoir operations with the operations of other facilities and other basin practices which are intended to minimize the impact of non-native fish on the endangered fish (such as timing of releases, timing of unavoidable escapement, etc.).

Additional Investigations

Unfortunately much is still unknown about the extent that non-native fish actually escape or could escape from Elkhead reservoir and provide a threat to native fish. To a lesser extent, there is also some uncertainty concerning the prospective physical success of fish separation. As a result, the actual benefit of fish separation for the cost involved is impossible to estimate. The expected benefits will likely be cumulative as more separation projects are implemented basin wide and will be largely qualitative versus economically quantitative.

While it may not be prudent to delay implementation of fish separation measures at Elkhead, neither does it make sense to install expensive measures especially capital cost intensive features, which may do little to actually solve a problem which is of unknown severity. With our current knowledge at this site, a cost-effective solution to the problem is, at worst, out of reach, and is most probably, unknown.

We believe that a more physically effective and cost effective fish separation project will result if the following issues are more thoroughly investigated:

- The extent to which non-native fish escaping Elkhead Reservoir survive, reproduce, etc. and thus provide a threat to endangered fish.

- The extent to which non-native fish escaping Elkhead Reservoir contribute to the overall threat from all sources to endangered fish.

- The total numbers of non-native fish by type and size classes which are available to escape and actually do escape.

- The temporal pattern and means of escapement (via service spillway and primary outlet respectively) for the different classes of non-native fish.

- The value of a more reliable separation system (95%+ effective) for a more frequent event (e.g. prohibiting nearly all escapement but, for a shorter period of time say every 10 years).

APPENDIX A

Endangered Species Background

The Endangered Species Act which was passed by the U.S. Congress in 1973 (and modified in 1978, 1982, and 1988) basically directs the Federal government to conserve listed species and their critical habitats and prohibits Federal action which would jeopardize a listed species' existence. Federal action consists not only of direct Federal construction activity, but applies broadly to any activity by others, which involves a federal funding or permitting process. Administration of the Act is through a consultation process with the U.S. Fish and Wildlife Service (Service) or the National Marine Fisheries Service in the case of marine species.

In the late 1970's the Service concluded that all water depletions in the Upper Colorado River Basin were "jeopardizing" endangered fish. The potentially significant, long range impact of this jeopardy decision encouraged the Colorado Water Congress to implement a "Recovery Program" which would recover the endangered fish while allowing water development activities to continue. Participants in the Recovery Program include the states of Colorado, Wyoming and Utah, the Service, the Bureau of Reclamation, Western Area Power Administration, Wyoming Water Development Association, Utah Water Users Association, and environmental organizations. Funding of the Recovery Program is from the participants and a "new project" fee based on net water depletions.

APPENDIX B

Highline Fish Separation- A Condensed Project History

General

One of the off-stream reservoirs which was identified by Recovery Program as a potential source of competing non-native fish is Highline Reservoir, and artificial impoundment on Mach Wash which is tributary to the Colorado River downstream of its confluence with the Gunnison River. This facility was one of two off-stream reservoirs examined as prototype facilities for implementation of fish separation measures (Miller 1997). The State of Colorado (Division of Wildlife) owns this facility and it is operated by a sister agency (Division of Parks and Outdoor Recreation, DPOR) for recreation, including sport fishing for non-native fish. Sport fishing is supported through a stocking program, which now is governed by a non-native fish stocking policy that was developed to minimize conflict between non-native sport fish and endangered fish.

A fish separation project at Highline Reservoir was first evaluated by Miller Ecological Consultants (Miller 1997) and Ayres Associates. The District subsequently retained Ayres Associates to develop an acceptable fish separation plan for Highline Reservoir. Ayres also provided technical services in the preliminary design, final design and preparation of plans and specifications of the selected barrier net. Funding for the design and construction of the fish separation project was provided by the U.S. Bureau of Reclamation through the Recovery Program. An ad-hoc committee called the Highline Advisory Workgroup was formed to ensure that all the interested parties would have input and be kept informed on the progress of the project. This group began the fish separation evaluation at Highline using the Miller (1997) report option "exclusion to current technology" as the technical criteria. At Highline this initially meant reconstructing the primary outlet and installing cylinder screens with 2.35-mm openings on the new intake. The service spillway was to be protected with a barrier net with 6.35-mm openings. A net with only 6.35-mm openings, reflecting a state-of-the-art net, was proposed for the service spillway due to cost considerations and the understanding that the primary outlet handled most of the flow. This design concept was carried forward into the project design process. A minor revision to the project design criteria was decided upon at the time the design was initiated in order to be consistent with the Colorado Division of Wildlife procedures for stocking non-native fish in the Upper Colorado River Basin, which requires containment of fish in floodplain ponds up to a 50-year event instead of the 100-year event.

After the consultant and committee reviewed the fish separation plan suggested by the Miller (1997) report, in view of more detailed site conditions, they realized that it would be very difficult to reconstruct the primary outlet and install screens, because the intake to the outlet is covered with about 20 feet of sediment. The sediment would have to be removed before the outlet could be reconstructed, which would mean a public relations problem for both the Recovery Program and the DPOR. In addition, normal reservoir operation was found to actually be via the service spillway rater than the primary outlet. Other alternatives for fish separation were therefore explored.

In response, Ayres completed a conceptual design and cost estimate for an alternative of providing an inclined (Coanda wedge-wire) screen in the creek downstream of the reservoir to

screen flow from both the primary outlet and the service spillway. The barrier would involve installing a large concrete structure with screens that would cost more than $650,000. This cost did not include dealing with the captured fish, which would have to be disposed of or returned to the reservoir. Additionally, space for such a structure did not appear available on State land downstream of the dam. This alternative was felt to be excessively costly from both a capital cost and operation and maintenance standpoint.

A subsequent alternative involving a change in design criteria was then suggested. This involved placing a barrier net in the service spillway and limiting releases through the primary outlet using management techniques without a permanent screen on the outlet. As part of the management techniques, the committee agreed to operate the primary outlet once a year for 1 1/2 hours for dam safety operations and during emergency situations. A temporary net or screen will be installed downstream the dam for when the outlet is used. This net has not been selected to date. Normal fish netting procedures employed by CDOW have been suggested for use.

In order to ascertain the acceptability of this solution, two memos to the Recovery Program Participants were posted through the Recovery Program list server, one on August 20 1998, and one on December 5, 1998, summarizing committee recommendations, the operational limitations such as outlet screening and the release of 5 acre-feet of water discharged at the net annually, and requesting any comments. Very little response (negative or positive) was received in response to these memos. Another similar memo posted on November 4, 1998 also received little response. The committee proceeded with the plan to place a barrier net with 6.35-mm openings near the service spillway that will protect up to the 50-year flood.

The barrier net plans and specifications were completed in January 1999. Four contractors submitted bids on February 23, 1999. The bids ranged from $198,000 to $609,100. The contract was awarded and the net constructed. The net went into operation in the fall of 1999. In the interim the DOW has evaluated its performance and has found it to be operating in accordance with the expected level of exclusion and has made valuable suggestions for improvements.

Net Characteristics

When changes in dam operation reduced the need to screen the primary outlet, such screening was eliminated. The barrier net then became the primary fish separation measure. Therefore, for better performance its area was increased to handle the same flow rate at a lower approach velocity. The original net had been designed (Miller 1997) for a velocity of 2 feet/second for more infrequent flows. Most fish could die or be harmed by impingement on the net at this velocity. The velocity was decreased to <0.3 feet/second (0.18 actually) when it was decided to use the larger net across the service spillway for routine flow handling, the operation preferred by DPOR.

Nylon and Spectra-Dyneema polyester blend were considered for the net material. The more expensive Dyneema netting was selected because of its high strength and resistance to abrasion. This specific type of net has no knots, making it stronger. The net is manufactured in 25 foot panels, which are attached to a ribline. Should design parameters be exceeded, the barrier net is

designed to fail in the middle of the 25 foot panel, leaving the ribs, top and bottom lead intact. Once the net fails the stress will be taken off of the net framework and it will remain in place attached to the bottom anchors. This is to avoid fouling of the spillway by the net if it were to fail as a unit. The net has "skirt" at the top and bottom to help limit the number of fish escaping. The skirts extend perpendicular to the net about 5 feet; the top skirt floats and the bottom skirt is weighted down at the edge so fish cannot swim under it. When the net is not stretched, the net opening is 5.5-mm by 6-mm. The gross net pattern is 7-mm x 9-mm. The net has a 12-mm stretch, resulting in a 8 +/- mm by 0+/- opening. Each individual strand of the mesh has a 95-lb breaking strength. The buoy system which floats the net consists of 85-ounce buoys for the main panel and 23-ounce buoys for the skirt.

Anchor Characteristics

Manta Ray anchors were selected for the net anchoring system because they are reliable, relatively inexpensive and easy to install underwater. They are driven into the reservoir bottom to the proper depth, then the base is spread out and twisted to provide resistance when tensioned. The anchors are approximately 25 feet apart, which corresponds to the ribline spacing on the barrier net. Other anchors considered were steel pilings and concrete slabs, both of which would be more expensive and would require more labor.

The force on the anchor is approximately equal to the maximum net flotation and is a function of the net weight, anchor spacing and depth below the water surface. Each anchor has to hold at least 3,000 lbs of uplift. The Manta Ray M3 can hold 10,000 lbs uplift when properly installed.

Test pits and borings were made prior to the dam modification in 1997 to analyze the stability of the dam. Several of those test pits were in the area of the proposed net and were used for the purpose of net design. Sand with varying amounts of gravel and fines were encountered near the eastern side of the net. No test pits were dug near the western edge of the net. Because of the uncertain soil conditions the anchor manufacturer recommended that the anchors be installed at least seven feet below the bottom of the reservoir.

The advisory group also discussed lowering the reservoir so the anchors of the net could be installed in the dry. The DPOR felt that avoiding the public displeasure associated with this drawdown would justify the extra cost to install the anchors in the wet.

APPENDIX C

MEETING SUMMARY

Date & Time:

Thursday December 7th

10:00 AM to 3:00 PM +

Location:

Colorado River Water Conservation District Office

201 Centennial St. Suite 203

Glenwood Springs, CO 81602

Location contact: Ray Tenney (970) 945-8522

Subject:

Advisory committee meeting to discuss analysis and design of an adequate fish management/containment system to separate endangered and sport fish at Elkhead Reservoir. This is an update to the report "Upper Colorado River Basin Recovery Implementation Program: Feasibility Evaluation of Non-native Fish Control Structures" and part of preliminary design now being completed for dam rehabilitation (and possibly enlargement).

Attendees:

Pat Martinez, CDOW

Dave Langlois, CDOW

Ray Tenney, CRWCD

Jim Ferree, City of Craig

Sherman Romney, City of Craig

Bill Early, City of Craig

Bob Norman, USBR

Terry Stroh, USBR

Robert Muth, USFWS

Gerry Roehm, USFWS

Chris Foreman, CSPOR

Doug Laiho, Ayres Associates

Jon Radloff, Ayres Associates

NOTES

- The meeting began with a description by Doug Laiho of the history of many of the issues at Elkhead as well as a history of the fish management/containment effort at Highline Reservoir. Theoretic criteria had been a 3/32" (2.38-mm) opening size, a 50-year design frequency, and a 90% reliability, or "exclusion." The agreed-upon values for the net installed at Highline include a ¼" (6mm) opening size, a 50-year design frequency, and a 60% exclusion. This net was designed to be used in conjunction with a fish management program and is still considered experimental. The fish management/containment at Elkhead was originally envisioned as the second of three prototype applications in Colorado to apply fish separation.
- Life cycle costing of this type of net has not been evaluated.
- Behavioral techniques such as flashing lights or electronic fields are not considered positive enough control to be effective.
- The initial presumption is to use a fish net at Elkhead, but the design criteria must be revisited. In addition to opening size, design frequency, and exclusion, structural velocity versus impingement criteria guidelines must be determined (for net and screens).
- Other options considered at Elkhead include:
    - If outlet has to be replaced, go to a 10-year design frequency with cylinder screens and no service spillway protection
    - Cylinder screens on the primary outlet with electrical barrier in the service spillway
    - Cylinder screens on primary outlet with inclined screen, drum screen, or coanda screen in spillway floor or crest.
- Ray Tenney began organizing the issues being discussed as a "Fact and Issues" table on the dry erase board.

FACTS:	ISSUES:
o The Elkhead drainage basin area is 204 square miles	o Should the outlet structure be screened?
o The spillway capacity must be modified with enlargement of the reservoir	o What should the net opening size be?
o Should the design flow be 2,000 cfs (Q_{50})?	o Should impingement/killing of game fish be allowed?

- There was a comparison of Elkhead and Highline physical characteristics.
- Pat Martinez recommended ¼" (6mm) net opening size as standard. The resulting 60% target exclusion is more realistic than 90% from a 3/32" (2.38-mm) opening.
- Would it be beneficial for Ayres Associates to do a cost-benefit analysis for a net and outlet screen vs. impingement?
- Ray Tenney posed the question: Is the net going to give us (collectively) what we want?
- Pat Martinez gave a presentation on the Highline fish screen. It generally covered maintenance issues and fish counts in and downstream of Highline Reservoir. It brought up some additional information that was not available at the time the Highline net was designed, illustrated some of the "lessons learned" for the first year of the net being in place, and discussed some of the criteria which were and were not met by the net. Some of the issues discussed include:
    - Wave action pushes gravel on to the net at the shoreline (north or west side only), keeping the net from raising completely. This creates small gaps between the floats where fish (probably only very small fish) could pass.
    - 125 cfs caused the main floats to pull down (submerge). This occurred at a time when algae was on the net.
    - Maintenance cost for the first year was estimated at approximately $15K ($10K + fed. Share of $5K).
    - Colorado Parks would like to have a "buoy maintenance barge" ($18K, not included in project cost). This makes it possible to easily clean the top 10 feet of the net.
    - Algae collection on the net is an important maintenance issue. The net algae growing season may be more important than light penetration. Highline has a clarity of less than 3 feet, but there was still a lot of algae accumulation on the net. The net can be cleaned to near new conditions with a pressure wash.

- There was no damage to the net as a result of leaving it in the water over the winter.
- The top skirt tends to stay pushed up against the main net float line. Tying the skirt floats to the warning buoy line did not work well and also prevented access to area between the buoy line and the net. 1-1/2" diameter PVC stiffeners, kept in place via skirt tension, were used to keep the top skirt separated from the main float line, which worked well. The question was raised weather the top skirt should be designed to float on the downstream side of the net versus the upstream side, theoretically keeping the skirt separated from the main floats with no other modifications needed. This design modification would probably not be as effective as the current design in preventing fish from jumping over the net.
- Anoxic or low oxygen level conditions should be considered in net design.
- The net had a target exclusion of around 60%. Preliminary counts (limited study) indicate 60% to 80% exclusion.
- There are lots of smallmouth bass (< 3" in length) in Elkhead, indicating good reproductive rates but poor recruitment. Larger fish need to be put in Elkhead.
- No northern pike were found in Elkhead.

- Bob Muth thought that the current technology/criteria (used at Highline) would be transferable to Elkhead.
- There was a discussion of varying the opening size and the design recurrence interval, with caution being given to enlargement of the opening size criteria.
- At Elkhead, the primary outlet structure will be inside (downstream) of the net, eliminating the need to screen this structure.
- Should consideration be given to a two-tiered net? Perhaps the net can be designed with a larger opening size for depths where fish may not go due to low oxygen levels? This type of net may have a smaller opening size (¼") at shallower depths (down to 30') and a larger net opening size (up to 1") as depth

increases. One thing to consider here is if the cost of manufacturing a net with two opening sizes worth the benefit, i.e. is it cheaper to manufacture a net with just one opening size rather than two?

- Operation and maintenance costs should be included in the cost estimate for the net, provided life cycle costing is done.
- There has been no effort to determine the actual value of the fishery, but it is undoubtedly important. Establishment and maintenance is necessary. These nets are being designed as part of the establishment and management of this fishery.
- Dave Langlois discussed the Yampa Basin Management Plan. The transition of northern pike to Elkhead was not mentioned but is desired. The replacement scenario preserves the sport fishery (with the alternative being no fishing) and endangered fish with public support.
- The Elkhead net design report should be stand-alone from the 1997 MEC report and should include information from Pat Martinez.
- Design should consider options such as recurrence interval, hydrographs, and exposure time to escapement for comparison.
- Design should consider the use of a "grater" or "pike-o-matic" device downstream of the net, exposing all fish that pass the net to fatal trauma. See article relating to study done at Lake Davis, CA (January 18, 2000) provided by Pat Martinez.
- It may be worthwhile to put together a list of options that were considered which could be applicable to other reservoirs.
- There should probably some type of life cycle costing done. A 50-year analysis seems appropriate. This is partly dependent on who is responsible for the various costs.

SUMMARY

The design of a fish control/management system at Elkhead Reservoir fits in to current management practices in Colorado and is desired. The design at Elkhead will be a net,

similar to the one currently in place at Highline. The criteria to be used include ¼" (6-mm) opening size, 50-year design frequency, and 60%-90% exclusion. No outlet structure screening is necessary since it will be located inside (downstream) of the net. Items to be considered in the design include:

- Cost and effectiveness feasibility of a two-tiered (opening size) net
- Top skirt vs. main float line separation methods
- Keeping gravel and other debris off the net when the water level is low
- Extent of algae growth which will influence cleaning and maintenance practices
- The effect of higher altitude and deeper water (Elkhead vs. Highline) on maintenance
- The use of a device downstream of the net that exposes any fish that pass the net to fatal trauma

The Elkhead net design report should be a stand-alone version, separate from the 1997 MEC report and should include information from the Division of Wildlife (Pat Martinez) relating to the net at Highline Reservoir. The report should include a list of criteria/options considered. A 50-year life-cycle cost estimate (including maintenance costs) should be performed, but care should be taken to consider who will be responsible for various costs. Design by Ayres Associates is to be completed between March 1st and March 15th, 2001.

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