River Basin Management to Meet Competing Needs

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Preface

The papers included in these Proceedings were prepared for the **1998 USCID Conference on Shared Rivers**. The theme of the Conference was *River Basin Management to Meet Competing Needs*. The Conference, sponsored by the U. S. Committee on Irrigation and Drainage and the Bureau of Reclamation, was held in Park City, Utah, October 28-31, 1998. The Conference was a multi-disciplinary review of how management of river basins is changing and evolving to meet the needs of all water users and stakeholders in a river basin.

In five half-day sessions, the Conference featured in-depth examinations of issues involving U.S. and international river basins. A Poster Session offered an additional opportunity to examine river basin management activities. A one-day study tour of the Weber Basin Water Conservancy District was also featured during the Conference.

Papers presented during the Conference Technical Sessions and Poster Session addressed five major topics:

- Emerging Social and Technical Issues in Shared River Management
- Endangered Species and Adaptive Management Issues
- Downstream Impacts of Irrigation and Drainage Management
- Stakeholder Participation
- State Line/Boundary Issues

Twenty-six papers are included in these Proceedings. The papers cover a wide diversity of both success stories of stakeholder participation and evolution of communication, analysis and negotiation systems, and of a few failures. The topics and contexts of the papers describe state-of-the-art means for addressing water management and sharing issues. Various issues described include water supply, water quality, impacts on fisheries, recreation, endangered species, aesthetics, wilderness, wildlife, economy, social structure, historical heritage and ways of life. The papers and presentations provide for encouraging testimonies and case studies of how careful, thoughtful and patient communication and negotiation have paid dividends for all stakeholders and for future users. Several of the papers provide great insight into the perceptions and approaches of state and federal organizations in facilitating integrated and shared system management.

The general conclusions that can be drawn from these papers and the Conference are:

1. There are many players at the "table" in today's water management planning and administration decision-making processes.

2. All uses of water have multiple facets regarding their impact on the resource and on other users.

3. All parties are typically willing to show flexibility and a desire to consider trade-offs that benefit most or even all interests.

4. Many of the ideas and experiences described provide insight for and shed positive light on future shared river management.

The U.S. Committee on Irrigation and Drainage and the Conference Co-Chairmen thank the authors, speakers, session moderators and participants for making this Conference successful.

Conference Co-Chairmen

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ELWHA RIVER RESTORATION PROJECT

Thomas E. Hepler[1] Timothy J. Randle[1]

INTRODUCTION

The Elwha River is located on the Olympic Peninsula of Washington State, and flows northward 45 miles from the base of Mount Olympus to the Strait of Juan de Fuca near Port Angeles. The river system includes over 100 miles of tributary streams and drains a watershed area of 325 mi^2, 83 percent of which lies within the boundaries of the Olympic National Park. The construction of two hydroelectric dams on the Elwha River in the early 1900's blocked the migration path for several species of salmon and trout, severely limited the downstream flow of sediment and nutrients necessary for spawning, and raised downstream water temperatures in late summer and early fall.

Although the projects helped in the early development of the peninsula by Euro-American settlers, the reservoirs inundated important cultural sites of the Lower Elwha Klallam Tribe, and virtually destroyed the fisheries which were the basis of the Tribe's economy. Reduced sediment supply to the river has changed the flow regime from active meandering to less active and more channelized, has caused the beach at the river's mouth to recede and steepen, and has contributed to the erosion of Ediz Hook, the sand and gravel spit that protects Port Angeles Harbor. The removal of Elwha and Glines Canyon Dams is proposed to fully restore the Elwha River ecosystem and native anadromous fisheries in a safe, environmentally sound, and cost-effective manner.

PROJECT HISTORY AND PURPOSE

Elwha Dam was originally completed in 1913 at river mile 4.9, and includes a 108-foot-high concrete gravity section, gated spillways on both abutments, a multiple-buttress intake structure with steel penstocks, and a powerhouse with four generating units rated at 14.8 MW. A massive stabilizing fill of earth and rock was placed upstream of the dam between 1913 and 1919, following a sudden blowout of the alluvial foundation for the gravity section during first filling. Sheet piles, fir mattresses, and a concrete lining were added to reduce seepage. Elwha Dam impounds Lake Aldwell, with a surface area of 267 acres and a storage capacity of 8,100 acre-feet at elevation 197.

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Glines Canyon Dam was completed in 1927 at river mile 13.4, and includes a 210-foot-high concrete thin arch dam section, a gated spillway on the left abutment, a concrete gravity thrust block and earthfill dike on the right abutment, a power penstock tunnel with intake tower and surge tank, and a powerhouse with a single generating unit rated at 13.3 MW. Glines Canyon Dam impounds Lake Mills, with a surface area of 415 acres and a storage capacity of 40,500 acre-feet at elevation 590.

Both dams are owned by the James River Corporation, and are operated by the Daishowa America Corporation to pass streamflow and generate about 40 percent of the electrical power required by their paper mill in Port Angeles. Sediment accumulation over the years has created large deltas at both reservoirs. The total estimated sediment volume of both reservoirs (including deltas and lakebeds) is 18 million yd^3, 52 percent of which is fine silt and clay. The dams are classified as high hazard due to the potential for loss of life in the event of failure. Dam safety improvements were completed in 1987 at Elwha Dam and in 1989 at Glines Canyon Dam, and both dams currently meet state safety standards for normal operating conditions, probable maximum floods, and earthquakes [3].

AFFECTED ENVIRONMENT

Fluvial Processes

Although the Elwha River above Lake Mills and the tributary streams have remained largely unaffected by the projects and are generally pristine, the natural fluvial processes of the Elwha River have been significantly altered below Lake Mills by the trapping of sediments within both Lake Mills and Lake Aldwell. The reduced sediment supply to the middle and lower reaches of the river has resulted in a coarser riverbed surface when compared to the upper reach and to other rivers in the region, with the natural sand and gravel being washed out to sea. The loss of riverbed material has produced an armor-layer of cobbles and boulders, reduced natural river meandering, allowed vegetation to become firmly established on gravel islands and floodplains, and lowered the flood stage. The lower river channel is primarily reworking older river deposits and locally eroding high banks of glacial outwash. At the mouth, this has caused the eastern edge of the predam Elwha River delta to erode, and the barrier beach at Freshwater Bay to recede and steepen. The offshore area of sand and gravel deposits has been reduced in volume, leading to oversteepened slopes and exposure of Ediz Hook to greater erosion.

Surface Water

The projects inundated over 5 miles of the Elwha River, and created reservoirs having a combined surface area of 682 acres. The reservoirs act as large settling basins during floods, reducing peak turbidity levels downstream but extending them over a longer period of time. Water quality is currently classified as extraordinary (Class AA) by the state. Water diversions are made by the city of Port Angeles from a Ranney well near river mile 2.8 for municipal needs, and from a small diversion dam and canal near river mile 3.3 for the Daishowa and Rayonier paper mills, and for a state fish-rearing channel. Additional diversions are made for a tribal fish hatchery, and for domestic and irrigation use. A number of individual and multiple use wells are also located along the river to supplement the surface water supplies.

Native Fisheries

Prior to construction of the dams, the Elwha River was known as one of the largest producers of salmon and steelhead on the Olympic Peninsula. Anadromous fish historically included stocks of spring and summer/fall run chinook salmon, coho, pink, chum, and sockeye salmon, summer and winter runs of steelhead, cutthroat trout, and native char. Current runs are only a small portion of their former size, largely because of the dams. In addition to blocking fish passage to over 70 miles of mainstem and tributary habitat, the projects have trapped sediments with the resulting loss of spawning substrate below the dams, retained a portion of the nutrients and woody debris that would normally pass downstream, and elevated water temperatures by as much as 7 °F. At least one Elwha River salmon stock may now be extinct (sockeye salmon), while spring chinook and pink salmon may only be present in very small numbers.

Salmon and steelhead are important biological, commercial, and recreational resources in the Pacific Northwest, and provided $1.25 billion in income and more than 60,000 jobs in 1988 [4]. Federal efforts to maintain and improve salmon runs in the Columbia River Basin since 1981 have cost more than $1.3 billion, and may exceed $7 billion over 25 years. Restoration projects are also underway in the Umatilla River Basin ($80 million over 15 years) and in the Yakima River Basin ($70 million over 20 years), and are proposed for the Klamath, Trinity, and Sacramento River Basins in northern California ($108 million over 10 to 20 years) [2].

Cultural Resources

The Elwha Klallam people have lived in and utilized the Elwha River basin for thousands of years, with the river serving as their cultural, spiritual, and economic center. The reservoirs inundated cultural resources of great importance to the Tribe, flooding villages, fishing camps, and sacred sites, including their "creation site" and possibly burial grounds. The dams have also caused significant declines in harvestable fish and shellfish, resources promised to the Tribe by the Federal Government under the 1855 Treaty of Point No Point. Although both projects are listed on the National Register of Historic Places and are also considered cultural resources, their removal would restore the cultural and economic focus of the Lower Elwha Klallam Tribe and uphold the Federal Government's trust responsibility to the Tribe.

Other Environmental Impacts

The bottomland floodplain and riparian areas inundated by the reservoirs once provided important habitat for grazing and shelter for a wide variety of wildlife. Three Federally protected bird species in the Elwha/Glines Canyon study area, the bald eagle, northern spotted owl, and marbled murrelet, have also been affected by the loss of riverine habitat and salmon as a food source. The marine environment within the Elwha River intertidal and subtidal zones has been impacted by the depletion of gravel and finer sediments, affecting Dungeness crabs and hardshell clams.

LEGAL ISSUES

FERC Licensing Efforts

The Glines Canyon Hydroelectric Project was originally licensed by the Federal Power Commission (precursor to the Federal Energy Regulatory Commission, or FERC) in 1926 for a period of 50 years, and has received annual licenses since 1976. The Elwha Hydroelectric Project has operated without a Federal license since 1913. During the 1980's, the FERC licensing process became extremely contentious and drawn out, due primarily to national policy implications of licensing a hydroelectric project within a National Park, the absence of fish and wildlife mitigation measures capable of meeting Federal, State, and Tribal goals, and legal challenges by several conservation groups. FERC began preparing an Environmental Impact Statement (EIS) in 1989 to evaluate the probable impacts of the two projects and of alternative courses of action, and issued a draft EIS in 1991 [1]

Elwha River Restoration Act

The Elwha River Ecosystem and Fisheries Restoration Act (Public Law 102-495) was enacted in 1992 to provide a legislative settlement of the FERC licensing issues. The Elwha Act suspended FERC's authority to issue licenses for the projects, and required the Secretary of the Interior to propose a plan to fully restore the Elwha River ecosystem and native anadromous fisheries. The Secretary determined in 1994 that removal of the dams was both feasible and necessary to restore the ecosystem and fisheries. The Elwha Report [2] described four options for removal of the dams, nine scenarios for managing the accumulated sediments, and a process for analysis of a full range of alternatives.

NEPA Compliance

Dam removal would constitute a major Federal action, requiring compliance with the National Environmental Policy Act (NEPA). The National Park Service assumed lead responsibility for preparation of an interagency, programmatic (or policy) EIS [3] for the evaluation of several alternatives, including no action, dam retention (with fish passage provisions), removal of Elwha Dam, removal of Glines Canyon Dam, and removal of both dams, and the environmental impact of each alternative. Cooperating agencies in this effort included the Bureau of Reclamation, Fish and Wildlife Service, Bureau of Indian Affairs, and the Corps of Engineers.

Following public comment and the issuance of the final programmatic EIS in June 1995, a Record of Decision was prepared by the National Park Service recommending removal of both dams. A second, implementation EIS [4] was issued as a draft in April 1996 to address the specific methods and mitigating measures necessary to remove the dams, drain the reservoirs, manage the accumulated sediments, restore the reservoir areas, improve the fisheries, and protect downstream water quality.

ALTERNATIVES ANALYSIS

No Action Alternative

This alternative would retain both projects as they currently exist, without fish passage or other mitigation, and is used as a basis for comparison of the potential impacts of all action alternatives. Continued operation of the dams would not be affected by sediment accumulations for about another 200 years.

Dam Retention Alternative

This alternative would retain both dams, but would add mitigating measures for fish passage and wildlife. Elwha Dam would require a fish ladder, holding and sorting pools, intake screens, and spillway modifications. Glines Canyon Dam would require a trap-and-haul operation to convey adult fish past the 190-foot vertical lift, intake screens, and year-round spillway releases of 450 ft^3/s to pass juvenile fish. In addition, 898 acres of project lands would be enhanced for wildlife habitat [3].

Dam Removal and River Diversion Alternatives

These alternatives included the removal of one dam and the retention of the other (with modifications for fish passage), and the removal of both dams using various river diversion methods. River diversion during removal is a critical element, and may be accomplished by surface diversion channels, diversion tunnels, low-level outlets, or by a series of excavated notches. The preliminary studies favored a surface diversion channel for removal of Elwha Dam, and a notch-down method for removal of the concrete arch portion of Glines Canyon Dam. Demolition methods and proposed limits of structure removal were also studied [5].

Sediment Management Alternatives

These alternatives included (1) the mechanical removal of all reservoir sediments, (2) the relocation and stabilization of all reservoir sediments within the reservoir areas, and (3) allowing the river to erode and transport reservoir sediments downstream, supplemented by the mechanical removal of any remaining sediments. Initial cost estimates for these actions alone ranged between $50 million and $200 million [2]. The mechanical excavation of all reservoir sediments and removal by trucks was the most costly alternative and was quickly eliminated. The sediment stabilization alternative was eventually eliminated from further consideration due to its high estimated cost ($60 million) and potential for downstream impacts similar to those for the less expensive river erosion alternative. Restoration of predam landscapes within the reservoir areas would also not have been possible.

An additional mechanical removal alternative focused on the dredging of fine lakebed sediments for transport through a slurry pipeline to the Strait of Juan de Fuca, with the river allowed to erode the coarser delta sediments. Costs for the dredging operation and slurry pipeline construction were estimated at $22 million [4].

PROPOSED ACTION

Dam Removal

The major steps for dam removal following project acquisition include decommissioning of the powerplants, site access improvements and mobilization, river diversion, structure removal, waste removal and disposal, and site restoration. At the Elwha damsite, all structures would be removed or buried to restore predam conditions. Portions of Glines Canyon Dam that do not impede fish passage, and are considered historically significant, would be retained. All project features would be fully documented by drawings, photographs, and written descriptions in accordance with provisions of the National Historic Preservation Act.

The dam removal contractor would begin site mobilization in November of the first construction year, and continue through the winter months. Lake Aldwell would be drawn down about 15 feet to elevation 182, using the right spillway and 15-foot-diameter penstock, to permit construction of an upstream sheetpile cofferdam and removal of the left spillway. A surface diversion channel would be excavated through the left spillway site to elevation 135, using a dragline within the earthfill materials upstream of the cofferdam, and by blasting within the bedrock downstream of the cofferdam. Following removal of the cofferdam, the bedrock channel plug would also be excavated to elevation 135, under flow conditions, by controlled blasting in five stages over a 3-week period.

Streamflow diversion would continue through the newly excavated channel for one year, while removal of the dam structures and upstream fill continued. The excavated surface of the concrete gravity section would remain above the level of the upstream fill until the underlying rockfill was reached (for erosion protection in the event of flood releases), and then be removed completely. The penstocks and right spillway would be removed, and a downstream cofferdam would be constructed, to provide construction access to the powerhouse. All mechanical and electrical equipment would be removed from the powerhouse, and the structure would be demolished and wasted in-place. Following spring runoff, excavation for the river channel would progress below the water level within the diversion channel, resulting in the diversion of streamflow along its original course through the damsite. During the low-flow period (August to October) of the second year, the river channel would be lowered in increments an additional 45 feet through the rockfill until reaching the desired final grade at elevation 90. The diversion channel and adjoining areas would be backfilled with waste materials and topsoil to provide final, natural-looking contours on the left abutment [5].

Glines Canyon Dam would be operated to provide flood protection for the downstream Elwha Dam until completion of the surface diversion channel in July of the first construction year. Lake Mills would be drawn down below elevation 537 (over 50 feet) using the spillway and power penstock, and a large ringer crane with 300-foot boom would be erected on the left abutment for waste removal. Removal activities would commence with the staged excavation of the concrete arch section in 7.5-foot lifts, using diamond-wire sawcutting methods exclusively within the upper reinforced portions of the dam, and combined sawcutting and controlled blasting elsewhere, to produce large concrete blocks. An average of two concrete blocks of 35 tons each would be removed from the dam and hauled off-site each day, using the ringer crane and a flatbed truck, with a 7.5-foot lift excavated about every two weeks.

Below the level of Lake Mills, a 15-foot-deep notch would be established for each lift, alternating between the left and right abutments, by controlled blasting under reservoir head to permit further reservoir drawdown. A typical notch width of 25 feet would be blasted in four sections, limiting the maximum hourly increase in flow rate to about 1,000 ft^3/s under full head, and lowering the reservoir level about 8 feet in 2 days. The design discharge capacity of 1,400 ft^3/s for a 7.5-foot head would be sufficient to pass normal streamflow, allowing the remaining portion of the lift to be excavated in the dry. The minimum 2-week period between reservoir drawdowns is critical to allow sediment in the delta at the upper end of the reservoir to redistribute and move closer to the dam. To further complement fishery restoration and minimize flood impacts, no demolition would be performed from mid-November to mid-December and during May and June of each year, when average flows would exceed the discharge capacity of the notch. Horizontal sawcutting operations would be suspended below the new sediment level at the dam (about elevation 460), with remaining demolition by blasting only. The lower portion of the arch dam section, including the final two lifts and the base of the dam, would be excavated to the desired final grade at elevation 400 in August and September of the second year, during minimum streamflow. Final channel cleanup would be completed by late October [5].

Other structures to be removed from the Glines Canyon damsite include the penstock intake/trashrack tower, surge tank tower, left abutment dike, and transformer yard. The concrete thrust block and earthfill dike on the right abutment would be retained as a visitor viewpoint and interpretive area, and retention of the gated spillway would provide a visitor viewpoint on the left abutment. The powerhouse and penstock would be retained to provide a unique historical exhibit. Final site restoration would include revegetation and improvements for public safety and recreation.

Removal of both dams would generate more than 210,000 yd^3 of waste concrete, rock, and earthfill. Nine potential disposal locations have been identified in the project area, within surface mines or open pits. All mechanical and electrical items, timber, glass, fencing, and hazardous materials (primarily chemicals, asbestos wiring, and batteries) would be removed from the sites for recycling, salvage, disposal, or retention as historical artifacts [4].

Sediment Management

The final river erosion alternative would allow the Elwha River to erode and transport reservoir sediments downstream by natural processes (without hydraulic or mechanical dredging) and was selected for the proposed action. This alternative requires mitigation for expected impacts to water quality from the release of fine (silt- and clay-sized) sediments carried in suspension, and for potential impacts to downstream flood stages due to riverbed aggradation from the release of coarse (sand-, gravel-, and cobble-sized) sediments as bed load. The dredge and slurry pipeline alternative was found to be more expensive and required many of the same water quality and flood mitigation measures as for the proposed action.

The rate at which sediment is eroded and transported downstream from the reservoirs is dependent upon the rate of reservoir drawdown during dam removal, in addition to the flow rate and particle sizes. For example, sediment erosion rates would be extremely high if the dams were completely removed in one day, but the impacts to downstream areas would be catastrophic. Computer model results indicate the proposed drawdown of Lake Mills in 7.5-foot increments every two weeks, under normal streamflow conditions, would not lead to excessive aggradation of the downstream riverbed, and would not exceed the river's sediment transport capacity [6]. An extensive monitoring program would be implemented to verify the results of reservoir drawdown, and could be the basis for a decision to further slow the rate of dam removal. Proposed monitoring would include sediment transport rates, river channel topography, water quality, and aquatic ecology.

As the dams are removed in controlled increments over time, coarse delta sediments would be progressively eroded and redeposited downstream over the fine lakebed sediments. During each new increment of dam removal, the river would incise erosion channels through the deltas. The river would widen these channels while the reservoirs are held at a constant elevation, in preparation for the next increment of dam removal. Additional channel incision and widening would occur during periods of high streamflow when dam removal activities would be temporarily suspended. Before being transported downstream, the delta sediments would reach depths of 60 to 70 feet behind the partially-excavated Glines Canyon Dam, and 30 to 40 feet behind the upstream fill at Elwha Dam. Peak rates of sediment release from the reservoirs would coincide with the rapid drawdown associated with each new increment of dam removal. Since the reservoirs are up to 10 times wider than the natural river channel, up to two-thirds of the reservoir sediment is expected to remain along the reservoir margins in a series of terraces and would resemble a predam landscape. Currently, fine sediments are primarily stored along the lakebed of each reservoir, while coarse sediments are primarily stored as delta deposits at the upstream ends of each reservoir. About half of the fine sediments would be eroded from the reservoirs and be transported in suspension to the Strait of Juan de Fuca. Between 15 and 35 percent of the coarse sediment is expected to be eroded and transported downstream as bed load. Some regrading of remaining sediment may be periodically required to provide stable slopes.

Water Quality Protection

Fine sediment concentrations released from the reservoirs during dam removal would be high, typically between 200 and 1,000 ppm, but occasionally 30,000 to 50,000 ppm for short periods (from 1 to 3 days). Release concentrations would decrease to less than 200 ppm (or natural background levels) during periods of high streamflow when dam removal activities would be suspended to accommodate spawning. Following dam removal, fine sediment concentrations would be low during periods of low streamflow, but would increase during progressively larger flood flows as erosion channels widen within the reservoir areas. Within 2 to 5 years, fine sediment concentrations would return to natural (predam) levels [6].

Proposed actions for water quality protection during dam removal include the construction of open-channel pretreatment facilities and an infiltration gallery at the diversion location for industrial users (following removal of the existing diversion dam), a second Ranney well for municipal use, and modifications to existing wells. The new facilities would be completed and placed in operation before dam removal begins.

Fishery Restoration

The proposed plan includes actions for assessing fish stocks, using expanded hatcheries to develop and maintain broodstock, reintroducing fish by outplanting, managing harvest through fishing restrictions, and evaluating restoration efforts. Outplanting of juveniles (including eggs, fry, fingerling, and smolt) by tank trucks and helicopters would begin when fish passage and water quality were acceptable, and continue for up to 10 years. With the exception of sockeye salmon, all native Elwha species have a good to excellent chance of full restoration within 10 to 20 years if both dams are removed. Sockeye salmon may be restored using related stock from neighboring lakes or rivers on the Olympic Peninsula.

Flood Protection

Dam removal and downstream transport of coarse reservoir sediments would cause local aggradation of the river bed, especially in the lower three miles of river near the mouth. Local riverbed aggradation would increase the 100-year flood stage up to 2 or 3 feet in the lower reach, with an average increase below Elwha Dam of about 1 foot. The middle reach between the two dams is much steeper than the lower reach and increases in flood stages are expected to be less than 0.5 feet [6]. The federal flood control levee on the right side of the river near its mouth would be raised to maintain the existing 200-year flood protection for Tribal lands. Additional modifications would include raising local roads, raising well heads, and mounding septic systems where required.

Other Mitigation Efforts

The former lake beds and remaining sediment terraces would be revegetated through a combination of natural recolonization and a planned program of planting native species, including ferns, grasses, shrubs, and trees. The Lake Mills area would become part of the Olympic National Park, while the Lake Aldwell area would probably be transferred to the Tribe for conservation and possible economic development. Replacement electrical power would be made available to the Daishowa paper mill from the existing Bonneville Power Administration power grid.

Project Costs

Preliminary cost estimates for the proposed action were prepared at an April 1995 price level, and are summarized in table 1 [4]. Activities associated with the dam removal and restoration efforts would generate about 1,200 new jobs in Clallam County over a 10-year period. Significant economic benefits would be derived from additional recreation, tourism, and sport fishing in the area following dam removal.

PUBLIC INVOLVEMENT

Public involvement and comment has been an integral part of the decisionmaking process for this project. Public comments were included in the FERC Draft EIS (1991), the Elwha Report (1994), and the programmatic EIS (1995), and are to be added to the draft implementation EIS (1996). For the programmatic EIS, about 1,000 copies of the draft document were distributed, public meetings were held in both Port Angeles and Seattle with about 400 people attending, and over 600 letters were received during a 60-day review period. All substantive comments were addressed by either providing further clarification, modifying the text, or responding directly in the final EIS.

CONCLUSIONS

Dam removal plans have been developed for the removal of all structures at Elwha Dam and for the removal of the arch dam section at Glines Canyon Dam. The proposed plans will accommodate river flows during dam removal through diversion channels and notches; facilitate sediment erosion through controlled releases and planned construction schedules; protect water quality for existing users by adding wells and pretreatment facilities; address environmental and cultural issues by planning work shutdowns during spawning periods and by restoring sacred sites to near predam conditions; retain historical structures at Glines Canyon Dam for public interpretation of the projects; and achieve reasonable costs by limiting structure removal at Glines Canyon Dam and by minimizing potential flood impacts during construction. The natural erosion alternative is expected to remove about one-half of the reservoir sediment, with the balance remaining stable along the reservoir margins outside the new flood channel.

Numerous Federal, State, and local permits and review processes are required to implement the proposed action. Estimated project costs for dam removal and restoration efforts are about $111 million. Although the President's proposed 1997 fiscal year budget includes project funding, Congress has not yet indicated it would approve funds for dam removal. The Elwha Act set project acquisition costs at $29.5 million, but required funding for dam removal to be made available within 2 years following acquisition by the United States.

Table 1. - Cost Summary for Each Proposed Action

Action	Cost (thousands of dollars)
Project/Land Acquisition	$29,800
Dam Removal	33,038
Sediment Management Monitoring	2,144
Water Quality Protection	29,770
Fishery Restoration	7,380
Flood Protection	3,998
Revegetation	3,205
Hazardous Waste Disposal	587
Road Rehabilitation	528
Cultural Resources	665
Total Project Cost	$111,115

REFERENCES

1. *Draft Staff Report*, Federal Energy Regulatory Commission, March 1993.

2. *The Elwha Report*, Department of the Interior, January 1994.

3. *Elwha River Ecosystem Restoration - Final Environmental Impact Statement*,

National Park Service, June 1995.

4. *Elwha River Ecosystem Restoration Implementation - Draft Environmental Impact Statement*, National Park Service, April 1996.

5. *Plan for Removal of Elwha and Glines Canyon Dams*, Elwha Technical Series Report, Bureau of Reclamation (in publication).

6. *Sediment Analysis and Modeling of the River Erosion Alternative*, Elwha Technical Series Report, Bureau of Reclamation (in publication).

REMOVAL OF EDWARDS DAM, KENNEBEC RIVER, MAINE: A LANDMARK APPROACH TO WATERSHED RESTORATION

Gordon W. Russell[1]

ABSTRACT

On November 25, 1997 the Federal Energy Regulatory Commission (FERC) denied a new license for the Edwards Dam hydroelectric project, located on the Kennebec River, in the City of Augusta, Maine, and ordered decommissioning of the existing 3.5 megawatt generating facilities together with removal of the 917-foot (280 m) long dam, which had been built in 1837. The FERC decided not to relicense Edwards Dam after it found that continued operation of the project was inconsistent with federal and state goals to restore historic fishery resources in the Kennebec River, even with costly, state-of-the-art fishways. Until this time, the FERC had never denied a new license for an active hydroelectric project with an accompanying order for dam removal. Its Edwards Dam decision was immediately appealed, not only by the project's current licensees, but also by industry groups and other hydroelectric development interests throughout the nation, fearing similar action at other sites.

Faced with the prospect of years of litigation over the FERC's dam removal decision, and uncertainty over whether Edwards Dam would actually ever come out, negotiations commenced in an effort to find a solution that would meet the needs of all interested parties. On May 26, 1998, those negotiations concluded successfully with the signing of the Lower Kennebec River Comprehensive Hydropower Settlement Accord. Major provisions of the agreement include:

- transfer of Edwards Dam and associated project works in January 1999 to the State of Maine, which will carry out actual dam removal in the summer of 1999;

- establishment of a $7.25 million Kennebec River Restoration Fund to pay for dam removal and fisheries restoration, collected from several upstream dam owners and from a major shipbuilding industry, located downstream from Edwards dam, as part of regulatory mitigation requirements; funds to be managed by the

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National Fish and Wildlife Foundation, which will seek to raise an additional $1.5 million to help achieve settlement goals.

- modification of established schedule for installing fish passage facilities at upstream dams, pending growth of fish populations and accomplishment of other restoration objectives; and

- withdrawal of appeals and other challenges to the FERC's regulatory order on dam removal.

In pledging their support for the terms of the accord, federal and state natural resource agencies, non-governmental conservation organizations, and private industry will be actively involved in helping to achieve timely dam removal and restoration of fishery resources in the Kennebec River. This cooperative approach will not only help restore 15 miles (24 km) of riverine habitat that has been impounded for over 160 years by Edwards Dam, but will foster a collaborative effort in helping to rebuild populations of migratory fish in the Kennebec River that have long suffered from the cumulative effects of industrial development.

INTRODUCTION

Private dam owners may operate a hydroelectric project for up to 50 years before they have to apply to the Federal Energy Regulatory Commission (FERC) for a new license. Over the course of a license term that lasts for decades, environmental statutes and regulations can change, along with public attitudes and priorities for using the waterways that hydroelectric developments occupy. Because it is difficult to modify a FERC-approved project before its term has expired, the renewal of its operating license is viewed by many as a once-in-a-lifetime opportunity to gain environmental improvements and to address watershed restoration needs (Echeverria et al. 1989).

The initial license for the Edwards Dam hydroelectric project, located on the Kennebec River, in the capital city of Augusta, Maine expired on December 31, 1993. Despite plans by the owner to continue operating the project, the FERC, on November 25, 1997 denied a new license, and ordered decommissioning of the existing generating facilities together with the removal of the 160-year old dam (FERC 1997b). Until this time, the FERC had never denied a new license for an active hydroelectric project with an accompanying order for dam removal. The FERC's decision, which was based largely on an analysis of alternatives for restoring migratory fish populations in the Kennebec River, immediately sparked a series of appeals by the dam's owners and other hydropower interests throughout the country.

Faced with the prospect of years of litigation over the FERC's precedent setting decision on Edwards Dam, a number of stakeholders engaged in intense negotiations over the next several months, and on May 26, 1998 signed a comprehensive settlement agreement, which will result in removal of the dam in 1999. In this paper I explain the rationale for removing Edwards Dam, and discuss the anticipated benefits to fishery resources. I also identify the major provisions of the stakeholder settlement agreement, and describe current plans for removing Edwards Dam. Finally, I provide insight on how the collaborative approach to achieving fishery restoration goals in the Kennebec River watershed might be used elsewhere.

THE CASE FOR REMOVING EDWARDS DAM

Edwards Dam was built on the Kennebec River in 1837, and was used initially in the lumber and textile industries. Hydroelectric generating facilities were added in 1913, and the project received its first federal license in 1964 (FERC 1997b). The project includes a 917-foot (280 m) long, 25 foot (7.6 m)-high dam, which creates a 1,143-acre (462 ha) impoundment that extends approximately 15 miles (24 km) upstream. Three separate powerhouses, containing a total of nine generating units, provide a combined hydroelectric capacity of 3.5 megawatts (MW). Total annual electrical generation is roughly 20 gigawatt-hours, most of which is sold to the local utility, Central Maine Power Company. As it currently exists, the Edwards Dam project represents about 0.13% of the total electrical generating capacity that is available in the state of Maine (ME SPO 1993).

The Kennebec River is one of the major rivers in the state of Maine, flowing from its source at Moosehead Lake approximately 132 miles (212 km) to the Atlantic Ocean (Fig. 1). The drainage contains over 20 hydroelectric projects, 10 on these on the main stem of the river (ME SPO 1993). Edwards Dam is the most downstream barrier on the main stem, and is located in what is now the head of tide. Below Edwards Dam, the Kennebec River flows into Merrymeeting Bay, one of the largest freshwater tidal bays in the eastern United States (FERC 1997a).

The Kennebec River and its associated estuary (Merrymeeting Bay) contain a diverse fish community, known to contain at least 43 species (USFWS 1996). Prior to construction of Edwards dam and other barriers in the 18th and 19th

centuries, the river contained large runs of anadromous fish [2], including Atlantic salmon, American shad, alewife, blueback herring, striped bass, Atlantic sturgeon, shortnose sturgeon, and rainbow smelt, which provided sustenance to native Americans and the colonial settlers occupying the area (ME SPO 1993). Absence of adequate fish passage facilities at dams, together with pollution and overfishing led to the virtual extinction of most of the historic runs of fish. State and federal natural resource agencies have achieved some success over the past 20 years in reestablishing spawning populations in the Kennebec River drainage, although the numbers of fish returning to the river each year continue to be critically low compared to historic levels. One species, shortnose sturgeon is listed as endangered under the federal Endangered Species Act.

Fig. 1. Location of Edwards Dam in Kennebec River Drainage

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2 Anadromous fish are those species that grow to maturity in the ocean before returning to freshwater to spawn.

Current fishery management goals call for restoring anadromous fish to their historic habitat in the Kennebec River (ME SPO 1993). For several species (striped bass, Atlantic and shortnose sturgeon, and rainbow smelt), the area to be restored is limited to the 17-mile (27 km) segment of the main stem of the river between Edwards Dam and the next upstream barrier, located in Waterville, Maine (Fig. 1). Habitat for other anadromous species (Atlantic salmon, American shad, alewife and blueback herring) existed historically for many miles beyond Waterville on the main stem, and in several tributaries. Numerous dams throughout the drainage have altered the suitability of historic habitat, thereby reducing the size of the potential runs of anadromous fish to a fraction of their former magnitude.

Improvements in water quality since the 1970's along with restrictions in recreational and commercial fishing leave dams as the major impediment to restoring self-sustaining runs of migratory fish in the Kennebec River. Strategies for reestablishing historic fish populations are therefore focused largely on the installation of fishways at dams, for the species that will use such facilities (salmon, shad, alewives and blueback herring). Other species that historically spawned in the Kennebec River (striped bass, sturgeon and rainbow smelt) are not known to use fishways, making it necessary to breach or remove barriers in order to achieve restoration goals (USFWS 1996). Permanent fishways do not exist at any of the lower Kennebec River dams. In 1989 the owners of Edwards Dam installed a vacuum-pump fish lift to allow for the collection of upstream migrating river herring (alewives and blueback herring), which the state fishery agencies have transported to upstream spawning locations (FERC 1997b).

In its order requiring removal of the Edwards Dam, the FERC concluded that the installation of permanent fish passage facilities at the project could allow for the partial accomplishment of restoration goals for the Kennebec River (FERC 1997b). Atlantic salmon, American shad and river herring are known to use fishways, and would be expected to pass Edwards Dam, given the installation of properly designed facilities. However, the FERC concluded that Edwards Dam would have to be removed, in order to accommodate the migratory needs of the other species historically occupying the river (striped bass, sturgeon and smelt). Removal of the dam would also restore 15 miles (24 km) of riverine habitat, which would benefit a number of species that spawn under free-flowing conditions, and would reduce the adverse cumulative impact of hydropower development in the drainage. Although the 15-mile (24-km) impoundment created by Edwards Dam has existed for 160 years, studies that were done for the FERC indicated that the return to riverine conditions would result in minimal impacts to wetlands and to resident fish (SWETS 1995). The FERC also found that angling and other river-related recreational opportunities would increase in the lower Kennebec River with the removal of the dam, resulting in substantial economic benefits.

The FERC also concluded that the cost of dam removal, estimated to be approximately \$2.7 million, would be far less than the \$10 million that would be needed to install fishways, which as previously noted would not accommodate all of the species targeted for restoration (FERC 1997b). The FERC also found that alternative sources of energy, currently available in the region are far cheaper than the power that is produced at Edwards Dam, particularly when the costs of fish passage and other mitigative measures are taken into account. Considering the availability of a cost-effective alternative for energy, together with the biological objectives that could not be met entirely with the project remaining in place, the FERC concluded that relicensing Edwards Dam was not in the public interest.

LOWER KENNEBEC RIVER COMPREHENSIVE HYDROPOWER SETTLEMENT ACCORD

On May 28, 1998 a number of parties[3] successfully completed several months of negotiations, and collectively filed with the FERC a comprehensive settlement agreement designed to achieve timely removal of Edwards Dam and to accomplish fishery restoration goals for the Kennebec River. On September 16, 1998 the FERC approved the Lower Kennebec River Comprehensive Hydropower Settlement Accord, which sets into motion a series of steps, including:

- transfer of Edwards Dam and associated project works in January 1999 to the State of Maine, which will carry out actual dam removal in the summer of 1999;

- establishment of a \$7.25 million Kennebec River Restoration Fund to pay for dam removal and fisheries restoration, collected from several upstream dam owners and from a major shipbuilding industry, located downstream from Edwards dam, as part of

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3 Settling parties include: Edwards Manufacturing Company and the City of Augusta, Maine (licensees for the Edwards Dam Project); U.S. Fish and Wildlife Service; National Marine Fisheries Service; State of Maine; Central Maine Power Company, Merimil Limited Partnership, UAH-Hydro Kennebec, Ridgewood Maine Hydro Partners, L.P. (collectively, the Kennebec Hydro Developers Group); and American Rivers, Inc., Atlantic Salmon Federation, Kennebec Valley Chapter of Trout Unlimited, Natural Resources Council of Maine, and Trout Unlimited (collectively, the Kennebec Coalition).

regulatory mitigation requirements; funds to be managed by the National Fish and Wildlife Foundation, which will seek to raise an additional $1.5 million to help achieve settlement goals.

- modification of established schedule for installing fish passage facilities at upstream dams, pending growth of fish populations and accomplishment of other restoration objectives; and

- withdrawal of appeals and other challenges to the FERC's regulatory order on dam removal.

The Kennebec River Restoration Fund ($7.25 million) is larger than the amount that considered to be necessary for removing Edwards Dam ($2.7 million). The remainder of the funds are to be used for a variety of projects that are designed to enhance migratory fish stocks in the Kennebec River, including expansion of an existing hatchery for American shad, continuation of an interim trap-and-transport program for river herring, and studies for helping to site and evaluate the effectiveness of permanent fish passage facilities at barriers upstream from Edwards Dam. The cooperative agreement among parties is to remain in effect until at least 2014 depending upon the progress in achieving fish restoration goals.

HOW EDWARDS DAM WILL BE REMOVED

In reaching its decision to remove Edwards Dam, the FERC relied heavily on studies that were done to identify impacts to existing environmental resources and to evaluate potential benefits to fish populations and associated aquatic communities (SWETS 1995, ORNL 1997). Those investigations concluded that removal of the dam would not result in any significant adverse environmental impacts, due in part to the minor amount of sediment accumulation behind the low-head dam, and to the slope stability of the mostly undeveloped, wooded shoreline surrounding the impoundment (FERC 1997b). Never the less, the studies and subsequent dam removal plans have identified a number of criteria that should be followed in order to achieve removal of the dam in 1999. These include:

- controlled drawdown of the impoundment to minimize potential slumping of impoundment embankments and discharge of sediment to the river, and to reduce potential stranding of freshwater mussels and other aquatic organisms;

- modification of existing intake and outfall structures of industrial and municipal waste treatment facilities located in the proximity of the dam;

- implementation of erosion and sedimentation controls to minimize impacts associated with demolition and removal of debris;

- modification of boat launching facilities in the impoundment to ensure continued recreational access; and

- seasonal restrictions in construction work to avoid impacts to threatened and endangered species (shortnose sturgeon and bald eagle).

As currently proposed, dam removal would commence in early July, 1999 after river flows have receded to normal mid-summer levels, and following the end of the spawning season for the majority of anadromous fish inhabiting the river (ME SPO 1998). The first stage of removal would consist of blasting of a 150-foot (46 m) segment of the dam that had been breached during high runoff in 1974. (It is estimated that this segment of the dam, which is located near the center of the 917-foot (280 m) long spillway, and was repaired shortly after the 1974 breaching, is most susceptible to demolition through blasting.) Using the newly created breachway, together with existing control gates at the project, the impoundment water level would be lowered gradually to a level permitting dry access for heavy equipment (thus avoiding the need to construct cofferdams). Demolition of the remainder of the spillway and removal of debris would then continue from each shoreline, until the structure is gone. The final stages of work would consist of removal of appurtenant structures at the project, filling of the existing power canal (using debris from the dam), and completion of identified mitigation measures (e.g., extension of outfall structures and boat ramp). The impoundment shorelines that become exposed following dam breaching are expected to be stable (avoiding the need for rip-rap or other measures) and should vegetate naturally. The area immediately adjacent to the dam, including that which is occupied by the existing powerhouse and ancillary structures is to be used as a recreational facility by the city of Augusta.

THE COLLABORATIVE APPROACH TO WATERSHED RESTORATION

Approval of the Lower Kennebec River Comprehensive Hydropower Settlement Accord effectively resolved a long-running dispute over the future of the Edwards Dam project (FERC 1998). Although the FERC has the authority to deny applications for new licenses and to order decommissioning and dam removal, as was done in the case of Edwards Dam, such decisions are likely to be contentious.

Aggrieved parties can seek administrative and judicial relief, if they disagree with the FERC's conclusions. Years may pass before an issue is resolved in the courts, with the outcome never certain until the end.

Parties who were involved in the Edwards Dam project sought to avoid protracted litigation and delays in achieving watershed restoration goals. The settlement that was reached not only provides for the removal of Edwards Dam, but ensures that fish passage and other mitigative measures are implemented at the barriers that are upstream from the project. Most importantly, the settlement process guarantees that federal and state resource agencies, municipalities, non-governmental conservation organizations, and other stakeholders will continue to support the watershed restoration efforts in the Kennebec River basin. The diversity of participants also will bring a wealth of experience and expertise to help generate solutions to problems that are encountered, as was necessary in the case of securing funds for dam removal and fish restoration activities.

The FERC's action on Edwards Dam is an important precedent because it established the fact that renewal of an operating license can no longer be taken for granted. Although it is unclear whether the FERC will take similar action at other projects undergoing relicensing, the alternative of project decommissioning and dam removal will likely be evaluated in future applications. However, an equally important message to be taken from the FERC's approval of the subsequent settlement agreement is that a collaborative approach by affected stakeholders can be an efficient means for achieving watershed restoration goals.

REFERENCES

Echeverria, J.D., P. Barrow, and R. Roos-Collins. 1989. Rivers at risk. The concerned citizen's guide to hydropower. Island Press, Washington, D.C. 217 p.

FERC (Federal Energy Regulatory Commission). 1997a. Final environmental impact statement. Kennebec River basin, Maine. FERC/FEIS-0097. Office of Hydropower Licensing, Washington, D.C.

FERC (Federal Energy Regulatory Commission). 1997b. Order denying new license and ordering dam removal. Washington, D.C. 28 p.

FERC (Federal Energy Regulatory Commission). 1998. Order approving settlement, transferring license, and amending fish passage requirements. Washington, D.C. 16 p.

ME SPO (Maine State Planning Office). 1993. Kennebec River resource management plan: balancing hydropower generation and other uses. Natural Resources Policy Division, Augusta, ME 196 p.

ME SPO (Maine State Planning Office). 1998. Dam removal plan for the Edwards hydroelectric project (FERC Project No. 2389). Augusta, ME 69p. + App.

ORNL (Oak Ridge National Laboratory). 1997. Cost of removing Edwards Dam on the Kennebec River, Maine. Prepared for the Federal Energy Regulatory Commission, Office of Hydropower Licensing, Washington, D.C.

SWETS (Stone & Webster Environmental Technology & Services). 1995. Edwards dam removal evaluation, physical and biological study results. Prepared for the Federal Energy Regulatory Commission, Office of Hydropower Licensing, Washington, D.C.

USFWS (U.S. Fish and Wildlife Service). 1996. U.S. Department of the Interior's decision document and final prescription for fishways [for the Edwards Dam Project] pursuant to section 18 of the Federal Power Act. U.S. Fish and Wildlife Service, Hadley, MA.

WATERSHED AND RIVER SYSTEMS MANAGEMENT PROGRAM: CURRENT AND FUTURE APPLICATIONS IN THE BUREAU OF RECLAMATION

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Don K. Frevert[3]

ABSTRACT

Water management agencies and utilities face increasingly difficult challenges in managing water resources. Environmental considerations, increasing demands on dwindling water supplies, outspoken recreational interests, the specter of climate change, and the restructuring of the power utility industry all have converged at a time when Federal resources for developing modeling tools are minimal. Planning and operational river basin models developed in the previous decades are often not adequate to represent the changing multiple objectives of the projects and cannot be updated without significant expense.

To meet this challenge, the U.S. Bureau of Reclamation, the Tennessee Valley Authority (TVA), and the U.S. Geological Survey (USGS), are cooperating in the research and development of computer tools with the Center for Advanced Decision Support for Water and Environment Systems (CADSWES) at the University of Colorado in Boulder, Colorado.

A data-centered decision support system (DSS) is being researched and developed that utilizes a relational database and advanced modeling technologies to integrate water, power, and weather data, both historical and forecasted. The DSS system facilitates the postulation, testing, and analysis of alternative operational and planning scenarios with respect to competing objectives and provides a practical

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tool to ensure the most efficient and responsible use of basin resources. The DSS system is being developed using generic tools, yet is easily customized to meet site-specific needs. Current applications include the Colorado, Yakima, and Rio Grande River basins, and it is anticipated that it will ultimately be applied to many other basins throughout the Western United States.

INTRODUCTION

The demands placed on water resource systems have increased greatly over the past few decades. Meeting consumptive use demands, while still vitally important, is no longer the only objective to be considered in operational and planning decision making. Key issues in the management of Reclamation river basins include:

- flood control
- rainfall and snowmelt runoff forecasting
- increased consumptive use demands
- water quality (especially salinity)
- hydropower production
- recreational uses on reservoirs and rivers
- endangered species and other environmental concerns
- water rights (particularly for Native American Nations)

These issues are common Reclamationwide. In order to address these and other issues, water managers need the ability to predict the outcome of a wide range of water management actions under a wide range of hydrologic conditions. Necessary predictions range from long-term simulations of the operation of complete water resources systems under modified management strategies to short-term simulations involving forecasts of inflow and demand to predict the impact of specific management actions. The entire hydrologic and water management process must be represented by both models and data. System state variables to be examined include water quantity, water quality, sediment transport, and channel morphology. Furthermore, all of this information must be presented to the human decision maker in an intuitive format and in a timely manner.

Decision support systems (DSS) have been discussed in the literature since the early 1970s (Scott Morton, 1971), when it was recognized that "real world problems are often much more complex, much less structured, and require much more human input and judgment" than those contemplated by model developers (Loucks, 1995). Management of natural resources, particularly watersheds, falls into this category of problem. By the late 1980s, research in DSS applied to water management problems primarily focused on the use of artificial intelligence technology (Savic and Simonovic, 1989), although many of these applications apparently did not prove to be successful in practice. Subsequent research focused on the development of "user-friendly" models (Fulp, et al.,1991).

It is our thesis that a decision support system is the best way to provide the tools to address these key issues. In particular, we have adopted the data-centered approach to decision support (Ryan and Sieh, 1993) which uses relational data base technology as the cornerstone for the decision making.

In this paper, we will briefly describe our research and development program, present an overview of the major components of the DSS, and describe how the system is being applied in the Colorado, Yakima, and Rio Grande River basins. We conclude with a discussion of some of the important issues that we have encountered for successful implementation of the system.

WATERSHED AND RIVER SYSTEMS MANAGEMENT PROGRAM (WARSMP)

The goal of the Watershed and River Systems Management Program (WARSMP) is the research, development, and implementation of a data-centered, decision support system for integrated watershed management. The WARSMP is a multi-year, cooperative effort between Reclamation and the U.S. Geological Survey (USGS) that was officially begun in Fiscal Year 1995. Current plans call for continued financial support through Fiscal Year 2000.

Our program strategy is governed by the premise that the water resources issues and our field offices' needs should dictate our research and development priorities. This interaction is depicted in Fig. 1. This strategy calls for involvement of the potential users throughout all phases of the program (research, development, and implementation). Furthermore, following this strategy allows us to implement developed products and provide feedback to the development team in a timely manner. An important objective of the research program is the applicability of the developed products to basins other than those initially chosen for implementation. Clearly, the products must be developed to have generic application, yet be able to be customized to meet site-specific objectives.

Throughout the duration of the program, partnering with other agencies has been and continues to be an important avenue to leverage limited funding. To this end, the Tennessee Valley Authority (TVA), the University of Colorado's Center for Advanced Decision Support for Water and Environmental Systems (CADSWES), the Electric Power Research Institute (EPRI), the National Oceanic and Atmospheric Administration (NOAA), and the Department of Agriculture have also participated in the development of certain aspects of the system.

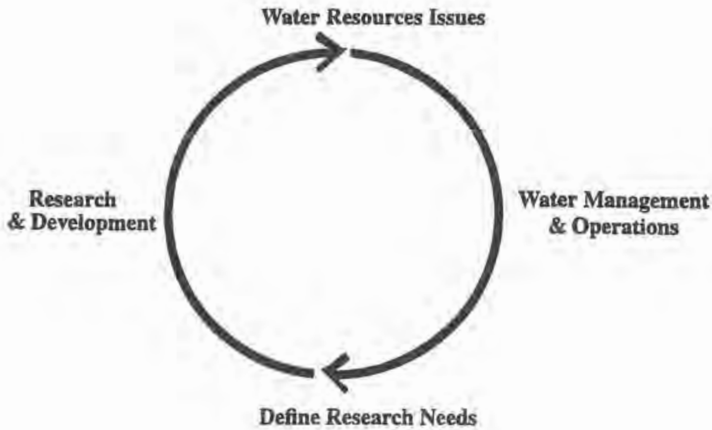

Figure 1. Interaction of research, development, and implementation phases in WARSMP.

MAJOR SYSTEM COMPONENTS

The major components of the system developed and implemented to date include the Hydrologic Data Base (HDB), the RiverWare reservoir and river system modeling environment, and the Modular Modeling System (MMS) environment. These components are shown in Fig. 2.

The Hydrologic Data Base (HDB)has been designed for the storage of hydrologic time series data, attribute data, statistical information, and other types of data pertinent to water management activities. It was initially implemented using the Ingres Relational Database Management System (RDBMS), but has recently been ported to the Oracle RDBMS. The design includes a significant number of metadata tables for optimal storage and retrieval of data, and for the management of applications which use the data. The design also features a number of data integrity constraints to maintain data integrity. Currently, over 100 data types (i.e.average streamflow, power generation, maximum temperature, snow water equivalent, total dissolved solids, etc.) have been defined in HDB. Sites are categorized into object types (i.e.; reservoir, powerplant, streamflow gage, etc.). The HDB also allows the storage of modeled (forecasted) time series data. This data is stored in tables separate from the "real" data. Clearly, not all simulated data belongs in a database for long term storage; however, when significant forecasts of the state variables are obtained (such as an official operational forecast), these results are formalized by placing them in HDB for further reference. This ensures a consistent view of the projected state of the system throughout the organization.

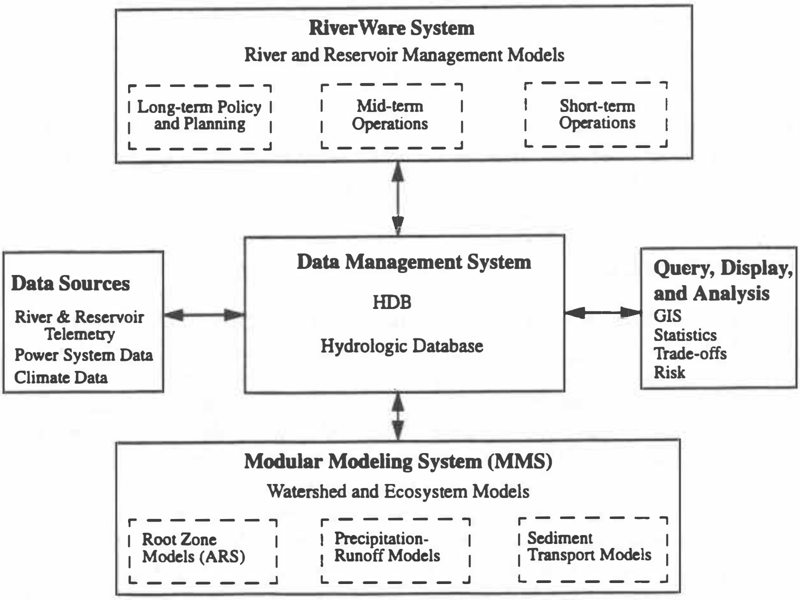

Figure 2. The data-centered decision support system.

The USGS Modular Modeling System (MMS) is an integrated modeling environment that can be used to simulate a variety of water, energy, and bio-geochemical processes (Leavesley, et al., 1996). To date, the primary use of MMS has been for the development and analysis of physical based, precipitation-runoff models (PRMS) for the watersheds of interest. The PRMS component of MMS provides Geographic Information Systems (GIS) tools that can be used describe and analyze the spatial distribution of the hydrologic parameters needed for the runoff prediction. Various physical processes are available and users can even develop their own modules as needed.

RiverWare is a generic river basin modeling environment that can be used for both operations and planning. RiverWare provides point-and-click model building, user selection of engineering methodologies to customize the behavior of the modeling objects, and alternative solution algorithms to solve the resulting network (simulation, simulation with user-specified policies, and optimization/ goal programming), all through a user-friendly interface. Timestep size ranges from hourly to yearly, with no limit on the time range of a model run (Zagona and Fulp, 1998).

By developing appropriate Data Management Interfaces (DMIs) to HDB, additional tools are being integrated into the DSS as needed. Many of these tools are "off-the-shelf" providing additional functionality with essentially no development cost. For example, a statistical package (S-Plus) has been integrated to facilitate the analysis of both historical and modeled data.

CURRENT APPLICATIONS

To date, our main focus has been on the Colorado River. Starting in Fiscal Year 1997, we began implementation on the Yakima River basin in Washington and on the Rio Grande River basin in New Mexico. In this section we will briefly describe each of these applications.

Colorado River Basin

The Colorado River Basin is one of the most heavily legislated river basins in the United States, covering seven states with a drainage area of some 245,000 square miles. Total storage in the basin (approximately 60 million acre-feet) is four times the average annual inflow. Operations and planning decision-making on the Colorado River is shared between the Upper and Lower Colorado Regions and their respective area and facilities offices. A hierarchical view of the decision making and some examples of models that were used to support these decisions is shown in Fig. 3. The models included: a monthly time step policy and planning model of the entire basin used to assess the long-term effects of policy decisions with regard to water and energy supply, as well as salinity mitigation; a monthly time step operations model of the entire basin used to set the Annual Operating Plan and to adjust that plan throughout the year as hydrologic forecasts are updated; and a daily time step operations model for the Lower Basin which is used to set the daily releases to meet short-term water and energy demand, within the monthly targets. These models were used for a relatively long period of time (over two decades) and their results were trusted both within and outside our agency. However, they lacked the flexibility needed to model increasing demands and constraints on the system, as well as expanding operational objectives.

Through the WARSMP program, we have successfully implemented HDB and RiverWare in both our Upper and Lower Colorado River regional offices for both operational and planning use. The HDB is running as a "quasi-distributed" data base, in that both historical and forecasted data pertinent to each region is stored only in the HDB at that region and appropriate meta-data (such as site definitions) are automatically coordinated between the databases to ensure data sharing. RiverWare has been used to replace all three of the previously mentioned models, and in the case of the two operational models, is completely integrated with HDB. For example, each month the Upper Colorado Region receives the latest inflow forecasts from the National Weather Service Colorado River Forecasting Center (CRFC). These forecasts are automatically processed and entered into the database. RiverWare is then used by both regions to forecast the state of the system, given the updated forecasts, demands, and operational objectives. Upon agreement by each operations office, reports are generated automatically by extracting data from each database. The MMS has been used successfully in a demonstration mode on the

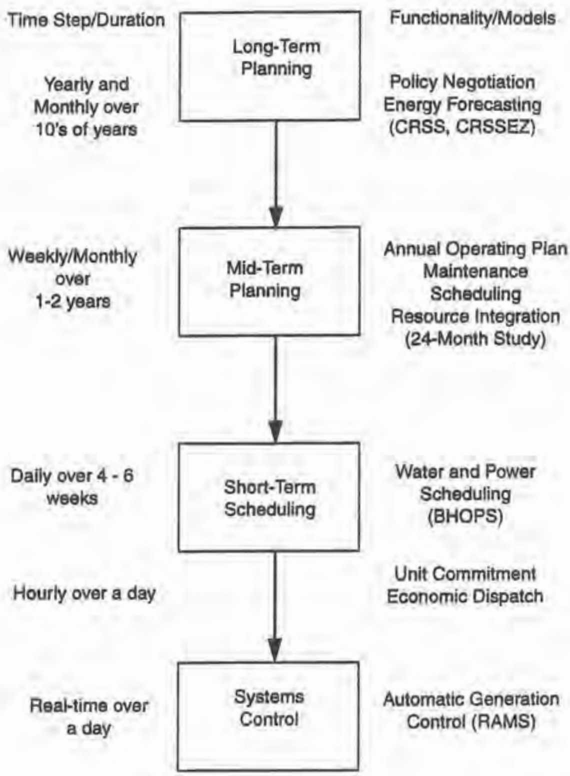

Figure 3. Hierarchical view of decision making on the Colorado River.

Gunnison Basin (Ryan, 1996) to generate alternative inflow forecasts throughout the runoff season. Further work is warranted to fully integrate these forecasts with the CRFC forecasts.

RiverWare has also been used to develop a model of the San Juan basin for use in consultations with other agencies regarding meeting endangered species habitat requirements. The MMS has been used in that study to analyze the sediment transport requirements for building and maintaining appropriate habitat, as well as to generate inflow forecasts using the PRMS module. Based on the success of this planning application, implementation in an operational mode is anticipated.

Yakima River Basin

The Yakima River Basin in eastern Washington has a drainage of about 6,100 square miles, with an average annual inflow of about 3.4 million acre-feet and about 1 million acre-feet of storage. It is a much smaller basin than the Colorado and presents a variety of new issues in terms of operational and planning strategies. For our program, it provides the opportunity to apply and extend the generic tools that have been developed to date, as well as to push the research and development with regard to new water management needs.

Our focus in the first year has been the implementation of HDB. In Fiscal Year 1997, our agency adopted the Oracle RDBMS as the agency-wide standard and we decided to port HDB to Oracle prior to installation at the Yakima Area Office. Although this caused some delays in our schedule, we were able to avoid a costly move to new hardware and software in the future. The HDB design has proven to be easily extended to incorporate new datatypes, such as fish monitoring data necessary for the anadromous fish, as well as new climatological data.

Application of the modeling components of the DSS also began in 1997. A PRMS model has been developed using MMS by USGS staff for use on the Yakima system and a basin planing model is under development using RiverWare. We anticipate development of an operational model in 1998.

Rio Grande River Basin

The Rio Grande River in New Mexico drains approximately 30,000 square miles and has an average annual inflow of about 660,000 acre-feet. The flow is augmented by a trans-basin diversion from the San Juan River of about 85,000 acre-feet annually. This diversion offers an opportunity to extend the DSS tools to incorporate the tracking of water ownership, as the diversion project "is operated to assure that there are no effects on the natural flow of the Rio Grande" (URGWOM, 1996). In 1997, our research focused on the extension of water ownership to RiverWare (Zagona and Fulp, 1998). This work will continue in 1998 and beyond, as well as the extension of HDB to store the state of each account over time.

SOME ISSUES FOR SUCCESSFUL IMPLEMENTATION

Movement to a computer-based, decision support system represents a major paradigm shift for our agency. We have encountered several major issues over the past three years, and although we cannot say that we have solved each and every one, we do feel that we have some experiences that may help others in similar pursuits.

A primary issue is whether an agency is really committed to making such a paradigm shift. Although having the commitment to an R&D budget is most important (and was a commitment that we had), we also realized that we needed to make available appropriate agency technical personnel if we were to succeed. Prior to entering into the program, several technical staff personnel formed a working group to discuss this and other issues and make a recommendation to

FTE (full-time equivalent) each year, primarily to define needs, review the proposed research, test the developed software, and transfer the technology.

Transfer of the technology is not guaranteed, however, even with up-front involvement of the target users. We have used a "side-by-side" approach to technology transfer where the Reclamation personnel involved directly in the program work with end users to solve real problems. Although this approach has proven successful, it's drawback is that we cannot transfer the technology as rapidly has we would like. We are now moving to a more formal approach to technology transfer, including the development of formal training courses in use of the DSS.

Another critical issue is the long-term viability of the products that are being developed. This includes providing funding mechanisms for long-term maintenance and support. Our approach has been to provide mechanisms for some external funding (through the use of the products outside of our agency), as well as receiving a commitment from the operating groups involved to budget a share of the costs for the long term.

Finally, the real "proof of the pudding" will be if we become better water resource managers with use of the technology. Although we have received feedback indicating real improvement in our ability to reach new decisions in a timely manner, we are attempting to define metrics and collect the appropriate data so that we can more definitively answer this question in the future.

REFERENCES

1. Fulp, T. J., D. M. Theobald, B. Williams, and B. Vickers, 1991, Decision Support for Colorado River Operations, Proceedings of the WaterPower '91 Conference, American Society of Civil Engineers.

2. Leavesley, G. H., P. J. Restrepo, S. L. Markstrom, M. Dixon, and L. G. Stannard, 1996, The Modular Modeling System (MMS)—User's Manual, U.S. Geological Survey Open File Report 96151.

3. Loucks, D. P., 1995, Developing and Implementing Decision Support Systems: A Critique and a Challenge, Water Resources Bulletin, Vol. 3 1, No. 4, American Water Resources Association.

4. Ryan, T. P., 1996, Development and Application of a Physically Based, Distributed Parameter, Rainfall Runoff Model in the Gunnison River Basin, Global Climate Change Response Program Report, U.S. Bureau of Reclamation, Denver, CO.

5. Ryan, T. P., and D. Sieh, 1993, Integrating Hydrologic Models, Geographic Information Systems, and Multiple Data Bases: A Data Centered Approach, Proceedings of the Federal Interagency Workshop of Hydrologic Modeling Demands for the 90's, U.S. Geological Survey Water Resources Investigations Report 93-4018, Denver, CO.

6. Savic, D. A., and S. P. Simonovic, 1989, A Pilot Intelligent Decision Support System for Reservoir Optimization, Proceedings of the 3rd Water Resources Operation Management Workshop: Decision Support Systems for Water Managers, American Society of Civil Engineers, New York.

7. Scott Morton, M. S., 197 1, Management Support Systems, Computer-Based Support for Decision Making, Division of Research, Harvard University, Cambridge, MS.

8. URGWOM: Upper Rio Grande Water Operations Model Plan for Development, 1996, a joint report by the U.S. Army Corps of Engineers, U.S. Bureau of Indian Affairs, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Section of the International Boundary and Water Commission.

9. Zagona, E., and T. Fulp, 1998, RiverWare: A General River and Reservoir Modeling Environment, to be published in the Proceedings of the First Federal Hydrologic Modeling Conference, Las Vegas, NV.

CORPS OF ENGINEERS ROLE

IN SOLVING PACIFIC NORTHWEST SALMON PROBLEMS

Cindy Henriksen[1]

ABSTRACT

The Corps and other involved federal and state agencies and tribes are cooperating to recover Columbia River sockeye and chinook salmon runs listed under the Endangered Species Act. This paper describes our agency's new role, responsibilities and priorities, and our continuing effort to maintain a balanced, multi-purpose approach to resolving an extremely complex issue that transcends the boundaries of a broad spectrum of water users.

INTRODUCTION

The Columbia River Basin is approximately 262,000 square miles of drainage, about the size of France (see Figure 1). The hydropower system had traditionally operated as one system for flood control and power generation up until recently. With three listed fish species, and the fourth (and maybe more) on the way, conflicting demands on the river are becoming greater and greater. The lines are being drawn between upstream and downstream users, between fishery agencies and environmental interests on the one hand, and navigation, irrigation and hydropower interests on the other hand.

Among the many State, Federal, and Tribal players involved in solving this puzzle, the Corps of Engineers (Corps) has a pivotal role to play. The Corps operates eight lower Columbia and lower Snake Rivers dams located right in the path of the main fish migration corridor. Although there are many possible causes for the decline of the Snake River salmon, fingers are first pointed to these dams. Furthermore, the actions carried out by the Corps in fulfillment of its Congress-mandated multi-purpose mission --especially in flood control-- are bound to affect fish migration conditions. Therefore, any operational, flow-related measures designed to benefit anadronomous fish fall directly or indirectly within the Corps purview.

This paper will describe the complex water management issues associated with measures recommended for salmon recovery by the National Marine Fisheries Service (NMFS). It will highlight problems related to the move from the traditional river system operation for maximized power generation and flood control to a river operation to improve fish survival. Conflicts between the many regional players and between their individual authorities and the Corps' role in the operation of this highly shared river system will be addressed.

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BACKGROUND

Operations of the storage reservoir system in the Pacific Northwest have changed dramatically in the past twenty years. Both the primary use of the water and the focus of attention have shifted.

Figure 1. Map of the Columbia River Basin

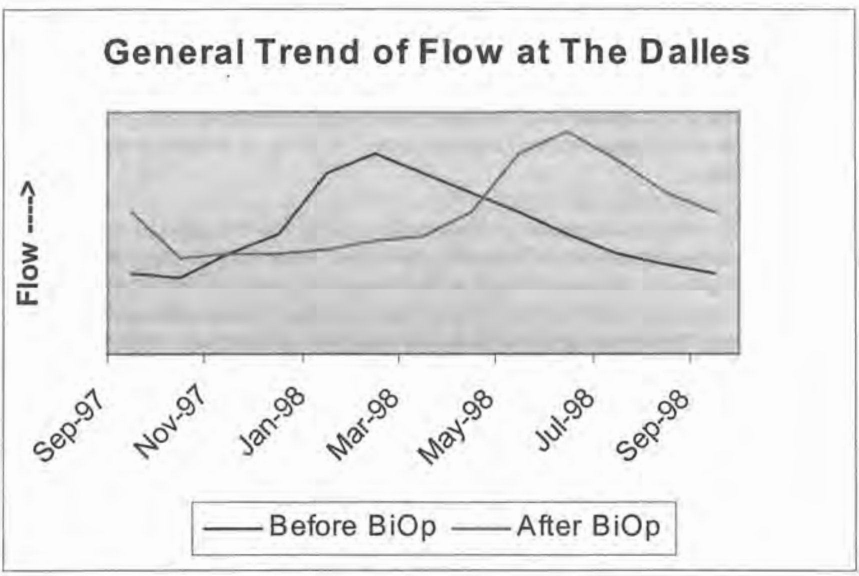
Into the early 1980's the Columbia River system operated primarily for flood control and power generation. The Columbia River Treaty with Canada (Treaty), signed in 1964, is primarily designed to enhance streamflow in the Columbia River in the United States and to optimize power generation and provide flood control protection in the United States as far away as Portland, Oregon. The Columbia River reservoir system was operated as a coordinated, single system under the auspices of the Pacific Northwest Coordination Agreement (PNCA) and the Treaty. This is equivalent to a one-owner system where if one party were short, all 18 PNCA signatories including privately and public utilities, Federal Reservoir parities, and the Federal marketing agency -- Bonneville Power Administration (BPA)-- would also be short.

Although the Corps operates its projects for other multi-purpose uses such as navigation, water quality, irrigation, water supply, fish and wildlife, and recreation, flood control and power generation are by far the most visible uses. Flood control is a primary authorized purpose for most storage projects. Power generation is very critical to BPA in serving its customers and trying to make regular payments to the

Treasury for the costs of building the dams. As a result, winter power drafts were often deeper than the drafts required for flood control.

In 1995, the Biological Opinion (BiOp) for the endangered Snake River salmon was developed by NMFS. That same year, the U.S. Fish and Wildlife Service (USFWS) also released its BiOp for the white sturgeon. Although the basic flood control operations remain unchanged, both BiOps significantly affected reservoir operations in the upper and lower river. The NMFSs BiOp recommends that the Federal Columbia River Power System (FCRPS) be operated up to the flood control evacuation requirements as much as possible in the wintertime. This action, designed to save as much water as possible for the spring and summer fish migration, led to changes in the general flow pattern in the lower Columbia River (see Figure 2). The NMFSs BiOp also included measures such as spill for-fish-passage past Corps mainstem dams in the lower Snake and lower Columbia Rivers.

Figure 2. Comparison of Pre-and Post-BiOp Flow



The goal of the BiOp for salmon is to try to meet flow objectives at Lower Granite and McNary in the spring and summer. At Lower Granite, the spring flow augmentation period is April 3 through June 20, and the summer period is June 21 through August 31. The magnitude of the flow objective is dependent upon the water supply forecast at Lower Granite and slides up and down as the water supply is adjusted from January through May. At McNary, the spring flow augmentation period is April 20 through June 30, and the summer period is July 1 through August 31. The seasons at McNary are slightly later because of river travel time from Lower Granite to McNary. The McNary spring flow objective also slides in the spring period based on the changing water supply forecast at The Dalles in January through March. The summer flow objective at McNary is always 200 kcfs.

In 1998 consultation for the Supplemental Biological Opinion for steelhead, a new flow objective was added at the Priest Rapids project for the period April 10 through June 30. The flow objective at Priest Rapids is 135 kcfs and is not variable based upon a water supply forecast.

To supplement the naturally low July-September flows, the NMFS BiOp recommends drafting FCRPS headwater projects in the summer to try to meet summer flow objectives at Lower Granite and McNary. Headwater projects have set draft limits such as 80 feet at Dworshak in Idaho, 20 feet at Libby and Hungry Horse in Montana, and 10 feet at Grand Coulee in Washington. The US Bureau of Reclamation (Reclamation) has also secured 427 thousand acre-feet (KAF) of irrigation storage in the upper Snake River for release during the summer and fall period to aid in the summer flow augmentation. Idaho Power Company (IDPC) participates in this operation by passing through the Reclamation's 427 KAF and shaping an additional volume of approximately 137 KAF in August to aid flow augmentation.

The NMFS BiOp also contains provisions for spilling for-fish-passage at the Corps lower eight mainstem dams. Originally, this was to achieve an 80 percent fish passage efficiency, meaning that for safety reason 80 percent of the juvenile migrants should be able to pass a dam without having to go through the dam's powerhouse. Significant spill had to be scheduled for this purpose, creating total dissolved gas (TDG) saturation levels in excess of the State standards. Starting in 1994, NMFS was able to obtain a waiver from the States to allow for this spill to occur at 120 percent TDG level (rather than at 110 percent per the standards).

The USFW BiOp for endangered sturgeon downstream of Libby dam includes keeping the Libby project as full as possible through April (up to flood control), then releasing water in pulses when the temperature reaches appropriate thresholds. The Libby project is then filled to store as much water as possible for later releases in July through August for salmon fish flow augmentation in the lower Columbia River.

BIOP IMPLEMENTATION PROCESS

The 1995 BiOp recommended a regional forum be developed for decision-making throughout the year in a cooperative effort to best use the FCRPS to enhance fish migration. Through 1995 and most of 1996, the regional forum consisted of the Corps, Reclamation, BPA, NMFS and USFWS. Later on, the forum was expanded to also include representatives from each of the five States --Oregon, Washington, Idaho, Montana and Alaska-- and the 13 sovereign Indians tribes. A seat at the table means the ability for the new members to participate in all of the meetings and have a direct voice in the decision-making process, which requires consensus. The 13 tribes and Alaska elected to be non-active members in the regional forum. In 1997 the state of Montana withdrew from active participation as well. As a result, the regional forum now consists of eight active members and an ex-facto member, the Northwest Power Planning Council.

The Regional Forum consisted of several layers of management. The Technical Management Team (TMT) includes agency technical staff such as fish biologists and reservoir regulation hydrologists. The TMT meets each week during the fish migration period to track the status of the fish migration and the reservoirs, and uses adaptive management to regulate the system to best meet the needs of the fish while meeting the other authorized purposes of the projects. The System Configuration Team (SCT) examines structural measures that may be undertaken at dams to enhance their ability to pass fish safely. This group prioritizes each proposal to try to get the most bang for the bucks out of each proposal. The Dissolved Gas Team (DGT) is responsible for finding the best ways to control potentially high levels of dissolved gas in the water, which may be harmful to fish. Each of these technical teams operates on a consensus basis. If any technical group cannot reach agreement on an issue, the issue is raised to the Implementation Team (IT), the next level in the regional forum.

The IT includes policy-level managers from each of the same agencies. The IT meets once each month to make decisions on technical disputes that may have come from the TMT, SCT, DGT, or other technical groups. The IT resolves disputes, or may return the technical dispute back to the appropriate technical team for more information before making a decision. The IT is also available for interpretation of the BiOp if needed. During the fish passage season, April through August, the IT is "on call" each week. If the TMT cannot reach consensus during its regularly scheduled meetings, the IT is also available the next day to expeditiously resolve the dispute.

The highest regional forum level is the Executive Committee (EC), which consists of executive members of the same organizations. The EC meets three to four times each year and may be called upon to resolve regional policy level decisions that were not resolved at the IT level.

Since the TMT is the most active group, they are the most visible and action oriented. In the fall period, after the fish passage season, they perform a post season review to determine what lessons were learned and what may be beneficial to do in the following year. In the January through April period, the TMT develops an annual Water Management Plan including general guidelines on the FCRPS operations during the upcoming fish migration period. The plan is redeveloped each year as new water supply forecasts become available. Appendices to the Plan include the Total Dissolved Gas Management Plan, developed by the Corps and approved by the DGT; the Fish Passage Plan, which provides detailed spill and fish facility operations at individual dams, and other documents.

CONFLICTING REGIONAL PROBLEMS

Most of the States directly affected by the BiOp's have their own problems to contend with.

MONTANA. Montana fights hard to keep water in the state for its own use, especially in view of the fact that the state's bull trout has also been recently listed as an endangered species. Bull trout resides in the Libby and Hungry Horse Reservoirs, as well as the streams downstream of these projects. Recovery plans, if and when developed, may recommend special summer and early fall operations to maintain resident fish habitat, and steady project outflow to emulate the natural hydrograph. Both of these actions may conflict with salmon flow objectives in the lower Columbia River and power generation needs.

IDAHO: As called for in the NMFS's BiOp, Idaho is allowing 427 KAF of Upper Snake irrigation water purchased by Reclamation to be used for flow augmentation in the lower Snake and Columbia Rivers. Reclamation and BPA are working with Idaho Power Company (IDPC) to get more use from this water and overcome the flow limitation issue imposed by Idaho water law. By law, Idaho water must be thoroughly usable by the state of Idaho. As such, water release from the upper Snake River cannot exceed 1,500 cfs, which is the powerhouse capacity of an IDPC dam located at Milner, upstream from Brownlee Reservoir. Such a limit prevents Reclamation's 427 KAF from getting past Idaho Power Company's Brownlee project during the fish migration period. One solution is for IDPC to deliver the water for Reclamation from Brownlee at a time that is useable for fish, and BPA compensates IDPC for performing this service. Another restriction that keeps Reclamation from a faster water delivery is endangered snails downstream of Milner. The snails need specific water rate of change rates that may be violated with a faster delivery rate.

The operation of the Corps' Dworshak Dam is also of concern to Idaho. Dworshak contains 2 MAF of active storage over a 155 foot operating range. In order to enhance salmon flow augmentation in the spring Dworshak now operates as full as possible in the spring up to the flood control upper limit through April. Then in May through June, the project operates for local and system flood control while delivering water for flow augmentation for endangered salmon. During the July and August periods, Dworshak reservoir drafts up to 80 feet down from full to elevation 1520 feet for summer flow augmentation in the lower Snake and Columbia Rivers.

Before the 1995 Biological Opinion set this draft limit, the reservoir often only drafted five to ten feet in the summer and was heavily used for recreation and lakeside camping.

The Idaho Department of Fish and Game (IDFG) represents Idaho at TMT. The IDFG's philosophy is often contrary to the provisions of Idaho State law, which may limit water deliveries. IDFG has appeared to be a strong advocate of the natural river concept.

WASHINGTON: Reclamation operates Grand Coulee Reservoir in Washington State, with approximately 5.2 MAF of active storage over 82 feet of operating range. It, too, is operated up to the maximum safe reservoir level in the spring for flood control. In the May June period it refills to its normal full pool elevation of 1280 feet while supplying flow at McNary for fish flow augmentation. In the summer period it drafts ten feet for summer flow augmentation.

Grand Coulee is also a source of irrigation water. During the summer months, as much as 9,000 cfs is pumped from Franklin D. Roosevelt Lake (FDR) behind Grand Coulee up into Banks lake (an irrigation lake). In 1998, Reclamation used 100 KAF of Banks Lake water for summer flow augmentation for salmon in the lower Columbia River instead of retaining that volume in Banks Lake for irrigation.

The Washington Department of Fish and Wildlife (WDFG) represents the State of Washington. WDFW is a strong advocate of flow augmentation -- the more water in the lower Columbia River, the better. WDFW has some concern for the level of FDR at Grand Coulee because they have hatcheries that need certain minimum elevation requirements in the fall.

OREGON: The Oregon Department of Fish and Wildlife (ODFW) represents Oregon. ODFW is a strong advocate of flow augmentation for fish, although no storage water has ever been released from Oregon reservoirs to contribute to annual fish flow augmentation goals.

CANADA: BC Hydro has three projects that operate under the Columbia River Treaty -- Mica, Duncan, and Hugh Keenleyside-- with 15.1 MAF of Treaty storage. This is almost as much storage as is contained in the remaining significant US system flood control storage projects combined. BC Hydro represents the Canadian Entity, and the Corps (flood control) and BPA (power generation) represent the US Entity.

Currently Canada has agreed to contribute up to 1 MAF of flow augmentation during May and June in less than average water years. This operation, agreed to by the US and Canadian Entities, is mutually beneficial to both the US and Canada. The 1998 Supplemental Biological Opinion recommends continued coordination with Canada to seek additional water to aid fish migration in the lower river.

The TRIBES: Although none of the tribes formally and consistently participated in the fish regional forum, some of them are very active in many meetings. The down-river tribes are interested in more spill for-fish-passage at mainstem dams, recommend less power peaking operations, and support dam removal. The up-river tribes around FDR Lake at Grand Coulee oppose the summer flow augmentation draft of Grand Coulee.

OPERATIONAL PROBLEMS

Refilling all the reservoirs by the end of June is desirable for the salmon managers because it enables the reservoirs to have as much water available for the summer migration period. The headwater projects draft to Interim Draft Levels that vary project by project. Even though the projects draft to these limits, the BiOp recognize that the summer objective at McNary may only be met in about five out of 50 historic water years studied.

Also it is important to recognize that the flow objectives are seasonal average. In the summer period projects may augment flow up to their maximum allowable level, but the downstream flow objectives still may not be met in late August. For example, in August 1998, the natural, unregulated flow at Lower Granite and McNary would have been 20.8 kcfs and 133.3 kcfs, respectively. This represents a month average flow that would have been receding across the month. In order to achieve 50 kcfs at the end of August at Lower Granite the upstream headwater projects would have to augment flow in excess of 30 kcfs. At Dworshak project this release level cannot be provided. First, the maximum allowable outflow without exceeding state water quality standards is only 22 kcfs. Second, with an inflow of only approximately 1 kcfs, the Dworshak project would have to have water available in storage to release. However, by late August the storage has already been used for flow augmentation in July and the reservoir typically will have already been at the interim draft limit. The same type of operational limitations applies when trying to meet McNary summer flow objectives.

Many operational problems arose as a result of conflicts, real or potential, between fish operations recommended by the salmon managers at TMT and system flood control requirements. Often to the dismay of the fishery agency representatives, flood control is placed on a higher priority than fish. In large water years, discussions on system operations to meet flood control and fishery requests during the spring period and reservoir refill by the end of June can be quite lively.

In the case of Libby, the sturgeon incubation flow operation frequently lasts into last June, and the project often does not refill completely by the end of June. This causes some consternation on the part of the salmon managers, who favor having Libby as full as possible at the start of the summer season beginning July. This is not easy to accommodate, since the USFWS also wishes to maintain high outflow from Libby in late June to provide for sturgeon incubation flow.

CORPS ROLE

In the face of all the complexities and conflicting water user requirements covered above, the Corps is trying its best to accomplish its multi-purpose mission and to cope with the new regional realities and needs brought about by the salmon (and white sturgeon) recovery and other water user needs. It continues to operate projects as authorized and in the order provided by Congress. In most cases, flood control has the highest priority, followed by power generation and fish.

Consistent with relevant provisions of the Endangered Species Act, Clean Water Act and other relevant pieces of legislation, the Corps is making a good faith effort to implement all the provisions of the NMFS and USFWS BiOps. The Corps is trying to meet the fish objectives by operating its headwater projects in the spring period up to the upper rule curve for flood control. At the start of the spring flow augmentation season, the headwater project operators strive to operate the reservoirs up to their flood control requirements, not below. The Corps representative chairs the TMT and, in this capacity, provides a well-rounded amount of technical expertise other TMT members can rely on before making operational decisions.

In addition to meeting flow objectives and providing spill for-fish-passage, the Corps also ensures that other water users including power generation, navigation, water quality, irrigation, and recreation interests are given reasonable operational flexibility in meeting their demands. In all these activities, being neutral, objective and rational is an absolute necessity. Other reservoir operations to benefit other fish species have been implemented, and new or experimental fish facilities have been installed to improve fish passage conditions. In making these changes, the Corps has to be sensitive to costs and perceptions by and interest of the general public. It must use reasonable and appropriate criteria to avoid making "capricious" and/or "arbitrary" decisions, especially in areas that are difficult to characterize in monetary terms.

The salmon recovery arena is full of uncertainties and controversies. For some, there is no clear scientific evidence behind any of the fish population changes in response to changes in the environment, reservoir operations, watershed management, etc. Others will strongly disagree, citing "irrefutable" proofs to the contrary. In this day and age where adaptive management is an acceptable mechanism for dealing with uncertainties in the hope of reaching one day the right solutions, the Corps has to be able to promote a healthy environment for testing hypotheses and exploring new promising techniques. Yet, because of the possible serious adverse impacts on other users and the taxpayers in general, the agency also has to have the institutional strength, wisdom and integrity to be able to say "no" under extreme conditions.

Over the years, the Corps has remained a neutral broker of information with unquestioned objectivity. The agency has fully engaged in a series of comprehensive studies looking at the merits of removing even some of its own dams, if this facility removal should prove to be in the region's best interest. The Corps has also shown its "esprit de corps" by openly endorsing the regional forum for salmon and by sharing Columbia River water management expertise with other regional players. The agency has been audited several times by the GAO and other congressional delegations with respect to its fishery programs; it has always been found to be beyond reproach when it comes to its ability, willingness and commitment to efficiently and objectively serve the public.

CONCLUSIONS

The salmon recovery issues facing the Pacific Northwest are very complex and involve a multitude of regional State, Federal and Tribal players. Measures recommended in the various Biological Opinions in the past few years have greatly changed the way the Corps of Engineers fulfills its multi-purpose mission in the Columbia River Basin. To bring back the salmon and other listed or endangered fish species will probably require even more changes in the future. By and large, the Corps has been a fully committed and willing partner in this regional endeavor, trying its best to make things happen physically within the confines of existing regulations, structurally and operationally. This agency's commitment and support are not provided without caution, however, because in the end the Corps still bears ultimate responsibility for its actions.

PLANNING FOR WATER DEVELOPMENT AND ENDANGERED SPECIES RECOVERY IN THE YAMPA RIVER BASIN

Ray D. Tenney[1] Charles M. Brendecke[2]
Edward J. Armbruster[3]

INTRODUCTION

Development of water resources in the Colorado River Basin is complicated by, among other things, the fact that the river contains four native fish species listed as endangered under the Endangered Species Act (ESA). To address the issues related to resource development and compliance with the ESA, the states of Colorado, Utah and Wyoming have joined with the U.S. Department of Interior, Western Area Power Administration, and representatives of the environmental and water development communities, to form the Recovery Implementation Program for Endangered Fishes of the Upper Colorado River Basin (Recovery Program). The purpose of the Recovery Program is to facilitate recovery of the listed fishes, a goal greater than the avoidance of jeopardy required by ESA, while water development proceeds.

BACKGROUND

As shown in Fig. 1, the Colorado River drains portions of seven western states extending from its mountain headwaters to the Gulf of California. The waters of the Colorado River system are apportioned by interstate compacts among the states through which it flows, and further allocated within each state by water laws based primarily on the prior appropriation doctrine.

The river is encumbered by numerous dams and diversions including Lake Powell, on the Utah-Arizona border, which divides the system into an Upper and a Lower Basin. Conditions in the river system above Lake Powell have allowed

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the persistence of the listed fishes in the mainstem and in many tributaries. Key to the recovery of the listed fishes is the hydrologic and habitat conditions afforded by the Yampa River, located in northwestern Colorado. As one of the least-altered tributaries of the Green River (a principal tributary to the Colorado), the Yampa River provides habitat believed to be critical to the survival of the Colorado squawfish, razorback sucker and humpback chub.

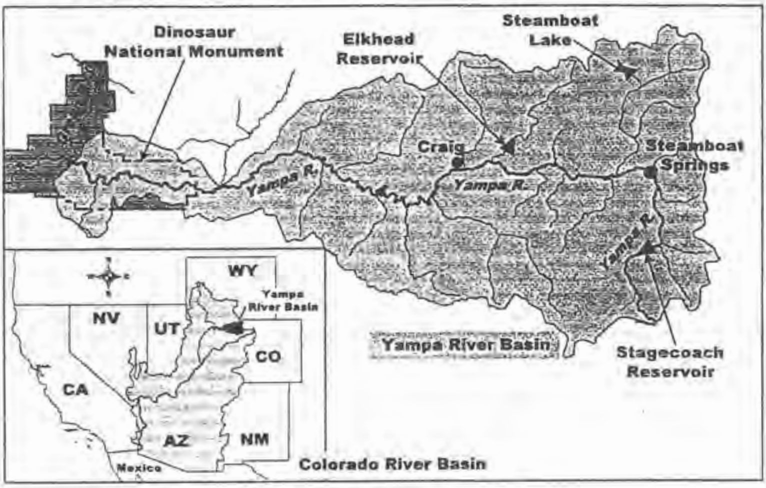

Fig. 1. The Yampa River Basin

Existing and future water development activities have potential impacts on the Yampa River flows necessary for the listed fishes. During base flow periods, consumptive water uses can reduce river flow in important reaches to nearly zero. At other times, low flows may impede fish migration between habitats and over natural and man-made barriers. A series of biological and engineering studies have been and continue to be conducted to estimate the seasonal water needs of the fishes and to evaluate water management measures which meet both those needs and the rising human demand for water.

There are also many complex institutional factors which must be addressed in planning for fish recovery and water development in the Yampa River basin. These factors include interstate compact entitlements and obligations; state water rights, multiple Federal, State and local jurisdictions; private property rights; potential Wild and Scenic River and wilderness area designations; and well-established non-native sport fishery. While some of these issues lend themselves to technical analysis, others are largely in the realm of "political" decisions. The various participants in the Recovery Program have been working, through an extensive public involvement process, with a coalition of local interests in the

Yampa River basin to craft acceptable and implementable water management solutions.

Scientific studies of the listed fishes in the Yampa River have been underway for twenty years. The earlier investigations were primarily focused on discovering the basic habits and life history of the listed fishes. In the last eight years, investigation has turned toward the identification of river management strategies to provide the flows necessary to maintain healthy native fish populations. These investigations have also included biological, hydrologic, and engineering components. Supported by the early biological research, the focus on management strategies for the Yampa River has been defined largely by the objective of providing the river flows necessary for recovery and delisting of the fish. The investigations have also included identification of current and future human water demands, evaluation of water development alternatives, and formulation of water management proposals to meet those competing needs.

BIOLOGICAL STUDIES

Numerous researchers (e.g., Tyus and Karp, 1989; Maddus, et. al, 1993) have taken advantage of the relatively stable condition of the listed fishes (particularly the Colorado squawfish) in the Yampa and Green river system to study their basic life history and habitat needs. These studies have generally resulted in a determination that the native fish require "natural" hydrology with peak-to-baseflow ratios of 15 or more. The USFWS has developed recommended flows for the Yampa River based primarily on the desire to maintain peak flows for habitat maintenance and to provide spawning cues.

Investigations are continuing to better estimate the base now levels needed to maintain habitat and support fish migration. These studies are being performed by the USFWS and Colorado Division of Wildlife (CDOW). The methods being employed include "traditional" techniques such as R2CROSS as well as development of relationships between flow and habitat quality telemetry tracking of radio-implemented fish through the low flow season. The telemetry tracking will provide information about fish movement and habitat utilization during low flow periods. Flow levels which impact ecosystem productivity and limit the ability of the fishes to utilize important habitat will then be considered when recommending minimum flows and when evaluating river management options.

WATER NEEDS FOR HUMAN USE

In addition to identifying water needs for the listed fishes, development of a management plan for the Yampa River requires consideration of human consumptive use needs. Reconnaissance-level studies (Hydrosphere, 1993, 1995a; BBC, 1998) estimated human water demands for existing and future conditions based on current water uses and projections of population and economic growth for the next 50 years. These initial projections were made using census data and informed by discussions with local governments, agricultural and industrial water users. Demands were estimated by sector to allow the review and revision as better information became available. Projections of patterns of use were developed to better estimate the impact on the seasonal flow regimes recommended by the USFWS.

EVALUATION OF WATER MANAGEMENT ALTERNATIVES

A monthly computer model was created to simulate basin hydrology and water rights administration, to simulate the operations of existing and proposed water storage facilities, and to evaluate the potential impact of current and future human water use on flows recommended for the listed fishes. A 64-year period of record was utilized to provide a robust sample of hydrologic conditions. Adjustments were made to current demand levels to reflect potential supply limitations on usage, and water demands were "backcast" to provide consistent current-level estimates over the entire period of record. The incidence of monthly average flows below the USFWS recommendations were then identified.

As in other areas of the Colorado River system, where augmentation water for base flow periods is being provided by Federal facilities, an initial plan was developed to fulfill the deficient months in the base flow period via reservoir releases. The primary source of these releases was to the enlarged reservoir previously identified. Augmentation release would average approximately 17,000 af/yr. The proposed reservoir enlargement would also be operated to include water for future human consumptive uses; by providing storage water to these uses, their reliance on direct flow diversions would be reduced.

The hydrologic modeling indicated that insufficient augmentation water would be available from the proposed reservoir enlargement in extremely dry years. With the cooperation of other reservoir storage pool owners, a plan to provide additional water supplies may be developed. The benefit to these cooperating water owners would be to advance recovery of fishes and obtain some associated relief in the Federal permitting process.

An additional feature of the management plan investigation was a reconnaissance evaluation (Hydrosphere, 1995b) of private diversion structures in the critical and occupied habitat reaches of the mainstem. This evaluation assessed the potential degree of obstruction to fish migration posed by the structures and identified possible modifications to mitigate that obstruction.

These reconnaissance investigations indicated that future water supply for the basin could effectively be provided by enlargement of the existing reservoir, By then integrating the operation of the enlarged reservoir with that of two other existing reservoirs in the basin, the studies showed that base flow regimes in river segments designated as critical habitat could be substantially improved over historic and the otherwise anticipated future conditions. The studies also indicated that fish passage obstruction at two diversion structures could be readily eliminated, and that in so doing, the recreational potential of the river would be enhanced.

Current Status of Planning Efforts

Concerns have arisen over the large investment required to enlarge the reservoir. Early estimates put the price tag at about $32M. Concerns have also been raised over the impact of reservoir storage on flow levels during the runoff period, since peak flows are believed to provide the listed fishes with some of their life history cues and to affect habitat maintenance.

It has been determined that additional studies of low flow needs for the listed fishes were required before participants in the Recovery Program could consider developing an augmentation water source for base flow periods. These studies include biological evaluation of the low flow needs of the listed fishes and the potential detrimental effects of extremely low flow. The demand estimates have also been refined using better information about industrial water use, primarily thermoelectric power generation, in the basin.

Currently the project anticipates refinement of the base flow needs of the listed fishes and initial development of a comprehensive water resources management plan for the Yampa River basin early in 1999. A NEPA process on the development of the management plan has been initialed, with the USFWS functioning as the lead Federal agency. Revised base flow recommendations will be evaluated against historical hydrology and revised . demands to assess the need to augment base flows and the most effective means for doing so.

REFERENCES

BBC, 1998. Yampa Valley Water Demand Study. Final Report.

Hydrosphere, 1993. Yampa River Basin - Alternatives Feasibility Study. Final Report.

Hydrosphere, 1995a. Yampa River Basin - Recommended Alternative Detailed Feasibility Study. Final Report.

Hydrosphere, 1995b. Reconnaissance Evaluation of Yampa River Diversion Structures: River Mile 53 to River Mile 179.

Maddux, H.R., L.A. Fitzpatrick, and W.R. Noonan, 1993. Colorado River Endangered Fishes Critical Habitat. Draft Biological Support Document. USFWS. Salt Lake City.

Tyus, H.M., and C.A. Karp. 1989. Habitat Use and Streamflow Needs of Rare and Endangered Fishes, Yampa River, Colorado. USFWS Biological Report. 27 pp.

THE PLATTE RIVER ENDANGERED SPECIES PARTNERSHIP:

AN EXAMPLE OF COOPERATIVE RIVER BASIN MANAGEMENT

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ABSTRACT

The States of Nebraska, Wyoming, and Colorado, and the U.S. Department of the Interior have entered into a partnership to address endangered species issues affecting the Platte River Basin. The *Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitat Along the Central Platte River, Nebraska* (*Cooperative Agreement*), was signed by the three Governors and the Secretary of the Interior July 1, 1997. The parties are to develop a recovery implementation program for the Central Platte River for the whooping crane, piping plover, and least tern; determine if these measures will also benefit the pallid sturgeon; prevent future listings under the Endangered Species Act (ESA); and mitigate impacts of new water projects in a manner that will not increase the burden on the other States.

The States and Interior believe that the best approach to addressing the ESA issues in the Central Platte region is a basinwide, cooperative effort to improve and maintain habitat for the species. This approach will be more effective, efficient, and equitable, and provide greater regulatory certainty for water users regarding compliance with the ESA.

HISTORY

The North and South Platte Rivers originate from snowmelt in the Rocky Mountains in Colorado. The Rivers enter Nebraska via Wyoming and Colorado and join to form the Platte River at North Platte, Nebraska.

Water projects on the North Platte store 4.3 million acre-feet in 84 storage facilities, irrigating 721,000 acres in Colorado, Wyoming and Nebraska. Approximately 2.8 million acre-feet of water is stored in 106 storage facilities on the South Platte, irrigating 983,000 surface acres. In addition, from the

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confluence of the North and South Platte Rivers in Nebraska to Grand Island, the Platte provides irrigation water for 225,000 acres of cropland (Eisel and Aiken, 1997).

These water projects and other water diversions have affected the River's flows and structure and, thereby, the habitat of certain threatened or endangered species that use the Big Bend reach of the Platte in Central Nebraska. Since water storage and diversions began, the Platte River channel has narrowed significantly in this reach (Simons & Associates, 1990). In recognition of the Platte River's importance to the whooping crane, a 3-mile-wide, 56-mile-long reach from Lexington to Denman, Nebraska, was federally designated as critical habitat on May 15, 1978, by the U.S. Fish and Wildlife Service (FWS) (50 CFR 17.95).

Concern for the effects of Platte River Basin water projects on the habitat of threatened or endangered species triggered potential regulation of these projects, among others, under the Endangered Species Act:

- The operation of Federal dams on the North Platte River in Wyoming and of the Colorado Big Thompson Project on a South Platte River tributary have been under Section 7 consultation for a number of years (Zallen, 1997);

- In 1994, FWS issued final biological opinions to the Forest Service for six municipal and industrial water projects along the Front Range of Colorado. These opinions required that certain measures, called "reasonable and prudent alternatives," be implemented to offset the depletions to the central Platte River in Nebraska to comply with the ESA (see, e.g., U.S. Fish and Wildlife Service, 1994). These measures are considered "interim" until a recovery implementation program for the central Platte is implemented.

- Relicensing of the hydropower and related facilities for Kingsley Dam in Nebraska, under the Federal Energy Regulatory Commission (FERC), has also been subject to Section 7 consultation under ESA. The FWS issued a Final Biological Opinion in July 1997, stating that the effects of FERC's proposed action were likely to jeopardize the continued existence of the endangered whooping crane, interior least tern, and pallid sturgeon, and the threatened piping plover; and was likely to result in the destruction or adverse modification of federally designated critical habitat for the whooping crane. The opinion identified "reasonable and prudent alternatives" that, if implemented, would offset jeopardy and adverse modification to critical habitat (U.S. Fish and Wildlife Service, 1997). These measures are also considered "interim" until a recovery implementation program for the central Platte is implemented.

THE *COOPERATIVE AGREEMENT*

These conflicts, which involve water use throughout the Platte River Basin, led state leaders, water users, environmental organizations, and the Federal regulatory agencies to seek a basinwide approach to resolving the conflicts. In July of 1997, Governors from the three States and the Secretary of the Interior signed the *Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitat Along the Central Platte River, Nebraska* (U.S. Department of the Interior and the States of Colorado, Nebraska, and Wyoming, 1997), a 3-year agreement to develop a phased recovery implementation program for the target species (whooping crane, piping plover, interior least tern, and pallid sturgeon) which provides for:

- Implementation of research, analysis, and other measures that will benefit the target species and their associated habitats;
- Development of plans to acquire, restore, and manage land or interests in land so as to provide and improve associated habitats for the target species;
- Development of a plan of certain water management, conservation and supply measures;
- Development of a basinwide Program to be implemented following evaluation of the proposed alternative and a range of reasonable alternatives in compliance with the National Environmental Policy Act (NEPA) and the ESA; and
- Establishment of a governance structure that will ensure appropriate state government and stakeholder involvement in the completion of NEPA compliance tasks, in the implementation of research and other projects beneficial to the target species and their associated habitats, and in the development of a basinwide Program.

Governance Committee

The *Cooperative Agreement* establishes a Governance Committee to review, direct, and provide oversight for the activities undertaken under the *Cooperative Agreement*. The Governance Committee meets approximately monthly, alternating locations among the three States. This Committee consists of the following 10 members:

- One member per signatory state selected by the Governor of that state;
- Two Federal members, one representing the U.S. Bureau of Reclamation (Reclamation) and one representing FWS;
- Two members representing environmental organizations;
- One member representing water users on the North Platte River in Wyoming, and also water users in Nebraska above Lake McConaughy, who have storage contracts for water in Federal reservoirs in Wyoming;
- One member representing water users on the South Platte River above the Western Canal diversion; and
- One member representing water users downstream of Lake McConaughy of the Western Canal and Nebraska users upstream of Lake McConaughy who do not have Federal storage contracts.

The Governance Committee has hired an Executive Director and established four subcommittees--Water Management, Land, Monitoring and Research, and Outreach.

Proposed Program

The *Cooperative Agreement* defines the major features of the proposed Program. The signatories anticipate that the process to evaluate this proposed Program and alternatives, under NEPA and ESA, will take approximately 3 years. During this period, data will be gathered and information developed to refine the proposed Program. The final Program must prove to be reasonable and prudent under ESA, Section 7, must benefit the species and their Platte River habitats, help prevent future listings under ESA, avoid jeopardy, mitigate impacts of new water projects in a manner that will not increase the burden on the other States, and be one to which all the parties can agree.

Water Component: In the Final Biological Opinion, FWS defined specific flow levels (target flows) for different times of the year to maximize available habitat for the target species. The Fish and Wildlife Service's target flows vary month to month, depending on species' needs, time of year, and hydrologic conditions within the Basin. Target flows are identified for wet, normal, and dry conditions and include recommendations for pulse flows (U.S. Fish and Wildlife Service, 1997). When flows do not meet those levels, a shortage exists. Increasing the amount of time that target flow levels are met is to "reduce shortages to target flows."

The States have not agreed that these target flows are biologically or hydrologically necessary to benefit or recover the target species. However, after 3 years of negotiation, the FWS and the States have agreed in the *Cooperative Agreement* to adopt an incremental, adaptive management approach to resolving the endangered species issues. Under this approach, water would be made available to use toward reducing flow shortages for the target species. The results of the actions would be closely monitored, with possible subsequent steps based on findings of the monitoring program.

Under the proposed Program, the objective of the first increment is to reduce the target flow shortage by an average of 130,000 to 150,000 af annually during the first increment of the Program. The water component provides for three proposed water reregulation projects, a water conservation and supply program, and programs for offsetting depletions from new water-related activities including ones not subject to the ESA.

The three proposed water reregulation projects, when operated together, are anticipated to reduce shortages by 70,000 af. Wyoming proposes to modify Pathfinder Dam to recapture storage capacity lost to sedimentation. Part of the additional water stored will be used for the downstream habitat and the remainder will be reserved for additional municipal water. Nebraska's share of water will be supplied by the Central Nebraska Public Power and Irrigation District and the Nebraska Public Power District, who have agreed to include an environmental account in Lake McConaughy to be administered by the FWS. The environmental account will accrue 10 percent of the inflows between October and March, and the Districts will release water for their project operations in a manner that will also benefit the habitat. Colorado will make its contribution with the Tamarack Project, a groundwater recharge project near the Nebraska state line which will withdraw excess flows and release water during times when shortages are most likely.

The remaining 60,000-80,000 af of shortage reduction during the first increment is to be achieved through incentive-based water conservation and water supply projects. These projects are being identified through a study being conducted for the Governance Committee by a consultant.

In addition, each state will be responsible for tracking and mitigating within its own state future depletions to target flows. Depletions caused by both surface water and groundwater use are included. Colorado is developing a methodology based on population growth to measure the amount of mitigation needed, while Wyoming and Nebraska will develop their proposals during the term of the *Cooperative Agreement*. All three States have committed to reviewing and modifying, if necessary, their water laws and regulations in order to protect Program water flows from point of origin to the habitat area.

Land Component: The current long-term goal for habitat land acquisition is restoration, maintenance, and protection of 29,000 acres. The Land Subcommittee was established to develop a plan for the first increment to protect 10,000 acres based on a willing participant basis. The initial focus will be on obtaining and protecting wet meadow and channel habitat within blocks of land between Lexington and Chapman, Nebraska.

The Land Subcommittee will develop incentives as needed to encourage participation in the Program. The terms of the *Cooperative Agreement* specify that all land will be acquired from willing participants only. Acquisition of land may be in the form of fee simple acquisition, acquisition of suitable conservation easements and leases, purchase or transfer of development rights, donation of lands appropriate for Program purposes, and the dedication of the use of lands acquired by the States, private or public entities, or conservation entities, to the Program. The Nebraska Public Power District's 2,600-acre parcel known as the Cottonwood Ranch will be counted as part of the initial 10,000 acres.

In addition, land currently protected and managed by the Platte River Whooping Crane Habitat Maintenance Trust, the National Audubon Society, the Nebraska Game and Parks Commission, and the Nature Conservancy within the Central Platte River Valley will be credited to the Program's long-term objectives if it meets criteria established by the Governance Committee.

Adaptive Management: The proposed Program involves an incremental and adaptive management approach. By this approach, the Governance Committee will monitor and evaluate the impacts of the activities implemented in the first increment of the proposed Program (10-13 years) on the associated habitats and the response of the target species to those impacts. Based on the monitoring and evaluation results, additional actions and/or adjustments to existing actions will be identified and implemented, consistent with the purposes of the Program.

The adaptive management process will include:

1. Baseline documentation of existing quantity and quality of habitat for the target species;

2. Monitoring of the target species and the associated habitats to observe their response to different Program activities;

3. Development of a schedule for the implementation of adaptive management, including monitoring and evaluation;

4. Specific milestones for land and water management and other activities during the first increment, as developed by the Governance Committee;

5. Systematic observation and evaluation of the habitat and population responses of the target species and other species of concern;

6. Evaluation of Program effectiveness–changes/improvements/curtailment of an activity will be made as soon as possible;

7. Evaluation of information gained through the monitoring and research activities, to periodically examine whether habitat management practices and Program goals and objectives should be modified or continued.

Contributions: The costs of the *Cooperative Agreement* activities, $15 million, and of the proposed Program (approximately $60 million for the first increment) will be shared equally by DOI (50 percent) and the States (50 percent). The States have agreed to split their share through the first increment, with Colorado and Nebraska each responsible for 20 percent, and Wyoming responsible for the remaining 10 percent.

Notable Features of the Proposed Program: There are several features of the *Cooperative Agreement* and the proposed Program that mark it as an exceptional step toward shared river management for water use and endangered species.

- Agreement by the States and Interior that joint action is the best approach; that "No Action" is not a feasible option, given the respective goals of the parties.

- The concern for improved habitat to aid in species recovery is shared by the States, Interior, and private entities--the *Cooperative Agreement* recruits a broad range of participants;

- Any land or water acquisitions or management be done on a willing-participant basis only;

- Broad participation in decisionmaking–most of the potentially affected or implementing parties are represented on the governing entity;

- Use of the "Adaptive Management" approach, in which parties jointly develop (1) a monitoring program to assess the success of initial measures and (2) protocols for adjusting the future course of the Program;

- Each state will develop institutional mechanisms to track Platte River depletions from new water-related activities and ensure complete mitigation or offsetting of any impacts to target flows in return for regulatory certainty for the States' existing water projects; and

- The Proposed Program will be cost-shared by the States and Interior, on a 50-50 basis.

LITERATURE CITED

Eisel, Leo, and Aiken, J.D., 1997. *Platte River Basin Study, Report to the Western Water Policy Review Advisory Commission*, McLaughlin Water Engineers, Ltd., Denver, Colorado, and University of Nebraska, Lincoln, Nebraska.

Simons & Associates, 1990. *Appendix V, Platte River System Geomorphic Analysis*, prepared for the Central Nebraska Public Power and Irrigation District and Nebraska Public Power District, Holdrege, Nebraska.

U.S. Department of the Interior and the States of Colorado, Nebraska, and Wyoming, 1997. *Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitats Along the Central Platte River, Nebraska.*

U.S. Fish and Wildlife Service, 1994. Biological Opinion from U.S. Fish and Wildlife Service Acting Regional Director to U.S. Forest Service Regional Forester Regarding Special Use Permit to the City of Greeley for Peterson Lake Reservoir, June 2, 1994.

U.S. Fish and Wildlife Service, 1997, *Biological Opinion on the Federal Energy Regulatory Commission's Preferred Alternative for the Kingsley Dam Project (Project No. 1417) and North Platte/Keystone Dam Project (Project No. 1835)*, Grand Island, Nebraska.

Zallen, Margot, 1997, *Integrating New Values With Old Uses in the Relicensing of Kingsley Dam and Related Facilities (Making Part of the Problem a Part of the Solution)*, Paper Presented at National Resources Law Center, University of Colorado School of Law, Boulder, Colorado, June 2-4, 1997.

ESTABLISHING REGIONAL INSTREAM FLOW RECOMMENDATIONS FOR THE MAINTENANCE AND PROTECTION OF AQUATIC LIFE WITHIN THE SHEYENNE RIVER BASIN, NORTH DAKOTA, USA

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ABSTRACT

The Garrison Diversion Conservancy District (the District) is a political subdivision comprised of 26 counties located in central and eastern North Dakota. The District is charged with the responsibility for completing the Garrison Diversion Unit (GDU) Project, as currently proposed in the Dakota Water Resource Act of 1997 (the Act). The Act's purpose is to determine the best source of affordable, reliable water to meet the water supply needs of eastern North Dakota, including the Red River Valley. The Missouri River is a probable water supply source.

Completion of the GDU project would require delivery of Missouri River water to the Red River Basin and would likely be accomplished by the construction of several new project features. Assuming Missouri River Water is the water supply source, these features include the 1) McClusky Diversion and Screen Facility; 2) the Lonetree Pipeline; 3) an ozone disinfection treatment facility; 4) and the Sheyenne River pump station and pipeline. Water would be diverted from Lake Audobon to the Sheyenne River, using the existing and new project features. The Sheyenne River would serve as the terminal delivery conduit. Preliminary design data consider the delivery of up to 300 cfs to the Red River Valley.

Included within the Act, is a provision for using water to enhance fish and wildlife habitat by augmenting instream flows within the Sheyenne River. However, the District lacked information about instream flow needs for fish and other aquatic life within the Sheyenne River.

The District initiated a study during the summer of 1997 to evaluate instream flow needs for aquatic life within the Sheyenne River. The study approach was based on applying multiple instream flow methodologies to reference reaches; i.e., portions of the Sheyenne River intended to represent a larger reach or "region" of the river. Reference reaches for the Sheyenne River were selected using aerial and

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ground surveys and based on discussions with state and federal agency personnel. Instream flow methods applied to the reference reaches included the wetted perimeter method, the Tennant Method, and a modified Physical Habitat Simulation Model (PHABSIM).
The study resulted in seasonal recommendations for each of the reference reaches. Summer-time instream flow recommendations ranged from 25 cfs within the upper portion of the Sheyenne River basin to 200 cfs on the Red River of the North downstream of the confluence with the Sheyenne River. The District plans to use these recommendations during future project planning and design efforts.

INTRODUCTION

The Garrison Diversion Conservancy District (the District) is a political subdivision comprised of 26 counties located in central and eastern North Dakota (Figure 1). The District is charged with the responsibility for completing the Garrison Diversion Unit (GDU) Project, as currently proposed in the Dakota Water Resource Act of 1997 (the Act). The Act's purpose is to determine the best source of affordable, reliable water to meet the water supply needs of eastern North Dakota, including the Red River Valley. The Missouri River is a probable water supply source.

Assuming the Missouri River is the water supply source, a completed GDU project would deliver water to the Red River Basin for municipal, industrial and residential use and require the design and construction of several new features. These features include the 1) McClusky Diversion and Screen Facility; 2) the Lonetree Pipeline; 3) an ozone disinfection treatment facility; 4) and the Sheyenne River pump station and pipeline. Water would be diverted from Lake Audubon to the Sheyenne River, using the existing and new project features. The Sheyenne River would serve as the terminal delivery conduit. Preliminary design data consider the delivery of up to 300 cfs to the Red River Valley.

Instream flow recommendations for portions of the Sheyenne River and the Red River have previously been suggested, although the technical basis for these recommendations is unclear. There are no known previous recommendations, developed solely to maintain and protect the ecological integrity of the aquatic community.

The Souris-Red-Rainy River Basin Commission (1972) recommended a *minimum* instream flow of 7 cubic feet per second (cfs) at Fargo to provide a factor of safety for water needs and insure that some minimal river flow is maintained below each withdrawal point. The basic flow needs at each withdrawal point consist of the minimum base flow and the downstream allocated withdrawals. The Bureau of Reclamation (1997) used the minimum value of 7 cfs for the Red River and 13 cfs for the Sheyenne River below Lake Astabula in a recent assessment of municipal, rural and industrial water supply needs. The Souris-Red-Rainy River

Basin Commission (1972) suggested a minimum flow of 100 cfs at Fargo, to protect the fishery value of the river and aid in waste assimilation.

Because the Red River is a resource shared by the States of North Dakota and Minnesota, each state has also been involved in considering instream flows. The Minnesota Department of Natural Resources ("MnDNR"), which follows eastern water law, generally establishes minimum instream flows using a hydrologic method; i.e., 90% exceedance flow. This flow for the Red River of the North at Fargo is 38 cfs.

The North Dakota State Water Commission ("NDSWC"), which follows western water law, considers instream flow needs during the issuance of water appropriation permits. However, the NDSWC presently has no *legal* requirement for maintaining minimum instream flows. One proposal presented to NDSWC by the North Dakota Game and Fish Department for instream flow within the Red River near Wahpeton, North Dakota during discussions of the ProGold appropriations permit, consisted of the following:

- June – September 40% of average annual flow (i.e., recommendation of 220 cfs)
- October - March 80% of average annual flow (i.e., recommendation of 440 cfs)
- April-May 100% of average annual flow (i.e., recommendation of 551 cfs)

ProGold is a "value added" high fructose corn syrup processing plant, which began operation in 1997.

Little is known about the potential affects of increased stream flow on fish and other aquatic life within the Sheyenne River (and the Red River of the North) or how habitat can be improved through flow augmentation. The Act includes a provision for using a portion of the diverted water to enhance fish and wildlife habitat by augmenting instream flows within the Sheyenne River. However, the District lacked information about instream flow needs for fish and other aquatic life within the Sheyenne River, hampering informed decision-making about the amount of water needed for fish and other aquatic life.

Various definitions for instream flow have been advanced. Bayha (1978) defined instream flow as the amount of water flowing through a stream course, which is needed to sustain instream values at an acceptable level. The maintenance of fish and wildlife populations, outdoor recreation, navigation, hydropower generation, waste assimilation, conveyance of water to downstream diversion locations and ecosystem maintenance are potential instream values, which occur when water remains within the stream channel.

Instream flow for aquatic life is defined here as the amount of water or discharge within a stream, necessary for maintaining and protecting the ecological integrity of the aquatic community. The fish community is the most commonly used surrogate for the aquatic community when developing instream flow recommendations for aquatic life. Therefore, for the purposes of this study it was assumed instream flow recommendations established using the fish community, including the use of hydrologic and hydraulic methods based on protecting important habitat, were protective of the ecological integrity of the aquatic community. The study focused on obtaining the information needed to develop seasonal discharges (i.e., instream flow needs[3]) necessary for maintaining and protecting the ecological integrity of the aquatic community within the study area on a regional basis, using existing methodologies and data.
The data presented herein are considered to be of sufficient accuracy for planning purposes. This work forms the basis for the future application of more detailed, intensive methods, if deemed necessary by policy makers.

METHODS

The District initiated the study during the summer of 1997. The study area consisted of the Sheyenne River from the U.S. Geological Survey gage located at Harvey, North Dakota (Gage No. 05054500) downstream to the confluence with the Red River. The study area also included the Red River of the North ("Red River") from upstream of Fargo, North Dakota (Gage No. 05054000) downstream to the confluence with the Buffalo River (see Figure 1).

The study approach was based on applying multiple instream flow methodologies to reference reaches; i.e., portions of the Sheyenne River intended to represent a larger reach or "region" of the river. Reference reaches for the Sheyenne River were selected using aerial and ground surveys, and based on discussions with state and federal agency personnel. The level of effort and detail used to develop the instream flow recommendations were determined by time and fiscal constraints. (Time and fiscal constraints prevent the full application of the Physical Habitat Simulation Model -PHABSIM.)

We broadly categorized the methods for developing instream flow recommendations as: 1) hydraulic rating methods (i.e., wetted perimeter); 2) hydrologic methods (e.g., Tennant method); and 3) habitat preference methods (modified PHABSIM). These methods were considered appropriate for developing reasonable and defensible regional instream flow recommendations for the Sheyenne River, using a moderate level of effort and complexity. The approach used assumes habitat, rather than other factors like water temperature or water quality, is the factor limiting fish abundance.

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[3] This effort does not address legal issues associated with the allocation of water for instream flow needs.

Hydraulic Rating Method

We applied the wetted perimeter method to develop instream flow recommendations at a number of locations on the Sheyenne River and the Red River. Instream flow recommendations derived by using hydraulic rating methods like the wetted perimeter method assume a direct, functional relationship between channel characteristics (e.g., cross-sectional area or wetted perimeter) and the amount of fish habitat. Instream flow recommendations are established using the wetted perimeter method by identifying the inflection point on a curve relating wetted perimeter to discharge. The discharge corresponding to the inflection point is the instream flow recommendation.

The inflection point is that location on the curve where the change in slope of a line drawn tangent to the curve starts becoming asymptotic. Figure 2 shows an example of how instream flow recommendations are derived using the wetted perimeter method. We fitted curves to the plotted points (wetted perimeter and discharge) to aid in determining the inflection point. The HEC-RAS model developed by the U.S. Army Corp of Engineers was used to develop the relationship between wetted perimeter and discharge.

Channel cross section data from riffle habitat is used to develop the relationship between wetted perimeter and discharge, because the method is based on the premise that providing adequate flow within riffle habitat protects other habitats. Riffle habitat, the portion of the stream characterized by shallow, rapid flow, typically becomes dewatered prior to other types of habitats.

Existing channel cross section data from U.S. Geological Survey gaging stations and new data generated during this study, were evaluated for use when performing the wetted perimeter method. The U.S. Geological Survey provided stream geometry data for gaging stations located within the study area. These locations and their gage numbers are:

1. Harvey, North Dakota	05054500
2. Warwick North Dakota	05056000
3. Cooperstown, North Dakota	05057000
4. Below Baldhill Dam	05058000
5. Valley City	05058500
6. Lisbon	05058700
7. Kindred	05059000
8. West Fargo	05059500
9. Below Fargo[4]	05054020
10. Fargo	05054000

[4] Only limited discharge data are available at this location. Therefore, the hydrologic record may not be sufficient to calculate meaningful statistics.

A review of stream geometry data for the gaging stations showed that few gaging stations represented riffle habitat. Therefore, additional stream geometry data within the Sheyenne River from known riffle habitats, were gathered during this study. (see Habitat Preference Method). Stream geometry data from these locations was used to develop the functional relationship between wetted perimeter and discharge.

Hydrologic Methods

Three hydrologically based methods were used to develop seasonal (i.e., spawning and nonspawning) instream flow recommendations at the gaging stations identified previously. The three hydrologic methods used were the: 1) Tennant method; 2) 25% of the mean annual flow (25% MAF); and 3) the flow equaled or exceeded 90% of the time.

The Tennant Method, a technique developed in the State of Montana, is based on the premise that habitat is related to a percentage of the mean annual flow (MAF). Tennant (1976) developed the method by studying the percentage change in the widths, depths and velocities relative to the change in the MAF for 58 streams in Montana, Wyoming, and Nebraska. The approach suggests that aquatic habitat conditions are similar for streams with similar MAF.

Recommended instream flows based on a percentage of the MAF as employed by the Tennant method are summarized in Table 1 (Tennant 1976). One seeming advantage of the Tennant method is the ability to separate minimum flow requirements by season; i.e., the minimum flow required during the low flow period (October - March) and a suitable flow conditions for aquatic biota and recreational activities during the high flow period (April - September) (Tennant 1976). Separation of the season into low and high flow periods can vary by region of the country.

Determining instream flow requirements using the Tennant method is obtained rather simply. First, the mean annual flow for a particular stream reach is calculated using data from a representative gage. The MAF is then multiplied by the percentages indicated in Table 1 for each of the seasons. Tennant (1976) suggested field observations be combined with the calculation procedure to ensure a relationship between habitat and MAF.

Although Tennant developed the method for stream and rivers in the western U.S., the method has been used throughout North America. Comparisons between the Tennant method and habitat based methods (e.g., Physical Habitat Simulation Model) often show general agreement. A modified Tennant Method has been used in some cases; i.e., a percentage of MAF different from those in Table 1 or a percentage based on the mean monthly flow (e.g., 25% MAF used in Atlantic Canada).

Habitat Preference Method

A variation of the PHABSIM method and computational procedures was used to develop instream flow recommendations for the Sheyenne River and the Red River. Because this study is oriented toward developing regionalized instream flow recommendations for the Sheyenne and Red River, study sites were selected to be representative of larger portions of the Sheyenne and Red River. Channel geometry data were surveyed at each study site and used to perform hydraulic modeling to determine the cross-sectional velocity and depth distributions for each transect within a study site. We used the habitat preference curves developed by Aadland et al. (1991) to calculate Weighted Useable Area ("WUA") from the velocity and depth distributions.

We completed field work on September 3rd, September 4th, September 5th, and September 8th to: 1) identify and select "study sites" representative of specific portions of the Sheyenne River and the Red River of the North; 2) determine habitat types within each study site; 3) estimate the proportion of each habitat type within each study site; and 4) place transects within the various habitat types and obtain stream geometry data along these transects.

Five study sites were selected as representative of the following portions[5] of the Sheyenne and Red Rivers:

- Sheyenne River above Lake Ashtabula (Warwick site – Sec. 3, T149N, R64W, Tiffany Township, Eddy County);
- Sheyenne River below Lake Ashtabula (Lisbon site – Sec. 30/31, T135N, R56W, Tuller Township, Ransom County);
- Sheyenne River through the Sand Hills (Kindred site – Sec. 3, T135N, R52W, Sheyenne Township, Richland County);
- Sheyenne River through the Agassiz Lake Plain (Horace site – Sec. 25, T138N, R50W, Warren Township, Cass County); and
- Red River of the North near Fargo (Fargo site – Sec. 28/29, T140N, R48W, Oak Port Township [Clay County, Minnesota] and Reed Township [Cass County, North Dakota]).

Field activities were oriented toward finding and selecting study sites representative of larger portions of the Sheyenne and Red Rivers, identifying habitat types at these sites and obtaining stream geometry needed for completing hydraulic analysis for each of the habitat types at a study site.

Specific field activities undertaken to ensure selected study sites were regionally representative included:

[5] The reaches also correspond to ecoregion boundaries for North Dakota.

- Conducting an aerial reconnaissance of the Sheyenne River and the Red River on July 21, 1997;
- Discussing potential study site locations with staff from the North Dakota State Department of Health and Consolidated Laboratories and the North Dakota Game and Fish Department. Based on these discussions preliminary study sites were selected preferably to correspond with ongoing biological studies; and
- Determining whether each study site represented a greater portion of the Sheyenne and Red River, based on observations made during the aerial reconnaissance and field observations. New study sites were selected if the preliminary study site showed evidence of excessive disturbance (e.g., influence of bridge on stream geomorphology).

To ensure stream geometry (transect) data were obtained from each habitat type present at a study site we:

- Floated and walked each study site in waders noting changes in depth, width, substrate (i.e., mesohabitat types) prior to placing transects;
- Systematically placed transects within each habitat type;
- Surveyed each transect;
- Recorded field observations by transect – observations consisted of classifying the habitat type and recorded qualitative information about substrate and cover types; and
- Obtained photo documentation of each site.

Study site lengths ranged up to 1,385 feet and the distance between transects within a study site was typically less than 50 feet. Descriptions of the type of habitats within a study site are presented elsewhere (Houston Engineering, Inc., 1997).

Sufficient water surface elevations were measured within a reach to "calibrate" the HEC-RAS hydraulic model for energy loss between transects measured within a reach for the discharge at the time of the site visit. Discharge data came from nearby gaging stations. The field work provided valuable information to ensure stream geometry data were representative of the habitat types present within the Sheyenne and Red River. Detailed transect information (e.g., measured velocity distributions, cover types and substrate types) needed for site-specific PHABSIM analyses was beyond the present effort.

We used fish species from a number of guilds to establish instream flow needs for spawning and nonspawning periods. Aadland et al. (1991) identified representative fish species for six guilds: 1) shallow pool; 2) medium pool; 3) deep pool; 4) raceway; 5) slow riffle; and 6) fast riffle. Flow needs for spawning and nonspawning periods were developed by using preference curves for species life history stages present during these periods. We also used the work of Owen et al. (1981), Peterka (1978), and Niemela et al. (1997) to ensure that species selected as guild representatives are present within each stream reach. Fish species presence and absence data for the Sheyenne and Red Rivers were compared to existing preference curves developed by Aadland et al. (1991) to ensure the availability of habitat preference data. The fish species selected as guild representatives are shown in Table 2. Comparison of the velocity and depth preference curves for these species shows "coverage" throughout the range of velocities and depths anticipated within the study sites.

The depth and velocity preference curves developed by Aadland et al. (1991) for guild representatives, were used to calculate WUA for the range of discharges. Preference curves for substrate are typically included in computing WUA when using habitat preference methods. Because of a lack of detailed information about substrate characteristics for each study site, substrate preference curves were not used in performing this assessment.[6]

Stream discharge data are needed for each study site to perform hydraulic modeling, determine stream cross section velocity and depth distributions and compute WUA. We selected a range of discharges, which encompassed the seasonal variability (i.e., spring, summer, fall, winter) in discharge to compute WUA.

Transverse depth and mean velocity distributions for each transect within a study site were computed using the U.S. Army Corps of Engineeers HEC-RAS model. Model calibration for a reach consisted of matching the mean cross section velocity and discharge using measured discharges from nearby U.S.G.S. gaging stations for the period we performed the field work. Measured water surface elevations for each transect at a study site were used to calibrate the model for energy losses between transects.

Weighted useable area for each study site was computed for each discharge by guild species. Two methods were used to compute WUA. We computed WUA for each species by multiplying cell area at (at 1 to 3-foot increments across the transect) by the product of the velocity and depth preference curve values for the cell. This is referred to as the multiplicative method. The second computational method focused on computing WUA based on the presence of optimum habitat. We assigned the cell area associated with each 1 to 3-foot increment across the channel a value of 1, if the product of the velocity and depth preference curves for that area equaled or exceeded 0.8. A value equaling or exceeding 0.8 represents optimum habitat. We assigned a value of zero, if the product of the velocity and depth preference curves for that area was less than 0.8. The areas for all cells assigned a value of 1 within a study site were summed to obtain total WUA. This

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[6] Substrate preference has previously been found by some to be of lesser importance in computing WUA than velocity and depth. We found little variation in substrate type at most locations.

is referred to as the optimum method. The monthly WUA time series for each species was computed from median monthly discharge derived from the nearest U.S.G.S. gaging station and the discharge – WUA relationship for each species.

Instream flow recommendations for spawning and nonspawning periods were derived by applying the technique of Bovee (1982) to WUA calculated by the multiplicative method. Application of the technique to spawning and nonspawning periods requires identifying the minimum amount of habitat for all species at each discharge. The instream flow recommendation is equal to the discharge corresponding to the maximum, of the minimum habitat values. Figure 3 graphically shows how the technique is used to derive an instream flow recommendation. The premise for the technique is that the recommended discharge will maximize the amount of habitat for the species with the least amount of habitat. Instream flow recommendations derived using the technique were qualitatively compared to plots of WUA versus discharge based on the optimum method to ensure consistency of the results. WUA computed used the optimum habitat method are presented elsewhere (Houston Engineering, Inc., 1997).

RESULTS AND DISCUSSION

Regional instream flow recommendations for the Sheyenne River are dependent upon the method used, which complicates establishing regional instream flow recommendations. Table 3 compares instream flow recommendations derived using the hydraulic rating method (i.e., wetted perimeter), hydrologic methods and the habitat preference method. These recommendations can be compared to the median monthly discharges shown in Table 4 to provide a qualitative idea of their magnitude (also see 10 and 90th percentile exceedance flows in Table 3).

Table 3 shows that recommended instream flows derived using the wetted perimeter method ranged from between 50 and 100 cfs at Warwick to between 75 and 100 cfs at Horace (also see Houston Engineering, Inc., 1997). These recommendations are surprising considering the much greater drainage area at Horace. Because the wetted perimeter recommendations were developed using only a few riffle cross sections for each reach of the Sheyenne and Red Rivers, more cross sections are needed for computing the recommendation.

Instream flow recommendations derived using the Tennant method and assuming optimum habitat, range from 6 cfs for the Sheyenne River above Harvey, to 36 cfs near Warwick, and 120 cfs near West Fargo. The recommended instream flow for the Red River at Fargo is 370 cfs. The discharge needed for optimum habitat is 60% of the mean annual flow.

Depending upon the aquatic life habitat goals desired by resource agencies, instream flow recommendations based on the Tennant Method could be reduced. For example, Table 3 shows that to maintain "good" habitat on the Red River at Fargo instream flows derived by the Tennant method should be 246 cfs from

April to September and 123 cfs from October to March. This compares to 369 cfs for optimum habitat. An evaluation of how frequent low flows might occur and the amount of time needed for recovery of the aquatic community could assist in deciding on habitat goals.

Results from the habitat preference method generally compared to "optimum habitat" at the study sites on the upper and "fair habitat" at the study sites on the lower Sheyenne River, respectively (Table 3). Instream flow recommendations derived using the habitat preference method at Warwick are 100 cfs (spawning) and 25 cfs (nonspawning), compared to 250 cfs (spawning) and 75 cfs (nonspawning) at Lisbon. Nonspawning and spawning instream recommendations for the Red River at Fargo are 200 cfs.

Agreement between the Tennant, wetted perimeter and habitat preference methods is desirable; i.e., the recommended instream flows derived from the habitat preference method should provide the same quality of habitat (e.g., "good" or "fair") at all sites using the Tennant and wetted perimeter methods. Otherwise, establishing instream flow recommendations requires considerable (subjective) judgement about which method provides the most accurate and realistic results. The seeming lack of agreement between these methods likely results from extrapolating the recommendations derived at Lisbon to the other upstream study sites. The Lisbon site contained a truly unique riffle, pool, run sequence that may in fact represent unique habitat within the Sheyenne River system. Therefore, extrapolating instream flow recommendations derived at the Lisbon site upstream may not be appropriate.

Comparing the instream flow recommendations to annual exceedance discharge statistics, provides some perspective about the magnitude of the recommendations. The instream flow recommendations based on the habitat preference method generally fall between the median and 10% annual exceedance discharges at the upper Sheyenne River study sites, compared to the 90% annual exceedance and median discharges and at the lower Sheyenne River study sites. The instream flow recommendation based on the wetted perimeter method generally fall between the median and 10% annual exceedance discharges at the study sites on the lower Sheyenne River. Future comparison of the instream flow recommendations to monthly discharge statistics is needed to evaluate policy considerations.

The lowest instream flow recommendations would result by using the 90% annual exceedance discharge. The 90% annual exceedance discharge ranged from 0 cfs at Harvey to 20 cfs at West Fargo (Table 3). The 90% exceedance flow represents a hydrologic statistic indicative of drought conditions and is typically considered inappropriate for establishing instream flow recommendations. We would not recommend using this hydrologic statistic for establishing instream flow recommendations.

The relationship between WUA and discharge (using the multiplicative method) for spawning and nonspawning periods showed a consistent trend among sites (Figures 4 and 5). The graphs for nearly all species showed that WUA increased as discharge increased, reaching a maximum value and then declined as discharge continued to increase. The reason for the trend is increasing discharge resulted in preferred velocity and depth for a species. However, velocity and depth associated with high discharge is too great and preference declines. One exception to the trend in juvenile channel catfish which prefer relatively deep water (~3 feet) and low velocity (~0.4 feet per second). These conditions occur at Kindred and Horace because of a channel characterized by high, defined banks.

The second exception is WUA versus discharge data generated for the Horace site. These graphs showed an initial increase in WUA with increasing discharge, followed by a small decline and then some oscillation in WUA with increasing discharge. The oscillation in WUA is due to the relatively large overbank areas, which become inundated, once discharge exceeds bankful. These areas have depths (<1-foot) and velocity (<1-foot per second) useable by many species, although the habitat may be of marginal quality.

Monthly habitat time series data are useful for understanding seasonal trends in species habitat. Figure 6 shows an example habitat time series for the Red River at Fargo computed using median monthly discharges Figure 4 shows that adult Longnose Dace tend to have the least amount of habitat. Meaningful interpretation of these data requires correlation with fish abundance measurement.

The data presented here show consistency between the Tennant method and habitat preference method for study sites along the lower Sheyenne River (i.e, Kindred, West Fargo and Red River @ Fargo). We believe use of the habitat preference method in combination with providing good or optimum habitat derived by the Tennant method, is the most defensible approach to establishing instream flow recommendations for the study area.

Therefore, our recommendations are:

	Spawning (April/May) (cfs)	Nonspawning (June-March) (cfs)
Sheyenne River above Harvey	6	2
Sheyenne River near Warwick	50	25
Sheyenne River near Cooperstown	71	25
Sheyenne River at Valley City	74	25
Sheyenne River at Lisbon	185	55
Sheyenne River at Kindred	135	45
Sheyenne River at West Fargo	135	45
Red River at Fargo	200	200

These recommendations are based on weighing the data presented in Table 3 and selecting a value near the center of the range derived from the Tennant, wetted perimeter and habitat preference methods. Habitat goals for the Tennant method were assumed to be optimum from April to September and good from October to March. Instream flow recommendations for Lisbon are greater than for downstream locations on the Sheyenne River, because this site represents ideal habitat.

This work provides a foundation for establishing instream flows within the study area. The rational in completing this study has been to provide sufficient analysis to develop defensible recommendations for immediate use for planning purposes and to lay the foundation for additional future refinement. Additional analysis of monthly habitat time series data derived from additional discharges can provide greater insight into habitat variability. Future field work could focus on gathering site-specific measurements of velocity, substrate and cover under different discharges for application of the PHABSIM model.

LITERATURE CITED

Aadland, L.P., C.M. Cook, M.T. Negus, H.G. Drewes, and C.S. Anderson. 1991. Microhabitat Preferences of Selected Stream Fishes And A Community-Oriented Approach to Instream Flow Assessment. Minnesota Department of Natural Resources Section of Fisheries Investigational Report No. 406. 125pp.

Annear. T.C. and A.L. Conder. 1983. Evaluation of instream flow methods for use in Wyoming. Wyoming Game and Fish Department. Cheyenne, Wyoming.

Bayha, K. 1978. Instream Flow Methodologies for Regional and National Assessment. Instream Flow Information Paper No. 7. Western Energy Land Use Team. Office of Biological Services, U.S. Fish and Wildlife Service. FWS/OBS-78/61.

Bovee, K. 1982. A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 12. FWS/OBS-82/26.

Bureau of Reclamation. 1997. Red River Valley Municipal, Rural, and Industrial Water Needs Assessment, Review Draft Appraisal Report. U.S. Department of Interior. 135 pp.

Houston Engineering, Inc. 1997. White Paper - Instream Flow Needed for Aquatic Life. Prepared for the Garrison Diversion Conservancy District. 25 pp.

Kulik, B. 1990. A method to refine the New England aquatic base flow policy. Rivers, 1(1): 8-22.

Owen, J.B., D.S. Elsen, and G.W. Russell. 1981. Distribution of Fishes in North and South Dakota Basins affected by The Garrison Diversion Unit. Fisheries Research Unit, Department of Biology, University of North Dakota, Grand Forks, North Dakota. 201 pp.

Niemela, S., E. Pearson, T.P. Simon, R.M. Goldstein, and P.A. Bailey. Development of Index of Biotic Integrity Expectations for the Lake Agassiz Plain Ecoregion. U.S. Environmental Protection Agency, Region V, Water Division, Standards and Applied Science Section, Chicago, IL. EPA 905-R-96-005.

North Dakota State Water Commission. 1997. Upper Sheyenne River Channel Capacity Study. Devils Lake Feasibility Study Project No. 416-1. 19 pp.

NGPRP. 1974. Northern Great Plains Resource Program. Instream Needs Subgroup Report, Work Group C.

Peterka, J.J. 1978. Fishes and Fisheries of the Sheyenne River, North Dakota. Annual Proceedings, North Dakota Academy of Science 32: 29-44.

Souris-Red-Rainy River Basins Comprehensive Study. 1972. Appendix O, Supporting Data for Type II Study Program Formulation and Alternatives. Souris-Red-Rainy River Basin Commission.

Tennant, D.L. 1976. Instream flow regimens for fish, wildlife, recreation and related environmental resources. In: Proceedings of Symposium and Specialty Conference on Instream Flow Needs. J.F. Orsborn and C.H. Allman Ed. American Fisheries Society, pp. 359-373.

USFWS. 1981. Interim regional policy for New England stream flow recommendations. Memorandum from H.N. Larsen, Director, Region 5 U.S. Fish and Wildlife Service.

Table 1
Instream Flow Recommendations Using the Tennant Method*

Narrative Description of Flows	Recommended Flow (% of MAF)**	
	October – March	April – September
Flushing or maximum	200	200
Optimum range	60 – 100	60 – 100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair or degrading	10	30
Poor or minimum	10	10
Severe degradation	<10	<10

*For streams in Montana, Wyoming, and Nebraska (Tennant 1976).
**MAF, mean annual flow.

Table 2
Guild Representatives Proposed for Performing Assessment of Instream Flow Needs for Aquatic

Common Name	Scientific Name	Guild
Spawning (April/May)		
Longnose dace (adult)	*Rhinichthys cataractae*	Shallow riffle
Shorthead redhorse (spawning)	*Moxostoma macrolepidotum*	Fast riffle
Walleye (spawning)	*Stizostedium canadense*	Medium pool
Bluntnose minnow (adult)	*Pimephales notatus*	Shallow riffle
Channel catfish (juvenile)	*Ictalurus punctatus*	Medium pool
White sucker (juvenile)	*Catostomus commersoni*	Shallow riffle
Nonspawning (June through March)		
Longnose dace (adult)	*Rhinichthys cataractae*	Shallow riffle
Longnose dace (young)	*Rhinichthys cataractae*	Fast riffle
Shorthead redhorse (young)	*Moxostoma macrolepidotum*	Fast riffle
Bluntnose minnow (adult)	*Pimephales notatus*	Shallow riffle
Bluntnose minnow (young)	*Pimephales notatus*	Shallow pool
Channel catfish (juvenile)	*Ictalurus punctatus*	Medium pool

Table 3
Sheyenne River and Red River
Instream Flow Recommendations (in cubic feet per second) for Aquatic Life

	05054500 Sheyenne R. above Harvey, ND		05056000 Sheyenne R. near Warwick, ND		05057000 Sheyenne R. near Cooperstown, ND		05058000 Sheyenne R. Below Baldhill Dam		05058500 Sheyenne R. at Valley City, ND	
	Apr./May	June-Mar.	Apr./May	June-Mar.	Apr./May	June-Mar.	Apr./May	June-Mar.	Apr./May	June-Mar.
Mean Annual Flow (MAF)	9.2		59.3		118.0		147.0		124.0	
Tennant Method	Apr. - Sep.	Oct. - Mar.	Apr. - Sep.	Oct. - Mar.	Apr. - Sep.	Oct. - Mar.	Apr. - Sep.	Oct. - Mar.	Apr. - Sep.	Oct. - Mar.
Optimum Range	6 to 9	6 to 9	36 to 59	36 to 59	71 to 118	71 to 118	88 to 147	88 to 147	74 to 124	74 to 124
Outstanding	5.5	3.7	35.6	23.7	70.8	47.2	88.2	58.8	74.4	49.6
Excellent	4.6	2.8	29.7	17.8	59.0	35.4	73.5	44.1	62.0	37.2
Good	3.7	1.8	23.7	11.9	47.2	23.6	58.8	29.4	49.6	24.8
Fair	2.8	0.9	17.8	5.9	35.4	11.8	44.1	14.7	37.2	12.4
Poor	0.9	0.9	5.9	5.9	11.8	11.8	14.7	14.7	12.4	12.4
25% MAF	2.3		14.8		29.5		36.8		31.0	
90% Annual Exceedance	0		1.5		4		9.2		N.A.	
50% Annual Exceedance	1.5		9.5		24		42		N.A.	
10% Annual Exceedance	21		110		247		293		N.A.	
Wetted Permimeter Method	(a)		Range: 50 to 100 Mean = 75 n = 4		(a)		(b)		(b)	
	Apr./May	Jun. - Mar.	Apr./May	Jun. - Mar.	Apr./May	Jun. - Mar.	Apr./May	Jun. - Mar.	Apr./May	Jun. - Mar.
Habitat Preference Method	(a)	(a)	100.0	25.0	(a)	(a)	(b)	(b)	(b)	(b)

Note: Valley City Gage is a seasonal Station.
Optimum range is 60 to 100% of MAF.
Outstanding is 60% of MAF for April to September and 40% of MAF for October to March.
Excellent is 50% of MAF for April to September and 30% of MAF for October to March.
Good is 40% of MAF for April to September and 20% of MAF for October to March.
Fair is 30% of MAF for April to September and 10% of MAF for October to March.
Poor is 10% of MAF for April to September and 10% of MAF for October to March.
(a) Assumed to be similar to the Sheyenne River @ Warwick.
(b) Assumed to be similar to Sheyenne River @ Lisbon.
Wetted perimeter method based on known riffle cross sections, excluding Red River of the North.
Habitat preference method based on discharge needed to species with least amount of habitat among guild members.
Habitat preference and wetted perimeter study sites were located near gage stations at Warwick, Lisbon, Kindred and West Fargo.

Table 3 (cont.)
Sheyenne River and Red River
Instream Flow Recommendations (in cubic feet per second) for Aquatic Life

	05058700 Sheyenne R. at Lisbon, ND		05059000 Sheyenne R. at Kindred, ND		05059500 Sheyenne R. at West Fargo, ND		05054000 Red River of the North at Fargo, ND	
	Apr./May	June-Mar.	Apr./May	June-Mar.	Apr./May	June-Mar.	Apr./May	June-Mar.
Mean Annual Flow (MAF)	185.0		225.0		200.0		615.0	
Tennant Method	Apr. - Sep.	Oct. - Mar.	Apr. - Sep.	Oct. - Mar.	Apr. - Sep.	Oct. - Mar.	Apr. - Sep.	Oct. - Mar.
Optimum Range	111 to 185	111 to 185	135 to 225	135 to 225	120 to 200	120 to 200	369 to 615	369 to 615
Outstanding	111.0	74.0	135.0	90.0	120.0	80.0	369.0	246.0
Excellent	92.5	55.5	112.5	67.5	100.0	60.0	307.5	184.5
Good	74.0	37.0	90.0	45.0	80.0	40.0	246.0	123.0
Fair	55.5	18.5	67.5	22.5	60.0	20.0	184.5	61.5
Poor	18.5	18.5	22.5	22.5	20.0	20.0	61.5	61.5
25% MAF	46.3		56.3		50.0		153.8	
90% Annual Exceedance	15		33		20		39	
50% Annual Exceedance	55		82		74		305	
10% Annual Exceedance	410		478		437		1360	
Wetted Permimeter Method	Range: 50 to 150 Mean = 94 n = 3		Range: 100 to 200 Mean = 142 n = 4		Range: 75 to 100 Mean = 88 n = 2		Range: 150 to 225 Mean = 181 n = 4	
	Apr./May	Jun. - Mar.	Apr./May	Jun. - Mar.	Apr./May	Jun. - Mar.	Apr./May	Jun. - Mar.
Habitat Preference Method	250.0	75.0	38.0	15.0	50.0	25.0	200.0	200.0

Note: Valley City Gage is a seasonal Station.
Optimum range is 60 to 100% of MAF.
Outstanding is 60% of MAF for April to September and 40% of MAF for October to March.
Excellent is 50% of MAF for April to September and 30% of MAF for October to March.
Good is 40% of MAF for April to September and 20% of MAF for October to March.
Fair is 30% of MAF for April to September and 10% of MAF for October to March.
Poor is 10% of MAF for April to September and 10% of MAF for October to March.
(a) Assumed to be similar to the Sheyenne River @ Warwick.
(b) Assumed to be similar to Sheyenne River @ Lisbon.
Wetted perimeter method based on known riffle cross sections, excluding Red River of the North.
Habitat preference method based on discharge needed to species with least amount of habitat among guild members.
Habitat preference and wetted perimeter study sites were located near gage stations at Warwick, Lisbon, Kindred and West Fargo.

Table 4

MEDIAN MONTHLY DISCHARGES (CFS)

USGS Gaging Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
05056000 Sheyenne R. near Warwick, ND	5.24	9.85	131	292	106	55.3	42	24.7	11.6	13.5	12.5	7.79
05058700 Sheyenne R. at Lisbon, ND	65.8	83.6	33.6	711	306	167	165	109	68.2	67	76.1	70.7
05059000 Sheyenne R. at Kindred, ND	73.4	85.5	311	767	465	269	233	140	86.8	86.8	94.3	81.8
05054000 Red River of the North at Fargo, ND	207	208	722	1761	1047	1024	855	412	315	315	273	225
05059500 Sheyenne R. at West Fargo, ND	58	66.2	249	736	428	251	199	122	76.1	73.5	80.7	66.6

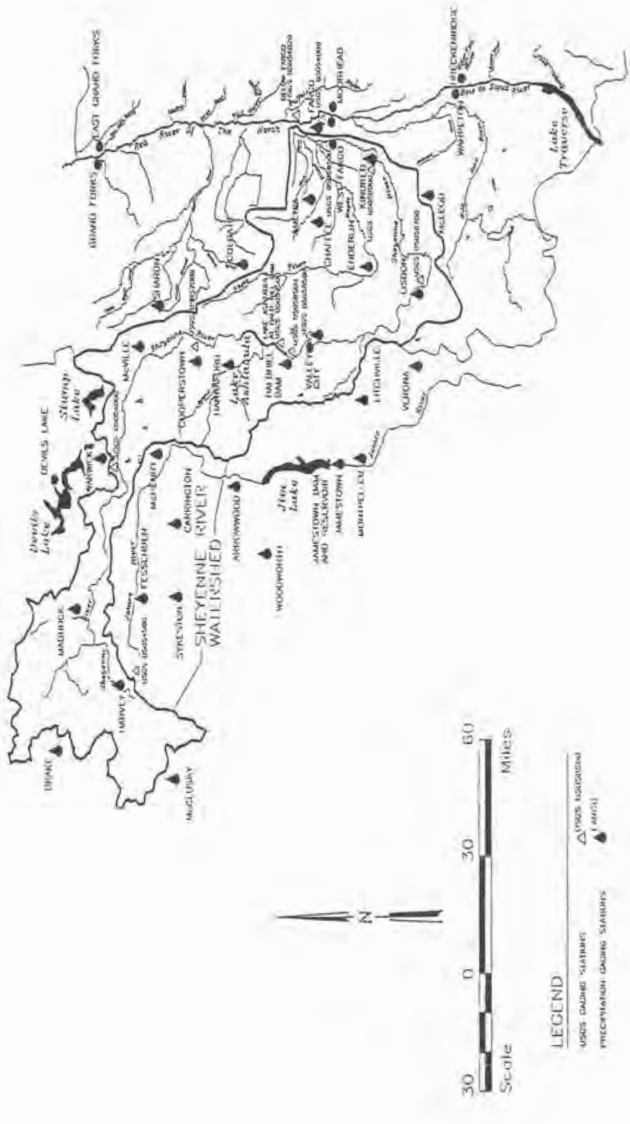


Figure 1. Study area instream flow for aquatic life.

Figure 2
Establishing Instream Flow Recommendations Using the Wetted Perimeter Method - An Example

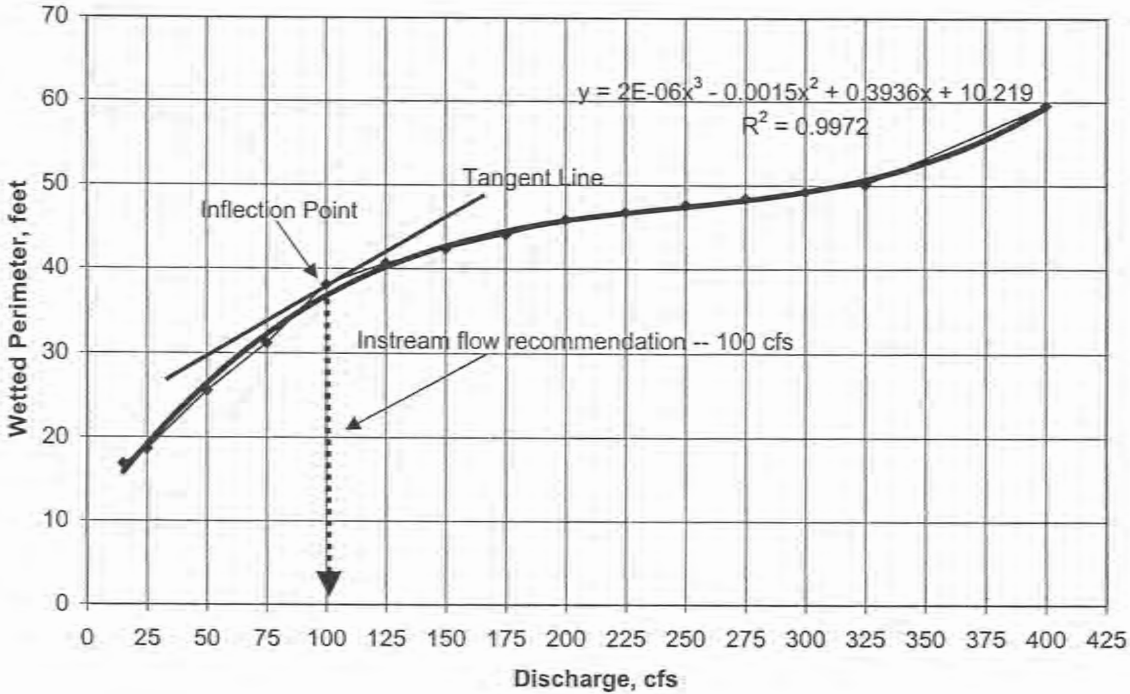


Figure 3
Developing an Instream Flow Recommendation using the Technique of Bovee (1982)

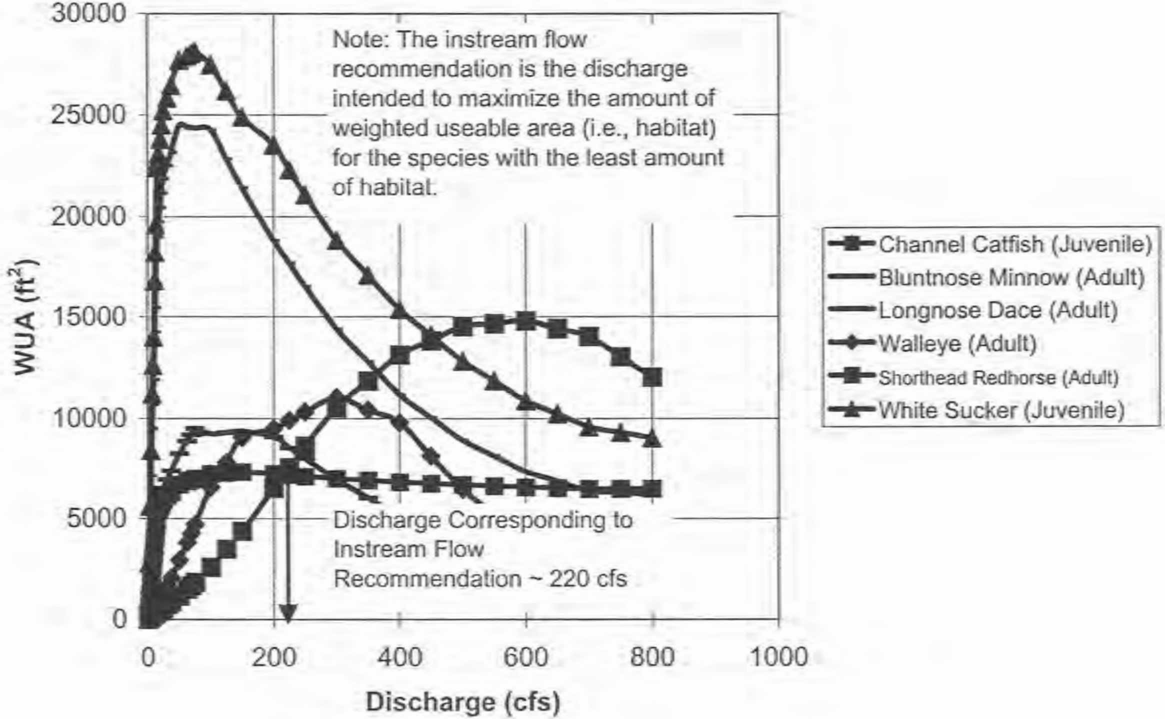


Figure 4
April/May Spawning
Weighted Usable Area Versus Discharge for the Lisbon Study Site

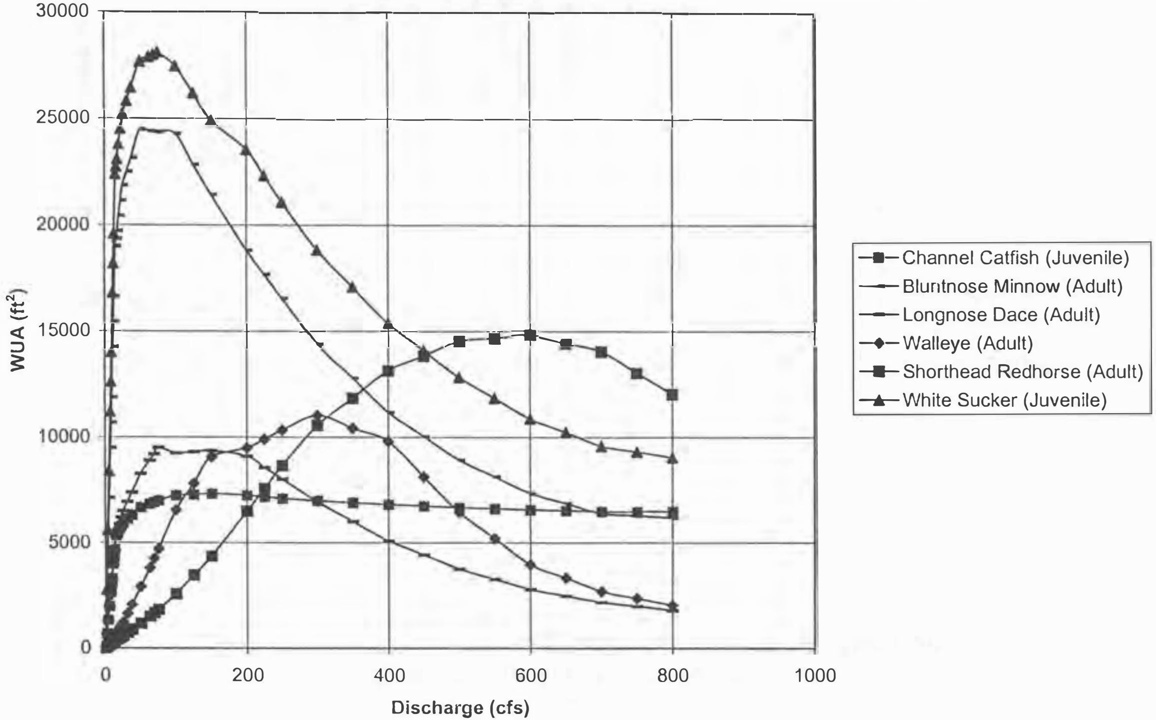


Figure 5
June Through March Nonspawning
Weighted Usable Area Versus Discharge for the Lisbon Study Site

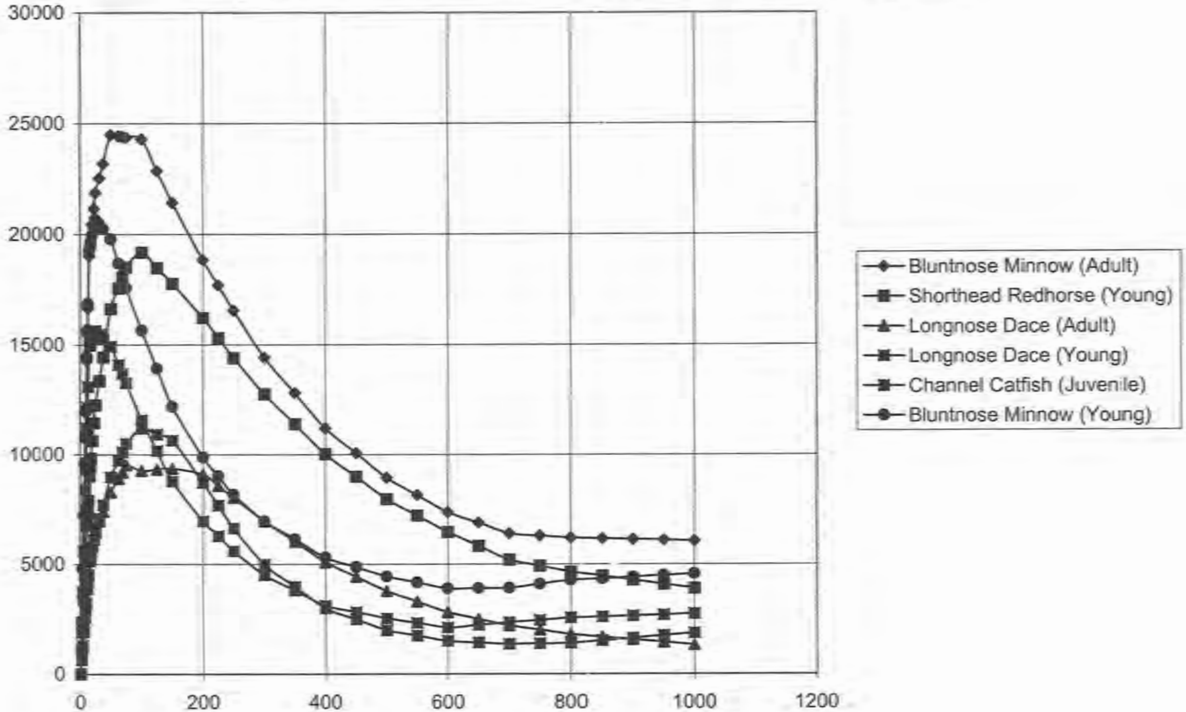
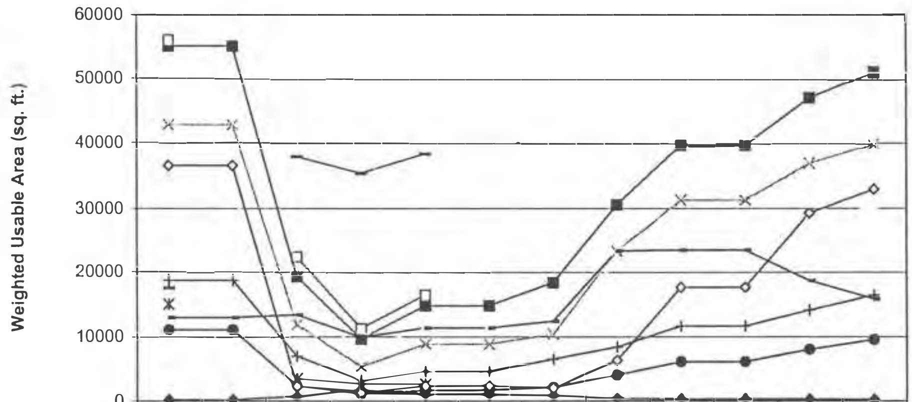


Figure 6
Red River -- Fargo Site
Habitat Time Series Based on Median Monthy Discharge



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Monthly Discharge (cfs)	207	208	722	1761	1047	1024	855	412	315	315	273	225
Bluntmose Minnow Adult	55149	55149	19339	9698	14866	14866	18402	30551	39716	39716	47082	51115
Bluntmose Minnow Young	31689	31689	15833	7703	11583	11583	14993	20991	26116	26116	28617	30153
Shorthead Redhorse Young	42903	42903	11895	5315	8854	8854	10419	23330	31237	31237	36908	39905
Shorthead Redhorse Adult (Spawing)	15094		3473	2658	2651							
Longnose Dace Adult	11088	11088	2335	1083	1662	1662	2155	4053	6121	6121	8039	9563
Longnose Dace Young	18777	18777	6998	3199	4603	4603	6504	8438	11668	11668	14163	16470
Channel Cat Juvenile (Nonspawning)	13037	13037	13460	9894	11384	11384	12434	23361	23514	23514	18690	15864
Channel Cat Juvenile (Spawning)	17559		37957	35398	38405							
Walleye Adult	36596	36596	2312	1270	2365	2365	2026	6326	17677	17677	29258	32927
White Sucker Juvenile (Spawning)	56133		22430	11331	16533							

PROSPECTS FOR REINVESTMENT IN SIERRA NEVADA HEADWATERS

Richard Kattelmann[1]

ABSTRACT

The headwaters of the Sacramento / San Joaquin River system have been extensively developed to provide water for California's farms, cities and hydroelectric facilities. Despite the enormous economic value of water generated in the Sierra Nevada that is used in the lowlands, virtually none of the water-related revenue is shared with the headwaters. A group of rural counties has been promoting the idea that downstream beneficiaries of high-quality water have a responsibility to reinvest some of that benefit in the source areas. New institutional mechanisms are being explored that could return some of the economic value of exported water and hydroelectric power back to Sierra Nevada watersheds. A growing awareness of links between environmental conditions in the headwaters and water quality downstream is generating further interest in lands that contribute water to the tributaries of the Sacramento and San Joaquin Rivers. Investment from downstream water users is a logical means of financing watershed protection and rehabilitation.

INTRODUCTION

The notion of shared rivers in California generally implies sharing an economically-scarce good between competing users. The main conflicts in sharing water are often portrayed as North vs. South, California vs. other Colorado River users, urban vs. agriculture, environmental uses vs. economic uses, irrigation district vs. irrigation district, state vs. federal, junior vs. senior water-rights-holders, etc. Most of the conflicts and the sharing arrangements occur at the downstream end of the river systems. Until recently, there has been little discussion of upstream

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vs. downstream interests or source areas vs. consumption areas. However, residents and managers of the headwaters of many California rivers have begun to exercise a perhaps-belated concern about water resources in the source regions of the uplands.

Throughout the world, mountain ranges are recognized as the primary water source for the populated, irrigated plains and valleys of the lowlands (e.g., Bandyopadhyay, et al., 1997). The hydrologic situation in California follows this generality, where the mountain regions receive far more precipitation and generate far more runoff than the low-elevation parts of the state (e.g., Kahrl, 1978; California Department of Water Resources, 1998). The principal mountain range of California, the Sierra Nevada, extends for about 400 miles on the east side of the state and produces on average about 20 million acre-feet of runoff (28 percent of the total for the state). The rivers of the Sierra Nevada have been extensively developed to provide water for irrigation, cities, and hydroelectric generation. Widespread public concern about the consequences of resource development in the range led to a comprehensive assessment of environmental conditions of the Sierra Nevada (Erman, et al., 1996). Evaluations of streams, watersheds, riparian areas, and aquatic biology found that a century and a half of disturbance has resulted in dramatically altered hydrologic regimes and impaired aquatic ecosystems (Kattelmann, 1996; Moyle and Randall, 1996).

WATER AND WEALTH FROM THE SIERRA NEVADA

As the streams and rivers of the Sierra Nevada were developed, first for hydraulic mining and then for hydropower, irrigation, and urban supply, the end-users were well downstream of the point of diversion. Today, the primary beneficiaries of Sierra Nevada water are farmers in the Central Valley and urban consumers of water and electricity far from the mountains. The economic values of the diverted water are often highest hundreds of miles from their source. Aggregation of estimated values of all water exported from the Sierra Nevada yields a total value of about

$1.2 billion per year (Stewart, 1996). However, virtually all of that value accrues outside of the mountain range. Operation and maintenance of the hydro-technical structures requires relatively little labor, and property taxes on the facilities represent a small fraction of the revenue generated (Stewart, 1996). Unlike other natural resources of the Sierra Nevada, water for export and hydroelectric generation supports few jobs and circulates minimal revenue through rural businesses and communities (Sierra Business Council, 1996).

The export of the water wealth of the Sierra Nevada has been highly contentious since the Owens Valley "water wars" of the 1920s(e.g., Sauder, 1994; Walton, 1992). Because California water law allows water to be appropriated for distant uses without any financial compensation to the source area, there has been little legal action to challenge the financial disconnection between source and use. Nevertheless, political activity in this matter seems to be growing. Community leaders of some economically-depressed rural areas have been promoting the concept that the geographic areas that produce water should be entitled to some financial benefit. Several mountain counties have been exploring the idea that the "areas of origin" of water are entitled to a greater economic and legal stake in "their" water that is exported for distant uses.

A task force within the Regional Council of Rural Counties was established in December 1995 to protect water rights in the area of origin in rural parts of California. The group was initially formed in reaction to a proposal before the State Water Resources Control Board that could have appropriated additional water from water-source areas without any compensation. Even though the proposal sought water rights to unappropriated water for fisheries and environmental enhancement of the Sacramento-San Joaquin Delta, the water would have been considered "abandoned" before it entered San Francisco Bay and could have been pumped into the State Water Project and delivered to users in southern California. Having recognized that substantial downstream demands exist for the remaining water supplies of the rural uplands, the task force is attempting to ensure that water-source counties receive some financial return from providing additional water.

At least one county has been able to market surplus water stored in a county-controlled reservoir. The Yuba County Water Agency has sold thousands of acre-feet of water from its New Bullards Bar Reservoir to the state Drought Water Bank in the 1980s and in 1997 (Martin, 1998). Like many rural counties, Yuba County has few other economic options and desperately needs the revenues from selling the water. However, other water users are contesting Yuba County's legal right to sell water that it has not previously put to "beneficial use". A pending decision by the State Water Resources Control Board may resolve some of the issues regarding rural claims on water.

RESTORATION AND REINVESTMENT

As the degradation of Sierra Nevada river basins documented by the Sierra Nevada Ecosystem Project (e.g., Erman, et al., 1996; Kattelmann, 1996; Moyle and Randall, 1996), becomes more widely known and accepted, public interest in rehabilitating headwater areas continues to grow. Recognition of degraded watersheds and streams has led to a variety of restoration programs for riparian and aquatic habitat. Many of the past efforts on watershed rehabilitation in the Sierra Nevada have focused on reducing sediment and channel degradation related to timber harvests and forest roads. Unfortunately, funding for watershed rehabilitation projects on national forest lands has been declining in recent years. Decreases in receipts from timber sales have severely limited finances for road maintenance and obliteration. Similarly, riparian areas that have lost vegetation and bank stability from decades of overgrazing continue to erode with little hope of adequate financing for stabilization efforts, such as fencing and revegetation. Restoration of quasi-natural flow regimes has been limited to a few high-profile adjustments of water rights (e.g., Mono Lake), but there is tremendous potential to improve aquatic conditions in some streams by fine-tuning reservoir operations.

In November 1996, California voters approved ballot proposition 204, the Safe, Clean, Reliable Water Supply Act. The 63% margin of approval was a clear signal that the state's voters were concerned about their water supply and willing to pay for improvements in the state's water system. Among the provisions of the Act that deal with the Sacramento-San Joaquin Delta is the creation of a grant program to finance some pilot programs of watershed rehabilitation in tributaries to the Delta. Although funding of this portion of the Act is less than two percent of the Act's total budget, its inclusion acknowledges both the role of upstream water sources in Delta issues and potential benefits of watershed management. Another major bond proposal, intended for the November 1998 ballot, which included substantial funding for watershed management in the Sierra Nevada, was defeated by the state legislature in late-August 1998 over conflicts concerning dam-engineering studies and canals in southern California.

The dual concerns about the lack of financial returns to water-source areas and needs to restore damaged watersheds may provide an opportunity to establish a long-term funding mechanism for watershed management in the Sierra Nevada. The concept of surcharges on delivered water or taxes on diverted water to finance watershed restoration and maintenance is gaining some consideration by the public and policy makers. Many aspects of water-use fees in California were explored by Allen (1992) and Kattelmann and Dunning (1996). Such fees were considered as a means to offset losses of revenue to forest-dependent communities from reductions in timber harvest on national forest lands (Ruth, et al., 1994). Water taxes applied to some form of watershed trust fund would provide a direct means of reinvesting some of the benefits of high-quality water back into the source areas.

An important precedent in California is the surcharges on water and power produced by the federal Central Valley Project that were authorized by The Central Valley Project Improvement Act. The general surcharges are capped at \$6/AF for agricultural users and \$12/AF for municipal and industrial users. Water contractors served by the Friant Division may be assessed an additional surcharge (U.S. Bureau of Reclamation, 1997). These fees finance a restoration fund that is used to implement habitat and watershed restoration measures required by the Act.

Despite heated controversy over proposed increases in the cost of delivered water, most studies have found that the demand for water in most applications tends to be inelastic with respect to price (e.g., California Department of Water Resources, 1998). For both urban and agricultural use, demand drops by smaller proportions than the proportional increase in price. Water taxes of a few dollars per acre-foot are small in comparison to the average prices for municipal water supply of more than $500/AF in the San Francisco Bay Area and Metropolitan Water District of Southern California. Prices for agricultural water are highly variable, with averages in different regions of the state ranging from $10/AF to $370/AF (California Department of Water Resources, 1998). Water costs as a proportion of total production cost are also quite variable for different crops and would influence the relative impact of taxes on water.

Because the State of California holds all (non-federal) water in trust for the public, imposition of taxes on water for the purpose of improving water supplies and water quality should meet little legal challenge. Political challenges would be another matter. There is strong anti-tax sentiment in California, regardless of the merits of a particular proposal. When a tax is mentioned in association with water, which has long been regarded as a free good (or nearly so), political opposition is likely to be intense. However, the public may be slowly accepting the concept of use fees (or taxes) that have a direct association with some product or service. As more people learn about benefits of watershed management in the headwaters of their water supply, support for water taxes should increase. However, the theoretical benefits cannot be accepted solely on faith. Measurable reductions in sediment, improvements in water quality, and benefits in aquatic habitat will need to be demonstrated before there is widespread public support for reinvestment in watersheds.

SUMMARY AND CONCLUSIONS

Legal and economic institutions in California have not recognized the hydrological and ecological continuity of rivers. However, residents of the source areas of some of the state's primary water supplies are objecting to the lack of economic return from water produced in their area and lack of interest from downstream users in maintaining favorable conditions for producing the water they depend on. Various proposals for some form of tax on water that would finance watershed management in the headwaters are being discussed. However, before there will be widespread support for this idea, water users must be convinced that such investment will yield a worthwhile improvement in their water supply. Basin-wide watershed management efforts offer a means of involving downstream interests in concerns about landscape conditions upstream. The potential for reinvestment in the source areas will depend on the level of concern and cooperation generated from the initial efforts now underway.

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REFERENCES

Allen, J., 1992. Liquid assets: the potential for water use fees. Manuscript prepared for the California Policy Seminar and Senate Office of Research, Sacramento.

Bandyopadhyay, J., J. C. Rodda, R. Kattelmann, Z. W. Kundzewicz, and D. Kramer, 1997. Highland waters – a resource of global significance. in: Messerli, B. and J. D. Ives (eds), Mountains of the World: A Global Priority, Parthenon, New York, pp. 131-155.

California Department of Water Resources, 1998. California Water Plan Update, Bulletin 160-98, Sacramento.

Erman, D. C. and 36 others, 1996. Sierra Nevada Ecosystem Project: Final Report to Congress. University of California-Davis, Centers for Water and Wildland Resources.

Kahrl, W., 1978. California Water Atlas. California Governor's Office of Planning and Research, Sacramento.

Kattelmann, R., 1996. Hydrology and water resources. Sierra Nevada Ecosystem Project: Final Report to Congress. University of California-Davis, Centers for Water and Wildland Resources, vol. II, chapter 30, pp. 855-920.

Kattelmann, R. and H. Dunning, 1996. Diversion taxes on water to finance watershed management. in: McDonnell, J. J., J. B. Stribling, L. R. Neville, and D. J. Leopold (eds), Watershed Restoration Management: Physical, Chemical, and Biological Considerations. American Water Resources Association, Herndon, VA, pp. 237-244.

Martin, G., 1998. Water-rich Yuba County fights for its liquid asset. San Francisco Chronicle, May 25, 1998, pp. 1, 13.

Moyle, P. B. and P. J. Randall, 1996. Biotic integrity of watersheds. Sierra Nevada Ecosystem Project: Final Report to Congress. University of California-Davis, Centers for Water and Wildland Resources, vol. II, chapter 30, pp. 975-985.

Ruth, L. and 16 others, 1994. Conserving the California Spotted Owl: Impacts of Interim Policies and Implications for the Long term. Report of the Policy Implementation Planning Team to the Steering Committee for the California Spotted Owl Assessment, Report 33, Wildland Resources Center, University of California, Davis.

Sauder, R. A., 1994. The Last Frontier: Water Diversion in the Growth and Destruction of Owens Valley Agriculture. University of Arizona Press, Tucson.

Sierra Business Council, 1996. Sierra Nevada Wealth Index: Understanding and Tracking Our Region's Wealth. Sierra Business Council, Truckee, CA 48 p.

Stewart, W. C., 1996. Economic assessment of the ecosystem. Sierra Nevada Ecosystem Project: Final Report to Congress. University of California-Davis, Centers for Water and Wildland Resources, vol. III, chapter 23, pp. 973-1073.

United States Bureau of Reclamation, 1997. Central Valley Improvement Act proposal on the San Joaquin River. Mid Pacific Region, Sacramento.

Walton, J., 1992. Western Times and Water Wars: State, Culture, and Rebellion in California. University of California Press, Berkeley.

DEVELOPMENT OF A REGIONAL INTEGRATED WATER RESOURCE PLAN FOR THE LOWER RIO GRANDE VALLEY, TEXAS

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ABSTRACT

This plan for the Lower Rio Grande basin management is designed to meet competing needs. The development of this comprehensive plan has considered demand-side and supply-side management options, an open and participatory decision-making process, the impacts of environmental concerns, and the multiple institutions concerned with water policy. Historically, approximately 85% of the 1,300,000 acre-feet of annual consumption has been in the agricultural production through irrigation. Cameron, Hidalgo, and Willacy Counties are currently experiencing high population growth rates with the combined population expected to increase from approximately 900,000 persons in 2000 to approximately 2,100,000 persons in the year 2050. The quantity of developed water readily available in Falcon-Amistad Reservoir System to the Lower Rio Grande Valley is essentially equal to the current usage level. Most of the adjudicated water rights are held by 28 irrigation districts that supply water diverted from the Rio Grande to both irrigators, municipalities, and water supply corporations through open canals and closed conduits with frequently conflicting demand patterns. Numerous meetings with the Lower Rio Grande Valley Development Council Policy Management Committee, local citizens, and stakeholder groups, under the guidance of a professional meeting facilitator, were included in an effort to achieve the maximum benefit from an open and participatory development process. The Lower Rio Grande Valley is a highly sensitive environmental area with major concerns for water quality as well as for endangered and threatened species, plant communities, fish communities, and animal populations. The management of water currently involves the irrigation districts, municipalities, water supply corporations, Texas Natural Resource Conservation Commission Watermaster, and International Boundary and Water Commission.

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DESCRIPTION OF THE PLANNING AREA

The planning area for the Lower Rio Grande Valley Integrated Water Plan consists of Cameron, Hidalgo and Willacy Counties as illustrated on Fig. 1. The Lower Rio Grande Valley, which developed in the twentieth century as a major agricultural center, is now experiencing one of the nation's highest population growth rates. This population growth causes a stronger competition for the finite quantity of water, primarily from Falcon-Amistad Reservoir System, that is currently available to the Lower Rio Grande Valley.

The vast majority of the water rights in the Lower Rio Grande Valley are held by the Irrigation Districts for use in the agricultural production. Approximately, eighty five percent of the current water consumption in the Lower Rio Grande Valley is used in the agricultural sector. Under the existing agreements, municipal and industrial water demands will always be protected and given a priority over agricultural demands. In other words if the quantity becomes limited, the water supply management rules are designed in such a manner to meet the municipal and industrial water demands and limit the amount available for lower priority uses.

Working within this framework of an integrated water resource plan, the following key goals were established for this study.

- Development of options for more effective, efficient and environmentally-sound ways to supply water to the region
- Review of the roles and potential working relationships among regional organizations involved in managing the supply of water
- Development of a Drought Management Plan

The recent drought conditions have made everyone aware of the significant impacts a dwindling water supply can have on a region. This integrated water resource plan was undertaken during the early stages of the drought in recognition of the following:

- Only a specific amount of water is currently available to the Lower Rio Grande Valley.
- The management of the available water is critical to the continued development of Cameron, Hidalgo, and Willacy Counties.

SOCIAL ECONOMIC CONDITIONS

The Lower Rio Grande Valley has received a lot of national attention as the area transitions from a predominately agricultural region to a center with increasing

FIG.1 Lower Rio Grande Valley Region

manufacturing, trade, and retail. In January of 1998, USA Today identified three of the nation's top 10 fastest-growing metro areas as located along the Mexico border in South Texas. These were Laredo (2nd), McAllen (3rd), and Brownsville (10th). For example, the McAllen metro area, with an estimated 29.2% increase in its population from 1990 to 1996, leaped from 77th place to the nation's 3rd in terms of growth rate. Brownsville metro area, with an estimated 21.1% increase in its population, also leaped from being ranked 119th to being ranked 10th in the nation. The article noted that in these areas, where many jobs are low paying, thousands of immigrants have nevertheless settled, attracted by the communities' strong cultural and family tie with Mexico.

Agribusiness has been a major contributor to the economy of the Lower Rio Grande Valley. All too often, it requires a natural disaster or unfavorable market forces to boost agriculture and agribusiness into the forefront of the minds of the public. As generations of Americans have become further removed from their agricultural roots, it becomes all too convenient to take for granted the contribution that agribusiness provides to the economy and well-being of rural and urban citizens alike.

The production segment of the agribusiness industry continues to play an important role in the area's economy. The Lower Rio Grande Valley has a wide variety of agricultural production, ranging from the traditional to the non-traditional. The region is home to more than 1,600 farms and ranches that produce everything from beef cattle to bees to palm trees to peanuts. If you consider typical harvesting dates, there doesn't appear to be any off-season for the Rio Grande Valley agriculture. Approximately 57%, 66%, and 68% of the lands in Cameron, Hidalgo, and Willacy counties, respectively, are used for agricultural production. According to the 1993-1998 "Annual Increment Report," agricultural commodities produced in the Lower Rio Grande Valley had an average annual value of $528.68 million. The annual value of agricultural commodities and the annual payroll of agribusiness firms was recently estimated at $1.4 billion with an estimated impact of more than $3.4 billion.

Agribusiness is indeed big business in the Lower Rio Grande Valley. Agribusiness accounts for 30 percent of the employment, 24% of annual payrolls, and 19% of all business establishments in the Rio Grande Valley. The impact of agribusiness will continue to expand across both new and existing horizons as the industry adopts more-efficient production, processing, manufacturing, and marketing practices. The Lower Rio Grande Valley stands poised to lead the state in agribusiness due to its geographic location, proximity to and excellent relationship with Mexico, its developing workforce and outstanding local leadership.

FALCON-AMISTAD RESERVOIR SYSTEM

The Falcon-Amistad Reservoir System and two downstream channel diversion dams (Anzalduas and Ratamal) are operated as a system by the International Boundary and Water Commission (IBWC) to regulate streamflows in the Lower Rio Grande. Several dams have been constructed on the upper reaches of the Rio Grande, and many other dams are located on tributaries in both Mexico and the United States. The Falcon-Amistad Reservoir System provides primary storage to meet the water supply needs of the Lower Rio Grande Valley. Reduction of flood flows along the Lower Rio Grande is also a primary objective of the system operation.

In terms of either total capacity or conservation storage capacity, Amistad Reservoir is the second largest reservoir in Texas. Falcon is the fifth largest reservoir in Texas. The two-reservoir storage system has a combined total conservation storage capacity of 5,800,000 acre-feet. An additional storage capacity of 2,1000,000 acre-feet below the top of the spillway gates in the two reservoirs is used for flood control.

Using a reservoir operations model, the current annual dependable yield has been estimated to be 1,194,000 acre-feet per year for the United States and 992,000 acre-feet per year for Mexico. This annual dependable yield is based on historical hydrologic conditions. Additional hydrologic analysis are underway to improve the firm yield estimate by: 1) reviewing and improving the estimate of the historical reservoir inflows, 2) accounting for the changes to the historical inflows due to tributary reservoir development, and 3) extending the hydrologic record to cover more of the 1994-1998 drought.

The Falcon-Amistad Reservoir System is owned and operated jointly by the Mexican and United States Sections of the IBWC under the Treaty of 1944. The system is operated to store, conserve, and regulate the waters of the Rio Grande and to generate hydroelectric energy. During normal non-flood periods, releases from conservation storage are made as necessary to meet water supply demands. Hydroelectric power is generated almost entirely by water released for downstream water supply or spills to evacuate the flood control pools.

Most of the water used in the Lower Rio Grande Valley is regulated by the Falcon-Amistad Reservoir System. Most of the water from these two large reservoir projects is diverted form the river below Falcon Dam. To the extent possible, the Amistad conservation pool is maintained at fairly constant high storage levels, with most of the pool level fluctuations occurring in Falcon Reservoir. In the United States, water users divert water from the river at hundreds of locations throughout the entire length of the lower Rio Grande. The majority of the diversions are made by irrigation districts that supply water to municipalities and industries as well as agricultural users. The Watermaster's Office of the Texas Natural Resource Conservation Commission (TNRCC) administers the water rights allocation system for use of water in Texas.

Allocation of the water resources of the Rio Grande Basin is governed by two international treaties and, within the United States, by two interstate compacts. Allocation of the Texas share of the water to irrigators, cities, and other water users is based on state law.

The United States share of the water supply in the Falcon-Amistad Reservoir System is used to meet the demands in the lower basin as administered by the TNRCC in accordance with the water rights system. Irrigation districts, individual farmers, and cities communicate their water needs directly to the TNRCC Rio Grande Watermaster Office, with headquarters in McAllen, Texas which in turn schedules releases from the Falcon-Amistad Reservoir System with IBWC.

The Watermaster makes daily requests to the IBWC for releases from the reservoirs. In determining Falcon Reservoir releases for the Lower Rio Grande Valley, the Watermaster Office considers the quantities of water requested by all users and their diversion locations, potential channel losses and gains, watershed runoff and tributary inflows, channel and bank storage, waters stored by weirs, and storage at Anzalduas Dam. Some water users near the coast are more than 200 river miles below Falcon Dam. Requests for releases are made five to seven days in advance to allow for travel time.

Using the diversion information and IBWC reported available storage, the Wastermaster allocates the storage in the Falcon-Amistad Reservoir System to each of the water rights each month. Each water right is limited by both its permitted annual diversion amount and the water available in storage to supply the diversion.

Each month, the IBWC informs the TNRCC Watermaster of the total volume of water in storage in the Falcon-Amistad Reservoir System allocated to the United States. The Watermaster Office distributes the storage to all the water rights accounts. The allocation procedure followed by the Wastermaster is based on the steps outlined below.

1. From the total amount of usable United States water stored in the Falcon-Amistad Reservoir System conservation pools, the first step consists of reserving 225,000 acre-feet for domestic, municipal and industrial uses. This is called the municipal pool. Domestic, municipal, and industrial uses are given highest priority by deducting the municipal pool as the first step in the monthly reallocation.

2. From the remaining storage, the total end-of-month account balances for all irrigation and mining rights are deducted.

3. Next, available water is allocated to an operating reserve that normally fluctuates between 380,000 acre-feet and 275,000 acre-feet, depending on the amount of water in storage. If the amount of water available is between 275,000 acre-feet and 150,000 acre-feet, that amount is allocated to the operating reserve. However, if the balance available for the operating reserve happens to fall below 150,000 acre-feet, deductions are made from the irrigation and mining accounts as necessary to provide 150,000 acre-feet for the operating reserve. The operating reserve provides for loss of water by seepage and evaporation, adjustments required as the United States-Mexico water ownership computations are finalized each month, and emergency requirements.

4. Any remaining water in storage is allocated among all the irrigation and mining rights accounts. The storage is basically allocated in proportion to annual diversion rights, except the Class A rights are multiplied by a factor of 1.7 to allow them a greater storage allocation than Class B rights. Other provisions include limiting each storage allotment to not exceed more than 1.41 times its authorized diversion right. If an irrigation right is use for two consecutive years, its storage amount is reduced to zero.

COORDINATION WITH IBWC

During the development of this study, a number of contacts and coordination meetings were conducted with the IBWC. Much of the coordination has focused on developing a better understanding of the IBWC methodology used in the monthly water accounting procedures.

The analysis of the IBWC monthly water accounting data for the 1945-1996 period was prepared and reviewed with IBWC. This step was extremely important in establishing an official set of hydrologic data for the Falcon-Amistad Reservoir System that can be used to measure the combined impacts of developments that have occurred in the total watershed during the existence of the reservoirs and to evaluate potential changes in basin reservoir operating procedures, in both the United States and Mexico, that will impact the quantity of water available from the system in the future.

COORDINATION WITH MEXICO

Representatives from the Lower Rio Grande Valley have been joining with representatives from Mexico in meetings arranged by IBWC for a number of years. A meeting was held in February 1998 to discuss the reservoir operation models. A meeting was also held in Monterrey, Mexico on June 16 and 17, 1998 to discuss a number of issues of concern to both countries. Presentations were made by United States representatives on the initial results of Falcon-Amistad Reservoir System modeling work that was underway at that time. The representative from Mexico also presented optimization studies of the Mexico reservoirs in the Rio Conchos watershed. The Rio Conchos is a major tributary to the Rio Grande in Mexico.

One result of the above meeting was the scheduling of another meeting to discuss in greater detail the methodologies and hydrologic data utilized by each country in the development of the reservoir system models. That meeting occurred in McAllen, Texas on July 10, 1998. Representatives of both the United States and Mexico presented detailed descriptions of their country's development of the reservoir model system.

POPULATION PROJECTIONS

The State of Texas most-likely scenario populations adjusted for known municipal changes for the Lower Rio Grande Valley Integrated Water Resource Plan study area have been summarized in Table 1. The total 1990 three-county population was 661,370. Of the total, 58.0 percent resided in Hidalgo County, 39.3 percent in Cameron County, and 2.7 percent in Willacy County. In Hidalgo County, 68.3 percent of the population resided in the cities with the remaining 31.7 percent representing the rural county population. For Cameron County, 76.6 percent of the population resided in the cities with the balance, 23.4 percent, local rural county area. In Willacy County, 59.6 percent of the population is located in the cities while the remainder, 40.4 percent, representing the rural county population.

For Cameron County, the most-likely population projection is based on the assumption that the migration rate will continue at the 1980-1990 through 2000. The migration rate is then assumed to decline over the 2000-2050 period. If the migration rate remained at the 1980-1990 level throughout the planning period, the projected population for the year 2050 would be 794,045, or approximately 22.4% greater than the most-likely population scenario. If the assumed reduction in the immigration into the U.S. from Mexico does not occur, then the total population could be significantly increased and, therefore, the total municipal water demand.

Table 1. Most Likely Scenario of Population Projection for Counties in Planning Area (1990-2050)

County	1990	2000	2010	2020	2030	2040	2050
Municipal	199,317	262,690	309,586	423,258	451,926	451,926	482,386
County Res.	60,803	72,483	93,010	116,014	127,655	158,705	166437
Total Cameron	260,120	335,173	402,596	473,775	550,913	610,631	648,823
Municipal	262,019	378,774	459,902	553,272	658,502	761,592	881,694
County Res.	121,526	166,225	234,589	305,319	395,902	467,028	522,603
Total Hidalgo	383,545	544,999	694,491	858,591	1,054,404	1,228,620	1,404,297
Municipal	10,554	12,674	14,231	15,541	16,436	17,076	17,741
County Res.	7,151	7,484	8,354	9,089	9,579	9,915	10,048
Total Willacy	17,705	20,158	22,585	24,630	26,015	26,991	27,789
Total Regional	661,370	900,330	1,119,672	1,356,996	1,631,332	1,866,242	2,080,909

For Hidalgo County, the most-likely population projection is also based on the assumption that the migration rate will continue at the 1980-1990 rate through 2000 and then decline over the 2000-2050 period. If the migration rate remained at the 1980-1990 level throughout the planning period, the projected population for the year 2050 would be 2,113,180, or 50.5% greater than the most-likely population scenario. The assumed decline in the immigration rate represents a major decrease in the migration rate.

For Willacy County, the most-likely population projection is the same as that projected for zero migration rate. The data indicate that, if the 1980-1990 migration rate is extended through the planning period, lower population projections would be obtained. This condition must indicate that a negative migration rate occurred in Willacy County during the 1980-1990 period.

The number of citizens residing in the counties outside of the municipalities represents a significant percentage of the total county population. Summarized in Table 2 are the changes in these percentages projected for the most-likely scenario populations. Both Cameron and Hidalgo Counties show an increase in the percentage over the 60-year planning period, while Willacy County shows a decrease in the percentage. In terms of actual numbers, Cameron County is projected to have approximately 200,000 citizens outside the municipalities by the year 2050 and Hidalgo is projected to have approximately 575,000 citizens outside the municipalities by the year 2050. These populations equate to a significant water requirement and raise significant issues for the County governments and the water supply corporations to address.

Table 2. Percent of County Population Outside of Municipalities

	1990	2020	2050
Cameron	23.4%	24.5%	25.9%
Hidalgo	31.7%	39.1%	41.0%
Willacy	40.4%	36.9%	36.2%

PROJECTED WATER REQUIREMENTS

The total regional water requirements are summarized in Table 3. The total domestic requirements increase to slightly more than 400,000 acre-feet per year in the year 2050. The rate of consumption is approximately one third of the yield of the Falcon-Amistad Reservoir System. Even with domestic consumption at this increased level, a significant amount of water remains available for other uses including agricultural irrigation.

The projections are based on the important assumption that certain water conservation and water management programs will be implemented and that urban development will occur. A primary assumption associated with the definition of municipal water conservation is that these levels of saving are likely to occur from both market forces and regulatory requirements. The typical plumbing fixtures and appliances available for purchase are noticeably more water-efficient than those sold in earlier decades. The availability of water-efficient landscaping in the marketplace and improved landscaping practices are changing outdoor water uses. Better public education on efficient indoor and outdoor water uses and pricing "signals" from the marketplace is also changing consumer behavior.

In addition to the market-type forces, a driving force underlying the expected municipal water conservation savings is the likely effect produced by the State Water-Efficient Plumbing Act passed in 1991. Not only are these potential water savings from the implementation of the Act substantial, but they are also economically sound from a cost-saving perspective, do not require day-to-day behavior changes by the consumer, affect the larger year-round base water use, and will occur with a relatively high degree of predictability.

On the agricultural side, the savings due to on-farm conservation are assumed to

Table 3. Projected Lower Rio Grande Valley Water Requirements, Below-normal Weather, Expected Case (Values in Acre-Feet)

	2000	2010	2020	2030	2040	2050
Cameron County Municipal	55,000	62,058	68,669	79,947	84,540	89,974
Cameron County Citizens	11,448	13,544	15,854	17,016	20,622	21,626
Hidalgo County Municipal	77,280	88,456	99,623	115,707	132,075	151,887
Hidalgo County Citizens	25,136	31,007	37,620	47,894	55,453	62,051
Willacy County Municipal	6,834	7,407	7,807	8,192	8,449	8,753
Willacy County Citizens	1,190	1,254	1,283	1,320	1,333	1,317
Total Domestic Demand	176,888	203,726	230,856	270,076	302,472	335,608
Domestic Transmission Losses @ 20%	35,378	40,745	46,171	54,015	60,494	67,122
Total Domestic Requirement	212,266	244,471	277,027	324,091	362,966	402,730
Agricultural Demand	1,053,863	761,507	699,912	623,342	556,003	491,062
Agricultural Transmission Losses	295,521	217,238	203,404	186,027	170,788	156,031
Total Agricultural Requirement	1,349,384	978,745	903,316	809,369	726,791	647,093
Manufacturing	4,975	5,506	5,878	6,169	6,731	7,292
Steam Electric Power Cooling	4,500	5,000	5,000	5,000	5,000	5,000
Mining	701	686	717	754	796	850
Livestock	2,363	2,363	2,363	2,363	2,363	2,363
Total Other Requirement	12,539	13,555	13,958	14,286	14,890	15,505
Total Water Requirement	1,574,189	1,236,771	1,194,301	1,147,746	1,104,647	1,065,328

be achieved. The basis of the analysis considers in-depth three key factors that should influence the total quantity of water required for irrigation in the Lower Rio Grande Valley in future years. These key factors are:

- Assumptions on the amount and general location of currently rural areas that will be converted to urban to accommodate the population increase
- Assumptions on the impact of metering irrigation water as well as an increase in the use of poly or gated pipe for on-field applications
- Assumptions on appropriate irrigation application rates based on projected crop mixes.

The potential impacts of urbanization of the irrigation requirements can be clearly seen traveling through the Lower Rio Grande Valley. This impact not only includes acres that are taken out of production by actual construction, but also limitations that are placed on agricultural practices due to its proximity to an urbanizing area. Summarized in Table 4 are the estimated current rural acres inside irrigation districts and the projected reductions in acres by decades that are anticipated to occur due to the urbanization of the Lower Rio Grande Valley. The Cameron County irrigation district rural acres are reduced by 27.4 percent during the planning period. Hidalgo and Willacy Counties' irrigation districts rural acres are reduced 52% and 1.7%, respectively. Obviously, the impact on the Hidalgo county irrigation districts is much greater than occurs in the other two counties.

Early on in the study it became apparent that one of the most promising areas for saving water within agriculture lay with the increased use of metering as well as poly or gated pipe. Metering, in lieu of pricing water on an estimated per acre basis, gives the producer and the irrigation district much better information on total water use, and when combined with some form of volumetric pricing, provides strong incentives for water conservation. Use of gated and poly pipe has increased significantly in the Valley in recent years and reduces seepage losses in conveying water from the lateral to the individual furrows. It can also reduce overall labor requirements, and it, if adequate head is available in the system, provides additional water savings over conventional furrow application with siphon tubes and dirt ditches.

Efficiency reported in the Lower Rio Grande Valley range from 10% to 44%. Consultation with several irrigation district managers revealed the opinion that although widespread use of metering and poly-pipe was possible, a third potential area that needed to be considered was the issue of system delivery pressure as well as the soil types. Differences among the various district's delivery systems and the resulting water delivery pressure (or head) as well as the presence of lighter soils in some areas made Valley-wide high use of these two techniques improbable. High levels of management were assumed possible only when metering and/or poly-pipe were in use as well as only in those areas in which

Table 4. Projected Rural Acres in Irrigation Districts Lost due to Urbanization

	Cameron County	Hidalgo County	Willacy County	Total
Current Rural Acres	265,745	396,611	36,906	699,262
Lost 2000 to 2010	15,656	35,858	209	51,722
Lost 2010 to 2020	16,524	39,362	176	56,062
Lost 2020 to 2030	17,909	46,969	117	64,995
Lost 2030 to 2040	13,885	41,791	81	55,737
Lost 2040 to 2050	8,868	42,136	32	51,037
Total	72,822	206,116	615	279,553

adequate head could be assured. As a result of this observation, the potential areas considered for improvement included the three components of use of metering, the use of poly or gated pipe, and the adoption of higher management levels at the field level were reduced.

The overall estimated reductions in water requirements that result from these assumptions are summarized in Table 5. The total savings are the additional amounts of water that would be required if the water conservation measures were not implemented and if the impacts of urbanization were not taken into account.

In the planning an integrated regional water system for an area as large as the Lower Rio Grande Valley, consideration should be given to the general distribution of the water demands. This information is needed to assist in the planning improvements to diversion pump stations, main delivery canals, transmission pipelines, and local and regional water treatment plants.

Table 5 Reductions in Water Requirements Due To Assumed Water Conservation Measures and the Impacts of Urbanization (Values in Acre-feet per Year)

Year	Domestic Water Conservation Savings	On-farm Water Conservation Savings	Urbanization Impact on Irrigation Water Requirements	Total
2000	8,900	0	0	8,900
2010	22,400	221,000	71,000	314,400
2020	40,100	201,000	153,000	394,100
2030	52,800	176,000	255,000	483,800
2040	64,700	153,000	345,000	562,700
2050	73,700	132,000	431,000	637,700

The impacts of the population increases on the domestic water requirements without the transmission losses for both the municipal and rural areas can be reviewed in Table 3. Several important facts can be determined from the data. By the year 2050 nearly twice as much demand will occur in Hidalgo County as in Cameron and Willacy Counties combined. Within Hidalgo County, approximately forty percent of the demand will be in the rural areas which will place a significant responsibility on the water supply corporations and the county government if no other institutional changes are made. In Cameron County, approximately twenty percent of the domestic demand in 2050 will occur in the rural area.

CONCLUSIONS

The Falcon-Amistad Reservoir System does not provide all the water requirements of the Lower Rio Grande Valley, but it does provide the vast majority of the water consumed. The projected domestic and other water requirements and the total water requirements are compared to the current estimate of the yield of the Falcon-Amistad Reservoir System, 1,021,514 acre-feet per year available to the study area, in Table 6. These water requirements are based on the assumptions that water conservation methods described above will be implemented and that the projected impacts of urbanization will occur.

Two important conclusions can be drawn from this comparison. First, the domestic and other water requirements will represent approximately forty percent of the estimated yield of the Falcon-Amistad Reservoir System during the year 2050. The TNRCC current operating rules for the Falcon-Amistad Reservoir System of providing a reserve for these demands and of recognizing a higher priority for these uses should continue to provide a high level of protection. The portion of the estimated yield of the Falcon-Amistad Reservoir System available to the Lower Rio Grande Valley is less than the projected total requirements throughout the planning period. Normally, a greater reserve for the total demand would be appropriate, but in the case of the Lower Rio Grande Valley, this is provided in the irrigation water which can be reduced under the operating rules.

Table 6.Comparison of Water Requirements and Supply

Year	Domestic and Other Water Requirements	Percent of Falcon-Amistad Reservoir System	Total Water Requirements	Percent of Falcon-Amistad Reservoir System
2000	224,805	22.0%	1,574,189	154.1%
2010	258,026	25.3%	1,236,771	121.1%
2020	290,985	28.5%	1,194,301	116.9%
2030	338,377	33.1%	1,147,741	112.4%
2040	377,856	37.0%	1,104,647	108.1%
2050	418,235	40.9%	1,065,328	104.3%

Second, the water requirement projections for both domestic and irrigation are based on a very proactive water conservation program as well as considering the impacts of urbanization on the irrigation demand. Because these activities will have a significant impact of the balance between the available supply and the requirements, an annual program to collect the basic data and monitor the changes is recommended.

COLORADO RIVER BASIN SALINITY CONTROL PROGRAM

1998 REVIEW

D. P. Trueman[1]

ABSTRACT

The Colorado River provides water for more than 18 million people and irrigation for more than 700,000 ha (1.7 million acres) of land. Recent salinities in the lower portion of the Colorado River are typically about 700 mg/L, but in the future may range between 600 and 1,200 mg/L depending upon the amount of water in the river system. Salinity damages in the United States portion of the Colorado River Basin are currently at $750 million per year and could exceed $1.5 billion per year if future increases in salinity are not controlled. Although salinity impacts cannot be eliminated, the Basin States[2] and federal government agreed to limit future increases through the adoption of salinity standards. In June 1974, Congress enacted the original Colorado River Basin Salinity Control Act. In 1993, the Inspector General concluded that the lengthy Congressional authorization process for Reclamation projects was impeding the implementation of cost-effective measures. In 1994, Reclamation conducted a public review of the program in response to the Vice President's call for a performance review of the federal government. In 1995, Congress authorized the Bureau of Reclamation to implement a competitive, basin-wide approach to salinity control and manage its implementation.

Reclamation has now completed three rounds of solicitations (requests proposals), ranked the proposals based on their cost and performance risk factors, and awarded funds to the most highly ranked projects. The cost of salinity control has been cut in half by this new flexible/competitive process.

OVERVIEW OF LAST 20 YEARS

The Colorado River provides water for more than 18 million people and irrigation for more than 700,000 ha (1.7 million acres) of land. The total annual salt load of

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[2] The seven Colorado River Basin States (Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming) are referred to as the "Basin States."

The Colorado River is about nine million metric tons per year (USDI, 1995). Salinity measurements observed in the lower portion of the Colorado River are typically around 700 mg/L, but may range between 600 and 1,200 mg/L depending upon the amount of water in the river system. About half of the present salt concentration in the river can be attributed to natural sources. Reservoirs and dams along the river system have all but eliminated the seasonal fluctuation of salinity, but water use by agriculture and other users has nearly doubled the natural salinity of the river. Based on an economic impact model (Lohman, et al., 1993) developed by the Milliken Chapman Research Group, salinity damages in the United States portion of the Colorado River Basin are currently at $750 million per year. These damages could exceed $1.5 billion per year if salinity is not controlled. The impacts mainly affect municipal, industrial and agricultural water users in the lower portion of the basin. Although salinity impacts cannot be eliminated, the Basin states and federal government agreed to limit future increases through the adoption of salinity standards. The standards and compliance with the standards are reviewed (CRBSC Forum, 1993) every 3 years by the Colorado River Basin Salinity Control Forum which represent the seven Basin States.

In June 1974, Congress enacted the Colorado River Basin Salinity Control Act (P.L. 93-320, 1974). This was the first of a series of laws in the evolution of the Salinity Control Program. Title II of the Act directed the Secretary of the Interior (through the Bureau of Reclamation) to complete planning reports on 12 future salinity control units and to proceed with construction of the Paradox Valley, Grand Valley, Crystal Geyser, and Las Vegas Wash Units. Congress allocated 75 percent of the program's cost to the federal government. This allocation considered the vast federal ownership of land in the basin and its relative contribution to the salinity problem. In 1984, Congress adjusted this allocation down to 70 percent. The remainder of the program's cost is paid from a surcharge on power sold from Reclamation hydropower facilities in the basin.

Early in the 1980's, Reclamation completed studies on two, new, cost-effective units. In October 1984, the original Salinity Control Act was amended (PL. 98-569, 1984) to authorize Reclamation to construct these two additional units. At the same time, the United States Department of Agriculture (USDA) had completed preliminary studies on how they might assist the Salinity Program with on-farm, irrigation improvements. The 1984 amendments authorized the USDA to cost share onfarm salinity control practices with farmers. Unlike the unit-specific authorities provided to Reclamation, the 1984 Act allows the USDA broad authority to implement controls anywhere in the Colorado River Basin. The Department of the Interior's Inspector General would later find this kind of basin-wide approach would improve Reclamation's program.

PROGRAM REVIEW

By 1993, Reclamation had gained from its experience with the program and identified new and innovative opportunities to control salinity, including cooperative efforts with the USDA, Bureau of Land Management, and private interests, which would be very cost-effective. However, these opportunities could not be implemented because they were not specifically authorized by Congress. The Inspector General's audit report (USDI, 1993) noted the Salinity Control Act directed "the Secretary shall give preference, to implementing practices which reduce salinity at the least cost per unit of salinity reduction." The Inspector General concluded that the Congressional authorization process for Reclamation projects impedes the implementation of cost-effective measures by restricting the program to specific, authorized units (specific areas).

The Inspector General recommended that Reclamation seek changes in the Salinity Control Act to simplify the process for obtaining Congressional approval of new, cost-effective salinity control projects. Specifically, the Inspector General recommended Reclamation seek authorities similar to those provided to the USDA in the 1984 amendments to the act, wherein the USDA was empowered with programmatic planning and construction authority. The USDA has only to submit a report to Congress and wait 60 days before it may proceed if Congress does not object. In contrast, Reclamation was required to seek approval of its projects through legislation. This has proved to be a cumbersome way to manage the program, costing the taxpayer more than was necessary. With broader authorities, Reclamation would be able to take advantage of opportunities as they present themselves, reducing costs.

Reclamation agreed with the Inspector General and wanted to explore any other innovative ideas which would help improve the effectiveness of its program and take advantage of opportunities which were not envisioned 20 years ago. At about this time, Vice President Gore began his initiative to streamline and reinvent the federal government. With most of the cost-effective portions of the authorized program nearing completion, this was a pivotal moment for the program. It would either be reauthorized or end in 1998. From Reclamation's point of view, it seemed a very appropriate time to reassess the direction of the program.

In 1994, Reclamation initiated a public review of the Colorado River Basin Salinity Control Program. The goal of the public review was to completely re-examine the program and its authorities, to gather a broad range of new ideas, to review the lessons of past experiences, to formulate new guidelines and methodologies, and to draft new salinity control legislation to bring this program into the next century.

The public review began on March 24, 1994, with a news release and individual notices mailed to more than 400 entities including: Congressional Representatives; members of the Colorado River Basin Salinity Control Forum; federal, state and local agencies; environmental organizations; and other interested parties. The notices stated Reclamation's purpose in conducting the review, provided background on the salinity problem in the Colorado River Basin and the current program for addressing those problems. The notices then suggested several options regarding the salinity control program.

Reclamation received responses from private individuals, local, state, and federal agencies. The majority of the comments were from state and local agencies expressing support for Reclamation's leadership role in the program, but found the old program could be improved in several ways.

The public review of the program found that in the future, the program should:

- consider alternatives to government planned projects
- allow non-federal construction
- consider proposals to control salinity anywhere in the river basin
- consider non-traditional methods
- be competitive (consider cost and performance risk in its ranking criteria)
- continue to be voluntary (rather than regulatory)

The comments supported implementing the Inspector General's recommendation (to seek broader authorities for Reclamation). In 1994, Reclamation and the Basin States developed legislation to broaden Reclamation's authorities so that it could completely manage the implementation of the program without further Congressional approval. This legislation was introduced to Congress late in 1994 and was approved and signed into law (P.L. 104-20, 1995) in 1995. Congress will retain its fiscal oversight, but will leave the program's management to Reclamation. The 1995 amendments to the Salinity Control Act authorize Reclamation to pursue salinity throughout the Colorado River Basin and required Reclamation to develop guidelines on how it would implement this new, basin-wide approach to the salinity program.

BASINWIDE APPROACH

Guidelines (USDI, 1996) for the new Basinwide Salinity Control Program have been prepared by Reclamation which implement the recommendations made in the review of the program. As an alternative to adopting new, specific regulations, Reclamation plans to administer the program through existing procurement techniques and established federal regulations. The program has been opened to participation by the general public. On February 7, 1996, Reclamation released a Request for Proposals (USBR, 1996) to more than 100 interested parties. Reclamation plans to award funding through this competitive process.

In 1984, Public Law 98-569 directed the Secretary of the Interior to give preference to those projects which reduce salinity for the least cost per ton of salinity control. Since that time, cost effectiveness (cost per ton of salinity control) has been used to prioritize the implementation of salinity controls. However, cost effectiveness is only an estimate (prediction) of the project's cost and effectiveness at controlling salinity. Depending upon the project, there can be a degree of uncertainty in either of these values. Given the diversity of proposals that may be received by Reclamation, an evaluation of the proposal's risks has been included in the selection process.

All proposals (including those studied by Reclamation) will be first ranked on their cost per ton of salinity control. This ranking will then be adjusted for risk factors which might affect the project's performance. The performance risk evaluation will consider both financial and effectiveness risks. For example, the government is interested in limiting its risk of cost overruns. One way that performance risk could be reduced would be for the proponent to accept some risk through contractual limits on the government's payments. Another method of limiting the costs would be to have the work bonded through a private bonding agency. The other major area of performance risk is in the amount of salinity control realized versus projected. Some types of salinity control are inherently more predictable or consistent than others. For example, industrial processes might have very little salinity control performance risk if the payments were based on a measurable product. On the other hand, the effectiveness of water management is often highly variable from farmer to farmer. Automation would be one way a farmer might propose to reduce this type of risk.

Ultimately there is a tradeoff between risk and cost. In the end, eliminating risk may cost more than accepting some risk. A ranking committee will be assembled to evaluate the tradeoffs between cost effectiveness and performance risks. The ranking committee will be made up of representatives from the two cost-sharing partners, the Basin States and Reclamation. After the committee ranks the proposals, Reclamation will attempt to negotiate the final terms of an agreement with the most highly ranked proponents. The first awards under this new process started in fiscal year 1997.

TWO YEARS INTO THE NEW PROGRAM

Past projects (Grand Valley, Paradox, Lower Gunnison, Dolores) have averaged slightly over $70 per ton. For a number of reasons the new projects are much more cost effective, ranging between $20 to $35 per ton (see Table 1).

One of the greatest advantages of the new program comes from the integration of Reclamation's program with the U.S. Department of Agriculture's program. Water conservation within irrigation projects on saline soils is the single most effective salinity control measure found in the past 30 years of investigations. By integrating the USDA's on-farm irrigation improvements with Reclamation's off-farm improvements, extremely high efficiencies can be obtained. If the landscape permits, pressure from piped delivery systems (laterals) may be used to drive sprinkler irrigation systems at efficiency rates far better than those normally obtained by flood systems. The new authorities allow Reclamation much greater flexibility (in both timing and funding) to work with the USDA to develop these types of projects.

The new authorities also allow Reclamation to respond to opportunities that are time sensitive. Cost sharing partners (states and federal agencies) often have funds available at very specific times. Under its old methods of planning, authorization, funding, and construction, it would often take decades for Reclamation to be ready to proceed with a project. None of Reclamation's past projects were able to attract cost sharing because of this. For example, the Ashley Project (a join effort by Utah, the Environmental Protection Agency (EPA), and Reclamation) will eliminate 9,000 tons per year of salt. Reclamation's salinity program is a relatively minor but important part of the project ($3 million in an $18 million project). Once Reclamation had committed to fund its part of the project, funds were included in the EPA's budget by Congress to complete the partnership.

Another significant advantage of the program is that projects are "owned" by the proponent, not Reclamation. The proponent is responsible to perform on their proposal. Costs paid by Reclamation are controlled and limited by agreement. Yet, unforseen cost overruns do occur. The proponent has several options. The project may be terminated. The proponent may choose to cover the overruns with their own funds or borrow funds from state programs. The proponent may also choose to reformulate the project costs and recompete the project through the entire award process.

For example, pipeline bedding and materials costs for the Ferron Project were underestimated in the proposal and subsequent construction cooperative agreement. The proponent was denied permission to award materials contracts for the pipeline since the costs were beyond those contained in the agreement. After months of negotiations and analysis, the proponents chose to terminate the project, reformulate it, and recompete against other proposals the following year. Their project was found to be competitive at the reformulated cost and was allowed to proceed.

In 1998, Reclamation received a record number of proposals. Many are well within the competitive range awarded in 1997. This last round of proposals included: a proposal to improve the efficiency of Reclamation's deep well injection project (Paradox Valley Unit), an extension of a project awarded in 1997, one reformulated project awarded in 1997, an industrial use proposal, a cost-shared selenium control demonstration project, and several irrigation improvement projects.

Table 1.–Bureau of Reclamation Salinity Control Unit Summary

Unit/Study	Implementation	Salt Removal (Tons/Yr)	Total Capital Cost ($1,000's)	Annual O&M Costs ($1,000's)	Cost Effectiveness ($/Ton)
	"Original" Units Individually Authorized by Earlier Legislation				
Meeker Dome	1980-1983	48,000	3,100	0	5
Las Vegas Wash	1978-1985	3,800	1,757	50	51
Grand Valley	1980-1998	127,500	160,900	635	108
Paradox Valley	1988-1996	128,000	67,400	2,800	71
Dolores Project	1990-1996	23,000	44,700	33	160
Lower Gunnison	1991-1995	41,380	24,000	444	57
Total		371,680	301,857	3,962	77
	"New" Basinwide Salinity Program				
Hammond	1996-2001	48,130	13,486	0	23
Ferron	1998-2002	47,407	14,803	0	25
Wellington	1997-1999	14,532	3,903	0	21
Castle Valley	1997-1999	8,506	2,100	0	19
Ashley	1999	9,000	3,269	0	30
Duchesne County	1998-2002	20,417	9,127	0	36
Navajo	1998-1999	500	71	0	12
Administration (10%)	Ongoing	NA	4,676	NA	NA
Total		148,492	51,435	0	28

REFERENCES

1. Colorado River Basin Salinity Control Forum. 1993.1993 Review, Water Quality Standards for Salinity, Colorado River System, Final Report, October 1993. 120 p.

2. Lohman, L.C., J.G. Milliken, W.S. Dom, and K.E. Tuccy. 1988. Estimating Economic Impacts of Salinity of the Colorado River, February 1988. Bureau of Reclamation, Denver, Colorado. 105 p.

3. Public Law 93-320. The Colorado River Basin Salinity Control Act, June 24, 1974.

4. Public Law 98-569. Colorado River Basin Salinity Control Act Amendment, October 30, 1984.

5. Public Law 104-20. Amendments to the Colorado River Basin Salinity Control Act, July 28, 1995.

6. U.S. Bureau of Reclamation. 1996. Request for Proposals, Colorado River Basin Salinity Control Program. Bureau of Reclamation, Salt Lake City, Utah, February 1996. 14 p.

7. U.S. Department of the Interior. 1993. Implementation of the Colorado River Basin Salinity Control Program, Bureau of Reclamation. Office of the Inspector General, Washington, D.C., Audit Report No. 93-1-810. 27 p.

8 U.S. Department of the Interior. 1995. Quality of Water, Colorado River Basin, Progress Report No. 17, January 1995. Bureau of Reclamation, Salt Lake City, Utah. 199 p.

9. U.S. Department of the Interior. 1996. Report to Congress on the Bureau of Reclamation Basinwide Program. Bureau of Reclamation, Salt Lake City, Utah, February 1996. 58 p.

HENRY'S FORK WATERSHED COUNCIL — FIVE YEARS OF LEARNING TO SHARE A RIVER

Lyn Benjamin[1]

ABSTRACT

The Henry's Fork Watershed Council (HFWC) was formed in 1993 in response to several years of conflict over natural resources management in the Henry's Fork of the Snake River basin. HFWC participants use a nonadverserial, consensus-based approach to assess and manage natural resources in the region. The Council is cofacilitated by the Henry's Fork Foundation (a fishing-based conservation organization) and the Fremont-Madison Irrigation District (that oversees the distribution of irrigation water in the Henry's Fork basin). It is composed of three component groups: agency, citizen, and technical that use the Watershed Integrity Review and Evaluation (WIRE) criteria to evaluate projects that are presented to the Council. Volunteers from the HFWC serve on four subcommittees: Water Quality, Sheridan Creek Restoration, Native Trout, and Million Acre-Feet committees that perform in-depth studies of specific topics and then report back to HFWC. Issues dealt with by HFWC include: water management and water quality; forest service land management; agricultural conservation programs; land development and planning and zoning; and one-time seed funding for watershed based projects. Successes have included the development of working relationships between previously adversarial groups, educational programs about natural resources management, and a venue for agencies to present and receive feedback about projects. Critiques of the Council include the lack of prioritization of projects, lack of legal authority and lack of long-term funding.

THE HENRY'S FORK OF THE SNAKE RIVER WATERSHED

Watershed Description

The Henrys (North) Fork of the Snake River watershed lies in eastern Idaho and western Wyoming at the head of the Snake River Plain (Figure 1). Most of the upper watershed is forested public land, while the lower half is dominated by private agricultural land, including Idaho's largest seed potato production area.

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Water stored in Henrys Lake and Island Park Reservoir is diverted downstream of Ashton to irrigate potato and grain crops. Elevations in the 3,000 mi2 (7,770 km2) watershed range from over 10,000 ft (3,050 m) along the continental divide to 4,800 ft (1,460 m) at the South Fork confluence. Mean annual precipitation ranges from 60 inches (152 cm) at the highest elevations to 10 inches (25 cm) at the lowest; most precipitation falls as snow. The basin's geology is dominated by volcanic features; correspondingly, groundwater strongly influences surface hydrology. An estimated 42 percent of total discharge at Ashton originates from springs at the base of the Yellowstone Plateau rhyolite flows (Whitehead, 1978). Volcanic geology and spring-influenced hydrology combine to create a river characterized by relatively constant discharge and water temperature, low gradient, and abundant macroinvertebrates. Because of these features, the Henrys Fork is one of the best known rainbow trout fishing rivers in the country (Brooks, 1986). The most popular angling reach is the 15 river miles (24 km) immediately downstream of Island Park Dam, a stretch of river that also provides habitat for trumpeter swans, bald eagles and other wildlife.

Figure 1. Map of Upper Snake River Region Showing Henry's Fork and South Fork of the Snake River

The Henry's Fork Basin is sparsely populated with a total of 38,000 residents (Idaho State Water Plan, Henry's Fork Basin, 1992). The principle cities are Rexburg, St. Anthony, Driggs, and Sugar City and urbanization onto agricultural lands is not considered a problem. Summer tourist influxes are heavy and since the 1980s the basin has experienced population growth in upper Fremont County and Teton County in relationship to the recreation industry and retirement populations. In Teton County most of the residents are from out-of-state.

Natural Resource Management Issues in the Henry's Fork Basin

A billboard on the south edge of Ashton welcomes visitors to the "world's largest seed potato producing area"; a 1998 Trout Unlimited member poll voted the Henry's Fork the "country's best trout fishing stream". Despite the basin's proximity to Yellowstone and Grand Teton national parks and a myriad of other recreational opportunities, it remains potatoes and fish that the basin is most famous for. It is also these two items that underlie much of the conflict over resource management that we see in the basin. Since the 1970's, and the heyday of the Henry's Fork fishery, advocates for wild trout management, riparian protection and consideration for fish and wildlife in water management decisions have come into conflict with agricultural interests who have depended heavily on irrigation water to maintain their livelihoods. As in many other regions in the western United States, "rich out-of-state anglers" and third- and fourth- generation farmers, loggers and ranchers struggled for control over natural resource management (Van Kirk and Griffin, 1997).
In 1992 the conflicts peaked with three events: the first was a construction accident on the Marysville canal (a component of a controversial small hydroelectric facility) that caused failure of the canal and a sediment spill into the Fall River; the second was a massive sediment spill from Island Park Reservoir into the most popular angling reach of the Henry's Fork; the third was the completion of a draft of the Henry's Fork basin plan,. The development of the basin plan had been marked with controversy for three years and culminated in the protection of 195 stream miles from further hydroelectric or irrigation development; it was adopted unanimously by the state legislature in 1993. Following the sediment spills local residents were becoming weary of conflicts over natural resource management in the area and the idea that a cooperative watershed based approach to develop constructive solutions to resource management issues was advanced by several individuals.

FORMATION OF THE HENRY'S FORK WATERSHED COUNCIL

Following discussions between citizens, scientists, and government agency personnel throughout 1993 the Henry's Fork Watershed Council (HFWC) was formed to coordinate management activities in the watershed. The two groups most at odds over the basin plan, the Henry's Fork Foundation and the Fremont-Madison irrigation District, volunteered to work together and lead the new organization. The HFWC was chartered by the 1994 Idaho legislature as a "grassroots, community forum which uses a nonadverserial, consensus based approach to problem solving and conflict resolution among agencies, citizens, and scientists with varied perspectives." (State of Idaho, 1994). The HFWC's charter identifies four duties: 1) promote cooperation in resource studies and planning that transcends jurisdictional boundaries; 2) review, critique, and prioritize proposed watershed projects; 3) identify and coordinate funding for research, planning implementation, and long-term monitoring programs; and 4) serve as an education resource about the Henry's Fork basin (State of Idaho, 1994). The primary source of funding for HFWC activities and projects sponsored by the council comes from a fund established by Idaho Department of Environmental Quality using mitigation money from Marysville Hydro Partners following the Marysville canal accident (approximately $115,000). Other funding has included a $20,000 Basic American Foods challenge grant, $2,000 Chevrolet/Geo Outdoor Conservation award and $1,000 from J.R. Simplot.

HFWC ORGANIZATIONAL AND MEETING STRUCTURE

HFWC is jointly facilitated by Henry's Fork Foundation staff and Fremont-Madison staff and board members. The council is composed of three component groups: 1) a citizen's group of local community members representing commodity, conservation and community development interests; 2) an agency roundtable of representatives from federal, tribal, and local entities with land and resource management jurisdiction in the watershed; and 3) a technical team of agency, university, and independent scientists from various disciplines. HFWC has no formal membership or appointed positions; all meetings are open to any person. Bimonthly meetings are attended by an average of 50 people. Additionally, HFWC subcommittees have been created on an as needed basis to do more specialized research and advisory work and report back to the council. Currently there are four subcommittees: 1) The Water Quality Subcommittee that has examined water quality issues in the basin and has served in an advisory capacity in the Total Maximum Daily Load (TMDL) process; 2) The Native Trout Subcommittee that has adopted goals for maintaining and recovering populations of Yellowstone Cutthroat Trout; and has implemented inventory and recovery projects; 3) The Sheridan Creek Restoration Committee that received a $142,000 319 grant to restore the hydrology and stream habitat conditions of Sheridan Creek (a tributary to Island Park Reservoir); and 4) The Million Acre-Feet Committee that was formed to examine the implications for the Henry's Fork basin of the Army Corps of Engineers proposal for an additional million acre-feet of water to be provided by the upper Snake River basin for endangered salmon recovery.

HFWC meetings open with a community building circle and generally consist of educational programs about specific issues or proposals in the morning, followed by discussions in component groups in the afternoons. Meetings close with a wrap-up session of the whole group. Proposals are evaluated in component groups using a 10 point set of criteria, the Watershed Integrity and Review Evaluation (WIRE). The WIRE criteria include: 1) Watershed Perspective: Does the project employ or reflect a total watershed perspective? 2) Credibility: Is the project based on credible research or scientific data? 3) Problem and solution: Does the project clearly identify the resource problems and propose workable solutions that consider the relevant resources? 4) Water Supply: Does the project demonstrate an understanding of water supply? 5) Project Management: Does the project employ accepted or innovative practices, set realistic time frames for their implementation and employ and effective monitoring plan? 6) Sustainability: Does the project emphasize sustainable ecosystems? 7) Social and Cultural: Does the project sufficiently address the watershed's social and cultural concerns? 8) Economy: Does the project promote economic diversity and help sustain a healthy economic base? 9) Cooperation and Coordination: Does the project maximize cooperation among all parties and develop sufficient coordination among appropriate groups and agencies? 10) Legality: Is the project lawful and respectful of agencies legal responsibilities? Each component group reports its findings back to the entire council, which then decides whether to endorse and/or provide financial support for the proposal. An annual "State of the Watershed Conference" is held each fall to monitor the progress of Council-endorsed projects and to provide research and monitoring results. An annual council field trip is held in July to show membership and the public current issues and projects.

ISSUES ADDRESSED BY HFWC

A wide range of issues has been addressed by HFWC that fall under the following categories: water management and water quality; forest service land management; agricultural conservation programs; land development and planning and zoning; one-time seed funding for watershed based projects. Water quality and management have proved to be the most controversial of the topics addressed in the council. The State of Idaho is currently developing TMDLs, and HFWC serves as the Watershed Advisory Group (WAG) for eastern Idaho. The council subcommittee on water quality has been pivotal in providing data and feedback to DEQ both about specific streams in the watershed and about the methodology used by DEQ to assess stream health. Additionally, the Sheridan Creek restoration project was spearheaded by HFWC and its activities are coordinated under the auspices of a council subcommittee. Several council meetings have been devoted to developing a council position and Henry's Fork watershed perspective on endangered salmon recovery. Most recently the 1 million acre-feet flushing flow proposal and lower Snake River dam breaching was presented by a panel of experts from the irrigation community, NMFS, the Bureau of Reclamation, and Idaho Fish and Game and later WIREd by component groups. Managed aquifer recharge has emerged as an important topic in Idaho water management and has been presented to and discussed by HFWC. The different perspectives of the irrigation and conservation communities were discussed quite openly. Winter discharge levels (minimum instream flows) on the Henry's Fork of the Snake River below Island Park reservoir have been a source of controversy between irrigators and anglers for a long time. A winter flow committee, aided by recent hydrologic research and attended by participants in HFWC, now meets twice in the fall to decide winter flow levels out of the reservoir. Additionally, another committee monitors and regulates temperature of water released in the spring and early summer to produce optimal temperature ranges for juvenile trout. The most important issue that faces HFWC participants in the near future is the proposed title transfer of Island Park and Grassy Lake Reservoirs from federal ownership to local ownership under Fremont-Madison Irrigation District.

U.S. Forest Service proposed land exchanges and the Targhee National Forest plan (including large areas of road closures to protect grizzly habitat) have been debated heatedly at HFWC meetings. The Targhee forest has also presented less controversial projects like the Willow Creek vegetation management project for council discussion and endorsement.

HENRY'S FORK FOUNDATION'S RESEARCH PROGRAM AND ITS RELATIONSHIP TO HFWC

The Henry's Fork Foundation (HFF) was formed in1984 by a group of anglers who were initially concerned with riparian degradation on the Henry's Fork, their first project was to construct fencing to protect 12 miles of streambank along the Henry's Fork. In 1987 HFF successfully lobbied for a change in fishing regulations to catch and release below Island Park Dam. Additionally, HFF was able to protect several stretches of the Henry's Fork and its tributaries against future hydropower and irrigation development. Until 1992 HFF opposed local and agricultural interests and based its lobbying efforts on generic science (e.g. cattle degrade streambanks or catch-and-release regulations improve trout populations) (Van Kirk and Griffin, 1997). HFF was, until this time, not involved in cooperative efforts.

As detailed earlier, in 1993 HFF became actively involved in creating, and a cofacilator for, HFWC. At the same time a group of researchers in the Henry's Fork basin and interested HFF board members formed the HFF Research Committee and began to outline strategies to address the question:

" What environmental factors are impacting the Henry's Fork watershed and its unique hydrologic and biologic resources?"

By 1994 the following approaches to research in the basin were adopted:

Hydrogeologic investigations including compilation of hydrologic data; Henry's Fork geomorphology; flushing flow investigations below Island Park dam; interconnections between Snake River Plain aquifer and Henry's Fork basin; long-term monitoring of Henry's Fork and its tributaries.

1. Aquatic ecology investigations including management of Island Park Reservoir and its downstream effects; relationships between macrophytes, water level and waterfowl grazing; baseline macroinvertebrate studies; Henry's Lake water quality.
2. Fishery investigations including trout overwintering, trout movement and socioeconomic studies of anglers
3. Research integration and application at the Henry's Fork Watershed Center and research committee meetings.

Several months later a research director was hired and the research program at HFF was developed. The program was designed to improve understanding of watershed processes, determine restoration needs in the watershed, and provide information to assist in ongoing stewardship programs. Research has been seen at HFF as an integral part of education and stewardship programs that HFF is involved with.

HFF research projects have included the following: a watershed-wide stream condition and native trout inventory; juvenile rainbow trout overwinter survival research; hydrologic analysis of the upper Henry's Fork basin and assessment of Island Park Reservoir operations; tubifex worm and whirling disease inventory; riparian health assessment; and spring recharge study. Results from these research efforts have formed the basis for stewardship activities by HFF and have also provided data to HFWC. HFF researchers have consistently reported findings at HFWC meetings and have been able to articulate the management implications of their work. The council has relied on the HFF research program to provide accurate and informative data with which to approach natural resource management issues. Unfortunately, at present, due to downsizing pressures, HFF employs no technical or scientific staff.

ACCOMPLISHMENTS OF HFWC AND CRITIQUE OF HFWC APPROACH

"The Henry's Fork Watershed Council promotes coordination rather than restores habitat."

The greatest strength, and perhaps weakness, of HFWC is that it provides a context for working relationships to be created; it does not initiate and administer projects. There is little doubt amongst participants in the council from government agencies, the private sector, environmental organizations, agricultural interests, and scientists that HFWC fosters relationships between former adversaries and enables different stakeholders to work together on issues of mutual interest. Unfortunately there remains no formal process within

the council for prioritizing projects or legal authority to carry out projects. HFWC provides a venue for local, state and federal agencies to present proposals and receive feedback from the public and educates participants on natural resource management issues. Educational presentations are a critical part of decision-making at council meetings. Another accomplishment is HFWC's emphasis on community building and the consensus-based model of decision making as a method of encouraging people to work for better natural resource management. Although participants disagree they have agreed to do so in a non-adversarial manner. Development of the WIRE criteria has been seen as a major accomplishment of the council that has enabled participants to focus on the specifics of a proposal instead of on blanket endorsement or rejection. Finally, the HFWC has used monetary incentives to encourage private landowners to improve natural resource management.
Critiques of the council include: 1) as mentioned above, the lack of legal authority and process to prioritize projects; 2) lack of established long-term funding for HFWC; 3) concerns as to whether all stakeholder interests participate in HFWC (for example, few outfitters or guides attend the meetings); 4) many participants feel that the council has not been tested by decision-making about controversial issues (for example, since HFWC was formed a series of high precipitation years have occurred therefore decision-making about water allocation can be made without the pressure of a drought situation.

REFERENCES

Brooks, C. E., 1986. The Henry's Fork. Winchester Press, Piscataway, New Jersey.

Idaho Water Resources Board, 1992. Comprehensive State Water Plan, Henry's Fork Basin.

Van Kirk, R. W. and C. B. Griffin, 1997. Building a Collaborative Process for Restoration: Henrys Fork of Idaho and Wyoming. In: Watershed Restoration: Principles and Practices, J. E. Williams, C. A. Wood and M. P. Dombeck (editors). American Fisheries Society, Bethesda, Maryland, Chapter 16.

Whitehead, R. L., 1978. Water Resources of the Upper Henrys Fork Basin in Eastern Idaho. Water Information Bulletin No. 46, Idaho Department of Water Resources, Boise, Idaho, 91 pp. plus maps.

THE SAN JOAQUIN RIVER AGREEMENT AND THE VERNALIS ADAPTIVE MANAGEMENT PLAN

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ABSTRACT

This paper describes a unique negotiated settlement, The San Joaquin River Agreement (SJRA), which has been developed by a group San Joaquin River Basin water rights holders as a voluntary effort to provide water to meet flow objectives of the California State Water Resources Control Board's (SWRCB), San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality Control Plan (WQCP) for the protection of San Joaquin Basin chinook salmon. The SJRA includes a study called the Vernalis Adaptive Management Plan (VAMP), which is a proposed 12 year evaluation of San Joaquin River flows, Delta export pumping rates and San Joaquin Basin salmon smolt survival. This agreement is an important effort to resolve a difficult issue regarding the sharing of the flow of the San Joaquin River between irrigators, municipal users, fishery and other environmental uses and to avoid a protracted controversial water right hearing and potential subsequent litigation. Also explained in this paper is the SJRA, the VAMP, how each was developed, why they are necessary, how they will work, whether or not the fish resources will be protected, where the water will come from to meet the target flows and the proposed operation details.

INTRODUCTION AND BACKGROUND

On May 22, 1995, the SWRCB adopted controversial San Joaquin River "Vernalis Flow Standards" in it's Bay-Delta WQCP for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (WQCP 95-1, 1995). In response to the adopted flow standards, a group of San Joaquin River Basin water right holders (five irrigation districts) filed litigation challenging the scientific basis for the standards, the environmental documentation supporting the standards and the fact that the WQCP did not require a fish protection barrier at the head of Old River. The litigants, and other interested parties recognized that extended litigation would frustrate rational and timely improvement of the salmon fishery, which is one of the stated goals of the WQCP standards. Consequently, the parties agreed to settle the litigation with certain conditions and assembled a group of experts to develop an implementable, scientifically based program to increase knowledge concerning the salmon resources of the San Joaquin River

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Basin which will aid in resolving difficult regulatory issues involving river flows, export pumping rates, and physical facilities which affect salmon survival.

DISCUSSION

The San Joaquin River Basin

The San Joaquin River flows north through the southern portion of the great Central Valley of California. It has three major tributaries; the Merced River, the Tuolumne River and the Stanislaus River. The headwaters of each of these streams originate from the western slope of the Sierra Nevada Mountain Range which is on the eastern side of the San JoaquinValley. Each of the tributaries has a major reservoir constructed at the edge of the Valley to control flooding from the spring runoff of melting winter snow pack, to generate electrical energy and to store water for use by irrigators during the long hot summers in the Valley. The City and County of Also, San Francisco diverts municipal water to the San Francisco Bay Area from its Hetch Hetchy Project on the Tuolumne River. Water from the upper San Joaquin River, which is owned and controlled by the U.S. Bureau of Reclamation's (USBR) Friant Dam, only reaches Vernalis during floods, as normally all of the runoff is diverted for use in the Valley for irrigation and municipal use.

The Controversy

The majority of the San Joaquin River flow at Vernalis (where the San Joaquin River joins the southern end of the Sacramento-San Joaquin Delta and the San Francisco Bay Estuary, which is the monitoring point for the SWRCB salinity and flow standards) consists of water originating from the three major tributaries to the San Joaquin River. The remainder of the flow in the San Joaquin River at Vernalis is from agricultural return flows, ground water accretions and other minor tributary flow. The water from the three main tributaries is controlled by the five irrigation districts and the City and County of San Francisco all which hold senior water rights, and the USBR which operates the major reservoir, New Melones Dam, on the Stanislaus River. Historically, permits and agreements have made the USBR responsible to provide the water necessary to comply with the SWRCB's Vernalis salinity standards. Prior to 1995 the SWRCB had not established any specific flow standards. The current controversy arose from the establishment of the new flow standards and the potential that the SWRCB would assign some of the responsibility for meeting these required flows to the irrigation districts holding the senior water rights on the San Joaquin River tributaries. In fact, the SWRCB is currently (summer and fall of 1998) holding a water right hearing to determine what water right holders should contribute water to meet the standards established in the 1995 WQCP.

The San Joaquin River Group and Participating Interests

Following the adoption of the WQCP by the SWRCB in 1995 the San Joaquin River Group (SJRG) was formed to protect the water interests of the participating entities: the Merced, Turlock, Modesto, Oakdale and South San Joaquin Irrigation Districts, the City and County of San Francisco, and the San Joaquin River Exchange Contractors (four districts receiving exchange water from USBR Central Valley Project (CVP) facilities), all holders of senior water rights; and The Friant Water Users Authority which consists of 29 districts receiving water from the USBR San Joaquin River Friant Dam. The three tributaries have required minimum in-stream flows established in licenses issued by the Federal Energy Regulatory Commission (FERC) or through other requirements of either the California Department of Fish and Game (CDFG) or the SWRCB. Also, interested in the outcome of issues involving the San Joaquin River are several environmental groups, two of which, the Natural Heritage Institute and the Bay Institute of San Francisco, joined the discussions, and the water users that contract for water which is pumped from the Delta and exported into the San Joaquin Valley and Southern California by either the USBR or the State of California Department of Water Resources (DWR).

Negotiations

Discussions on the responsibility for providing water to meet the SWRCB Vernalis flow standards began with the irrigation districts when they filed litigation against the SWRCB. During the initial discussions regarding settlement of the litigation, the export interests and the Friant Water Users Authority joined, as each of their water supplies could be impacted depending on the results of either the litigation or the SWRCB water right hearing process. In addition, several environmental groups joined the discussions as these groups have an interest in the protection of environmental resources in the San Joaquin Basin and the Bay-Delta Estuary through implememtation of the SWRCB 1995 WQCP.

Many meetings were held between 1995 and 1998 to discuss various options to provide water to meet the SWRCB 1995 WQCP and to meet the other water needs of the water right holders, in addition to contributing to the state and federal goal of doubling anadromous fisheries including the production of San Joaquin Basin fall run salmon. Potential additional limits on export pumping brought the export water users into the discussions to protect their water supply. The Friant Water Users were interested in not having to provide water from Friant for Bay-Delta flows. Instead, the Friant Water Users' proposed to use money paid into the Central Valley Project Environmental Restoration Fund from their purchases of water from the CVP to purchase water from others to mitigate any obligation the Friant users may have for in-stream flows. The Central Valley Project

Improvement Act (CVPIA), passed by Congress (Public Law 102-575, 1992), authorized the USBR and the USFWS to purchase such water from willing sellers. After bringing interested environmental groups into the discussions, an agreement was finalized to accomplish most of the goals of most of the participants.

THE SAN JOAQUIN RIVER SETTLEMENT AGREEMENT

Structure of the SJRA

The SJRA is based on six principles:

1) That there be increased flows in the San Joaquin River above the level that would occur without the agreement, and decreased export limitations greater than currently exist,
2) That a Head of Old River (HOR) fish barrier be constructed at the Old River-San Joaquin River split,
3) That there be payment for the water offered by the water right holders,
4) That the agreement be developed around certain operating assumptions for the USBR's Stanislaus River New Melones Project,
5) That Monitoring be conducted to determine the effectiveness of the agreement, and
6) That there be assurances to all parties that the agreement will be operable, including dispute resolution procedures.

The SJRA is intended to achieve three primary objectives:

1) "Implement protective measures for San Joaquin River fall-run chinook salmon within the framework of a carefully designed management and study program which is designed to achieve, in conjunction with other non-VAMP measures, a doubling of natural salmon production by improving salmon smolt survival through the Delta. However, the parties recognize that future salmon production cannot be guaranteed."

2) "Gather scientific information on the relative effects of flows in the lower San Joaquin River, CVP and SWP export pumping rates, and operation of a fish barrier at the head of Old River on the survival and passage of salmon smolts through the Delta."
3) "Provide environmental benefits in the lower San Joaquin River and Delta at a level of protection equivalent to the San Joaquin River portion of the 1995 WQCP for the duration of the agreement."

The design of this investigation is based, in large part, on experience gained in earlier fisheries investigations and on expected opportunities for providing increased fisheries protection during the spring. As stated, the study requires the construction of an operable fish barrier at the head of the Old River. However, such construction may also require the construction of additional barriers in the south Delta to mitigate impacts of the HOR fish barrier, CVP/SWP export pumping, and other factors affecting water quality and water elevation in the Delta channels. Other non VAMP monitoring and studies may also take place within the San Joaquin Basin to evaluate other factors that affect the fisheries.

The Vernalis Adaptive Management Plan

The key question is: "What if any relationship is there between 1) flow in the San Joaquin River and water pumped from the southern Delta through the federal and state export facilities and 2) the survival of salmon smolts migrating from the San Joaquin River Basin to the Pacific Ocean through the Delta Estuary?" Data show that under flood or high uncontrolled flow conditions salmon smolts survive rather well. However, at lower controlled river flows, it is not clear whether or not incremental changes in flow or exports will enhance the survival of salmon smolts, particularly if many of the out migrating smolts swim to the export pumps. It is fairly well accepted that the installation of the fish protection barrier to keep the salmon smolts from swimming directly to the export pumps will significantly improve salmon smolt survival regardless of the flow or export pumping rates.

As part of the SJRA, a 12 year Vernalis Adaptive Management Plan (VAMP) study was designed to evaluate the relationship between river flows, the rate of state and federal water exports from the southern Delta and salmon smolt survival.

The SJRG members have agree to provide up to 110,000 acre-feet per year or the amount needed to meet established target flows, whichever is less, during a 31-day pulse flow in the months of April and May each year, which is the main out migration period of the San Joaquin Basin salmon smolts. This will be done for the 12 years of the agreement except during years when extraordinary events such as facility failures, floods or droughts make the providing of such water impossible.

A San Joaquin River Technical Committee (SJRTC) will be appointed to successfully implement the VAMP. A Management Committee will be appointed to review reports and recommendations of the Technical Committee and to resolve all issues and disputes that the cannot be resolved by the SJRTC. The Management Committee will consist of one representative from each signatory to the agreement and the Management Committee will make its decisions by a unanimous vote, which allows any representative to veto any Management Committee decision.

The duties of the San Joaquin River Technical Committee will be as follows:

1) Annually coordinate flow releases, export and Old River fish barrier operations, and use of hatchery fish to implement the VAMP study,
2) Determine best management of flow releases during the pulse flow period to achieve target flows,
3) Plan and oversee monitoring activities, in coordination with the Interagency Ecological Program and existing monitoring programs on the San Joaquin tributaries, and
4) Develop annually the VAMP flow calculation protocols.

The SJRTC has no authority to adjust any export limitations imposed pursuant to the SJRA or to adjust target flows below those set pursuant to the SJRA, but the SJRTC may recommend such changes to the Management Committee.

<u>Biological Experiment</u>

The VAMP focuses on water years when the existing flow at Vernalis is expected to be less than 7,000 cubic feet per second (cfs). The upper edge of test flow conditions resulted from the need to have flow rates in the San Joaquin River within a range that accomodates the installation and operation of the HOR fish barrier. The following matrix of flow and export is intended to assess impacts of flow at three levels of export and impacts of export at four levels of flow. The 2,000 cfs flow rate is used to determine supplemental water to be provided by the SJRG. The VAMP test flow target is 3,200 cfs.

Table 1. Vernalis target flows and export rates to achieve the experimental goals

	Target Flows (cfs)				
Exports (cfs)	2,000	3,200	4,450	5,700	7,000
1,500	X	X	X		X
2,250				X	
3,000					X

The goal is to maintain, as much as possible, a constant flow during the 31-day pulse flow period. It is recognized that there will be years during the term of the agreement when the existing flows will be greater than 7,000 cfs during the pulse flow period and that in such years the HOR fish barrier will not be in place and that it may not be able to maintain a constant flow rate at Vernalis. The USBR and the CDWR agree that in non VAMP years or when the limits shown in Table 1 do not apply, their pumping plants will be operated in compliance with any other requirements then in effect. It is agreed that during high flow years it will also be advantageous to monitor salmon smolt survival.

Operations Plan

A Hydrology Group (HG) of the (SJRTC) is charged with the responsibility to develop and exchange information concerning forecasted hydrologic conditions, execute the protocols that establish the Test Flow Target and determine the SJRG Supplemental Water, establish the operations plan for the coordination of flows, and provide a post-analysis and report of operations. The makeup of the HG will be determined by the SJRTC with all signatories to the SJRA having the right to participate on an equal basis in the HG. Beginning in February each year, the USBR and CDWR will develop, in cooperation with the SJRTC, an operations plan that will describe how the VAMP will be implemented during that year. The USBR and the SJRG are lead Co-coordinators and will be responsible for tracking and periodic updating of forecasted/actual hydrologic conditions, initially on a bi-weekly frequency and later on a weekly basis as the test period approaches.

The flow target for the 31-day Test Period will be established as the Test Flow Target immediately greater (Single-step Criteria) than the average flow that is forecasted to occur during the Test Period at Vernalis. The test flow targets are shown in Table 2.

Table 2. Forecasted Flows and Target Flows

Forecasted Average Flow at Vernalis (cfs)	**Test Flow Target (cfs)**
0-1,999	2,000
2,000-3,199	3,200
3,200-4,449	4,450
4,450-5,699	5,700
5,700-6,999	7,000
7,000 or greater	Existing Flow

In any year, when the sum of the current year's forcasted and previous year's 60-20-20 Indicators is seven (7) or greater, the flow target for the Test Period will be established one level higher (Double-step Criteria) than that established by the Single-step Criteria. The 60-20-20 Indicator for the VAMP is related to the San Joaquin Valley Water Year Hydrologic Classification as described in the SWRCB 1995 WQCP. The 90 per cent probability of exceedence forecast will be used to calculate the current year's hydrologic classification as shown in Table 3. When the flows exceed 7,000 cfs, the SJRG will exert its best efforts to maintain a stable flow rate during the Test Period to the extent reasonably possible. Also, in consideration of multi-year drought sequences, when the summation of the current years and two previous years' indicator is less thatn 4, the SJRG's responsibility to provide supplemental water to achieve the target flow becomes discretionary.

The Biology Group (BG) will provide its initial estimate of the preferred period of the VAMP beginning in February, coincident with the HG's first report and with each subsequent report. The BG and the HG will jointly identify the tentative Test Period. One consideration for the scheduling of the VAMP is to coincide the Test Period with the peak out migration period for the naturally spawned San Joaquin Basin salmon smolts.

Table 3. San Joaquin Valley Water Year Hydrologic Classification and the 60-20-20 Indicator

San Joaquin Valley Water Year Hydrologic Classification	60-20-20 Indicator
Wet	5
Above Normal	4
Below Normal	3
Dry	2
Critical	1

Division of Responsibility

Each year, after the HG of the SJRTC determines the volume of water required to meet the VAMP flows, allocation of responsibility to the individual SJRG members will be determined in the order specified in the SJRG Division Agreement which is shown in Table 4.

Table 4. Allocation of volume of water to be provided by individual SJRG members.

Provision of Water In Descending Order	First 50,000 AF	Next 23,000 AF	Next 17,000 AF	Next 20,000 AF	Total AF
Merced ID	25,000	11,500	8,500	10,000	55,000
Oakdale & South San Joaquin IDs	10,000	4,600	3,400	4,000	22,000
Exchange Contractors	5,000	2,300	1,700	2,000	11,000
Modesto & Turlock IDs	10,000	4,600	3,400	4,000	22,000

PROSPECTS FOR IMPLEMENTATION

During 1998, in an extensive Bay-Delta Water Right Hearing, the SWRCB is receiving testimony form any interested parties on the SJRA and a number of other alternatives that have been reviewed in a draft Environmental Impact Statement issued by the SWRCB (DEIR, 1997). The fate of the proposed SJRA will not be finally determined until the SWRCB completes it's hearing on the allocation of responsibility for meeting the flow-dependent objectives in the 1995 Bay-Delta WQCP.

As of August 1, 1998, all participants in the negotiations on the SJRA, with the exception of the environmental organizations, have signed a letter of support indicating that, upon completion of the environmental documentation and acceptance of the SJRA by the SWRCB, each will sign the agreement and participate in its implementation. The environmental organizations have expressed concern regarding the use of the CVPIA funds to pay for the water and that the SJRA does not, in their words, "completely meet all of the flow standards specified in the 1995 Bay-Delta WQCP." Others have objected to the fact that the agreement does not solve all of the controversial issues related to the San Joaquin River.

The SJRG is offering the agreement as a settlement package which biologists have stated provides equivalent protection to the fisheries of the San Joaquin River and the Delta as the 1995 Bay-Delta WQCP. The SJRG is requesting that the SWRCB approve the SJRA, accepting the agreement as a binding contract without changes to the water rights of the SJRG members. The SJRG also expects the SWRCB to issue a water right order placing the responsibility to meet the SWRCB established water quality standards on the USBR and CDWR. If the package is not approved and implemented, as negotiated, there will then, more than likely, be a contested water right hearing to establish the responsibility of all San Joaquin Basin water right holders to provide water to meet the water quality standards established by the SWRCB in the 1995 Bay-Delta WQCP. Any contested water right hearing will undoubtedly be followed by extended litigation.

REFERENCES

Draft Environmental Impact Report for Implementation of the 1995 Bay/Delta Water Quality Control Plan. California State Water Resources Control Board, California Environmental Protection Agency. Sacramento, CA. November 1997.

Public Law 102-575, Reclamation Projects Authorization and Adjustment Act of 1992 Title XXXIV, The Central Valley Project Improvement Act (CVPIA). October 30, 1992.

San Joaquin River Agreement (Draft). San Joaquin River Group Authority, Modesto, CA. April 6, 1998

Water Quality Control Plan 95-1. California State Water Resources Control Board, California Environmental Protection Agency. San Francisco Bay/Sacramento-San Joaquin Delta Estuary. May 1995.

BALANCING CHANGING VALUES AND NEEDS

Bruce C. Moore[1]

ABSTRACT

The needs of the West have changed dramatically since the beginning of the century. Demands on Western water continue to grow rapidly, while changing societal values and greater environmental knowledge and awareness have demonstrated the need for Reclamation projects to be operated in a more environmentally beneficial manner. Today, residential, industrial, agricultural, recreational, hydropower, and environmental needs all compete for this finite resource. These changing needs have increased Reclamation's responsibilities and resulted in a fundamental shift and evolution in Reclamation's mission.

With concern growing over the negative impacts affecting the Glen and Grand Canyons, in 1982 the Secretary of the Interior (Secretary) initiated the two-phase, multi-agency Glen Canyon Environmental Studies (GCES) to better understand the environmental and recreational impacts associated with the operations of the dam. Findings from these studies led to a July 1989 decision by the Secretary for Reclamation to prepare an environmental impact statement (EIS) to reevaluate dam operations in order to determine specific options that could be implemented to minimize, consistent with law, adverse impacts on the downstream environment and cultural resources, as well as Native American interests in the canyons.

One of the key elements outlined in the Glen Canyon Environmental Impact Statement (GCEIS) and mandated by the Record of Decision (ROD) is an "Adaptive Management Program" (AMP). The AMP is intended to provide the organization with a process to ensure that scientific information and recommendations from a diverse group of stakeholders are incorporated into the evaluation, management, and future decisions of Glen Canyon Dam operations.

The AMP calls for the continued interaction of managers and scientists to monitor the effects of current dam operations on the Colorado River ecosystem, and to conduct research on alternative dam operating criteria that may be necessary to ensure continued protection of resources and improve natural processes.

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As the 21st century comes into focus, Reclamation is prepared to meet the continuing challenge of bringing together competing interests to find consensus-based solutions to contemporary Western water management challenges.

The paper will describe the sequence of events leading up to an EIS on Glen Canyon Dam operations, the implementation of the AMP, and a special event, the Beach Habitat Building Flow.

INTRODUCTION

The remarkable development that has taken place over the last 100 years in the Western United States is the direct result of the ability to carefully manage one vital and scarce resource: *water*. Most Western lands typically receive far less annual precipitation than that received by Eastern and Southern states. When settlers first began to inhabit the West, they discovered that survival in this area was extremely difficult because rainfall was neither plentiful nor reliable. The transformation of this dry, barren desert region into productive farmland and thriving towns and cities really began with the recognition that large-scale water projects were necessary to store and transport water.

President Theodore Roosevelt believed that water development was a national function and that Federal participation was necessary to construct large-scale projects because they would be beyond the means of states and local groups. He also believed a Federal presence was necessary to resolve the interstate conflicts that were sure to arise. Recognizing the many benefits that Western water development could bring, Roosevelt signed the Reclamation Act into law on June 17, 1902. This act formed the cornerstone for the founding of the Bureau of Reclamation, the agency charged with planning, designing, and constructing water projects throughout the West. By 1907, due to the immediate response for irrigation projects by Western farmers, businessmen, and politicians, work was already underway on 25 projects.

By 1928, Reclamation was the world's foremost builder of water storage, diversion, and distribution systems. Early projects such as Theodore Roosevelt Dam in Arizona and Elephant Butte Dam in New Mexico provided reliable irrigation water supplies for Western farmers as well as protection from damaging floods. As the West's desert lands were transformed into productive farmlands, a strong, stable economic base emerged and more people moved West, bringing with them new skills and trades. While this migration was beneficial in that it reduced the population pressures of the eastern United States, new demands were being placed on Reclamation projects to now supply water for growing cities and industries and to generate hydroelectric energy to run factories and light homes. As the population continued to increase, it was necessary to build additional water projects.

Today, after constructing more than 600 dams and reservoirs, Reclamation's initial mission of reclaiming the arid lands of the West to allow for settlement and development has been accomplished. The Western United States is remarkably productive and prosperous with highly populated urban centers throughout this diverse region that ranges from high snowpacked mountains to the desert Southwest.

Reclamation is the largest water wholesaler in the United States, bringing this precious resource to 31 million people and irrigating 10 million acres of land. Reclamation is also the Nation's second largest producer of hydroelectric power and the ninth largest electric utility. Reclamation's 56 powerplants annually provide more than 40 billion kilowatt-hours, generate nearly a billion dollars in power revenues, and serve 6 million homes.

But the needs of the West have changed dramatically since the beginning of the century. Demands on Western water continue to grow rapidly while changing societal values and greater environmental knowledge and awareness have demonstrated the need for Reclamation projects to be operated in a more environmentally-beneficial manner. Today, residential, industrial, agricultural, recreational, hydropower, and environmental needs all compete for this finite resource. These changing needs have increased Reclamation's responsibilities and resulted in a fundamental shift and evolution in Reclamation's mission.

Many of the challenges of managing these changing values and competing demands can be characterized by focusing on the history of the Colorado River, and more specifically, on the management of the river within Reclamation's Upper Colorado Region (UC). The UC Region encompasses almost all of Utah and New Mexico, the western portion of Colorado, northeastern Arizona, southwestern Wyoming, the far west corner of Texas, and small portions of Nevada and Idaho. The UC Region designed, constructed, and now operates the Colorado River Storage Project (CRSP), one of the most complex and extensive river resource developments in the world, of which Glen Canyon Dam is the key unit.

The Colorado River

The Colorado River has always been an important factor in the equation of Western water. Figure 1 shows the seven states that comprise the upper and lower Colorado River Basin which depend heavily on the water coursing through this river. As a result, the Colorado River is today, one of the most regulated rivers in the world. Structurally, this river is regulated with more than 20 major dams in the system. Legally, this river is regulated by numerous statutes, compacts, decrees, and a treaty, generally referred to collectively as the "Law of the River."

In the early 1900s, the Colorado River flowed freely, with very few diversions made for irrigation. In its natural state, the Colorado River was a seasonally variable river which fluctuated greatly depending on precipitation and inflows from side canyons. Flows in the Colorado would run from little more than a trickle during hot, dry summer months to raging floods in the spring. Because the threat of flooding left farmers vulnerable, demand began to grow for some type of permanent flood control to be developed. An early Reclamation engineering board report recommended construction of a dam and storage reservoir to help alleviate this problem.

Fig. 1. Seven Basin States.

Water law in most Western states was based on the "doctrine of prior appropriation." Utah, Colorado, New Mexico, and Wyoming were concerned that a storage reservoir would mean the faster-growing states of California, Arizona, and Nevada would establish prior rights to large amounts of the river's water before they could make use of flows passing through their streams. The proposed Boulder Dam (today, known as Hoover Dam) as part of the Boulder Canyon Project Act, caused bitter conflict between the "upriver" and "downriver" states over the establishment of each states' portion of Colorado River water. In order to resolve this conflict, the Colorado River Commission was formed in 1921, with representatives from each of the seven basin states. After a year of work, the historic document known as the Colorado River Compact (Compact) was created, dividing the river into the upper and lower basins at Lee Ferry, Arizona, near the Arizona/Utah border. Each basin was allocated use of 7.5 million acre-feet (maf) of water annually, to be divided up among each basin's states.

Although the Colorado River Compact was signed on November 24, 1922, differences of opinion among the basin states continued. Because Mexico also had a growing reliance on Colorado River water, treaty negotiations with Mexico were undertaken. It wasn't until 1941, when Mexico's annual usage of Colorado River water reached approximately 1.5 maf, that negotiations between Mexico and the United States were successful. A treaty was drafted by the International Boundary and Water Commission in 1944 that ensured Mexico a 1.5 maf annual apportionment of the Colorado River, as well as apportioning the flows of the Rio Grande.

Once the Colorado River Compact was established, the upper and lower basin states had the responsibility for dividing the use of their 7.5 million-acre feet apportionment. This proved to be a more difficult task for the lower basin states (California, Arizona, Nevada) than the upper basin states (Colorado, New Mexico, Utah, Wyoming). The upper basin states' agreement to divide water among themselves on a percentage basis was agreed to in the Upper Colorado River Basin Compact of 1948.

It wasn't until a 1964 United States Supreme Court Decree that the lower basin states reached an agreement on their water division issues. The heart of the lower basin's difficulty was the dispute between California and Arizona over differing interpretations of parts of the 1922 Compact, and the Boulder Canyon Project Act with respect to surplus water, and Gila River (a Colorado River tributary) flows. The 1964 Supreme Court Decree and subsequent negotiations between Arizona and California finally resulted in a lower basin water allocation agreement.

The Lower Basin and the Boulder Canyon Project Act

The Boulder Canyon Project Act was passed in 1928 to authorized facilities necessary to meet critical needs of the lower basin including flood control, flow regulation, water storage and delivery, and hydropower generation. The Boulder Canyon Project Act authorized the construction of Hoover Dam and the All-American Canal. These first two major structures controlled the erratic flows of the Colorado River and delivered water to California. Smaller downstream projects such as Parker Dam, Davis Dam, Imperial Dam, and the Colorado Aqueduct were built later.

The Upper Basin and The Colorado River Storage Project

The guiding force behind the development and management of water in the upper basin was the Colorado River Storage Project Act (CRSP) of 1956. This act provided for the comprehensive development of the water resources of the upper basin states while ensuring long-term regulatory storage of water to meet lower basin delivery requirements under the Compact.

As a basin-wide water resource development plan, the CRSP called for facilities to be built on the tributaries of the Colorado, as well as a major one on the main stem of the river. Four primary storage facilities were built, including the Wayne N. Aspinall Unit on the Gunnison River in Colorado (includes Blue Mesa, Crystal, and Morrow Point Dams), Flaming Gorge Dam on the Green River in Utah, Navajo Dam on the San Juan River in New Mexico, and Glen Canyon Dam on the Colorado River in Arizona. These facilities were constructed to regulate the flow of the Colorado River to provide storage of water for beneficial consumptive use, including irrigation, municipal and industrial use, flood control, and power generation, and to meet downstream obligations under the Compact. With the construction of these facilities, a combined total storage capacity of nearly 34 maf of water became available. The CRSP also authorized participating projects to develop water in the upper Colorado River system for irrigation and related uses.

Glen Canyon Dam

Several dams and canals were already in place in the lower basin by the 1950s, but only limited development had taken place in the upper basin. The upper basin states were anxious to begin putting their water to beneficial use before any potential claims by the lower basin were made on this water, even temporarily. The needs for water development in the upper basin, coupled with the undependable flows of the Colorado River, led to the Colorado River Storage Project Act and the construction of Glen Canyon Dam.

Glen Canyon Dam was constructed on the main stem of the Colorado River near the Utah/Arizona border. Completed in 1963, Glen Canyon Dam is the key unit of the CRSP, providing significant water storage, flood control, and hydropower generation. Additionally, Glen Canyon Dam controls water releases to the lower basin in accordance with the 1922 Colorado River Compact and 1944 Mexican Water Treaty.

The reservoir impounded by the 710-foot dam, is the second largest reservoir in North America. Lake Powell has a total storage capacity of over 26 maf, over 1,900 miles of shoreline, and is one of the most scenic lakes in the world. As with numerous other Reclamation reservoirs, it didn't take long for the wonderful recreational value of the lake to be recognized and utilized by people all over the country.

The powerplant at Glen Canyon Dam was completed and brought on-line in 1964. It provides about 80 percent of the power generated by CRSP facilities. When Glen Canyon Dam was first built, and for many years, the powerplant was operated to provide power during high demand periods (peaking power). As a result, the volume of the releases made from the dam fluctuated daily and hourly to respond to power demands.

By the late 1960s, however, evidence of the Nation's changing values and greater environmental awareness became apparent when Congress enacted the 1968 Colorado River Basin Project Act which provided for further comprehensive development of Colorado River Basin water resources. Additional benefits, including recreation, water quality, and fish and wildlife were now considered important purposes of water development in the Colorado River Basin.

The Act also mandated that the *Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs* (including Glen Canyon Dam) be developed. The Criteria, completed by a Federal/state group in 1970, requires that the Annual Operating Plan for Colorado River reservoirs:

> . . . shall reflect appropriate consideration of the uses of the reservoirs for all purposes, including flood control, river regulation, beneficial consumptive uses, power production, water quality control, recreation, enhancement of fish and wildlife, and other environmental factors.

With this evolution of the Nation's values, managing the operations of the dam was becoming more challenging. The demand for water and power continued to increase throughout the West, but this demand now had to be balanced with more diverse and potentially competing needs.

After Glen Canyon Dam had been in operation for a period of years, Federal, state, and tribal resource management agencies, fishing and rafting interests, and environmental groups became concerned over the detrimental effects the daily fluctuating releases were having on the downstream cultural, fish, wildlife, and other river resources. Because the dam was constructed prior to the enactment of the National Environmental Policy Act of 1969 (NEPA), no environmental impact studies were conducted or a final statement completed on the construction or operation of the dam.

Fundamental changes had occurred in the natural dynamics of the river after the dam was constructed. The Colorado River had once been a sediment-laden river with highly variable flow rates depending on the season. With the dam in place, the Colorado's natural flow pattern was forever altered. No longer did the tremendous raging floods wash through Glen and Grand Canyons in the spring carrying the sediment it once did. Behind the dam, the river flowed into a lake. Below the dam, the river became cold and clear. Downstream from the dam, a new ecosystem emerged as different wildlife species and vegetation appeared in the Grand Canyon. The enhanced riparian habitat resulted in a significant increase in the peregrine falcon population. In addition, a blue-ribbon trout fishery developed which increased the food base for bald eagles, allowing that population to flourish while attracting anglers and establishing fishing as a viable, highly valued recreation resource. However, there were also negative environmental impacts occurring downstream as a result of fluctuating releases.

With concern growing over the negative impacts affecting the Glen and Grand Canyons, in 1982 the Secretary initiated the two-phase, multi-agency GCES to better understand the environmental and recreational impacts associated with the operations of the dam. Findings from these studies led to a July 1989 decision by the Secretary for Reclamation to prepare an EIS to reevaluate dam operations in order to determine specific options that could be implemented to minimize, consistent with law, adverse impacts on the downstream environment and cultural resources, as well as Native American interests in the canyons.

Until the EIS was completed, Reclamation implemented interim flow operations and began a monitoring program in 1991 to protect downstream resources. The criteria of the interim operations were essentially the same as those specified in *Low Fluctuating Flow Alternative* under consideration in the EIS. This included restricted peak releases of fluctuating flows to 20,000 cfs; limited minimum releases to 5,000 cfs at night, and 8,000 cfs during the day; limited daily fluctuations between 5,000 and 8,000 cfs, depending on the monthly release volume; and limited rate of change to 2,500 cfs per hour (cfs/hr) during periods of increasing releases and 1,500 cfs/hr during periods of decreasing releases.

A total of eight action alternatives, representing a reasonable range of operational options, and one no action alternative were evaluated during the EIS process. This document would provide the necessary information and analysis for the Secretarial decision on how to best balance competing interests, meet statutory responsibilities for protection of downstream resources, produce hydropower, and to protect Native American interests.

In addition to the Secretary's decision for the re-evaluation of Glen Canyon Dam operations, Congress subsequently enacted the Grand Canyon Protection Act

(GCPA) of 1992. Section 1802 (a) of the GCPA requires the Secretary to operate Glen Canyon Dam ". . . in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use."

The GCPA directs the Secretary to implement section 1802 in a manner fully consistent with all existing laws that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin.

The Final Glen Canyon Dam EIS was completed and filed with the Environmental Protection Agency on March, 21, 1995. This document was prepared with an unprecedented amount of scientific research, public involvement, and stakeholder cooperation. Over 33,000 comments were received on the Draft EIS, reflecting the national attention and intense interest in the EIS. The Secretary signed the ROD on the EIS, on October 9, 1996, documenting the decision to implement the Modified Low Fluctuating Flow Alternative (preferred alternative) which included the use of beach/habitat-building and maintenance flows as an environmental restoration tool.

A New Era of Water Resource Management: The Beach/Habitat-Building Flows

The years spent conducting research and collecting and analyzing data on the dam's affect on the canyons, the preparation of the EIS, and the signing of the ROD are indicative of the changing environmental attitude in the United States in the latter part of the century, and a new era of water resource management for Reclamation.

The detrimental environmental impacts occurring in the Glen and Grand Canyons were primarily due to the greatly fluctuating releases from the dam and from the lack of flooding that historically occurred along the river each spring. These natural floods would regularly strip all but the highest vegetation from the channel banks, deposit sandbars along the river, and remove boulders from constricted rapids. With the dam in place, virtually all sediment coming from upstream is trapped above the dam. As the releases fluctuated with no new sediment being deposited downstream, the sandbars in the Grand Canyon were slowly eroding and steadily disappearing, reducing the backwater habitats available for endangered species.

The preferred alternative of the EIS included beach/habitat-building and maintenance flows as an integral element. The flows also fit within the intent of the GCPA which provides for the operation of Glen Canyon Dam for environmental purposes in addition to traditional water and power benefits. The objective of these scheduled short-duration high releases is to rebuild high elevation sandbars, deposit nutrients, restore backwater channels for endangered species, and provide some of the dynamics of a natural system. Reclamation tested this method for rebuilding sandbars and restoring habitat when it conducted the first such beach/habitat-building flow, or "spike" flow at Glen Canyon Dam in March 1996. Following 4 days of steady flows at 8,000 cfs, flows were increased to 45,000 cfs on March 26, through April 2, 1996. This volume of releases was accomplished by running the powerplant at full capacity and releasing water through the four jet valve bypass tubes.

Scientists conducting the flood experiment expected the high flows to redeposit sediment from the bottom of the river onto the banks above the fluctuating flow level of 20,000 cfs (since August 1991 when Interim Flows were implemented), thus rebuilding the sandbars. The sandbars are vital to the establishment of native vegetation, which increases insect populations, which in turn provides a strong food base for native fish and bird species. Greater recreational value and protection of cultural resources are also a benefit of newly created or improved sandbars.

At the conclusion of this flood experiment, scientists continued gathering and analyzing data for several months. Overall, the test was successful in increasing the number and volume of sandbars along the river, creating some new backwater habitats, and widening several constricted rapids. No negative impacts were observed on fish species, endangered bird species, or the endangered Kanab ambersnail, and no Native American cultural artifacts and sites in the canyons were harmed. Since this flood event, however, 50 percent of the aggradation has been lost to natural erosion which continues to take place, making it probable that future controlled flood events may be initiated periodically to restore what is lost to erosion.

A smaller-scale high flow event from Glen Canyon Dam took place from November 3-5, 1997, in an attempt to redistribute sediment deposited in the Marble Canyon reach of the Grand Canyon by the Paria River (a Colorado River tributary, just below Lees Ferry). During this smaller, high release event, releases from the dam were made at full powerplant capacity of 31,000 cfs. No water bypassed the powerplant as it did in the 1996 controlled flood. The objective of this high flow event was similar to the first flood event in that it was intended to stir up the sediment and redeposit it onto sandbars that had eroded from normal dam operations.

The use of this operational technique to maintain the ecological health of the Grand Canyon represents a new management approach within Reclamation in response to national concerns over environmental impacts associated with dam operations. This kind of science-based decision-making process is vital to protecting the environment and balancing competing needs.

The Adaptive Management Process

Throughout the environmental studies and EIS process, a vast amount of research was conducted, work completed, knowledge gained, and progress made toward understanding the environmental impacts of the dam's operations in the Glen and Grand Canyons. This process culminated in the completion of a Final EIS and ROD which implemented operational changes that would reduce the detrimental environmental impacts and balance the needs of the many stakeholders with an interest in the river and the canyons.

An important aspect of this new environmentally responsible management approach is continued long-term monitoring and research. Section 1805 of the GCPA requires the Secretary to ". . . establish and implement a long-term monitoring and research programs and activities that will ensure that Glen Canyon Dam is operated in a manner consistent with that of section 1802."

The Act also states that:

> Long-term monitoring of Glen Canyon Dam shall include any necessary research and studies to determine the effect of the Secretary's actions under section 1804 on the natural, recreational, and cultural resources of the Grand Canyon National Park and Glen Canyon National Recreation Area.

One of the key elements outlined in the GCEIS and mandated by the ROD is an AMP intended to provide the organization and process to ensure scientific information and recommendations from a diverse group of stakeholders are incorporated in the evaluation, management, and future decisions on Glen Canyon Dam operations.

The AMP calls for the continued interaction of managers and scientists to monitor the effects of current dam operations on the Colorado River ecosystem, and to conduct research on alternative dam operating criteria that may be necessary to ensure continued protection of resources and improve natural processes.

This long-term process of adaptive management is being implemented through the formation of a Federal advisory committee called the Adaptive Management Work Group (AMWG). The AMWG was chartered by the Secretary on January 15, 1997, and consists of Federal and state resource managers, Native American tribes, power marketers, environmental groups, recreationists, and other interested stakeholders. The AMWG was established to develop, evaluate, and recommend monitoring and research programs, modifications, and alternative operation strategies for Glen Canyon Dam, and make recommendations to the Secretary to meet the requirements of the GCPA. The AMWG does not displace the legal authority and responsibility of Federal agencies to manage resources in the best interests of both the environment and society.

In addition to the creation of the AMWG, the Technical Work Group (TWG) and the Grand Canyon Monitoring and Research Center (GCMRC) were created to play vital roles as part of the adaptive management process. The TWG is composed of technical representatives from various stakeholder groups, appointed by the AMWG. The TWG provides the AMWG detailed guidance on issues and objectives; develops criteria and standards for monitoring and research programs; designs research and monitoring programs; develops resource management questions for monitoring and research by, or under, the direction of the GCMRC; provides information for annual resource reports; and translates the AMWG's management objectives into research needs for the GCMRC.

The GCMRC was established on November 11, 1995, by the Assistant Secretary for Water and Science, during the transition from the GCES program to the AMP. The GCMRC was established to conduct the research and monitoring programs necessary to evaluate dam operations, as directed by the GCPA and GCEIS to ensure that Glen Canyon Dam is operated in a manner consistent with Section 1802 of the GCPA. In addition, an independent review panel will be created to provide outside review of, and credibility for, the monitoring and research programs and recommendations made to the Secretary.

A Continuing Challenge

For nearly 100 years, the Bureau of Reclamation has played an important role and provided a vital service to the Western United States. The return on the national investment made in the planning and construction of water projects to store and deliver water to the parched desert lands of the West is immeasurable. But there have been many challenges along the way. As the history of managing the Colorado River and Glen Canyon Dam operations demonstrate, Reclamation's role in managing water in the West has evolved to meet new and often conflicting demands with an increased sensitivity toward the environment, public opinion, and our customers' changing needs.

As the 21st century comes into focus, Reclamation is prepared to meet the continuing challenge of bringing together competing interests to find consensus-based solutions to contemporary Western water management challenges.

GROUP READINESS: A NECESSITY FOR PRE-NEGOTIATION ASSESSMENT

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Abstract

The use of a consensus process in resolving natural resource disputes is not a panacea. A failed process can do more damage than not having tried at all. Following the principle "Cause No Harm", government officials, stakeholder groups, and communities must carefully assess the probability of success before engaging in a consensus process.

Community groups or coalitions and newly formed or small grassroots groups, may lack professional expertise in negotiation process. Many groups depend on volunteers who have many commitments and demand for their time and attention. It is not realistic to expect the same level of expertise from some small community or special interest groups as from groups that have professionals with skills who may be able to commit full time to a consensus process.

Community groups have a special challenge when they evaluate and assess their involvement in a consensus-based negotiation. Retrospective interviews with thirteen community members involved with a major regional facilitated negotiation in northwestern Nevada suggested that currently available assessment tools, designed primarily for agencies, line organizations and groups with professional staff, are incomplete.

Based on these retrospective interviews, each of which lasted about an hour, we have developed assessment tools designed to help groups, with no prior experience in consensus-based negotiations, to evaluate their readiness to engage in negotiations.

Key Words: Conflict Management; Negotiation Theory and Practice; Alternative Dispute Resolution; Truckee-Carson; Community Groups; Water Management; Natural Resource Management.

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INTRODUCTION

Often entire communities, especially in rural areas, are impacted by federal decisions about the allocation and management of natural resources. Entire communities which typically include diverse interests, may be asked to come to the table. Or such communities may demand a seat at the negotiating table.

Much of the literature and background information about consensus process, such as facilitated negotiation, are most applicable to federal agencies, organizations with line authority or groups with an established organizational structure and professional staff. Assessment tools exist for such organizations. We believe that additional tools are needed, however, when grassroots community organizations or communities with diverse interests are evaluating their situation and their readiness to go into negotiation. Preliminary assessment tools can be especially helpful to rural communities and small, incipient, volunteer-based, or underfunded grassroots organizations where there may be neither full time staff nor professional expertise.

Non-professional grassroots and community groups may not have clear lines of authority for the decision-making that is necessary during a negotiation process. Such groups may have neither professional resource managers to analyze and evaluate data necessary for constructive discussion and resolution, nor participants skilled in consensus and dispute resolution processes. These factors can contribute to a flawed process or a failure to reach agreement, even when there is an expression of good faith and a strong willingness to negotiate. In any negotiation, skills and available resources matter.

Typically good faith and willingness to negotiate are key components evaluated in a pre-negotiation assessment. To enhance the probability of success where a community or non-professional grassroots organization is a stakeholder, we believe that a determination of group readiness, as well as good faith and willingness, must also be a component of any assessment prior to a decision to engage in consensus negotiations. In general, readiness means that the group has come to agreement on the substance of the issues and on what their interests really are. As important as substance, however, is that the group has examined procedural concerns and internal group dynamics and evaluated such process concerns effectively and realistically.

In this paper, we propose assessment tools designed primarily for non-professional grassroots and community groups to assess their readiness, as a group or organization, to be able to sit as a full partner at the negotiation table. These tools are intended as a supplement to enhance the effectiveness of existing tools for pre-negotiation assessment.

BACKGROUND

The Truckee-Carson basin in northwestern Nevada has had long standing disputes involving allocation of scarce water resources among several competing interests. In an effort to resolve the issues in a comprehensive way, P.L101-618 was passed by the U.S. Congress in 1990. Implementation of the legislation, however, proved difficult and threats of protracted litigation made negotiation appear to be less expensive and less time consuming, hence a desirable alternative. A facilitated negotiation seeking regional solutions took place over seven months from September 1994 to March 1995. One of the nine parties at the table represented two rural communities with diverse interests.

The Fallon-Fernley area, site of the first federal reclamation project, the Newlands Project, is a downstream high desert community. At the time of the negotiations, many residents felt themselves to be severely impacted by demographic changes upstream, changes in social values, and changes in federal policies. For most of its existence, this rural area had been able to operate in isolation from external pressures and events. With the Newlands Project in its midst, however, the area had use of a resource, water, that became increasingly scarce in an arid region as population grew upstream in the Reno area. In addition, declaration of an endangered species fish upstream, pressures to maintain a downstream national wetlands area, and growing criticism of use of water to farm in an arid region all resulted in a once, relatively isolated community, coming to feel it was increasingly under attack by outside interests.

Internally the area's roots are farming. Relatively small acreages provide families with enough to survive, and in good years, enough to put a little away for the future. The presence of a large naval air station with largely mobile military personnel, has not altered the community's relatively traditional structure and values. Many families proudly claim the status of homesteaders who once eked little more than bare subsistence out of the sandy, arid landscape. Politically it tends to be a conservative community of hard working farmers and entrepreneurs. There are few signs of material wealth in a community of modest homes and few luxury automobiles.

Beginning with passage of the Endangered Species Act and declaration of an endangered fish upstream in 1968, there was increasing and unrelenting pressure on irrigators to make water available for non-agricultural uses. There were ongoing and changing rules as a result of court decisions and federal government policy changes that disrupted internal rhythms that had been in place for decades.

With passage of P.L. 101-618 in 1990 came potential reallocation of large quantities of irrigation water and accompanying threat to the recharge for local drinking water sources. One of the provisions of the 1990 federal legislation stipulated maintenance of 25,000 acres of wetlands near, and adjacent to, the community. Reallocation of water from agricultural irrigation to wetland uses was to occur through willing buyer-willing seller purchases. The source for water purchases would be the Newlands Project where irrigation water recharged local aquifers used for drinking water.

Though the Fallon-Fernley area can be characterized as rural, it is urbanizing rapidly because of its proximity to an urban area, its naval air station, its desirable green alfalfa fields, its available land resources and its wide open spaces.

Despite external threats to its equilibrium, as late as1992 residents still tended to cluster in relatively isolated social groups. There were "city folks" and farmers. There were county government and city government. There were religious groupings. The City of Fallon, with one third of the population, tended to be an island in the middle of the larger Churchill County area. The nearby town of Fernley, 30 miles away and upstream in a different county, faced many of the same issues over water as its neighbors in the Fallon area to the east, but there was little formal or informal contact between the communities. Notably, and despite increasing pressures from outside, there was little communication or cooperation across socio-political lines.

Lack of communication between groups was not based so much on economic factors or class distinctions as on personal affiliation and interests. Residents, as always, were politely courteous to one another, but other than at church on Sunday, or at sporting events for their children, they seldom socialized or talked with one another across the invisible, but very real, barriers that existed between groups in the community.

With passage of P.L. 101-618 in 1990 and subsequent efforts to implement the law's provisions there was mounting external pressure on the community. As a result, some in the community began to develop an awareness of a need to come together as a community; a need to communicate across socio-political boundaries.

In 1992, a small grassroots group formed to begin to address concerns and issues generated by regional pressures on the local water resources. This group began to hold public meetings to which spokespersons representing various interests and stakeholders were invited to share their concerns and points of view. Speakers included representatives of federal agencies, environmental groups, nearby tribal representatives and experts on topics related to natural resource management. This was one of the first public forums that addressed water concerns as a broad community issue. It was also one of the first efforts to engage in dialogue between groups and interests both within the community and the region

Supported by some concerned leaders in the community, this initial, informal grassroots group eventually evolved into a consensus-based public entity approved as such by the attorney general of the state. Such an organization represented a departure from the more traditional top-down organizations that had been typical in the area. Pulling the diverse community interests together to develop such an organization required intensive education in consensus decision-making and extensive discussion of the roles of the various community entities that agreed to participate in the new organization.

Under the provisions of Nevada Law (NRS 277), the new group was formalized under an Interlocal Agreement that allows public entities to join together to pursue activities that reflect shared concerns.. The public entities who officially signed the formal agreement in October 1993 were Churchill County, the City of Fallon, the Truckee-Carson Irrigation District, the two local conservation districts and the Town of Fernley. The only public entity that elected not to participate was the nearby Fallon Paiute Tribe.

Over a period of months, local citizens met, first to develop the agreement that would serve as the organizing document for the new organization, then to attend workshops and meetings to learn about consensus decision-making. Both in large community groups and smaller working groups, people met to discuss issues confronting residents. In April 1994, after eight months of regular meetings and workshops, the nine member board of the new organization, called the Lahontan Valley Environmental Alliance (LVEA) met in formal session for the first time.

A significant challenge the new group faced was broad community education about water issues and about the potentially serious impacts on the community from implementation of P.L. 101-618. Implementation of the law created an inherent change in the scale of the impacts from decisions about water allocation and policy. Any significant change in the amount of water for irrigation in the area, for example, could have a serious impact on the drinking water for all residents. Both a local basalt aquifer and the sedimentary aquifers used for local drinking water could be seriously impacted by actions mandated in the legislation.

Undeniably, water issues had been elevated from being issues primarily affecting agriculture to issues of concern to the entire community. Yet, as is true in many places, most local residents tended to be apathetic as long as there was water when they turned on the taps. Furthermore, it might seem to the average resident that concern over water was no more than a continuation of concern expressed by local irrigators for decades. It was difficult for the average resident to understand that passage of P.L. 101-618 could mean anything different from what had happened in the past.

LVEA not only reflected a significant change in the way the community was doing business, it also had the challenge of educating an apathetic public on an issue that is technical and that, historically in the area, was seen as a concern primarily of irrigators and farmers. The agricultural community continued to see the water issue primarily as one of protecting a property right and upholding prior court decrees that allocated water in the region, and not as an issue of community drinking water. For many in the agricultural community, water concerns were a zero sum game, an either/or proposition in which focus on the community drinking water concern implied lack of concern for property rights of agricultural water users.

Some suggest that P.L. 101-618 crystallized issues and expanded the concerns about water reallocation in the area from being one of concern primarily to the agriculture community to becoming one of concern to the broader community. Efforts to implement the law also tended to create a dichotomy between agricultural interests and community interests, with irrigators primarily concerned about protecting water as a property right and the large community primarily concerned with maintaining a drinking water supply.

At the same time that the LVEA was developing as one of the first broadly based organizations in the community, there was growing interest both outside and from within the community to use negotiation as a way to resolve the multitude of issues and concerns that had surfaced with efforts to implement P.L. 101-618. As a group that could reflect the diverse interests in the community LVEA was seen as the logical choice to represent the community in proposed regional negotiations. Less than a month after the board for LVEA had met for the first time in April 1994, the group, still in its infancy and its formative stage as an organization, found itself drawn into assuming the representative role for the community at the negotiating table for a multi-issue, multi-party, intractable conflict.

As the community moved forward into negotiations, no one would have predicted the amount of time and energy the negotiations would require. A rough cumulative estimate made at the end of the negotiations was that members of the community team invested more than 6,000 hours over the seven month period. In the end, this large investment of time resulted in widespread feelings of burnout. One effect was dissipation of interest and energy to devote to community issues.

While the negotiations did not achieve any hoped-for resolution of issues, the LVEA, with its coffers emptied and its energy dissipated, was seriously crippled. Four years later the organization still has not recovered from the experience and may never do so. Some would consider this a serious loss to the community.

METHODOLOGY

Because the negotiations did not result in resolution of any issues and because the LVEA, in many ways, could be called a casualty of the negotiations, we were interested in how local participants viewed the experience of the negotiations some three years after they concluded. Through interviews with a cross section of community residents and participants in the negotiations, we used existing assessment tools to conduct a retrospective assessment. A primary focus of the interviews was to learn how internal decisions concerning participating in the negotiation were made. We also wanted to examine whether the use of existing assessment tools might have influenced either the decision to negotiate or how the negotiations were structured and conducted.

When we began interviews with community members, we believed we would discover that the list of questions we found in the literature would have helped participants had they been considered prior to the decision to go into facilitated negotiations in 1994-95. We added some questions of our own to elicit information we hoped would give us additional information to do a retrospective analysis of the negotiations.

It surprised us to learn that in most cases, the questions did not elicit thoughtful responses of the kind that we believe a community group must address prior to making a decision to go to the table. Hence our decision to develop an expanded list and format for the questions with a concern to avoid abstract concepts and jargon as much as possible.

Below are the questions we used in our interviews during July 1998. The first list includes questions we asked to elicit background information. The second is a list recommended in the literature.

Questions composed for the interviews

- What is your understanding of how the "Second Generation Negotiations" got started?
- What do you recall about how the community (LVEA) decided to participate in the negotiations?
- What was your understanding about why LVEA was representing the community in the negotiations?
- What were your expectations of the negotiations?
- How did you feel about the decision to negotiate at the beginning? At the end? And Now?
- Was there anytime during the negotiations when you rethought your decision (to negotiate)?
- During the negotiations was there anything significant that struck you in terms of process?
- How would you characterize "interest-based" negotiations?
- What were the communities' interests? What were the interests of the other parties?
- Do you think the process was "interest-based"? Why or why not?

- In retrospect, is there anything you would change about the process? What?

<u>Questions adapted from literature</u>

<u>Preliminary statement read to respondents</u>: "The following questions were developed by professionals in dispute resolution to help stakeholder groups determine whether to proceed to an assessment phase of a consensus process. By consensus process we mean a process that has the following attributes:

- Participants represent stakeholder groups or interests, and not simply themselves.
- All necessary interests are represented or at least supportive of the discussions.
- Participants share responsibility for both process and outcome.
- An impartial facilitator, accountable to all participants, manages the process.
- The intent is to make decisions through consensus rather than by voting.

<u>Questions</u>:

- Are the issues of high priority and are decisions needed?
- Are the issues identifiable and negotiable?
- Do the issues have a sufficiently developed factual base so that you are reasonably informed and are able to engage in meaningful discussion and resolution of the issues?
- Do you have a manageable number of interdependent or related issues?
- Are you as likely, or more likely to achieve your overall goals using negotiations as you would through alternatives to negotiations? Is this true of the other parties as well?
- Do you have enough time and resources to devote to the process? Recognize that the more contentious and intractable the issues are, the more time and resources are needed to achieve agreement.
- Is the political climate favorable?
- Apart from using professional mediators and negotiators, do you have enough information about consensus processes to make informed decisions? Are you an informed consumer?
- Do you have the necessary skills, abilities and experience to engage in the process?
- Are the interests identifiable? Do you represent an interest that has a stake in the outcome? Do the other parties represent interests that have an identifiable stake in the outcome? Do you understand the interests of the other parties?
- Do you have a process in place for ratifying an agreement reached at the negotiating table?

- If these questions were asked (prior to the negotiations), would you have done anything differently? What?

Final Set of Topics Covered in Interviews

"In your opinion, would the process have been improved by any of the following; 1. time, 2. additional resources, 3. open meetings, 4. more than one facilitator, 5. change in the participants, 6. opportunity to negotiate the groundrules face-to-face with the other stakeholders, 7. other?"

DISCUSSION AND GENERAL OBSERVATIONS

From information gathered in the interviews with community members involved in preparing or participating in the facilitated negotiations held in 1994-95, our conclusion is that the group's decision to negotiate was made by default. Interviews revealed a general perception that the community had no choice but to enter into negotiation. Indeed, the community embraced the idea of negotiating. It was not a carefully thought through decision based on examination of the resources and readiness of the community group, however. All pre-negotiation assessement was done by the professional mediator brought in from Washington D.C.

Many items that we believe should be included in a pre-negotiation assessment, appear in this case, to have been determined without any thoughtful and thorough internal discussion. Items not carefully examined included; that the community speak with "one voice"; the time frame for the negotiation; the parties who should be present; the groundrules; the scope of the issues; a clear ratification process; skills of the members of the group; and, especially, the internal dynamics of the group. In general, there was general lack of understanding that these are important.

In effect, there was no systemic internal community evaluation of the community group's readiness to go to the table. In retrospect, as a result of information gathered in these later interviews, we believe the community group would have benefited greatly by a process that carefully and systematically examined the group's readiness to negotiate. Assessment probably would not have changed the decision to negotiate, in great part because the negotiations were leveraged and convened by the senior senator from Nevada, Harry Reid. Many believed that refusal to negotiate could have had serious political consequences. Had an assessment been done, however, we believe the group would have gone in better prepared and with a heightened awareness of the importance of process in the facilitated negotiation and of their role in fashioning the process.

Having overlooked this examination of group readiness, the local group precipitously moved almost directly into selecting a professional to head the local team and developed a selection process to determine members for the local team.

In preparation for the negotiations, the group focused almost exclusively on substantive issues.

Two months before facilitated negotiations began many people, later on the local team, attended a one-day workshop on consensus-based negotiations conducted by a university professor with background in conflict resolution. In addition to the one-day workshop there was a session at a later date with the professional mediator hired for the facilitated negotiations. Prior to the first formal negotiating session, the mediator convened a meeting of the local group to emphasize the interest-based nature of the negotiations and to request that the group focus on both its interests and the interests of the other parties in preparing an opening statement.

We believe that even with an introduction to process and negotiation, rarely can the average, engaged and concerned individual appreciate the significance of process when confronting substantive issues of deep concern, especially where those issues give rise to strong emotions. Perhaps the most that education of a community group can accomplish is to make people aware that for a constructive and successful negotiation, issues and concerns about process are as significant as issues and concerns about substance.

For people with no experience in negotiations, a single workshop and a short session on interest-based negotiating does not develop skills and experience for the kind of complex negotiations which later occurred in this situation. In any event, neither the workshop nor the short session included an evaluation of the group's readiness.

In our retrospective interviews with 13 community members three years after the negotiations, only two could identify what interest-based negotiations are, yet the 94-95 negotiations were described as interest-based. Few of the interviewees could respond to questions about process. The professional consultant hired to lead the local team was an engineer who was present only sporadically at local team meetings during the negotiations. The two community members selected to sit at the table with the professional consultant during the formal negotiation sessions were local citizens and volunteers with no prior experience with negotiations. In our view, the team neither understood the significance of process nor designated anyone with experience and skills in process and interest-based negotiating to help or coach the local team.

Other groups involved in consensus-based negotiating may find themselves in similar situations. Even if education in process and interest-based negotiating is available to community members, they will find it difficult to fully participate at a table where other parties have professional or experienced staff present. We believe that under such circumstances, a group composed of non-professionals is well served by having some specific guidelines and checklists that help them focus attention on group readiness as well as on internal group dynamics and ongoing procedural concerns. In addition such guidelines may help them by bringing into focus substantive and process issues in the formal negotiation. Based on information collected from these retrospective interviews, we have developed some assessment tools to help non-professionals assess both their readiness to negotiate and ongoing internal process in the group. In an effort to target lay people with no prior experience in consensus-based negotiating, these assessment tools, included below, avoid use of jargon and abstract concepts in favor of focusing on specific behaviors and activities that can be readily observed and evaluated.

We include two checklists that can be used by participants to evaluate a group's readiness to engage in consensus-based negotiation. One checklist helps a group to evaluate process, i.e. internal structure, procedures and group dynamics and another helps to evaluate, broadly, potential concerns with substance. Further, we include a procedure to guide a group toward developing its problem statement and objectives for negotiating. Finally, we include guidelines to help the group monitor internal group dynamics, both in a pre-negotiation phase and throughout the entire negotiation process.

It is our conclusion, following the retrospective interviews, that a citizen-based community group or any stakeholder group without professional staff should seriously consider designating a skilled person within the community or group, or hire an outsider, to assist the group to monitor and evaluate process. This designated process person should be assigned a formal role to monitor and coach the group throughout the pre-negotiation planning phase. This individual is someone who should also play an ongoing advisory role in any subsequent activities

The checklists and guides below are designed for use by a community group, with or without a designated person to be a coach for process. They are intended to be a supplement to other assessment tools already available.

An important goal of a thorough group readiness process is to "level the playing field", especially during negotiations where a community group sits at the table with governmental entities or professionally staffed interest groups.

CHECKLISTS AND GUIDES

A Checklist for Evaluating Process

1.______ **Issues and concerns of the group are sufficiently interrelated to be represented by one voice.**

Members of the community group must decide how many voices should be at the table. For strategic reasons there may be advantages to have diverse interests represented by "one voice" during negotiations. If the diverse issues and concerns of the community conflict or if there is tension among those who represent different issues and concerns, it may be preferable to have the issues and concerns represented by more than "one voice" to assure equitable representation.

2._____ **Anyone in a position to undermine an agreement has been invited to participate, is represented, or is at least supportive of the negotiation.**

While it may be easier and more efficient, time-wise, to go into negotiations with groups composed of individuals who are in agreement, in the end, those not included in the process are in a position to sabotage an agreement. Being inclusive at the beginning may be what assures a sustainable agreement at the end. Sufficient time must be allocated for the group's internal "negotiation".

3._____ **The Group has time and resources available.**

Community members who plan to participate in a negotiation process should have a reasonably clear idea about how many sessions and how many hours will be involved. Not only is time necessary for the formal negotiation sessions, but time must be allocated for internal group meetings and caucuses throughout the process. Resources to hire qualified individuals with technical and process skills may be necessary and should be examined.

4._____ **There is clear agreement in the group about how decisions will be made and there is a process in place for ratification should agreement be reached.**

This is one of the major differences between line agencies and single interest groups with professional staff who have an established decision-making process.. If a group represents a coalition of interests, or if public entities are involved, developing a process for agreement and ratification may involve extensive discussions. Representatives of the group during any negotiation must be clear about their authority and about what might be necessary to achieve final agreement.

*5.*_____ **Any constraints such as compliance with open meeting laws, the need to have a vote of a group of constituents to approve the agreement, or limited time available for meetings on weekdays or at certain times of the year, must be addressed.**

Such concerns may impose limitations on how and when meetings and negotiation sessions can be held, who can participate, and how they should be structured. If the group makes decisions by consensus, time must be left for the group to consult with constituents during the negotiation. If the group represent the public, time must allocated for public education on the issues and process of the negotiation.

*6.*_____ **Given that any successful negotiation requires active involvement by all parties in process as well as in issues of substance, there is at least one skilled person in the group designated as responsible for monitoring process and for coaching the group in process.**

3. Mutual Trust and Confidence Within Group

_____ Members evidence suspicion of one another's motives.

_____ Members trust one another and do not fear ridicule or reprisal.

4. Attitude within Group toward Differences

_____ Members avoid arguments, smooth over differences, suppress or avoid conflicts

_____ Members not only respect and accept differences, they actively search for differences and work through them openly – they are not pressured to conform.

5. Mutual Support Present

_____ Members are defensive about themselves and their functions.

_____ Members are able to give and receive help.

6. Level of Involvement-Participation Consistent

_____ Discussion is dominated by a few members.

_____ All members are involved, free to participate in any way they choose.

7. .Control of Decision Making Clear

_____ Subject matter and decisions are controlled by the chairperson.

_____ All members accept responsibility for productive discussion and for decisions.

8. Procedures in Place to Respond to Changing Circumstances

_____ The group is locked in on established rules and members find it hard to change procedures.

_____ Members readily change procedures in response to new situations.

9. Member Resources Fully Utilized

_____ Individuals' knowledge, abilities, and experience is not utilized.

_____ Each member's knowledge, abilities, and experience are fully utilized.

10. Objectives Clear and Understood

_____ Objectives are not clear or not understood and there is not commitment to them.

_____ Objectives are clear, are understood, and there is full commitment to them.

(Reference: The Field Program Associate I the Partnership for Rural Improvement, Northwest Educational Laboratory, (NWREL), 1978).

<u>A Checklist for Addressing Substance</u>

1._____ **There is group consensus about the overall problem the negotiation is being convened to address.**

2._____ **The problem can be stated succinctly.**

The succinct problem statement becomes especially important as the group meets with other parties. The problem statement can help to keep the group from getting "bogged down" in issues and concerns that may be raised by other parties but which are not of core concern to the group. The succinct problem statement

In negotiations, the process is constantly changing. People easily overlook the importance of process to focus, instead, almost exclusively on substance, i.e, the issues and problems. To assure an equitable and constructive negotiation, every group must be sensitive to, and effectively participate in, design and monitoring of process throughout.

7._____ **The group is willing to devote some portion of every session to an overview, review or discussion of process, i.e. procedures, structure and group dynamics.**

Issues of substance, often invested with a lot of strong emotion, can easily overshadow review and discussion of process. Time to be together may be at a premium. Participants may believe that it is inefficient to "waste" time in discussing process concerns. It can help later on as time constraints may increase, if, at the beginning, the group acknowledges the importance of continuing to focus on procedures and group dynamics throughout the assessment and negotiation process. This ongoing overview make take only a few minutes at the beginning of every session but should be done on a regular and continual basis throughout.

8._____ **The group has a level of expertise in negotiation process that is comparable to the level of expertise of other parties at the table.**

If there is a disparity in level of expertise among the parties, the group needs to address ways to assure skill levels between and among groups are addressed through groundrules or hiring of skilled personnel. (The group should not depend on the professional mediator or facilitator to bridge the gap in expertise.) This may involve bringing in someone who is an outsider to be a coach for the group.

A Guide for Evaluating Internal Group Process

The following is a guide that can be used by a group in determining its readiness to go to negotiation. The guide can also be useful for ongoing evaluation and monitoring, both of a group's own internal processes and of the larger group's processes during the negotiation phase as well. If group members check the first alternative under any of the major headings, the group is well advised to discuss the concern before moving ahead with substantive issues. The first alternative, in each case, is an indicator of a potential problem and should be considered a red flag.

1. Listening

_____ Members don't really listen to one another – they interrupt and don't try to understand others.

_____ All members really listen and try hard to understand.

2. Open Communication

_____ Members are guarded or cautious in discussions.

_____ Members express both thoughts and feelings openly.

can act as a compass for the group, both in preparing for negotiation and as the negotiation process moves forward.

3._____ **The group can support what it says with relevant data**.

The group may have an interest it wants to have addressed during the negotiation, but a statement of the interest without supporting documentation may not be sufficient. Part of the pre-negotiation preparation should include an understanding of how much data will be necessary to support an interest statement.

4._____ Resources are available to gather needed data.

If additional data needs to be gathered and the group lacks resources for collecting that data, the group needs to consider seriously whether it is prudent to proceed to negotiation.

5._____ Data that will be used to support discussions is acceptable to all parties.

While data may be available, there may not be agreement about the validity of the data by all parties. A community group should assess both its own data and data that might be used during negotiations and determine whether the data is acceptable to everyone. If there is disagreement over validity of data, it may be necessary to do joint fact finding before the negotiations begin.

6._____ The facilitator or mediator for the negotiations has sufficient background or expertise in the substantive issues that will be on the table.

Where issues to be negotiated are relatively straightforward and uncomplicated, the mediator/facilitator may not need to have a strong background in the substantive issues. Where issues involve a complex legal history or where the issues are highly complex, it may be important that the mediator/facilitator have a background or experience in similar issues. This is often the case in conflicts involving natural resources. In multi-issue, multi-party negotiations where agreement and resolution may involve long standing, intractable conflicts with disagreement or lack of information about the more technical issues that will be on the table, the group should ask sufficient questions of the professional's background to be comfortable that the person being considered has adequate technical expertise.

7._____ If the group represents a community-wide constituency, local media resources are available to educate and inform the public about the issues as well as the substance of the negotiation as it progresses.

A Guide for Addressing Substance

In situations where the issues are complex and the conflict long standing, it becomes especially important that a group clearly define the over-arching problem and their objectives. This will help the group stay "on course" if there is a tendency to get lost in smaller issues or concerns. The overall problem statement can provide a group compass for subsequent discussions during the negotiations.

The steps listed below should leave the group with a succinct problem statement and a list of related objectives to be achieved during the negotiation.

1. Brainstorm the Issues. Develop a Community "wish list".
This is not the time to worry about duplication or the length of the list of concerns. The goal is to get as many thoughts and ideas written down as possible. It is important to be sure that all points of view are reflected in the list.

2. Develop a Problem Statement.
This should be a succinct statement of not more than two sentences that captures the essential problem(s) to be addressed in the negotiation. It is not necessary that reference be made to items on the "wish list" to develop the problem statement.

3. Evaluate each item in the list as either essential or not essential to solve the problem as defined in the problem statement.
The key word here is essential.

4. Decide whether the problem statement fully captures all those items listed as essential. Redefine the problem statement if necessary.

5. Remove those items on the "wish list" that are listed as not essential.

6. Check the wish list a second time.
Look for overlapping or duplicated concerns and reword the statements as appropriate.

References

Carpenter, Susan and John Kennedy. Managing Public Disputes. San Francisco: Jossey-Bass, 1988.

Fisher, Roger and William Ury. Getting to Yes. The Penguin Group, 1991.

Susskind, Lawrence and Jeffrey Cruikshank. Breaking the Impasse: Consensual Approaches to Resolving Public Disputes. New York: Basic Books, 1987.

Ury, William. Getting Past No. Bantam Books, 1991.

THE SNAKE RIVER RESOURCES REVIEW...

ONE RIVER, MANY VOICES

by Deb Kidd[1]

ABSTRACT

Through the Reclamation Act of 1902 the Reclamation Service, since renamed the Bureau of Reclamation (Reclamation), was created to develop irrigation works for storage, delivery, and development of water. More recent legislation has placed additional requirements on Federal agencies, including Reclamation, to comply with specific environmental protection measures. Reclamation recognizes that salmon and other water-related resource needs require it to look at the way it will operate in the future. The SR^3 Leadership Team has been tasked with developing the necessary technology to help decision makers assess the effects of potential operation decisions and better understand the trade-offs to the Snake River resources. Because SR^3 is not a decision making process, its public outreach is not geared towards identifying and evaluating alternatives. Public involvement, in its traditional sense, is not a part of SR^3. Public participation in SR^3 is taking two basic forms; outreach to the interested public and participation by key stakeholders. The public outreach and stakeholder participation activities are uniquely designed to meet the needs of SR^3. The SR^3 Leadership Team adopted the Bleiker Systematic Development of Informed Consent (SDIC) methodology. SDIC is a methodology in which management tools are systematically applied to improve public agencies' implementation capabilities. During the first half of SR^3, the SDIC methodology has served SR^3 well. SR^3's experience thus far has shown that reapplying the SDIC methodology at major transition points in the life cycle of a project is important. It is incumbent upon us to be knowledgeable of the different methodologies available, to select an appropriate methodology, and apply it properly. Productive stakeholder involvement does not happen by accident.

Why Snake River Resources Review (SR^3)?

To understand the need for SR^3, one must look to the history of the Snake River and Reservoir system. The 1894 Carey Act granted large Federal land holdings to the arid Western states on the condition that these lands would be irrigated and

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settled. Through the Reclamation Act of 1902 the Reclamation Service, since renamed the Bureau of Reclamation, was created to develop irrigation works for storage, delivery, and development of water. Under the Reclamation Act, the Minidoka Project, located in southeast Idaho on the Snake River, was authorized in 1905. Shortly thereafter, the Boise Project in southwest Idaho was authorized. Additional projects followed on the Snake River and its major tributaries in Wyoming, Idaho, and Oregon, with the last major construction taking place in the early 1970s.

Congress enacted the National Environmental Policy Act (NEPA) in 1969, the Endangered Species Act (ESA) of 1973 and the Clean Water Act of 1977, all of which, among other legislation, require Federal agencies to comply with specific environmental protection measures. A major consideration in water management in the Pacific Northwest developed when the National Marine Fisheries Service (NMFS) listed the Snake River sockeye salmon as endangered and the spring/summer chinook salmon as threatened in 1991 and 1994, respectively. The NMFS 1995 Biological Opinion on the operation of the Federal Columbia River Power System called on Reclamation to deliver 427,000 acre-feet of water for flow augmentation from the Snake River upstream of Lower Granite Dam to the Columbia River system. Flow augmentation is intended to improve migration conditions for salmon.

Reclamation recognizes that salmon and other water-related resource needs will require it to look at the way it operates in the future. Some issues potentially affecting Snake River operations include declining aquifer levels, state water rights, Clean Water Act standards, ESA listings, and conversion from irrigation to domestic water use.

In recent years, requests for water and system operation changes have out paced Reclamation's ability to adequately assess the potential effects. Reclamation realizes that it would be irresponsible to consider operation changes without better understanding of the effects—good and bad—changes in operations could have on Snake River resources. Understanding these potential effects, and in particular Reclamation's ability to meet contractual obligations, is needed prior to making any decisions on operational changes. The Snake River Resources Review was initiated in 1995 to develop technology to help solve this problem of understanding potential effects.

How Are We Helping to Solve the Problem?

The SR^3 Leadership Team has been tasked with developing the necessary technology to help decision makers assess the effects of potential operation decisions and better understand the trade-offs to the Snake River resources. Using the best available technology, SR^3 is building a Snake River Decision Support System (SRDSS) which will be a toolbox in which analytical tools, databases and geographic information systems (GIS) are linked to provide reliable and timely information about the river/reservoir system and its resources. Currently, technical experts can access certain information, data and tools, but do not always have the technology to use the information, data and tools together. With the SRDSS, technical experts will be able to use the information, tools and data in conjunction with one another, or use each independently, as is currently being done. This interaction will occur through an Integrated Information Environment (IIE).

The theory of the SRDSS was tested on a small scale by developing a Proof of Concept (POC). The POC was successfully completed in early 1998, and feed back for the design of the final system was obtained from staff, managers, partners and stakeholders throughout the basin. Alternative approaches for the design of the SRDSS were developed and assessed. A design approach was selected and the SRDSS Staged Development Plan was composed. Sequentially, analytical tools and data bases will be integrated and users brought on line. The SRDSS is being developed using an incremental building approach so that it will be functional at the conclusion of each stage.

What Are the Options?

Many people have concerns with SR^3. Some people say that Reclamation should not be looking at the effects that operational changes might have on Snake River resources. They fear that looking at effects of potential changes will lead to making a change in operations. Others say operational changes are inevitable and we must develop better tools to evaluate effects.

Reclamation believes that we should be looking at the effects that operational changes might have. If we do not, we cannot properly evaluate these options when they arise, and some of the following may occur:

- Managers of the Snake River/Reservoir system—Reclamation, the States of Idaho, Wyoming, and Oregon, and others—may make separate, uncoordinated efforts which could result in duplication, confusion, and conflicts.

- Future Reclamation decisions on Snake River operations will be made without adequate information about the effects in terms of all the Snake

River resources and the entire Snake River/Reservoir system, and the trade-offs involved will not be clearly understood.

- Adequate information on the benefits of existing operations will not be available in the face of growing demands being placed on the Snake River system.
- Opportunities to benefit or enhance fish, wildlife, water quality, recreation, and other resources or uses, while still meeting contractual and other legal obligations, may be lost due to a lack of information.

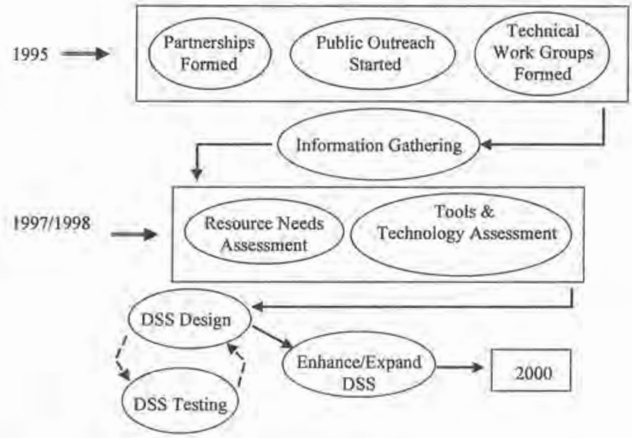
Where Are We in the SR^3 Process?

The Resource Needs Assessment (RNA) is an integral step in the SR^3 process. The RNA presents a compilation of existing information on natural and other resources, and describes possible effects of the Snake River/Reservoir system river flow or elevation conditions on resources in quantifiable terms which can be used in the SRDSS. In March 1998, the RNA was issued in draft form. It will be finalized this winter.

In order to build an SRDSS which would be useful to Reclamation and its partners, the SR^3 Leadership Team first needed to determine what tools and technology were available or desired for inclusion in the SRDSS. To this end, the SR^3 Leadership Team conducted a Tools and Technology Assessment (TTA). The TTA, which was issued in draft in March of 1998, contains a comprehensive inventory of the analytical tools and models, databases, data, GIS, and decision support systems available in the basin and throughout Reclamation. It attempts to match resource needs, as detailed in the RNA, with the identified tools and technologies, and with the requirements of building a DSS, to produce a list of candidate tools and technologies that may be included in the SRDSS. The TTA will be finalized this winter.

Presently, we are in the iterative process of system design and testing. A number of IIE software platforms were evaluated for use in developing the SRDSS, and in April of 1998, *Facet* was chosen. In August, the Information Network Assessment was completed, providing an inventory and assessment of the relevant LAN/WAN/Internet interconnections among different offices of Reclamation, SR^3 Partners, and other state and Federal agencies who may provide data for the SRDSS. A basic depiction of the SR^3 process and time line is shown below:

Updated SR³ Time Line (1997)



How Does the Public Participate in SR³ ?

The creation of a DSS, which is the primary focus of SR³, is not an activity that requires the NEPA process, or any other regulated form of public involvement. Because SR³ is not a decision making process, its public outreach is not geared towards identifying and evaluating alternatives. Public involvement, in its traditional sense, is not a part of SR³.

Public participation in SR³ is taking two basic forms, outreach to the interested public and participation by key stakeholders. The public outreach and stakeholder participation activities are uniquely designed to meet the needs of SR³. The outreach program is designed for a broad population with an interest in a healthy Snake River. A Public Outreach Plan was developed and is continually evaluated and periodically updated to reflect new information and outreach needs, more effective communication activities, and/or SR³'s evolution toward completion. Within the specter of key stakeholder participation, SR³ has two main forms of participation; partners and contributors.

Reclamation recognized from the start that it could not successfully carry out SR³ alone because Reclamation is not the only entity involved in managing the Snake River and Reservoir system. This made it necessary to form partnerships with other interests in the basin. The SR³ partnering program is an effort to include entities that have management responsibilities, expertise, or special knowledge of the resources of the Snake River basin. Partnerships have been established with entities such as state agencies, universities and tribes. The partners are particularly valuable sources of information in the identification of issues. Fully participating partners are typically represented on one or more of the Technical Work Groups established to gather and evaluate information needed for the development of the SRDSS. In this format, Reclamation, university, agency, and consultant staff are joined to compile existing data and information on resources and other factors. It is through these partnerships that many of the key stakeholders are participating in SR^3.

Contributors are also groups of key stakeholders who are participating in SR^3. Examples of contributing entities include water user organizations, watershed councils, special interest groups, universities, private power providers, and other tribes and state and Federal agencies. The SR^3 Leadership Team places high value on the sharing of information, data and concerns, and seeks input from those who may be affected by the decisions made concerning the operation of the Snake River/Reservoir system. Contributors often provide this input at the request of the SR^3 Leadership Team, and serve as important conduits of information between SR^3 and constituencies who often have legal, economic or social interests in the Snake River and its resources and/or uses.

What Are the Public Participation Goals for SR^3 ?

To be credible, it is necessary for SR^3 to communicate the needs for SR^3, and how the various SR^3 products are being developed to meet these needs. Thus, the public participation efforts are designed to meet the following goals and objectives:

- Identify public concerns and issues, so that the DSS created by SR^3 can address those areas of concern in the Snake River basin.
- Increase public awareness of the complexity of managing the Snake River by providing information about resources, river and reservoir system operation, and potential trade-offs in water operations.
- Facilitate people coming together in the future to solve the complex issues associated with the Snake River by creating an improved communications process between the interested public, key stakeholders, and decision makers.

What Is SR^3's Strategy for Meaningful Public Participation and Effective Outreach?

The SR^3 Leadership Team adopted the Bleiker SDIC methodology[2]. SDIC is a methodology in which management tools are systematically applied to improve public agencies' implementation capabilities. Often referred to as Citizen Participation by Objectives, the SDIC methodology contends that substantial effective agreement on a course of action (SEACA) is the minimum agreement required to make a project implementable in the public sector; an environment where some or all affected interests hold veto power.

Key to achieving SEACA is successfully communicating to the public that someone's quality of life will be reduced below what it is, or ought to be, unless a particular problem is solved or prevented. To communicate this, Bleiker suggests using the following key message points:

1. identify the problem (or potential missed opportunity) that has to be addressed. Often this is done by articulating the null alternative.

2. establish that you are the right entity to be addressing this problem/opportunity. Providing an audience-appropriate description of your responsibilities or raison d' etre communicates this point.

3. explain that the approach you are using in addressing the problem/opportunity is reasonable, sensible and responsible.

4. demonstrate that you are listening and you care.

Bleiker equates substantial effective agreement on a course of action to *informed consent*. In the SDIC methodology, informed consent is defined as "the grudging willingness of opponents to (grudgingly) go along with a course of action that they, actually, are opposed to."[3] The following depiction distinguishes Bleiker's definitions of "informed consent" and "consensus":

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[2]Bleiker, Hans and Annemarie; Citizen Participation Handbook for Public Officials and Other Professional Serving the Public; IPMP, Monterey, CA 1995.

[3](Bleiker; *ibid*)

How Has SR[3] Implemented Their Public Participation Strategy?

The SR[3] Leadership Team analyzed the draft public outreach plan to determine if the outreach techniques proposed in the plan fulfilled the fifteen citizen participation objectives defined by Bleiker[4]. Interestingly, the draft plan, as written, was very much consistent with Bleiker's methodology for achieving informed consent. Clearly, the Leadership Team's intuitive direction was syncronistic with Bleiker's approach. Perhaps this explains the Leadership Team's choice of strategy for public participation!

In addition to ensuring that the outreach plan was aligned with the SDIC methodology, the SR[3] Leadership Team made the SDIC training available to Reclamation, university, agency, and consultant staff who were involved in the SR[3] process. This enabled many key participants to gain a common understanding of the purpose of public participation in SR[3], and the approach which would be used.

In April 1997, SR[3] sponsored a workshop. All people working on SR[3] were invited, as well as partnership entities and key stakeholders who were contributors. At this workshop, participants went through the exercise of completing Bleiker's grid for identifying and relating Potentially Affected Interests (PAI's) and issues. This was a significant event in the public participation effort of SR[3]. Workshop attendees formed small groups, each a mix of water users, environmental interests, tribes and agencies. Through this process,

[4] (Bleiker; *ibid)*

these small groups with their divergent perspectives and interests jointly acknowledged each other as entities with interests likely to be impacted by the SR³ process, and identified the issues important to one another. Everyone began to realize the enormity, complexity and controversy involved in SR³.

Armed with the input from key stakeholders on their perceptions of PAI's and issues, the Leadership Team as a whole went through an intensive exercise of analyzing their situation and applying the SDIC approach. The Leadership Team:

- identified who they would consider the PAI's throughout the SR³ process;
- rigorously answered questions for each of the 15 SDIC citizen participation objectives;
- identified all of the SEACA needs for each objective;
- ranked the objectives by high, medium and low priorities;
- correlated the appropriate objectives to the citizen participation techniques;
- identified those techniques which would serve SR³'s purposes;
- selected those techniques which SR³ would use; and
- added other outreach techniques as they deemed appropriate.

This endeavor was important in that it resulted in a unified view and common understanding among Leadership Team members of what needed to be accomplished in the arena of key stakeholder participation and the broader public outreach program, as well as the weak and strong parts of the over all SR³ process.

What Is the Current Status of the SR³ Public Participation Effort?

To date, SR³ has implemented the following communication techniques:

- operating an SR³ Speaker's Bureau to provide presentations about SR³;
- conducting public forums and technical meetings throughout the basin to exchange information;
- disseminating an SR³ contact list which provides interested publics a way

to contact a specific work group member or staff person regarding a particular SR^3 issue;

- providing a toll-free phone number;
- establishing a homepage on the world wide web (www.pn.usbr.gov/sr3);
- producing an SR^3 video, *One River, Many Voices;*
- producing displays for use at meetings and conferences;
- distributing printed materials via the SR^3 mailing list of over 1600 people;
- periodically publishing bulletins called *River Currents*; and
- producing the SR^3 Mid Term Report.

Where ever appropriate in these communication techniques, SR^3 has incorporated Bleiker's four key message points. For example, the first *River Currents* and the script for the video *One River, Many Voices* both identify the problem/articulate the null alternative, establish Reclamation's authority to be addressing this subject, explain the approach SR^3 will be using, and emphasize SR^3's commitment to "involving people with an interest in a healthy Snake River".

The public participation effort for the first half of the Review has focused on:

- determining what strategy to use in getting the message out (SDIC chosen) and implementing the strategy;
- identifying, designing and developing the tools necessary to deliver the message; and
- delivering the general message to, and getting feedback from the appropriate audiences.

All of these objectives have been successfully accomplished. And, the SDIC methodology has served SR^3 well. Better communication is an intangible benefit which is difficult to quantify, and always leaves room for improvement.

However, it is possible to track progress towards this goal by noting the frequency and magnitude of interaction among people.

During the first half of SR^3, there have been substantive productive improvements in the communications between natural resource professionals and hydrology professionals both within Reclamation and across agencies and entities. Dialogue between Reclamation and the Tribes within the basin has become more frequent. Openly sharing information and frankly discussing tough issues with the water user community has become the norm in SR^3's program. Fielding inquiries from, and providing information to the general public is an ongoing routine. And, bringing all of these entities together has come to be expected within this basin, as evidenced by the reaction of disappointment to the cancellation of one SR^3 workshop in December of 1997.

What Are the Next Steps for the SR^3 Public Participation Effort?

Clearly, communication with all interests in the basin has opened up. Yet, there remains more work to be done if the communications network which facilitates people coming together to solve the complex issues associated with the Snake River basin is to continue beyond the lifespan of SR^3 itself. Achieving this long term change, which is the third goal of the SR^3 public participation program, will be a primary focus during the second half of SR^3's process.

The Leadership Team will reapply the SDIC analytical framework to guide the public participation and outreach activities in the last stages of SR^3. At this point, we expect that the public participation and outreach efforts will be designed to:

- keep people informed of progress;
- get input from appropriate sources as needed to continue the development of the best possible DSS and to maintain the most current data on natural and other resources;
- prepare for the transition from development to use of the SRDSS; and
- communicate the value to water management which results from the PN Region having conducted SR^3.

SR^3's experience thus far has shown that reapplying the SDIC methodology at major transition points in the life cycle of a project is important. In the case of SR^3, there was a shift in the issues around which informed consent needed to be developed.

Initially, issues around the need for SR^3, the legitimacy of the SR^3 process, and Reclamation's authority to conduct SR^3 were critical to address in order to develop informed consent among the PAI's who were most likely to impede the implementation of SR^3. Presently, SR^3 is at the mid term of its life cycle. At this point, accuracy of data, methodology for gathering data, characterization of information, and other technical issues are critical. For SR^3 to continue on towards implementation, informed consent around these technical issues must be developed so that the SRDSS is credible as a tool to be used to support decision making about operating the Snake River/Reservoir system.

The Leadership Team expects that as the SR^3 process progresses from building the SRDSS to implementing it, there will be yet another shift. At that time, developing informed consent around the newly emerging issues will be critical to keeping SR^3 on track towards the successful achievement of it's purpose.

SR^3's experience thus far has shown that reapplying this particular methodology at major transition points in the life cycle of a project is important. Furthermore, it is incumbent upon those of us working in the public participation arena to be knowledgeable of the different methodologies available, to select an appropriate methodology, and apply it properly. Productive stakeholder involvement does not happen by accident.

DEVELOPING WATER INDICES FOR DISTRIBUTING INCREASED NILE WATER YIELD AMONG THE NILE BASIN COUNTRIES

Hesham Mostafa Ali[1] Mohamed Rami Mahmoud[2]

ABSTRACT

The River Nile is one of the longest rivers in the world. It is shared by ten countries, all in varying states of development. Numerous studies indicate Nile water resources are not fully utilized. In fact, the Nile Basin's riparian countries utilize less than 50% of the river's total water resources. Cooperation amongst these countries has been recently encouraged to decrease river water losses and increase the water yield. In this study, expected water yield increase (losses saved) is divided amongst the riparian countries based upon each country's "water index". These indices are developed using several parameters that characterize/individualize each country, including its present available water resources and average water per capita as well as its population, aver-age income, future water demand and the dependence of the country's income on agri-culture and other resources. It was found that the most critical and difficult aspects of developing such indices is interlinking economic, social, institutional and environmental factors. All considered, the water index has a substantial and potentially equitable effect when estimating each country's share of the increased water yield.

INTRODUCTION

The Problem of allocating a limited water supply among a river riparian countries is not new. Reaching an agreement on the equitable allocation of an international river basin is a complex matter. For the principle of equitable use to be applied, there must exist a measure of equity. This measure should be relatively simple for each state to measure and determine its water share.

The Helsinki rules give some indications about the factors which could be taken into consideration. These factors include geography , Hydrology, climate, Past and present utilization, economic and social needs, population dependent on the water, comparative costs of alternative means to meet needs, availability of other

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resources, avoidance of unnecessary waste, practicability of compensation , and degree to which needs of one state can be met without substantial injury to another. Because of the difficulty of including all these factors in developing water indices of allocating the increased river Nile yield among the basin countries, only some of these factors have been used.

LITERATURE REVIEW

Different studies have been done to approach the equitable utilization of international river basins. Jong, 1995, recommended some steps to be taken in order to achieve optimum utilization of the Nile river water resources. These steps include:

a) A negotiating body for the basin needs to be established with a mandate to develop a strategy aimed at optimizing the water resources for the benefit of all.
b) The ground rules, including the choice of parameters to form the basis for an allocation formula, need to be agreed to by all relevant governments at an early moment.
c) A strategy should be formulated, with hydrological by significant and reliable allocations.
d) An institutional framework needs to be defined to ensure the smooth implementation of the strategy, including a mechanism to incorporate up to date hydrological socio-economic data into the allocation mechanism.

Fahmy et al, 1995, investigated the potential in using Multi-criteria Analysis (MCA) for ranking the riparian countries according to their water needs from any future water resources development projects. The investigation included the comparison between the different MCA techniques, the sensitivity of the rank reached to weight uncertainty and effect uncertainty. Socio economic issues and political aspects of the integrated river basin development are explicitly addressed through MCA.

Zarour et al, 1994, presented a formula for sharing international water resources. The formula is based on the concept of natural capacities and is compatible with the principles of international law.

Colombi, 1995, gives the principle of equitable utilization of the waters of the Nile which might actually be applied and the tools needed to determine the abstractions to which each country might be entitled and the monitoring needed to ensure compliance.

Thiessen et al, 1992, addressed the negotiation process required when there are multiple decision makers with conflicting objectives. He described a computer Program designed to assist such negotiation processes. This interactive computer assisted negotiation support system is designed for dynamic, muti-issue, multi-party negotiation problems.

HOW CAN WE DEVELOP A COUNTRY WATER INDEX?

A Country Water Index (CWI) can be developed by reducing measurements of two or more water factor variables to a single number or a set of numbers, words, or symbols that retain the meaning through a sequence of mathematical manipulations. Conceptually, a CWI is viewed as consisting of two fundamental steps:

a) Calculation of the sub-indices for the factor variables used in the index.
b) Aggregation of the calculated sub-indices into the overall index.

Suppose we are considering a set of numbers for Z factor variables, in which x_1 denotes the value for the first factor variable, x_2 denotes the value for the second factor variable, x_z denotes the value for the z^{th} factor variable. Then the set of numbers is denoted as $(x_1,x_2,x_3,\ldots\ldots\ldots,x_z)$. For each single water factor parameter variable x_z, a sub-index I_z is computed using sub-index function $f_z\,(x_z)$:

$$I_z = f_z\,(x_z) \tag{1}$$

Each sub-index function may consist of a simple multiplier, or the water factor variable raised to a power, or some other functional relationship.

Once the sub-indices are calculated, they should be aggregated together in a second mathematical step to form the final index:

$$I = g\,(I_1, I_2, I_3, \ldots\ldots\ldots, I_z) \tag{2}$$

The aggregation function usually consists either of a summation operation in which individual sub-indices are added together or a multiplication operation, in which a product is formed of some or all of the sub-indices, or a maximum operator, in which just the maximum sub-index is reported.

SELECTION OF WATER FACTOR PARAMETERS ON WHICH THE INDEX IS BASED

According to Helsinki rules, there are many water factor parameters which might be used in developing the country water Index. Some of these parameters have much more effect than the others. Therefore, it appears practical to use only those characteristics that are of greatest significance.

In the present study, six factors have been considered in developing CWI. These factors include:

1- Water availability in each Nile basin country.
2- Country population.
3- Population growth in each country.
4- Agriculture percentage in each country GNP.
5- Percentage of water withdrawal of total available water resources.
6- Country basin area.

Table (1) shows the values of the water factors which is used in developing CWI. Because of the shortage of data available about Eritria, only data of 9 Nile Basin Countries are used.

Table (1) Values of Water Factors Used in Developing CWI

Country	(1) $(10^9\ m^3)$	(2) (1992) (10^6)	(3) (%)	(4) (%)	(5) (%)	(6) $(10^3 * Km^2)$
1-Burundi	3.6	5.8	3.6%	63%	2.8%	28
2-Egypt	58.9	59	2.6%	16%	98%	1002
3-Ethiopia	110	50.3	3.1%	45%	2%	1131
4-Kenya	15	25.4	4.2%	26%	7.4%	583
5-Rwanda	6.3	7.4	3.8%	40%	2.4%	26
6-Sudan	120.8	25.9	2.7%	32%	14.3%	2506
7-Tanzania	76	27.2	3.3%	55%	0.6%	945
8-Uganda	66	19.3	3.4%	72%	0.3%	236
9-Zaire	1019	39.9	2.9%	32%	0.1%	2345

Sources : INBA. Bulletin, Vol. I (2), 1995
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DEVELOPMENT OF FUNCTIONS FOR SUB-INDICES

To develop a CWI, it was rational to start by defining the mathematical function to be used to calculate the sub-indices.

It is fundamental to find valid mathematical functions relating water factor variables to their effects on Nile Basin country water share. The Nile Basin can be considered as a one unit divided into subunits (countries). Each country has its water share according to the water factor part it has relative to what the whole

Basin has. Accordingly, Both population and area sub-indices can be calculated using these functions:

$$I_{i,j} = x_{i,j} / \sum_{i=1}^{i=n} x_{i,j} \qquad (3)$$

Where

- $i = 1, \ldots\ldots n,\ j = 1, \ldots\ldots m$
- n = No. of countries
- m = No. of factors
- $I_{i,j}$ = Country i sub-index due to factor j
- $X_{i,j}$= Water factor number related to country i and factor j

To calculate the population growth sub-index, the population growth in the next 25 years was first estimated for each country $x_{i,3}$ then the sub-index is estimated using equation (3).

% Agriculture sub-indices ($I_{i,4}$) are calculated by first estimating the value of the agriculture production ($X_{i,4}$) and then using equation (3) to find the sub-indices. To Calculate % withdrawal sub-indices ($I_{i,5}$), the water volume withdrawal of each country is first estimated ($X_{i,5}$) and then equation (3) is used to find each country sub-index.

The calculation of water availability sub-indices ($I_{i,1}$) is slightly different. It is clear that as the water availability increase, the sub-index should decrease. Two steps have been followed to estimate these sub-indices:

$$a_{i,1} = X_{9,1}/X_{i,1} \qquad (4)$$

$$I_{i,1} = a_{i,1} / \sum_{i=1}^{i=n} a_{i,1} \qquad (5)$$

Where:

- n = No. of countries
- $X_{i,1}$ = Water availability factor number related to country i
- $I_{i,1}$ = Water availability country sub-index

Table (2) shows the sub-indices of the different water factors.

Table (2) Subindices of Different Water Factors.

Country	(1)	(2)	(3)	(4)	(5)	(6)
Burundi	0.49	0.022	0.027	0.038	0.002	0.003
Egypt	0.03	0.227	0.176	0.234	0.719	0.114
Ethiopia	0.016	0.193	0.191	0.124	0.027	0.128
Kenya	0.118	0.098	0.151	0.105	0.014	0.066
Rwanda	0.28	0.028	0.038	0.033	0.002	0.003
Sudan	0.015	0.10	0.081	0.128	0.215	0.285
Tanzania	0.023	0.105	0.113	0.102	0.006	0.107
Uganda	0.027	0.074	0.084	0.148	0.002	0.027
Zaire	0.002	0.153	0.138	0.089	0.013	0.266

SELECTION OF AN AGGREGATION FUNCTION

Once the sub-indices are calculated, the aggregation process starts to reduce the information. This process is the most important step in developing a CWI. Aggregation of sub-indices reduced the number of sub-indices and adds analytical and interpretive value to the process.

There are many different aggregation functions which can be used. Weighted linear sum form is the function which is used to calculate CWI and can be presented mathematically as:

$$(CWI)_i = \sum_{j=1}^{m} I_{i,j}\, W_j \qquad (6)$$

$$\sum_{j=1}^{m} W_j = 1 \qquad (7)$$

where:

$I = 1, 2, \ldots\ldots\ldots, 9$

$m = 6$

W_j = Weight given to a water factor

Six different cases have been studied where a priority was given to one or more of the water factors with a higher weight (W_j) than the others. These six cases are:

Case (1) : $W_5 = 2/7$, $W_1=W_2=W_3=W_4=W_6=1/7$

Case (2) : $W_3=W_5=1/4$, $W_1=W_2=W_4=W_6=1/8$

Case (3) : $W_3=W_4=W_5=2/9$, $W_1=W_2=W_6=1/9$

Case (4): $W_1=W_3=W_4=W_5=1/5$, $W_2=W_6=1/10$
Case (5): $W_1=W_2=W_3=W_4=W_5=2/11$, $W_6=1/11$
Case (6): $W_1=W_2=W_3=W_4=W_5=W_6=1/6$

In these different cases a priority was given first to the percentage water withdrawal and then to the population growth, percentage agriculture in GNP, water availability, population, and country area.

Figures (1) to (6) show the Nile Basin countries indices for the six different cases. It is noticed from these figures that Egypt has the highest index and consequently the highest water share, which ranges between 0.25 and 0.317. Sudan has the second highest CWI and ranges between 0.124 and 0.148. Uganda has the lowest water share which ranges between 0.052 and 0.066 followed by Rwanda which has a share ranges between 0.051 and 0.074. These water indices can be easily used in distributing the expected increased Nile Water yield among the Nile Basin countries. Figure (7) shows the average CWI of each country

CONCLUSION

Simple country water indices (CWI) applicable for dividing the increased Nile Water yield among the different riparian countries have been developed. These indices take into consideration different factors which represent the country and have a considerable effect when estimating the country's share of the increased water yield. These factors included the water availability, population, growth population, % Agriculture in GNP, % country's water withdrawal of its water Resources, and country's area. The results show that Egypt has the highest water Index which ranges between 0.250 and 0.317 while Uganda has the lowest water Index which ranges between 0.052 and 0.066.

RECOMMENDATIONS

The procedure used in developing the Indices by suggesting different weights for each factor is a trial to put different priorities for the different factors. It is recommended that the different parties involved in the problem of determining the water share should decide together the different weights of the different water factors before using the previous procedure to develop the water indices.

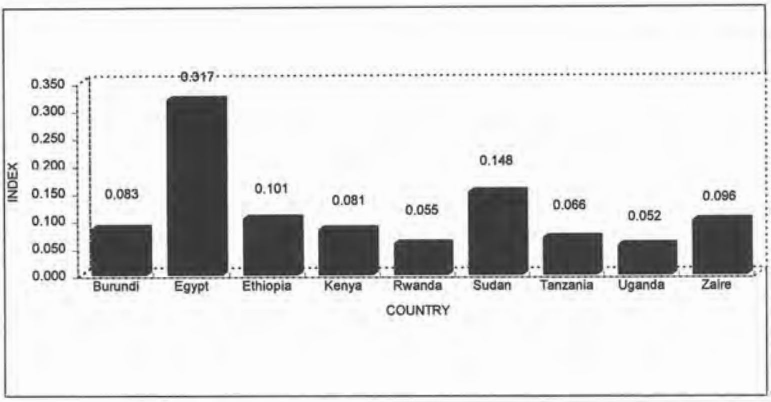

Fig. 1. Nile Basin Countries Indices (Case 1)

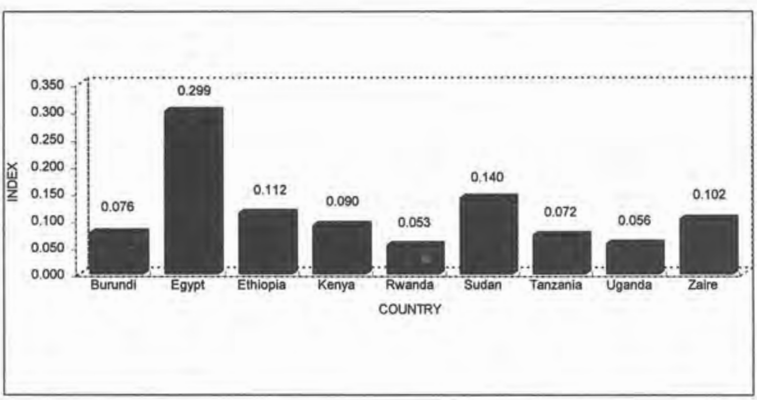

Fig. 2. Nile Basin Countries Indices (Case 2)

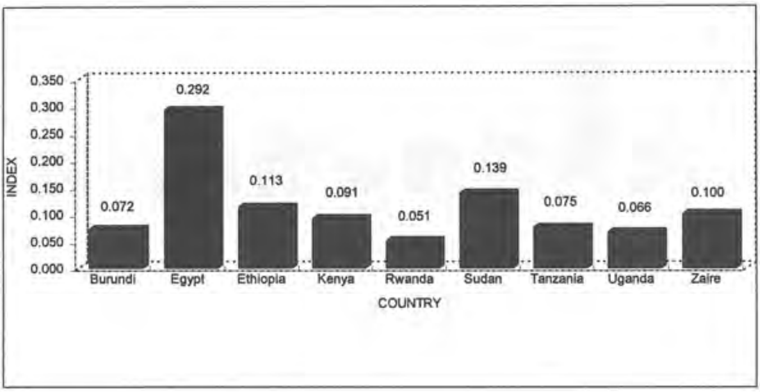

Fig. 3. Nile Basin Countries Indices (Case 3)

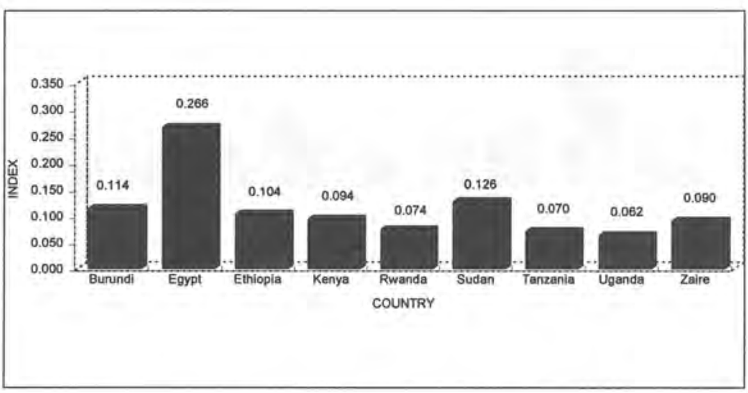

Fig 4: Nile Basin Countries Indices (Case 4)

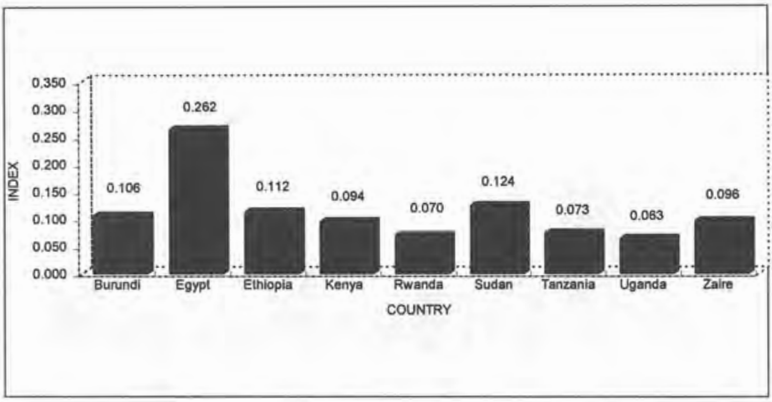

Fig 5: Nile Basin Countries Indices (Case 5)

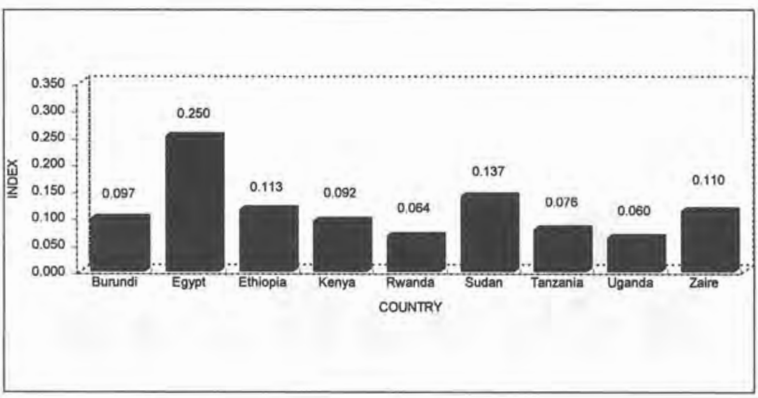

Fig. 6. Nile Basin Countries Indices (Case 6)

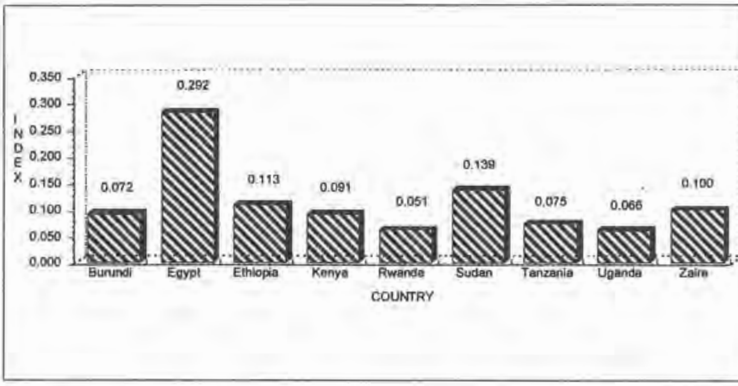

Fig. 7. Nile Basin Countries Average Indices

REFERENCES

Colombi, J. (1995), " Equitable use and the sharing of the Nile"Fourth Nile 2002 conference, Kampala, Uganda..

Fahmy, H. et al (1996)," A multi-criterion approach for equitable utilization of International River Basins"

Jong, R. (1995), " Strategy for the integrated management of the Nile water Resources" Fourth Nile 2002 conference, Kampala, Uganda.

Thiessen, E. et al (1992) " Computer assisted Negotiation of multiobjective water resources conflicts "Paper No. 91019 of the Water Resources Bulletin.

Zarour, H. et al (1994) " A novel approach to the allocation of international Water Resources" Water and Peace in the Middle East, Elsenier, Amsterdam-london- New York

"Development of water Quality Indices for sustainable development" expert group meeting on the implications of agenda 21 for integrated water management in the ESCWA Region, United Nations, October 1995, Amman, Jordan.

THE MACKENZIE RIVER BASIN BOARD,

A UNIQUE BODY FOR A UNIQUE RIVER

Thomas J. Cottrell[1] Richard L. Kellow[2]

ABSTRACT

The Mackenzie River, Canada's largest northward-flowing river, snakes through an area of northwestern Canada with a unique geographic, cultural and political setting. With six political jurisdictions having water-management responsibilities, it is truly a shared river. Eighty-eight percent of the population reside, and most development occurs, in the headwaters south of the 60th parallel. Hence, people in the north are concerned about downstream effects.

To address cooperative water management, the Governments of Canada, British Columbia, Alberta, Saskatchewan, the Northwest Territories and the Yukon Territory signed the "Mackenzie River Basin Transboundary Waters Master Agreement". This Agreement establishes common principles for management of the aquatic resources, creates an administrative organization to manage the Agreement and requires the negotiation of seven, bilateral agreements on transboundary streams.

The jointly-funded Mackenzie River Basin Board will have up to 13 members; eight from the Parties to the Agreement plus five Aboriginal representatives - one for Aboriginal organizations in each province and territory. The unique nature of the Board is in this Aboriginal representation. Many people in the north are Aboriginal with a traditional lifestyle dependent on a good quality and adequate quantity of water.

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All jurisdictions are committed to managing the shared water resources in a fair and equitable manner, recognizing differing interests and needs, while preserving the ecological integrity of the aquatic ecosystem.

INTRODUCTION

The notion of "Shared Rivers" means that governments, companies, organizations, interest groups and the people who live in a river basin must be creative in blending their interests, cooperating in their activities and managing the river to ensure its sustainability. The intent being to reduce conflict where jurisdictions may argue over what is their entitlement to a valued, transboundary resource. The Conference sub-title, "River Basin Management to Meet Competing Needs", completes this image by reminding us there are a variety of uses, each with their own needs that require different management regimes, and competing trade-offs that must be considered.

This is the challenge for the Mackenzie River Basin, one of Canada's largest water systems.

THE MACKENZIE BASIN

Geography

The Mackenzie River flows northward out of a vast area of northwestern Canada into the Beaufort Sea (Figure 1)(Lewis et al., 1991). One of the world's truly great river systems with a mean annual discharge of about 9,000 m^3/s, it encompasses 1,805,200 km^2 697,000 mi^2), ranks twelfth largest by drainage area and is over one-sixth the area of Canada*.

The size, geographical complexity, biological diversity and cultural mixture of the Basin are amazing. It encompasses four physiographic regions in Canada - western cordillera, the northern extension of the

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*total area is about 9,976,000 km^2

Figure 1

Mackenzie River Basin

interior plain, Precambrian shield and arctic coastal plain. It is Canada's largest northward-flowing river system with six major drainage subbasins - Peace River, Lake Athabasca including Athabasca River, Great Slave Lake including Slave River, Liard River, Great Bear Lake and the Mackenzie River itself with several large tributaries (Figure 2). There are a total of 87 transboundary sub-basins.

Great Bear and Great Slave lakes and Lake Athabasca are three of the world's four largest sub-arctic lakes. There are two significant freshwater deltas - the Peace/Athabasca delta off the western end of Lake Athabasca and the Slave River delta on the southern shore of Great Slave Lake. The vast Mackenzie River delta ranks as the world's tenth largest marine delta (Mackenzie River Basin Committee, 1981).

Major Lakes, Deltas and Rivers

Lakes	**water surface area (km2)**
Great Bear Lake	30 800
Great Slave Lake	26 900
Lake Athabasca	7 850
Deltas	**area (km2)**
Mackenzie River Delta	12 000
Peace-Athabasca Delta	6 070
Slave River Delta	385
Rivers	**length (km)**
Mackenzie River	1 650
Peace River	1 650
Athabasca River	1 280
Liard River	1 100
Slave River	415

Political Jurisdictions

Three provinces and two territories encompass the Mackenzie Basin. With the 60th parallel dividing the Basin roughly in half (Figure 1), British Columbia, Alberta and Saskatchewan house the headwaters of the Peace and Athabasca Rivers and Lake Athabasca respectively. The Yukon Territory has the headwaters of the Peel and Liard rivers. The Northwest Territories, being so vast, covers 45% of the total drainage area.

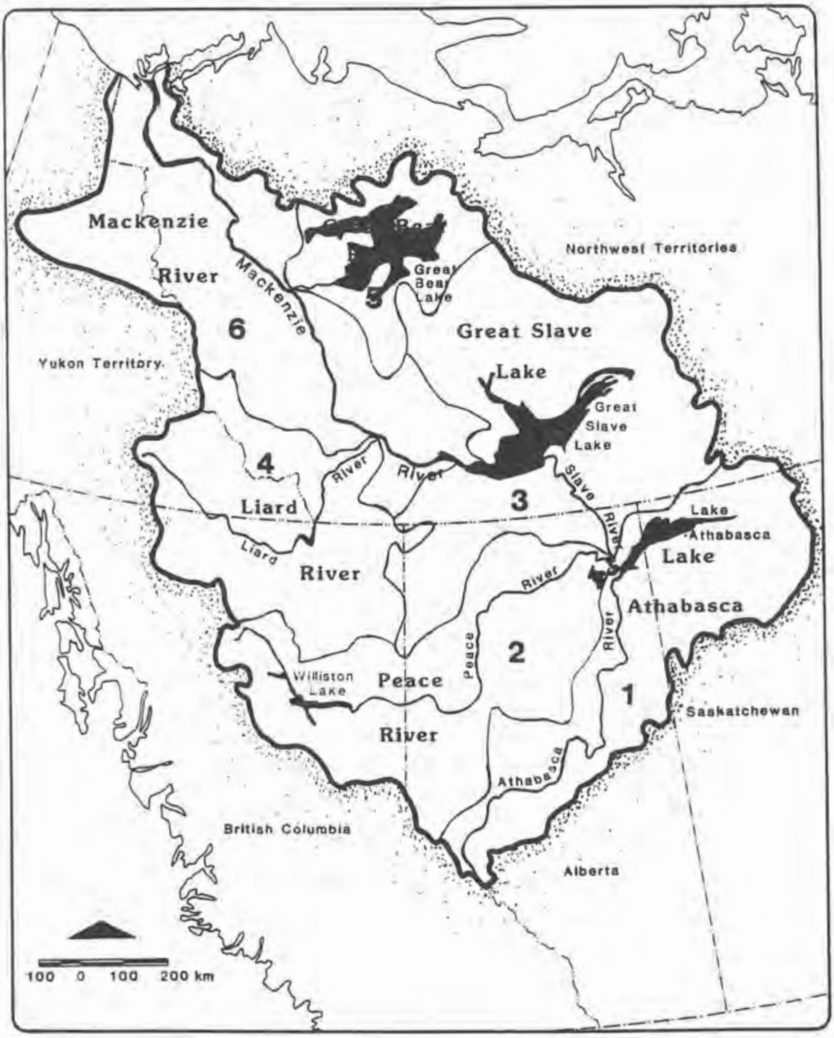

Figure 2
Drainage Subbasins

Responsibility in Canada to manage the environment and natural resources, including water, is shared by the federal and provincial governments. Within the provinces, the provincial governments have primary jurisdiction for management of water. The Government of Canada, however, has jurisdiction over international waters, navigation, fisheries and management of water on federal and Indian lands.

Within the Yukon and Northwest Territories, the federal government has direct water management responsibilities through the Department of Indian Affairs and Northern Development. Currently, however, some discussions are underway to devolve those responsibilities from the federal to the Yukon territorial government.

In addition to the governments' roles in resource management, Aboriginal organizations and First Nations* are gaining direct management responsibilities as a result of settlement of land-claim negotiations and modern interpretation of Treaty rights. This process will affect future water management throughout the Basin as settlements are achieved.

Cultural and Economic Setting

Major river basins world wide typically have a large port city which developed at the mouth of the river and spread its development and influence gradually upstream into pristine environments. The northward-flowing Mackenzie River is just the opposite. Most development is in the warmer, southern, upstream areas in British Columbia and Alberta. In contrast, development has not progressed as much in the northern, downstream areas in the Northwest Territories. As a result, the people and environment downstream get the cumulative impact of development.

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*First Nations: A term being used by the majority of different groups of self-governing Indian people in Canada who usually reside on reserve lands and in many cases were previously referred to as Indian Bands under the federal *Indian Act*.

The southern and northern portions of the Basin also have somewhat different cultural and economic conditions. The provinces have industrial economies based on the utilization of natural resources - hydroelectric power, forest products, oil and natural gas, oil sands, minerals and agriculture. As well, about 88 percent of the 360,000 people in the Basin resides in British Columbia and Alberta.

In the Northwest Territories and Yukon, however, the population of Aboriginal people to non-Aboriginal is higher than in the provinces. Generally, non-Aboriginal people live in urban centres while the population in the smaller communities is Aboriginal. As well, many Aboriginal people live a traditional lifestyle dependent upon the maintenance of the natural environment. Rivers and lakes are highly valued and at the core of the culture. They are primary sources of drinking water, habitat for fish and wildlife species that are hunted, trapped and fished for food and income, and transportation routes during both the summer and winter.

Throughout northern areas, the prime concern of many people is to be able to continue to have good quality water to drink and fish which are safe to eat. Therefore, maintenance of ecological integrity and the quality of the environment is critical.

THE MANAGEMENT CHALLENGE

In the late 1960s, public concern began to grow about the effect of industrial development in the headwaters. It became apparent that a number of large, water-related projects that were planned or underway in upstream areas had the potential to cause significant impacts on downstream neighboring jurisdictions. As a result, representatives of the six governments with responsibilities in the Basin began discussions in 1972 to explore a management program that could accommodate the different interests and needs of governments, industry and communities.

As a result of this preliminary work, it was recognized there was a need for a more comprehensive investigation to increase knowledge on which decisions could be made and what management program developed. To meet this need, the six governments agreed in 1977 to establish the Mackenzie River Basin Committee to undertake a cost-shared $1.6 million study to increase the understanding of the water and related resources of the Basin.

In August 1981, the Committee completed the research program and submitted to the governments the Mackenzie River Basin Study Report with nine recommendations. The most important recommendation called for the six governments to conclude "an agreement through which trans-boundary water management issues such as minimum flows, flow regulation and water quality could be addressed at boundary-crossing points in the Mackenzie River Basin and which establishes a permanent board to implement the provisions of the Agreement."

It was determined subsequently that this recommendation would best be achieved by having two sets of agreements among the jurisdictions. First would be a series of bilateral agreements between neighbouring governments dealing with specific water quantity and quality issues. Second, there would be an umbrella or master agreement, which all governments in the Basin would sign. It would provide a clear articulation of overall guiding principles in order to ensure a consistent approach among the governments in concluding bilateral agreements. The master agreement would also establish operating rules to guide relations among the jurisdictions.

In 1982, the Committee began to implement the recommendations, and work was undertaken on the bilateral agreements. By 1986 it became apparent that the process of negotiations would benefit from the articulation of overall guiding principles for water management that would be in the Master Agreement. So in 1988, serious negotiations among the governments began in earnest to craft a master agreement that would meet the challenge of inter-jurisdictional management of the shared rivers.

Development of the final draft master agreement required extensive public consultations across the Basin, particularly with Aboriginal organizations and First Nations. Their input was very important. Indeed, it had a significant impact on both the process of negotiations among the jurisdictions and the detailed provisions of the agreement. More than any other single aspect, it was their input which ensured that the shared rivers would be managed in a fair and equitable manner so as to maintain the ecological integrity of the aquatic ecosystem.

After several years of negotiations, the *Mackenzie River Basin Transboundary Waters Master Agreement* was concluded. It was signed by the governments of Canada, British Columbia, Alberta, Saskatchewan, the Northwest Territories and the Yukon Territory, and came into effect on July 24, 1997.

THE AGREEMENT

The Master Agreement has four main components. First, it contains common principles for the cooperative management of the aquatic ecosystem within the Mackenzie Basin. Second, it establishes a set of administrative mechanisms to facilitate enactment of these principles and manage relations among the Parties. The most important such mechanism is the creation of the Mackenzie River Basin Board and a Secretariat to manage the affairs of the Board. Third, the Agreement makes provision for the negotiation of the seven, bilateral sub-agreements on transboundary waters between neighbouring jurisdictions. Fourth, it contains a dispute resolution process so the Parties can sort out differences and disputes in an amicable fashion.

Principles

The Agreement describes a set of five principles on how transboundary water resources will be managed cooperatively. By signing the Agreement, each Party indicated they will operate by these principles in a collaborative and cooperative fashion. The Agreement states that the Parties are committed to:

1. Managing the Water Resources in a manner consistent with the maintenance of the Ecological Integrity of the Aquatic Ecosystem;

2. Managing the use of the Water Resources in a sustainable manner for present and future generations.

3. The right of each to use or manage the use of the Water Resources within its jurisdiction provided such use does not unreasonably harm the Ecological

Integrity of the Aquatic Ecosystem in any other jurisdiction;

4. Providing for early and effective consultation, notification and sharing of information on developments and activities that might affect the Ecological Integrity of the Aquatic Ecosystem in another jurisdiction; and

5. Resolving issues in a cooperative and harmonious manner.

Mackenzie River Basin Board

The Mackenzie River Basin Board (MRBB) will have a total of thirteen members. The federal government will have three representatives, one from each of the Departments of the Environment, Indian Affairs and Northern Development, and Health. There will be two members from each of the five provinces and territories. One of those two members will be an Aboriginal person representing Aboriginal organizations in each jurisdiction.

The unique nature of the Board is in this Aboriginal representation. Their presence recognizes the fact of the predominant Aboriginal population in the north with a special relationship to the land and water resources. Their presence also ensures a breadth of future decision-making and public participation that may not otherwise be possible.

Each provincial and territorial government is in discussions with the Aboriginal organizations and First Nations within their portion of the Basin to identify one person among them who would be their representative. Once that person is nominated by the Aboriginal organizations, he or she would be appointed by the government Minister responsible for the Agreement to be that jurisdiction's Aboriginal representative on the Board.

The MRBB will become fully operational after November 21, 1998 when the present Mackenzie River Basin Committee will be dissolved. Support to the MRBB is provided by an independent Secretariat. It is located in Edmonton, Alberta within the offices of Environment Canada which provides administrative support. The job of the Secretariat is to ensure that provisions of the Agreement are met, to manage the operation of the MRBB, facilitate the working relations among the Parties and initiate and undertake any study projects or public participation initiatives.

The Board is funded by contributions of all Parties up to a maximum, total budget of $280,000/year. The Government of Canada pays 2/7 of that amount. Environment Canada acts as the banker for the MRBB in the first instance.

Typical of intergovernmental agreements, the Master Agreement contains a termination clause. Any Party, upon one year's written notice to the other Parties, may end its participation whereupon the entire agreement is terminated, including any bilateral agreements attached as schedules to the Master Agreement.

Bilateral Agreements

An important component of the Agreement is the requirement for neighbouring jurisdictions to negotiate the seven, bilateral, water sub-agreements. As these are concluded, they will be added as schedules to the Master Agreement. It is in these bilaterals that the detailed water quality, quantity and flow parameters will be specified for transboundary streams at boundary-crossing points. These bilaterals will put the "meat on the bones" of the Master Agreement and create active, working relations among the jurisdictions. While the bilaterals will be between neighbouring provinces and territories, the federal Department of Indian Affairs and Northern Development will be involved in the bilateral agreements of the territorial governments since it is the water manager in the north.

The bilateral agreements of the upstream jurisdictions south of the 60^{th} parallel are critical components of the entire structure of water management regimes across the Basin. The Northwest Territories is intensely interested in the content of those upstream agreements. In fact, the principles of the Master Agreement ensure that the concerns and views of the Northwest Territories will be considered by upstream jurisdictions.

Dispute Resolution

This fourth major component of the Agreement is a process to resolve disputes among the Parties. Where Parties experience some difficulty under the Master Agreement with another Party or have a concern that goes unresolved, any Board member may refer the dispute or concern to the Board for review. The Board may undertake any studies, prepare a report of the facts and circumstances or may appoint a panel to review the case. The Board may recommend to the Parties solutions or means to address the dispute. Where disputes remain unresolved, the Chairperson of the Board, acting on instructions of the full Board, may refer the dispute for resolution to the Ministers of the affected jurisdictions. Disputes related to a bilateral agreement may be referred, by one of the Parties to that agreement, to the Board for resolution in the same fashion.

Duties of the Board

The Agreement presents nineteen specific duties of the Board which must meet at least once a year. Some are:

- developing and managing a budget required to fulfill the requirements of the agreement;
- providing an annual report to the Ministers of the Parties to the agreement;
- providing a forum for communication, coordination, information exchange, notification and consultation;
- identifying, recommending and implementing such studies, investigations, programs and activities as are required to carry out this Agreement;
- considering the needs and concerns of Aboriginal people through the provision of culturally appropriate communication and the incorporation of their traditional knowledge and values;
- recommending uniform objectives or guidelines for the quality and quantity of the water; and
- establishing technical committees as needed.

An important future duty is to report on the state of the aquatic ecosystem within five years and every five years thereafter. Through these reports, the Board will be able to track its success in meeting the agreement's goals.

CONCLUSION

The combination of the principles, administrative provisions (Board and Secretariat) and dispute resolution mechanism of the Master Agreement, together with the prescribed water parameters of the bilateral agreements, create a comprehensive set of conditions for cooperative management of the shared rivers. This unique institutional arrangement for a unique river will allow the Parties to collaborate to maintain the ecological integrity of the aquatic ecosystem. They will also be able to ensure that competing uses of the rivers can proceed within certain conditions, that water quantity will be maintained, and that people downstream will be able to rely on the quality of the water and the fish.

REFERENCES

Lewis, G.D., D. Milburn and A. Smart, 1991. "The Challenge of Interjurisdictional Water Management in the Mackenzie River Basin", *Canadian Water Resources Journal*, vol. 16, no. 4, 1991, 10pg.

Mackenzie River Basin Committee, 1981. "Mackenzie River Basin Study Report", A report under the 1978-81 Federal-Provincial Study Agreement respecting the water and related resources of the Mackenzie River Basin, 231 pg.

MEETING THE CHALLENGE OF IMPROVING MANAGEMENT OF A SHARED WATER RESOURCE IN THE LOWER COLORADO RIVER BASIN - A CALIFORNIA EXPERIENCE

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ABSTRACT

Specific entities in Arizona, California, and Nevada, (herein referenced as the Lower Basin states), are entitled to use in the aggregate either more than, an amount equal to, or less than 7.5 million acre-feet (maf) of Colorado River water in a year depending upon a determination to be made by the Secretary of the Interior (Secretary). In 1996, net water diversions from the Colorado River in the Lower Basin states exceeded 7.5 maf for the first time after accounting for unmeasured return flows. Net diversions in the Lower Basin states also exceeded 7.5 maf in 1997. It is projected that net diversions will exceed 7.5 maf in 1998 as well. Although entities in each state are entitled to use a certain yearly apportionment in the aggregate, entities in a Lower Basin state can utilize the unused apportionments of another Lower Basin state, subject to the approval of the Secretary. Also, entities in each state can use surplus Colorado River water when water in excess of 7.5 maf is available, as determined by the Secretary. No doubt, improved management of Colorado River water in each of the Lower Basin states is a challenge and a key element in meeting future demands to ensure economic stability and sustained development. Capital expenditures are necessary to improve water use efficiency by agricultural and urban users, and to facilitate cooperative programs in which agricultural users reduce their use of water to permit urban users to maintain their level of use. For several decades, California has been exploring and implementing a spectrum of programs aimed at improving the management of its water supplies and reducing its dependence on Colorado River water. A brief description of several of these programs is presented. To date, major progress has occurred. Continued cooperative efforts among water agencies are needed for the timely implementation of additional identified water resources management programs to ensure the availability of reliable water supplies of high quality for future generations.

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INTRODUCTION

The allocation and management of Colorado River water is governed by a complex body of laws, court decrees, compacts, contracts, agreements, regulations, and an international treaty collectively known as the "Law of the River." The Colorado River Compact of 1922 divided the Colorado River Basin into Upper and Lower Basins and apportioned 7.5 million acre-feet (maf) of annual use to each basin, and an additional one maf of annual use to the Lower Basin. The Upper Basin states include Colorado, New Mexico, Utah, and Wyoming, while the Lower Basin states include Arizona, California, and Nevada. The 1931 Seven Party Agreement (Agreement) defined California's Colorado River water use priorities (Table 1). The agricultural agencies, namely Palo Verde Irrigation District (Palo Verde), the Yuma Project Reservation Division, Imperial Irrigation District (Imperial), and Coachella Valley Water District (Coachella), (herein referenced as the California Agricultural Agencies) held the first three priorities collectively to use up to 3.85 maf per year under the Agreement while the Metropolitan Water District of Southern California (Metropolitan) holds the fourth and fifth priorities of 1.212 maf per year. Under the Agreement, which has been incorporated in the Secretary of the Interior's (Secretary) water delivery contracts with Metropolitan, Palo Verde, Imperial, and Coachella, Metropolitan holds the right to store up to five maf of water in Lake Mead by reason of reduced diversions. This right has not yet been implemented by the Secretary. The 1964 United States Supreme Court Decree in *Arizona v. California* confirmed basic apportionments for use of 2.8 maf, 4.4 maf, and 0.3 maf per year in Arizona, California, and Nevada, respectively, when 7.5 maf is available.

With increasing utilization of Colorado River water, entities in the Lower Basin states are faced with the challenge of improving their management of Colorado River water to meet present and future water demands. Although entities in each state are entitled to use a certain yearly apportionment in the aggregate, entities in a Lower Basin state can utilize the unused apportionments of another Lower Basin state subject to the approval of the Secretary. Also, entities in each Lower Basin state can use surplus Colorado River water when water in excess of 7.5 maf is available, as determined by the Secretary. To date, the U.S. Bureau of Reclamation (USBR), the agency that manages the allocation and use of Colorado River water in the Lower Basin states for the Secretary, has not implemented criteria for determining when surplus water will be available in the future. In 1996, net water diversions in the Lower Basin states from the Colorado River exceeded 7.5 maf for the first time after accounting for unmeasured return flows. Net diversions in the Lower Basin states also exceeded 7.5 maf in 1997. The USBR projects that 1998 net diversions by entities in the Lower Basin states will exceed 7.5 maf in the aggregate.

Table 1.--Seven Party Agreement Priorities

Priority	Entity	Acre-feet/year
1.	Palo Verde Irrigation District (Valley Lands)	
2.	Yuma Project, Reservation Division	
3a.	Imperial Irrigation District and Coachella Valley Water District	
3b.	Palo Verde Irrigation District (Mesa Lands)	
	Subtotal	3,850,000
4.	Metropolitan Water District	550,000
5.	Metropolitan Water District	662,000
	Subtotal	1,212,000
6a.	Imperial Irrigation District and Coachella Valley Water District	
6b.	Palo Verde Irrigation District (Mesa Lands)	
	Subtotal	300,000
	Total	5,362,000

In December 1996, the other six Colorado River Basin states expressed in writing concern that California agencies appeared to be assuming that the Secretary would continue to approve the use of surplus water for the foreseeable future, allowing entities in California to continue diverting water in excess of California's basic 4.4 maf per year apportionment. They requested that California develop a defined and enforceable plan to reduce its dependence on Colorado River water over its basic apportionment in a way that avoids undue risk of shortage to the other Basin states. Since then, the California agencies have been actively working together to develop a plan (herein referenced as "the California Plan") which would allow California to live within its basic apportionment of Colorado River water when surplus and unused water is not available. A description of the proposed plan is provided below.

Metropolitan, composed of 27 member cities, municipal water districts, and a county water authority, provides about 60 percent of the water used by more than 16 million people in its 5,200-square-mile service area in Southern California (Figure 1). Metropolitan wholesales its water to its 27 member agencies who in turn sell it to their subagencies and/or end users. Metropolitan obtains its water from the Colorado River through the Colorado River Aqueduct which it owns and operates, and from Northern California through the State Water Project owned by the State of California and operated by the California Department of Water Resources. Metropolitan also provides funding to its member agencies to develop

Figure 1.--Location Map of Metropolitan's Service Area and Other Entities Using Colorado River Water

additional local water resources through the recycling of waste water and recovery and treatment of otherwise unusable groundwater. Metropolitan's net diversions from the Colorado River averaged 1.21 maf over the past ten years (1988-97). In a year in which use of Colorado River water in California is limited to 4.4 maf per year and there is no unused water available, Metropolitan's diversions from the Colorado River could be reduced to 657,160 acre-feet per year, i.e. its basic apportionment of 550,000 acre-feet per year plus the water conserved under the Imperial-Metropolitan Water Conservation Program which totals 107,160 acre-feet in 1998, once Metropolitan has exhausted its use of water stored in central Arizona (described below).

Faced with the possibility of future water supply shortages within its service area, Metropolitan has been pursuing a full range of programs, jointly with the California Agricultural Agencies, Arizona, and Nevada, to increase its water supplies and improve its reliability for over a decade. These programs include the Imperial-Metropolitan Water Conservation Program, the Palo Verde Land Fallowing Program, the Arizona Interstate Underground Storage Program, the All American Canal and Coachella Canal lining projects, surface and groundwater storage of Colorado River water in California, and reclaiming agricultural drainage water.

Metropolitan and its 27 member agencies initiated an Integrated Resources Plan (IRP) process in 1993 in an effort to further meet the challenge of improved water management. The process aimed at identifying all water sources, local and imported, available to Metropolitan's service area, and selected a water resources mix which would meet agreed upon reliability, water quality, cost, and environmental criteria.

Some of the guidelines used in the IRP process included 100 percent reliability during a 10 year period (1995 to 2005) even under the worst-case drought, and an untreated water rate not to increase for 10 years. An IRP was adopted in 1996. The IRP targeted increased water conservation, recycling, storage, water transfers, and additional imported supplies to ensure the region's future water supply. Because of changing conditions, new demand projections, updated information from CALFED -- the state and federal agencies with management and regulatory responsibility in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, and with respect to Colorado River supplies, and emerging water transfer opportunities, the IRP is being updated. The planning horizon of the IRP is being extended from 20 years to 50 years. Additional water conservation, recycling, storage, and water transfers will be required to meet future demands.

On the other hand, the California Agricultural Agencies using Colorado River water have approached or exceeded use of 3.85 maf per year recently. Collectively, they provide irrigation water to about 650,000 acres. For the past

10 years (1988-1997), their use averaged 3.78 maf per year and exceeded the amount available to them under the first three priorities in 1989, 1990, 1994, 1995, 1996, and 1997. Their use is projected to exceed 3.85 maf in 1998 as well. Additional water conservation programs are expected to be implemented as one of the key components of the California Plan to reduce the Agricultural Agencies' total net diversions from the Colorado River without negative impacts on the agricultural economy or communities and to make the conserved water available to urban users. However, implementation of these conservation programs is contingent, pursuant to a statement made by the Secretary in December 1997, upon quantification of a baseline volume of beneficially-used water from which savings can be made. Quantification efforts are ongoing.

The California Plan

The California agencies have cooperatively developed a draft "Colorado River Board 4.4 Plan, California's Use of Its Colorado River Allocation" dated December 17, 1997 (herein referenced as the California Plan) aimed at reducing California's reliance on Colorado River water. One of the main premises of said California Plan is transferring the use of 400,000 acre-feet of water in its Phase I from the agricultural users to urban users without causing detrimental impacts in the agricultural service areas and to the other Colorado River Basin states. In April 1998, Imperial and the San Diego County Water Authority (Water Authority) signed an agreement to transfer 200,000 acre-feet per year from Imperial for use in the Water Authority service area for an initial term of 45 years with the option to renew for additional 30 years. Implementation of this agreement is subject to several conditions that need to be met including a satisfactory agreement with Metropolitan, as Metropolitan's facilities are to be used for transporting water to the Authority. In addition, the California Plan recognizes the need for California to enhance its water supply through conjunctive use programs. As mentioned below, opportunities to conjunctively use ground and surface water are being explored using the Arizona Water Bank, the Coachella groundwater basin, and other groundwater basins near the Colorado River Aqueduct. California plans to work with the other Colorado River Basin states and the USBR to develop and implement Lake Mead operating criteria that will make optimum use of the runoff and available storage without exposing the other Basin states to unreasonable risks.

Some of the programs that are a part of the California Plan, as well as Metropolitan's IRP are as follows:

Water Conservation Program with Imperial: Imperial and Metropolitan entered into a water conservation agreement (Conservation Agreement) in December 1988 which became effective in December 1989. The Water Conservation Program (Program) consists of 15 fully implemented projects plus two augmentation projects completed prior to 1989. Implemented projects include concrete lining of existing irrigation canals, construction of reservoirs and interceptor canals, installation of non-leak gates, system automation, tailwater return systems, 12-hour delivery of irrigation water, and on-farm irrigation water management. The Program is to continue for 35 years into the year 2033 and may be extended by mutual agreement of the parties. Metropolitan provided the necessary funds to construct the 15 projects and verify the projects' water savings. Capital costs totaled approximately $112 million ($96 million in 1988 dollars). Indirect costs totaled $23 million ($20 million in 1988 dollars). The annual direct costs for 1999 are estimated at $5.4 million with funding to be provided by Metropolitan. In return, Metropolitan is entitled to divert from the Colorado River a quantity of water equal to the amount of water conserved by the Program. In 1998, a total of 107,160 acre-feet was made available for diversion by Metropolitan. Pending continued verification, this amount is expected to be available to Metropolitan for the duration of the Program.

Test Land Fallowing Program in the Palo Verde Valley: In May 1992, Metropolitan and Palo Verde reached agreement to implement a two-year test land fallowing program which was implemented on August 1, 1992. Under the Program, 20,215 acres of agricultural farm land in Palo Verde (approximately 22 percent of the total agricultural acreage) were fallowed from August 1992 through July 1994 saving 185,978 acre-feet of Colorado River water. Metropolitan compensated participating farmers $1,240 per acre over the two-year period. Participating farmers paid all applicable taxes on the farm land, water tolls, and land maintenance costs. Fallowed fields were not irrigated for the two-year period and were required to be maintained weed free and managed according to pre-approved management plans to control dust and comply with existing wind erosion regulations. The saved water was stored in Lake Mead up until 1997 when it was released by USBR as a result of flood control operations.

Three surveys of Program participants were conducted during and after the Program, and a fourth survey of the local community was conducted following completion of the Program to evaluate the economic impacts from the Program on participating farmers and the community at large. The Program was not found to have affected overall regional economic performance to any significant degree. City officials and local bank representatives characterized the state of the regional economy during the Program as improved relative to pre-Program conditions. Additionally, the Program was not found to have affected the region's property or sales tax bases, or the provision of governmental services. In fact, the Program provided for timely financial relief to the region's agricultural producers who had been under significant hardship due to a major pest infestation and low prices for key commodities such as alfalfa.

Interstate Underground Storage Program with the Central Arizona Water Conservation District: In October 1992, Metropolitan and the Central Arizona Water Conservation District (CAWCD) executed an agreement for underground storage of Colorado River water in Arizona. Metropolitan and the Southern Nevada Water Authority (SNWA) paid CAWCD the cost associated with storing the water. CAWCD is responsible for the costs of recovery of the water. In December 1994, the agreement was amended to increase program capacity from 100,000 acre-feet to 300,000 acre-feet and extend the time for storage from December 31, 1996 to December 31, 2000. To date, 139,000 acre-feet of Colorado River water has been stored underground. Since USBR made surplus water available from the Colorado River in 1996, Metropolitan and SNWA have the option to recover approximately 90 percent of their shares of this water, 80,909 and 45,455 acre-feet, respectively, in the future.

Advance Delivery Program With Coachella and Desert Water Agency (DWA): Metropolitan holds contracts with Coachella and DWA which provide for Metropolitan to exchange its Colorado River water for those agencies' State Water Project entitlement water on an annual basis. Metropolitan delivers Colorado River water in advance to these agencies for storage in the Upper Coachella Valley groundwater basin. In years when supplies are insufficient, Coachella and DWA may use the stored water. In return, Metropolitan may continue to receive Coachella's and DWA's State Water Project water and suspend deliveries of Colorado River water for recharge while maximizing deliveries of Colorado River water to its service area. As of the end of September 1998, about 285,000 acre-feet of water remained in storage.

Imperial-Water Authority Water Transfer: On April 29, 1998, Imperial and the Water Authority signed a water transfer agreement, one of a number of important components of the California Plan. Under the agreement, Imperial agrees to enter into contracts with landowners in the Imperial Valley to undertake water conservation efforts to reduce their use of Colorado River water, and to transfer up to 200,000 acre-feet per year of this conserved water to the Water Authority for an initial term of 45 years with the option to renew for additional 30 years. The agreement allows for an additional amount of up to 100,000 acre-feet per year of conserved water to be transferred by mutual agreement of the parties. The Water Authority agrees to make payments to Imperial for the conserved water and to make arrangements to transport this water to the Water Authority's service area. The transfer of this conserved water is subject to the fulfillment of a number of conditions including environmental compliance, state and federal approvals, and the Water Authority and Metropolitan reaching a satisfactory agreement. Recently, Metropolitan and the Water Authority reached a 30-year exchange agreement, subject to specific contingencies. Under the agreement, the Water Authority will make up to 200,000 acre-feet of conserved water available to Metropolitan annually and Metropolitan will deliver an equal amount of exchange water to the Water Authority at a price of $90 per acre-foot for the first 20 years increased by 1.55 percent for every year after 1998. For years 21 through 30, the price will be equal to $80 per acre-foot increased by 1.44 percent for every year after 1998.

All American Canal and Coachella Canal Lining Projects: In 1988, Public Law 100-675 authorized the Secretary to concrete line the earthen All American Canal from the vicinity of Pilot Knob to Drop 4 and Coachella Canal from Siphon 7 to Siphon 32. It also authorized the Secretary to enter into a funding agreement, not to exceed 55 years, with one or more of the California contractors who hold a delivery contract for Colorado River water. Such agreement may be renewed if consented to by Imperial and Coachella. If the funding agreement or agreements are not renewed, Imperial and Coachella have to compensate the funding entity(ies) an amount equal to the replacement value of the lining works less depreciation.

In March 1994, the USBR released the Final Environmental Impact Statement/Environmental Impact Report (EIS/EIR) for the All American Canal Lining Project preferred alternative, i.e. construction of a parallel concrete-lined canal from Pilot Knob to Drop 3, a length of about 23 miles. In accordance with Public Law 100-675, Metropolitan expressed interest in June 1994 in providing funds for the project in return for the opportunity to utilize an estimated 67,700 acre-feet of conserved water for 55 years. In February 1995, Metropolitan and Imperial executed an agreement relating to the construction of a concrete lined canal parallel to the existing All American Canal (Lining Agreement) under which Imperial would construct the project with funds to be provided by Metropolitan. However, in December 1995, Imperial opted not to extend the Lining Agreement with Metropolitan beyond December 31, 1995.

On January 11, 1994, the USBR released a Draft EIS/EIR for the preferred alternative of lining the Coachella Canal from Siphon 7 to Siphon 32, i.e. construction of a lined canal in the existing cross section while bypassing the canal flow using temporary pipelines. In June 1994, Metropolitan expressed interest in providing funds for the lining of the cost effective sections of the Coachella Canal from Siphon 7 to Siphon 32 in return for the opportunity to utilize the water conserved for 55 years with a right of renewal, all in accordance with Public Law 100-675. However, environmental documentation activities were suspended due to a funding-related issue.

On September 25, 1998, Governor Pete Wilson signed Senate Bill No. 1765 which appropriated $235 million from the General Fund to assist with the implementation of the California Plan. The sum of $200 million is to be used to fund the lining of the All American Canal and its Coachella Branch. The remaining $35 million is to be used to finance the installation of recharge, extraction, and distribution facilities for groundwater conjunctive use programs necessary to implement the California Plan. Water stored in connection with the groundwater conjunctive use programs are to be for the benefit of Metropolitan's member agencies.

Groundwater Storage of Colorado River Water in California: In years of ample Colorado River water supplies, water could be stored in groundwater aquifers located in the Coachella Valley or along the Colorado River Aqueduct. Metropolitan, in cooperation with Coachella and DWA, is preparing environmental documentation and investigating the feasibility of a groundwater storage program in the Lower Coachella Valley groundwater basin. This program has two components: a transfer of State Water Project water and subsequent exchange for Colorado River water; and a groundwater storage program in the Coachella groundwater basin. Similarly, Metropolitan is preparing environmental documentation and technical studies for the Hayfield/Chuckwalla groundwater storage program. The Hayfield and Chuckwalla groundwater basins are located in the Mojave Desert between Metropolitan's Eagle Mountain and Hinds pumping plants. Under the program, Metropolitan would store approximately 500,000 to 1,000,000 acre-feet of available Colorado River Aqueduct water in these two basins. During years of insufficient supplies, this stored water would be recovered and placed in the Colorado River Aqueduct for use in Metropolitan's service area. Also, Metropolitan, in cooperation with Cadiz Land Company, Inc., is preparing environmental documentation for storing Colorado River water underground in the Cadiz and Fenner Valley groundwater basin. Under the program, Metropolitan would store a minimum of 500,000 acre-feet of Colorado River water in the groundwater basin and purchase a minimum of 1.1 MAF of indigenous groundwater over the 50-year term of the agreement. Metropolitan and Cadiz Land Company would equally share the $125 to $150 million design, construction, and implementation costs, with Metropolitan's share contingent upon state legislation which provides funding for Colorado River storage programs. Metropolitan would pay $90 per acre-foot for Colorado River water cycled through the basin plus a $5 per acre-foot per year storage fee which would be adjusted for inflation. With respect to the transfer water, Metropolitan would pay a base rate of $230 per acre-foot which would be adjusted higher or lower according to a price index, minus an appropriate discount rate of five percent to account for Metropolitan's development of the program, plus a water quality fee to recognize the benefit of low total dissolved solids indigenous groundwater. All of these groundwater storage programs are a component of the California Plan.

Reclaiming Agricultural Drainage Water

Each year over one maf of irrigation drainage water in the Imperial and Coachella valleys is discharged into the Salton Sea. A portion of this water, having a salinity of 2,000 to 3,000 milligrams per liter, could be intercepted and treated.

Treated water could be transferred through a pipeline to Metropolitan's Colorado River Aqueduct and used by Metropolitan in its service area or exchanged with Imperial and/or Coachella for a like amount of Colorado River water. Under contract to Metropolitan, Black & Veatch produced a draft feasibility study in July 1997. On September 9, 1997, Metropolitan filed separate applications with the State of California to appropriate water by permit from the Whitewater River and agricultural drains in the vicinity of the Whitewater River (100,000 acre-feet per year), and the Alamo River and agricultural drains in the vicinity of the Alamo River (475,000 acre-feet per year). Metropolitan and Coachella are developing a Facility Plan for the Whitewater Irrigation Water Desalting and Water Reuse Demonstration Project.

SUMMARY

Considerable progress in the implementation of water conservation programs has taken place in California. It is essential that California continue its efforts to implement programs included in the proposed California Plan. This will assure the other six Basin states that California is serious about reducing its use of Colorado River water. This will permit further discussions and negotiations that will result in implementation of criteria for the determination of when surplus water will be available benefiting the Central Arizona Water Conservation District, Southern Nevada Water Authority, and Metropolitan.

With funding now available from the State of California to fund the concrete lining of a portion of the All American and Coachella Canals as well as groundwater storage projects, California is moving closer to implementing its Plan. Similarly, significant progress has been made toward the implementation of the proposed Imperial-Water Authority water transfer. California's determination in moving forward with the implementation of its Plan illustrates its willingness to improve management of this resource which it shares with the other Basin states.

THE PRAIRIE PROVINCES WATER BOARD: A PARTNERSHIP FOR THE MANAGEMENT OF INTERPROVINCIAL WATERS IN WESTERN CANADA

R.L.Kellow[1]

ABSTRACT

In the prairie region of western Canada, most streams that provide reliable sources of good water quality are shared by the provinces of Alberta, Saskatchewan and Manitoba.

Because of the shared responsibility for these interprovincial waters, there was a need for a mechanism to facilitate cooperation among the provinces as well as between the federal and provincial governments to ensure the sustainability of these river systems. In response to this need, the governments of Canada and the three prairie provinces signed the *Master Agreement on Apportionment* in 1969. This agreement sets out an apportionment formula for the equitable sharing of the natural flow of interprovincial waters and ensures water quality at interprovincial boundaries is maintained at acceptable levels. The agreement also provides for a cooperative approach for the integrated management and development of interprovincial streams and aquifers.

The Master Agreement established the Prairie Provinces Water Board (PPWB) to administer the agreement, promote cooperation among the provinces, and prevent and resolve interprovincial water issues.

Although the PPWB has no legislative basis for enforcing its mandate, it has proven to be a successful partnership for the cooperative management of interprovincial waters for fifty years.

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INTRODUCTION

The prairie provinces of Alberta, Saskatchewan and Manitoba, an area of nearly 800,000 mi^2 (Figure 1), contains a diverse landscape. The western part of the region is in the Rocky Mountains. Moving eastward there is a rapid transition through the foothills into the Great Plains. The northern portion and the eastern edge of the region along the Ontario border are part of the Canadian Shield.

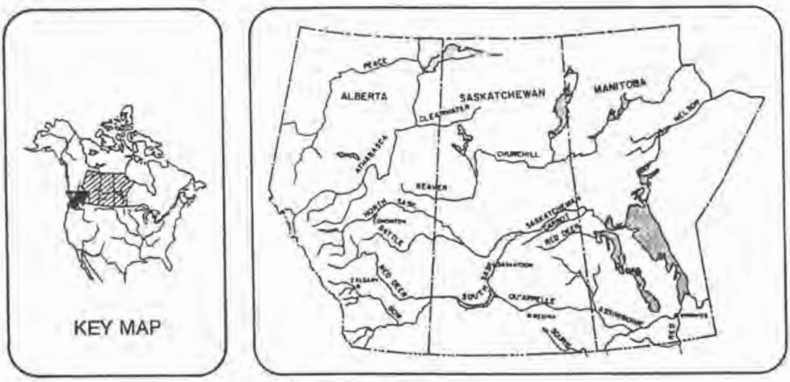

Figure 1. PRAIRIE PROVINCES LOCATION MAP

The 1996 population of the three provinces was 4.8 million of which 2.7 million people, or 56%, resided in Alberta. Over 90% of the population live in the southern portion of the region. Approximately 50% of the total population live in the five largest communities with Regina being the smallest (180 400) and Calgary the largest (768 082).

The southern portion of the region is generally dry with evaporation exceeding precipitation. Average annual rainfall is between 11 and 19 inches (300 and 500 mm). Drought and extended dry periods are common. These conditions together with the rolling terrain result in low local annual run off conditions. Most streams are small with intermittent flows and are therefore unreliable sources of water. Even the larger prairie streams often do not provide water when or where it is needed. Much of the flow on these streams occurs during a short period in late spring. Unless this water is stored, it is unavailable for use at a later time.

Because of these conditions, the major streams that originate on the eastern slopes of the Rocky Mountains and flow across Alberta and Saskatchewan into Manitoba are considered the best reliable source of good quality water. Approximately 80 percent of the flow in these streams originates in the mountainous upper 20 percent of the basin.

EARLY WATER MANAGEMENT

Water management in Western Canada began with the *Northwest Irrigation Act* of 1894 which provided legislation for the use of water in the area that ultimately became the provinces of Alberta, Saskatchewan and Manitoba. This act provided, among other things, for the appropriation of water for domestic and irrigation uses based on priority in time. It also established that all water belongs to the Crown and the right to use water may be regulated by licenses.

In 1906 the *Irrigation Act of Canada* was passed. This act, as amended in 1915, allowed for the allocation of water for domestic, municipal, industrial, irrigation and other purposes.

Water management in the region remained a federal responsibility until the *Natural Resource Transfer Agreements* of 1930. With a few important exceptions, this act transferred responsibility of water administration to the individual provinces. Each province adopted provincial statutes similar to the *Irrigation Act of Canada* and recognised all rights granted by the federal government prior to 1930.

As a result of the Transfer Agreements, water managers recognised the need to work together to promote:

1. co-operation among the provinces since actions in one province may have serious consequences to another, and;

2. federal-provincial co-operation since both levels of government had important, and, to some extent, overlapping water-related powers.

The idea of a regional water board was first suggested just prior to the transfer of responsibility for water resources to the provinces. In 1930, the three provinces signed an agreement for a Western Water Board. However, the federal government did not ratify the agreement because it was preoccupied with problems of the Depression.

In 1945, the three provinces established the Prairie Provinces Advisory Water Board. The problems with the lack of federal participation became apparent at the first meeting of the Board. At its second, and last, meeting in 1947 representatives from the federal government were invited to attend.

Participants at the second meeting, recognizing the federal-provincial division of powers and the overlap of provincial boundaries on river basins, recommended a partnership that would include both provincial and federal interests be struck.

THE PARTNERSHIP

In July 1948, the *Prairie Provinces Water Board Agreement* was signed by Canada and the provinces of Alberta, Saskatchewan and Manitoba.

The purpose of the 1948 Agreement was to recommend the best use of interprovincial waters and to recommend allocations of waters among provinces. The Board used an approach that allocated waters on a project by project basis. During the dry years of the 1960's problems with this approach emerged, most notably provinces were trying to lock up allocations for projects that would not be built for many years. In addition, the provinces were concerned that their licensing powers, as given to them under the *Natural*

Resource Transfer Agreements, may be perceived as being usurped by the Board.

As a result of these problems, negotiations among the provinces led to the four governments signing the *Master Agreement on Apportionment* in 1969. There are four parts to the Master Agreement:

1. A general agreement (Master Agreement) between Canada and the three provinces;

2. An Apportionment Agreement between Alberta and Saskatchewan which constitutes Schedule A of the Master Agreement;

3. An Apportionment Agreement between Saskatchewan and Manitoba which constitutes Schedule B of the Master Agreement; and

4. A *Prairie Provinces Water Board Agreement* between Canada and the three provinces which constitutes Schedule C of the Master Agreement.

The Master Agreement sets out the intent of the agreement along with administrative and cost sharing rules. The Master Agreement has no termination clause. It was envisioned that it would last forever. Any disputes that may arise between the parties would be referred to the Federal Court of Canada. The Master Agreement established that the apportionment agreements (Schedules A and B) become binding at the time of signing and remain in force until cancelled by an agreement in writing by the four parties. The Master Agreement also established consideration of interprovincial groundwater and water quality issues within the mandate of the Board.

The Apportionment Agreements among the provinces (Schedules A and B) were based on the principle of equitable sharing of available water and set out in detail the apportionment formula for natural flow. In general, Alberta may consume 50% of the natural flow before it enters Saskatchewan; Saskatchewan may consume 50% of the remainder and 50% of the added flow arising within its boundaries; and Manitoba receives the remainder of the flow. The agreements apply only to eastward flowing interprovincial streams, which represent most of the streams in the developed region of the provinces. In 1998, the agreement was amended to clarify that interprovincial lakes are also subject to apportionment.

The *Prairie Provinces Water Board Agreement* (Schedule C) established the Prairie Provinces Water Board (PPWB) to administer the *Master Agreement on Apportionment* and provide the mechanism for co-operation among the provinces and Canada on all questions related to interprovincial water management.

The Board, comprised of one representative from each of the three provinces and two from the federal government, operates by consensus. Technical support is provided by the Board's standing committees: Hydrology, Groundwater, Water Quality, and Water Demand. Each committee has similar representation as on the Board. Other committees may be established as required, such as the Instream Flow Needs Committee which is currently reviewing methodologies for estimating instream flow requirements.

The daily operations of the Board are the responsibility of its Executive Director who receives technical and administrative support from Environment Canada. The Executive Director is also the chair of all PPWB committees to ensure an integrated approach in responding to issues.

Current information about flows and water quality is vital to the work of the PPWB and water management of the provinces. Environment Canada is responsible for conducting monitoring on behalf of the PPWB.

The operating costs of the PPWB are shared. The federal government pays one half and each province one sixth. Monitoring costs are 100% federal responsibility.

PPWB RESPONSIBILITIES

The PPWB responsibilities can be divided into five areas of activities. Each of these is described below.

Ensuring the Equitable Sharing of Interprovincial Waters

The Master Agreement on Apportionment was established, in part, to provide for the sharing of interprovincial streams among the three provinces. A premise of the agreement is that the sharing of natural flow would be done on an equitable basis.

During the initial period after the signing of the Master Agreement, the primary emphasis of the PPWB was placed on developing methods for administrating and reporting on water apportionment. The determination of natural flow, the basis for apportionment, is a fairly complex undertaking given the large number of water users and the uncertainty of the amount of withdrawals that re-enter the stream as return flow. The PPWB through its Committee on Hydrology has produced natural flows studies on the interprovincial streams that require or could require apportionment calculations.

In general, Schedules A and B to the Master Agreement require an apportionment of one-half the natural flow on each water course. This apportionment is to be generally achieved over a 12-month period. An annual apportionment could however result in an unsatisfactory situation on the timing and/or volume of flow to the downstream province. It is for this reason that the Agreement requires the "actual flows be adjusted from time to time on an equitable basis." Since equitable is not defined in the Agreement, the PPWB facilitates negotiations between upstream and downstream jurisdictions in determination of what is equitable or fair. The PPWB also can establish minimum flows or conduct additional audits of the apportionment balance to help ensure the sharing of the flows is equitable. This is particularly useful during drought periods or on streams that are heavily allocated.

Currently, natural or apportionment flow calculations are only required on eight interprovincial streams. Data from over 90 hydrometric stations and 17 meteorological stations are used to determine natural flows for these interprovincial streams. If water uses grow in relation to available supply, other streams can be added using the established methodology for estimating natural flow.

Interprovincial lakes were not specifically mentioned in the *Master Agreement on Apportionment*. However, since these lakes are, for the most part, geographically part of eastward flowing stream basins, it would be impractical to exclude them in the apportionment of flow. The PPWB has, therefore, agreed that interprovincial lakes should be apportioned in the spirit of the Master Agreement. An amendment to the Master Agreement is currently being processed to clarify this matter.

Protecting and Enhancing Water Quality

The 1969 *Master Agreement on Apportionment* did not provide the same level of detail for dealing with water quality issues as it did for apportionment. The agreement only stated, "The parties mutually agree to consider water quality problems; to refer such problems to the Board; and to consider the recommendations of the Board thereon".

In response to this general mandate, the Board established its Committee on Water Quality in 1973 to design and implement a water quality program. One of the Committee's first activities was to develop an interim set of water quality objectives, which the Board applied to all interprovincial monitoring sites, and to design a monitoring program for those objectives.

The PPWB has been monitoring water quality monthly at 11 interprovincial sites since 1974, with a twelfth site added in 1993. The results of the monitoring program, which was expanded to include sediments and biota in 1992, are used to characterise the aquatic ecosystem as well as the water quality of interprovincial rivers and to determine if the PPWB Water Quality Objectives are being adhered to. Monitoring data are also used in trend analysis to help identify potential interprovincial water quality concerns. The Committee on Water Quality annually reviews the monitoring program.

Because of increasing importance of water quality issues, the *Master Agreement on Apportionment* was amended in 1992 to allow for a new schedule, the PPWB Water Quality Agreement. This new schedule established reach-specific water quality objectives at 11 interprovincial boundaries and committed each of the parties to take all reasonable and practical measures to maintain or improve existing water quality.

When objectives are exceeded, the Committee on Water Quality prepares a report to the Board with an explanation of the cause and impact of the excursion along with a recommended course of action. The Board, in turn, makes its recommendation to the provinces on how to resolve the problem.

Because spills and unusual water quality conditions can have an impact on interprovincial water quality or be of concern to the public, the PPWB established in 1984 an interprovincial contingency plan. This plan provides a mechanism to promptly inform downstream water quality management agencies of any spills or unusual water quality conditions. The agencies can then take appropriate precautionary actions to protect water users.

Protection of Interprovincial Groundwater

Approximately 90% of the region's rural population is dependent on groundwater. There are numerous aquifers that cross interprovincial boundaries. These aquifers are directly affected by how each jurisdiction protects and regulates them. The PPWB, through its Committee on Groundwater, facilitates co-operative management of interprovincial aquifers to ensure their protection and sustainable use.

The Committee on Groundwater has mapped the hydrogeologic profile along the Alberta-Saskatchewan and Saskatchewan-Manitoba boundaries. The Committee has also completed a set of maps that identify the vulnerability of interprovincial groundwater to surface contamination.

Prevention and Resolution of Interprovincial Water Issues

The PPWB not only provides a process that permits an unbiased review of the potential water quantity and quality impacts of proposed projects at interprovincial boundaries but, more generally, a forum to discuss and resolve interprovincial water issues and thereby avoids conflicts and litigation. The Board maintains a watching brief on potential future water management issues. If necessary, the Board will prepare factual reports with recommendations to governments on how interprovincial water issues should be assessed. To date, the Board has always been able to successfully reach consensus on all issues and, thus, has avoided the necessity of referring an issue to the Federal Court of Canada.

Promoting Co-operative Interprovincial Water Management

One of the important responsibilities of the PPWB contained in the Master Agreement is to promote and facilitate a co-operative approach to the integrated development and use of interprovincial waters. This is achieved through a number of different activities such as:

- providing a forum to foster co-ordination and communication about existing and proposed projects and studies which affect interprovincial surface and ground waters;
- participating in or undertaking planning studies which support the integrated development and use of the regions' interprovincial waters;
- identifying and promoting research for the sustainable development of interprovincial waters;
- co-ordinating water quantity and quality monitoring and streamflow forecasting; and
- promoting network strategies to rationalise data needs and reflect ecosystem and sustainable development objectives.

An example of co-operation was the creation of the Saskatchewan-Nelson Basin Board (SNBB) as a result of a PPWB recommendation. The SNBB, comprised of federal and provincial representatives, carried out a $5 million, five year study that was the most extensive water supply study ever carried out in the prairies. This 1972 study provided a master plan for major supply developments and established databases and methodologies that are still used.

To complement the SNBB report, the PPWB co-ordinated a federal-provincial, multi-year, water demand study. That study, completed in 1982, resulted in the most comprehensive water use database in Canada. The database is maintained and updated by the PPWB every few years.

WHY IT WORKS

The Westwater Research Centre of the University of British Columbia (Barton, 1983) has suggested several reasons for the Board's success.

1. The Board has maintained confidence in the Agreement by trying to do no more than define ground rules, leaving each province to manage its own water resources as it sees fit within the framework of these general rules. Thus, the PPWB's impact on the province's jurisdiction over water is minimized.

2. Because the Board has no powers to enforce its will, the Board is not perceived as a threat to the provincial or federal governments' jurisdictional rights. The Board has ensured this perception by maintaining a low public profile and a small operational staff and budget.

3. The general nature of the Master Agreement has provided flexibility in responding to issues that arise over time. The apportionment of waters was done by percentage of natural flow instead of fixed quantities or on a project-by-project basis. Use of broader principles for other aspects of interjurisdictional water management can be applied

to deal with issues such as water quality that did not exist when the Agreement was signed, thereby avoiding locking parties into positions that may not be acceptable today.

4. The members of the Board (the senior water managers for each jurisdiction) have brought a shared background to their deliberations and, therefore, an understanding of each other's concerns and motivations. Moreover, because the Board Members come to the table knowing they have to work by consensus, there is an additional need to work co-operatively.

SUMMARY

Because of the importance of shared rivers in the prairies, co-operative water management is critical to the economic development and environmental well being of the region.

The *Master Agreement on Apportionment* is often referred to as a model for dealing with interjurisdictional issues. The 1985 Inquiry on Federal Water Policy (Pearse, 1985) stated that, "*The most significant interjurisdictional water arrangement in Canada is the Agreement on Apportionment*". On the international scene, the Master Agreement has been presented as a successful Canadian model in the multilateral discussions on water resources as part of the Middle East peace process.

The many benefits of having the Master Agreement and the Prairie Provinces Water Board overseeing that agreement include:

- the equitable sharing and protection of interprovincial streams;
- ensuring an integrated approach to the development and management of interprovincial streams;
- a consensus solving approach to preventing interprovincial surface and groundwater problems, thereby avoiding political and legal entanglements among the jurisdictions;

- monitoring data that is acceptable to all parties;
- third party interpretative assessment of data and water issues;
- an information exchange network that has allowed an integration of federal and provincial monitoring programs, co-ordinated approaches to problem solving, transfer of experiences, and development of personal contacts that are useful in resolving both PPWB and other bilateral issues;
- the saving of money and time to all parties by elimination of monitoring duplication, pooling of resources for studies, and development of new methodologies and procedures;
- a constant renewal and interpretation of the Master Agreement to ensure it is responsive to the needs of the parties; and
- continuation of 50 years of goodwill and a common approach to problem solving.

Ultimately, the success of the Prairie Provinces Water Board is because its members have had a true desire to work in partnership. Each member respects and understands the other members' concerns and is fully committed to the spirit of the Master Agreement which states that the parties agree to "…work together and to cooperate to the fullest extent each with the other…".

REFERENCES

Barton, B.J., 1983. "The Prairie Provinces Water Board as a Model for the Mackenzie Basin." A Briefing Paper for the Banff Water Policy Workshop, May 26-29,1983. Westwater Research Centre, The University of British Columbia.

Pearse, P.H., 1985. "Currents of Change." Final Report--Inquiry on Federal Water Policy. Environment Canada, Ottawa.

MANNING'S N VALUES FOR FLOODPLAINS WITH SHRUBS AND WOODY VEGETATION

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David L. Derrick[3]
William Rahmeyer[2]
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ABSTRACT

An improved methodology has been developed for the determination of Manning's n and other hydraulic roughness values for shrubs and woody vegetation. This method involves the measurement of horizontal plant density, stem diameter, and the height and width of the leaf mass of a typical plant. Recent investigation has shown that the plant stiffness modulus may be predicted with good accuracy by using stem diameter and plant height in a non-linear relationship. New relationships have been developed for the calculation of Mannings n values for both submerged and partially submerged vegetation. These relationships for flow through vegetated channels still require a trial and error solution when both depth and velocity are unknown, but simplify the solution technique significantly. A stage-discharge table can now be directly constructed for flood elevation studies with out trial and error solutions. A simple example of the calculation of Manning's n values using the method is presented so that the practitioner can follow the method and apply it in the field.

INTRODUCTION

Previous research has indicated that hydraulic roughness in vegetated channels can be related to the frontal area of plants, the height of the plant, the stem stiffness, stem diameter, and the horizontal density of the plants (i.e. number of plants per unit area) among other factors. (Freeman, et. al., 1996) The purpose of this paper is to present data developed subsequent to the 1996 paper and current methodology that can be used in the estimation of hydraulic roughness in vegetated channels. The developments described in this paper will assist engineers

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and scientists in the determination of hydraulic roughness values for channels that are vegetated for either aesthetic or habitat values.

ESTIMATION OF MANNING'S N VALUE

Prediction equations for the estimation of hydraulic roughness and Manning's n value for the vegetation present in vegetated channels (equations 1 and 5) have been developed and reported previously in Freeman, et. al., 1996 and Rahmeyer and Werth, 1996. The equations have been further modified to allow calculation of C_D, V*/V as well as Manning's n value for the bed and channel combined as shown in Equations 2 through 4 and 6 - 8 (Rahmeyer, 1998).

The equations were developed for two types of flows, submerged (plants fully under water) and partially submerged flows (plants protruding above the water surface). The divide between the two types of flow is when flow depth is approximately 80% of the height of the plant. When flow reaches approximately 80% of the height, the plant bends sufficiently to become submerged in the flow.

Submerged Flows

For submerged flows (Y_o>0.8 Plant Height) the original prediction equation for only the vegetative portion of the total roughness is (See Figure 1 for plant variable definitions):

$$n_{veg} = 0.039\ K_n \left(\frac{E_s A_s}{\rho V^2 A}\right)^{0.141} \left(\frac{H}{Y_O}\right)^{0.175} (M\ A)^{0.191} \left(\frac{\nu}{V\ R_h}\right)^{0.0155} \tag{1}$$

For submerged conditions (Y_o > 0.8 H) the equations to predict the coefficient of drag of the plants and the total hydraulic roughness and Manning's n values are as follows:

$$C_D = 0.202 \left(\frac{E_s A_s}{\rho V^2 A_i}\right)^{0.247} \left(\frac{H}{Y_O}\right)^{0.328} \left(\frac{1}{(M\ A_i)}\right)^{0.631} \left(\frac{\nu}{V\ R_h}\right)^{0.156} \tag{2}$$

$$\frac{V*}{V} = 0.183 \left(\frac{E_s A_s}{\rho A_i}\right)^{0.183} \left(\frac{H}{Y_O}\right)^{0.243} (M\ A_i)^{0.273} \left(\frac{\nu}{R_h}\right)^{0.115} \left(\frac{1}{V^2}\right)^{0.481} \tag{3a}$$

Equation 3a can be solved for V resulting in Equation 3b:

$$V = 5.468 \left(\frac{\rho A_i}{E_s A_S}\right)^{0.183} \left(\frac{Y_o}{H}\right)^{0.243} \left(\frac{1}{MA_i}\right)^{0.273} \left(\frac{R_h}{\nu}\right)^{0.115} (V^*)^{1.481} \quad (3b)$$

This equation (3b) can be used in Manning's equation to solve for n. If we use the definition of $V^*=(gR_hS)^{1/2}$ the solution is direct for n if the depth of flow is known. This represents a major improvement over previous methodology.

$$n = 0.183\, K_n \left(\frac{E_s A_s}{\rho A_i}\right)^{0.183} \left(\frac{H}{Y_o}\right)^{0.243} (MA_i)^{0.273} \left(\frac{\nu}{R_h}\right)^{0.115} \left(\frac{1}{V^*}\right)^{1.481} R_h^{2/3} S^{1/2} \quad (4)$$

The variables in the above equations are defined as:

- A_i Frontal area of an individual plant blocking flow, ft². (H'xW)
- A_S Total cross-sectional area of the stem(s) of an individual plant measured at H/4 from plant base, ft².
- E_s Modulus of Plant Stiffness, lbs/ft².
- g Acceleration of gravity (32.2 ft/sec²)
- H Average undeflected plant height, ft.
- H' Undeflected height of the leaf mass of a plant, ft.
- K_n Units conversion for Manning's Equation = 1.49 $ft^{1/3}$/sec (1.0 $m^{1/3}$/sec in metric units).
- M Relative plant density, number of plants per ft².
- n_{veg} Manning's resistance coefficient for vegetation and channel bed.
- R_h Hydraulic radius (R=Channel Area/Channel Perimeter), ft. For a wide channel R_h is taken equal to Y_o.
- V Mean channel velocity, ft/sec.
- Y_O Flow depth, ft.
- W Width of "average" plant, ft.
- ν Fluid dynamic viscosity, ft²/s.
- ρ Fluid density, slugs/ft³

The Manning's n value calculated in Equations 3 and 4 is the total roughness while the value from Equation 1 is only the roughness due to the vegetation and does not include the bed roughness. Equations 3 and 4 (as well as 7 and 8 later) were developed from the same data as equations 1 and 5 but were based on total roughness rather than just the roughness of the vegetation. The equations presented here can now be easily implemented into a computer routine for use with models such as HEC-2, HEC-RAS or other hydraulic modeling packages.

The variable definitions for plant dimensions and water depth are shown in Figure 1. The plant widths and plant heights used in the development of the equations

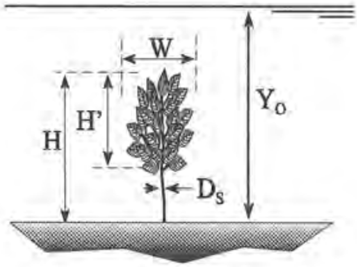

Figure 1 Plant Dimensions for Submerged Flow (From Rahmeyer, 1998)

represented the approximate averages of the plants evaluated. The average widths and/or heights used in calculations should be reduced if large voids exist in the leaf mass, for round or oval leaf mass shapes, and/or for the lack of leaves during winter flows. This reduction in frontal area will account for the reduced plant blockage area resulting from these factors. To calculate the frontal area of the plants blocking flow, the average plant width, W, is multiplied by the average height of the leaf mass, H'.

Partially Submerged Flows

Partially submerged flow is defined as flow at a depth of less than 80% of the plant height (H). The equation for the vegetation portion of Manning's n value for partially submerged ($Y_o < 0.8$ H) flow is:

$$n_{veg} = 2.2x10^{-6}\, K_n \left(\frac{E_s A_s}{\rho V^2 A_*}\right)^{0.242} (MA_*)^{0.0623} \left(\frac{\nu}{VR_h}\right)^{0.662} \tag{5}$$

The equations for CD, and V*/V for partially submerged flow are as follows:

$$C_D = 3.624e\text{-}09 \left(\frac{E_s A_s}{\rho V^2 A_i *}\right)^{0.448} \left(\frac{1}{(M\, A_i *)}\right)^{0.882} \left(\frac{\nu}{V\, R_h}\right)^{1.061} \tag{6}$$

$$\frac{V^*}{V} = 9.159x10^{-5} \left(\frac{E_s\, A_S}{\rho\, A_i^*}\right)^{0.207} (MA_i^*)^{0.0547} \left(\frac{R_h}{\nu}\right)^{0.490} (V^*)^{0.0761} \tag{7a}$$

Equation 7a can be reduced to solve for V as shown in Equation 7b, and using the definition of $V^* = (gR_hS)^{1/2}$ equation 7b can be solved for velocity directly if depth of flow is known for the calculation of A_i^*.

$$V = 1.092x10^4 \left(\frac{\rho A_i^*}{E_s A_S}\right)^{0.207} \left(\frac{1}{MA_i^*}\right)^{0.0547} \left(\frac{\nu}{R_h}\right)^{0.490} (V^*)^{0.924} \tag{7b}$$

Equation 7b can then be used in Manning's equation to give an equation for the calculation of n directly (when depth is known) for partially submerged vegetation as shown in Equation 8.

$$n = 9.159x10^{-05} K_n \left(\frac{E_s A_s}{\rho A_i^*}\right)^{0.207} (MA_i^*)^{0.0547} \left(\frac{R_h}{\nu}\right)^{0.490} \left(\frac{1}{V^*}\right)^{0.924} R_h^{2/3} S^{1/2} \tag{8}$$

A_i^* is defined as the undeflected frontal area of the plant that is partially submerged. It is calculated by:

$$A_i^* = \left[Y_O - (H - H')\right] W \tag{9}$$

with the variables required being shown in Figure 1. Again it should be noted that the plant widths and plant heights used in the development of the equations represented the approximate averages of the plants evaluated. The average widths and/or heights used in calculations should be reduced if large voids exist in the leaf mass, for round or oval leaf mass shapes, and/or for the lack of leaves during winter flows. This reduction in frontal area will account for the reduced plant blockage area resulting from these factors. To calculate the frontal area of the plants blocking flow for partially submerged conditions, the average plant width, W, is multiplied by the average height of the submerged leaf mass [Yo-(H-H')].

All equations are dimensionless (with the exception of Equations 4 and 8 which contain K_n) and units can be converted to metric values without change to the equations (K_n becomes 1.0 $m^{1/3}$/sec). Since the depth of flow is also an unknown in most flow problems, an iterative solution will still be required for partially submerged plants. The solution should converge rapidly, however.

<u>Determination of Plant Stiffness</u>

One of the major drawbacks to using this method has been lack of a method to estimate E_s for the various plant types. Very little data existed for plants other than those tested by Rahmeyer, et al., and new plants had to be checked in the field to determine the value to use for E_s. Subsequent work has yielded a method to facilitate field measurements and a method to estimate the stiffness without the need for extensive field measurements.

Variables used to calculate plant stiffness values (H, D_s, and F_{45}) are measured as shown in Figure 2. The values obtained are used in Equation 10 to obtain the stiffness values for the plant. The plant stiffness is calculated by measuring the force (applied at ½ of the plant height, H/2) necessary to bend the plant to a 45° angle and measuring the stem diameter at one fourth of the height (H/4). The plant stiffness modulus is defined as:

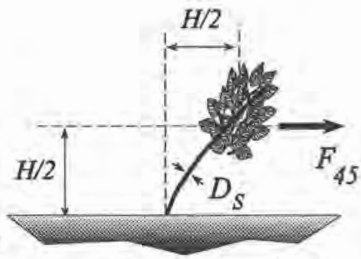

Figure 2 Plant Dimensions for Determining Stiffness

$$E_s = \frac{F_{45}H^2}{3I} = \left(\frac{64}{\Pi D_s^4}\right)\frac{F_{45}\ H^2}{3} = 6.791\left(\frac{F_{45}H^2}{D_s^4}\right) \qquad (10)$$

The calculation of E_s has been problematic requiring large amounts of field effort and time to evaluate the results of the field analysis. In an effort to reduce the amount of work required to estimate E_s, work was done that developed a good relationship between the stem area ($\pi D_s^2/4$) and the force required to bend the stem to 45°. This research produced a linear relationship between force (F_{45}) and stem area for an individual stem. (Freeman, 1997)

Subsequent to the field work which produced the linear relationship between force and stem area, Equation 11 has been developed which relates the plant height and stem diameter to E_s directly without the necessity of calculating F_{45}. Equation 11 was developed based only on data from the plants tested in the original flume work at Utah State University and early field work by Freeman. Figure 3 compares the predicted values of Equation 11 with those obtained by subsequent field measurements by Freeman (1997). This equation relates two of the three variables involved in the determination of the stiffness modulus to the observed modulus with good results. The prediction equation for E_s is:

$$E_s(psf) = 160{,}000\left(\frac{H}{D_s}\right) + 454\left(\frac{H}{D_s}\right)^2 + 37.8\left(\frac{H}{D_s}\right)^3 \qquad (11)$$

Equation 11 may be adjusted to give a slightly better fit to the observed data now that the additional data is available, but the observed data show good overall agreement when compared to the predicted values. The fact that Equation 11 does a generally good job of estimating E_s indicates that this method will be accurate enough to give guidance to engineers and scientists that must have an estimate of hydraulic roughness for project comparisons when field E_s data is not available.

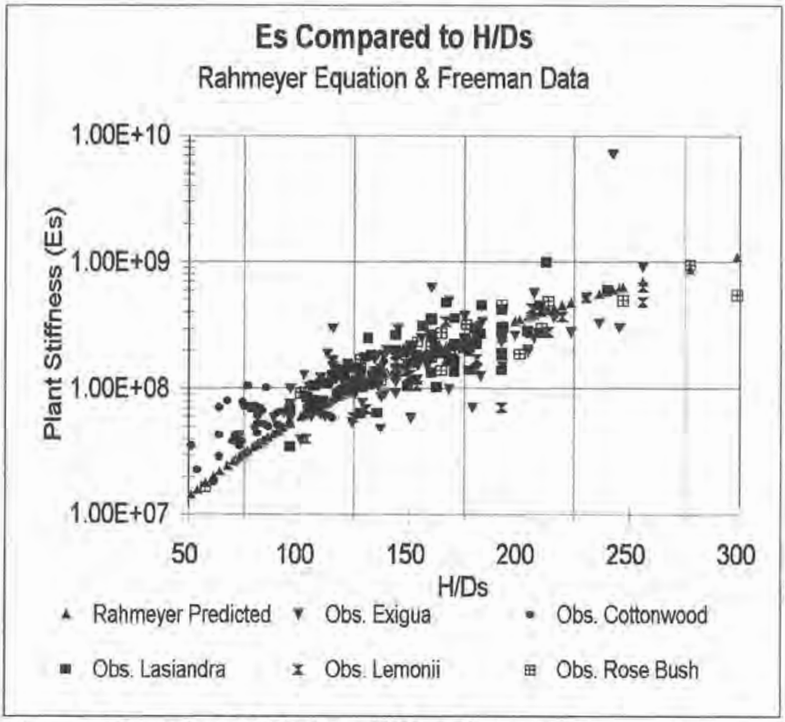

Figure 3. Comparison of field data with E_s prediction equation.

This equation requires estimation of only a stem diameter and a plant height -- both of which are quickly obtained in the field or estimated from growth studies. It appears that the equation may slightly under predict the value of E_s for low H/D_s values but equation 11 was not developed using any data from cottonwood trees which represent most of the small values of the H/D_s data shown in Figure 3. The data from the flume experiments used by Rahmeyer in developing the prediction equation are not shown in the figure.

EXAMPLE PROBLEM

Consider a simple flood plain 80 feet (ft) wide and covered with a stand of Salix exigua (sand bar) and Salix lasiandra (Pacific) willows. The flow is 1200 cfs and the flood plain slope is 0.0020. What is the hydraulic resistance (n value) of the flood plain and the depth and velocity of flow. (Here we assume no stream channel through area -- i.e. flow through an isolated flood plain for simplicity. If a channel is present one would use one of the standard methods of channel compositing to obtain the effective n value for the entire channel.)

From the field evaluation it was determined that the average plant density was 0.04 exigua willows/ft^2 (16 plants/400 ft^2) and 0.02 lasiandra willows/ft^2 (8 plants/400 ft^2). From field data we have determined that stem diameters for the willows vary from 0.12 in to 2.0 in with an average diameter of 0.87 in and a median diameter of 0.67 in. These are broken into bins as shown in Table 1 for the Salix exigua. Only one size class is used for the Salix lasiandra willows for simplicity. Note that the bins have been selected arbitrarily, are probably reduced in number from the results of a field study, and are only for exigua to conserve space. Willow height in the area of interest varies from 3 ft to 18 ft. We can now use Equation 11 to estimate the value of E_s for the plants. The results are shown in Table 1 for the size class bins and plants involved in this example.

If the stands are relatively uniform, a single distribution similar to Table 2 can be used for each willow type. If the characteristics of the willow stand (i.e. height, stem diameter, etc) vary significantly with respect to the location on the flood plain, it may be necessary to keep the areas distinct, depending on the resolution of the model and the desired accuracy of the modeling effort. If more than one area must be considered, it would be advisable to develop a distribution similar to Table 2 for each area or river reach. For the determination of hydraulic roughness for large areas under differing conditions, it may be acceptable to use an average value for the stiffness modulus and use the value to represent all plants of one variety over all conditions.

It can be seen from this example that the plant stiffness modulus can vary significantly over a group of plants. If there is a wide range for the stiffness modulus, it would be wise to incorporate the distribution of E_s and height into the calculation of hydraulic roughness presented below.

Once the values for E_s for each plant type have been obtained, the values must be composited together to give a usable value of n for the flood plain. This is especially true for one-dimensional modeling with such models as HEC-2. Even if using multi-dimensional models such as FESWMS or RMA-2 areas must also be composited to obtain a Manning's n value or roughness value for rather large areas to facilitate modeling.

The compositing process involves accounting for the relative number of each plant type found on the flood plain. This involves the combination of plant characteristic variables into a composite value for use in the above equations for predicting roughness values. This is done using the following equations:

$$A_{ave} = \sum\left[A_i \frac{M_i}{M_{total}}\right] \quad E_{ave} = \sum\left[E_i \frac{M_i}{M_{total}}\right] \quad A_{S_{ave}} = \sum\left[A_{Si} \frac{M_i}{M_{total}}\right]$$

Table 1. Example of Determination of Plant Tension and Stiffness Modulus from Field Data.

Determining Tension and Stiffness Modulus for Salix exigua Willow Stand			
Size Class Median (in)	Number of Stems in Sample	Willow Stand Average Height (ft)	Stiffness Modulus E_s[1] (from Eq. 11) (psf)
1.85	2	16.5	6.9 E+07
1.05	7	12	1.28 E+08
0.55	16	7	1.7 E+08
Mean = 0.78 Median = 0.55		Mean = 9.1 Median = 7	Mean 1.51 E+08 Med. 1.72 E+08
Salix Lasiandra			
0.65		6.0	7.47 E+07

[1] Note: Stem Diameters must be converted to ft before calculation of E_s in Eq. 11.

Table 2. Plant Data for Example Problem			
Item	Exigua	Lasiandra	Composite[1]
Average Plant Height (H)	9	6	8
Average Leaf Mass Width (W)	2	3	2.3
Average Leaf Mass Height (H')	9	6	8
Average Stem Diameter (D_s)	0.78	0.65	0.74
Number of Stems per Plant (#)	4	8	-
Calculated Stem Area ($A_s=\pi D_s^2/4$ * #)	0.133	0.184	0.0150
Calculated Frontal Area (A)	18.0	18.0	18.0
Calculated Stiffness Modulus (E_s)	1.72e+08	7.47e+07	1.39e+08
Area of Plot for Plant Count-400 ft^2	400	400	-
Average # Plants in Measured Plots	16	8	-
Calculated Plant Density (M_i=#/Area)	0.04	0.02	0.06[2]
Relative Plant Density	0.667	0.333	1.0

1. Methodology Described Above.
2. Total Plant Density is Sum of Individual Plant Densities

$$H_{ave} = \sum\left[H_i \frac{M_i}{M_{total}}\right] \quad A_{*ave} = \sum\left[A_{*i} \frac{M_i}{M_{total}}\right] \quad H'_{ave} = \sum\left[H'_i \frac{M_i}{M_{total}}\right]$$

The total plant density is the sum of individual plant densities. In this example we have two plants with individual densities of 0.04 (exigua) and 0.02 (lasiandra) plants/m^2, density the total density (M_{total}) is 0.04 + 0.02 = 0.06 and M_i/M_{total} is equal to 0.667 for the willows and 0.333 for the dogwoods. The plant density and other composited values are shown in the last column of Table 2 for the reach in consideration for this example.

The resulting "composited" or averaged values from the above equations are used in either equations 2, 3 and 4 or 6, 7 and 8 depending whether the plants are submerged or partially submerged.

The solution of the prediction equations is an iterative solution where a depth of flow is assumed and the velocity which results from the solution is compared to the velocity calculated from the continuity equation (Q=AV), the value for depth adjusted and the equation recalculated until the velocity from Equations 3b or 7b and the calculated depth (from the continuity equation, Q=VA) are equal. These calculations are presented in Table 3.

The resulting value for Manning's n in this example is 0.137 and the flow is in the submerged regime (8.475 ft > 8.0 ft composite height). The depth could have been as shallow as 6.4 feet (80% of 8 ft) and still be considered in the submerged

Table 3. Trial and Error Solution for Example Problem.

SUBMERGED FLOW CALCULATIONS					
Variable	Value	Trial 1	Trial 2	Trial 3	Trial 4
Assumed Depth	8	8.4	8.5	8.45	8.475
Rh (assume rect chan)	6.67	6.94	7.01	6.98	6.99
Ai = HW (S)	18.4	19.32	19.55	19.435	19.49
(Ea*As/rho*Ai)^0.183	7.45	7.39	7.37	7.38	7.37
(H/Yo)^0.243	1	0.99	0.985	0.987	0.986
(M*Ai)^0.273	1.03	1.04	1.045	1.043	1.044
(nu/Rh)^0.115	0.27	0.23	0.226	0.226	0.226
(1/V*)^1.481	1.87	1.82	1.80	1.808	1.805
n = (Equation 4)	0.14	0.140	0.138	0.138	0.138
V = (Equation 3b)	1.683	1.756	1.774	1.765	1.769
Vcon = Q/A	1.875	1.785	1.764	1.775	1.767

flow regime. Obviously the higher willows in the flood plain will be in the partially submerged regime at a flow depth of 6.4 feet, but the majority of the stand should be submerged if the measurements and compositing are properly done. If the depth had been calculated using Equation 8 for unsubmerged flow the resulting depth (10.5 ft) would be higher than the composite plant (8.0 ft) and the composite vegetation would obviously submerged, indicating the need to use Equations 3b and 4 for submerged flow.

ACKNOWLEDGMENTS

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REFERENCES

Gary E. Freeman, 1997. "Analysis and Prediction of Plant Stiffness Modulus for Selected Plants", Unpublished Report to U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS 39180.

Gary E. Freeman, David R. Derrick, and William J. Rahmeyer June 1996. "Vegetative Roughness in Flood Control Channels", Proceedings of the North American Water and Environment Congress '96, American Society of Civil Engineers, New York, NY.

William Rahmeyer 1998. Flow Resistance due to Vegetation in Compound Channels and Floodplains, Lab Report No. USU-607, Utah Water Research Laboratory, Utah State University, Logan, Utah 84322-8200.

William Rahmeyer and David Werth, February 1996. The Study of The Resistance and Stability of Vegetation Ecosystem Plant Groupings in Flood Control Channels, Utah Water Research Laboratory, Utah State University, Logan, Utah 84322-8200.

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ACKNOWLEDGMENTS

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REFERENCES

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COOPERATION AMONG CO-BASIN COUNTRIES - KEY TO EFFECTIVE MANAGEMENT OF THE GANGES WATER RESOURCES

Tauhidul Anwar Khan[1]

ABSTRACT

The Ganges is an international river with its basin encompassing parts of India, China, Nepal and Bangladesh.The flows of the Ganges are highly seasonal and heavily influenced by the monsoon rainfall. More than 80% of the total rainfall over the basin occur during only four monsoon months from June to September. Seasonal overabundance and scarcity of water are the two perennial impediments which have been frustrating the overall development efforts in the Ganges basin area.The area constituting the Ganges basin is one of the poorest in the world despite its rich natural endowments of land, water and people. The fate of the entire basin could have been changed dramatically through meaningful and effective cooperation amongst all the co-basin countries by harnessing, development and management of the water resources of this river. The desired development of this common resource however remained neglected. Basinwide development and management of water resources should be the major option for future development of the Ganges area. Conservation of waters would no doubt be the primary means for tackling the huge problems of alternative flooding and water scarcity during wet and dry seasons and meet the expanding water and power needs for sustaining a rapidly growing economy and population. Firm political commitment from the Governments of India, Nepal and Bangladesh for meaningful cooperation would be the essential prerequisite to launch a programme for effective development and management of water resources of the Ganges. A congenial atmosphere in the relations amongst the three countries shall therefore be crucial. With signing of the Ganges Water Sharing Treaty between India and Bangladesh in 1996 and the Mahakali Treaty between India and Nepal, a new climate of trust and confidence in the region has emerged. All concerned may, therefore, take advantage of this new climate. In the interest of all, the political and conceptual problems now need to be more purposefully addressed especially as the underlying commonality of interests in the Ganges is overwhelming.

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* The views and opinions expressed in this paper are the author's only.

THE GANGES RIVER AND ITS BASIN

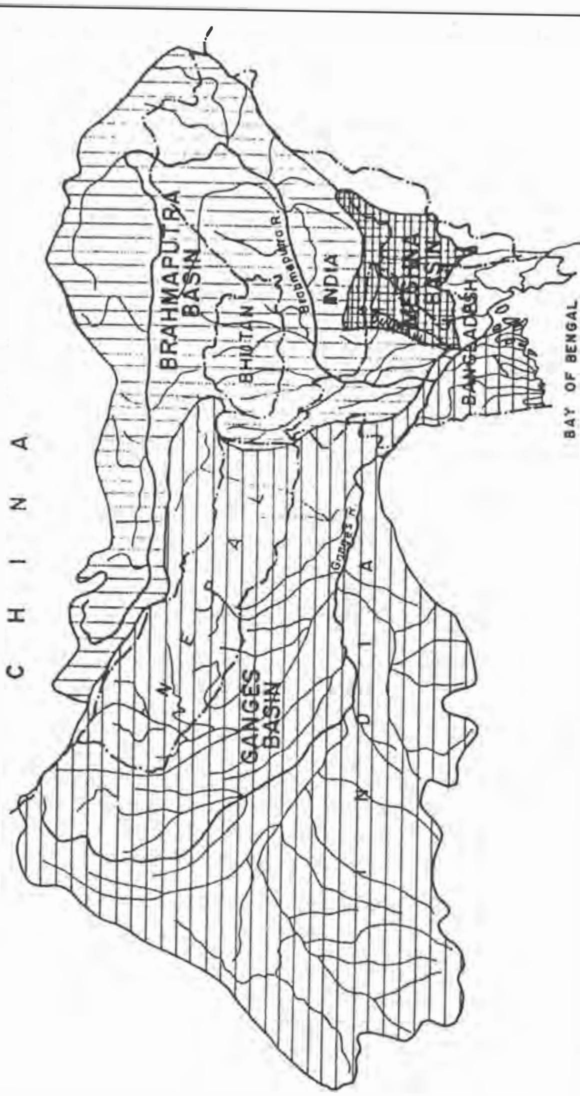
The Ganges is an international river. It ranks among the top ten large rivers of the world in terms of annual run-off. Rising in the Gangotri glacier at about 23,000 feet on the southern slopes of the Himalayas in India, the Ganges flows through the northeastern and eastern part of the south asian region. The Gangotri's melt water stream is a full fledged river even as it emerges from the sub-glacial tunnel at the glacier terminus, the holy Gaumukh (cow's mouth) of Hindu mythology. The Gangotri is considered to be the main source of the Ganges. The Yamuna, Ramganga, Gomti, Kosi, Karnali, Gandaki and Bagmati are important tributaries of the Ganges. The basin of the Ganges spreads over parts of China, India, Nepal and Bangladesh.

Eleven miles below Farakka (India), the Ganges enters Bangladesh and joins the Brahmaputra river near Aricha (Figure-1). The combined flow meets the Meghna river before they all empty into the Bay of Bengal. The total length of the Ganges from source to outfall is 1,570 miles (2530 km). The Ganges basin is one of the most densely populated areas of the world. In the Bangladesh portion of the basin, the population density is 1,917 per square mile (740 per sq. km). The estimated population of the Ganges basin is about 405 million including 346 million of India, 19 million of Nepal and about 40 million of Bangladesh. The total basin area of the Ganges is 433,938 square miles (1,123,899 sq. km).

The water resources of the Ganges have been playing an important role in the life and living of millions of people inhabiting the basin area. Over the centuries people from other regions have come to live in this area in view of the fertile alluvial soils in the plains, warm climate, good seasonal rainfall, numerous small and large rivers and easy agricultural production. The population of this area since then grew at a tremendous rate. The present population of the basin is likely to be doubled within next 30 to 35 years if the current growth rate is not effectively checked.

The flows of the Ganges are highly seasonal and heavily influenced by the monsoon rainfall. More than 80% of the total rainfall over the basin occur during only four monsoon months from June to September. The rainfall in other months is insignificant. As a result the rivers in the basin area swell to brims and often overflow during the monsoon months. On the other hand during dry months (Nov. - May) the flows in the rivers reduce dramatically. The basin area, therefore, faces two major hazards : floods during the monsoon and scarcity of water during the dry season. These hazards become more pronounced in the downstream regions particularly in Bangladesh which is the lowest riparian of the Ganges. Seasonal overabundance and scarcity of water are the two perennial impediments which have been frustrating the overall development efforts in the Ganges basin area.

Ironically, the Ganges basin area is among the poorest and most depressed in the world despite its rich natural endowments of land, water and people. A large number of people of the area live below poverty line. Land-man ratio and per capita food grain availability are steadily declining. It is a predominantly agricultural region and farming is central to the economy of all the national and federal units despite some industrial overlay. Agricultural yields are well below



The Ganges, The Brahmaputra, The Meghna River Basins their potential and unable to generate the income, employment and surpluses needed to stimulate industrial investment. As bulk of the energy requirement is met by fuelwood, there is massive deforestation in the region. Because of large scale use of agricultural residues and animal waste as energy source by the millions of poor, the availability of organic fertilizers have reduced greatly in the area. This has prompted increased use of chemical fertilizer which is causing harm to soil, drinking water, fishery and livestock.

STATUS OF WATER RESOURCES DEVELOPMENT IN THE GANGES BASIN

Vast amounts of water are available in the Ganges basin on an annual basis. But efforts to harness these resources through joint efforts by the co-basin countries in the past had never been noteworthy. Whatever development took place had been undertaken by individual countries. India has been the major actor in this regard. Efforts to develop the surface water resources of the basin began in India back in the nineteenth century. Since then it has taken significant strides in harnessing and developing the water resources of the Ganges basin areas. Information indicate that India has now more than a dozen barrages and other diversion structures in the basin and diverting significant amounts of river flows. Moreover, India has constructed about 200 major, medium small storage dams in the Ganges basin area. Of these, 51 major storage reservoirs have a total storage capacity of 51 Million Acre-feet (MAF) (62908 mcm).

Bangladesh, born in 1971, could not embark upon any major development of waters of the Ganges in the face of uncertainties of dry season availability of the river from across the borders. But in its frantic effort to increase food production and drinking water supply for the millions of its population, Bangladesh had gone for heavy exploitation of its ground water resources. In view of the current crisis of arsenic contamination of groundwater in the Ganges dependent areas of the country, Bangladesh has realised that over- dependence on groundwater has not been wise. Emphasis is now being given to conjunctive use of surface and groundwaters in the Gangetic area.

Besides India and Bangladesh, Nepal is another co-basin country of the Ganges. The headwaters of some of the major tributaries of the Ganges lie in Nepal which contribute about 40 percent of the annual flows and 71 percent of dry season flows of the Ganges available at Farakka (India). Compared to the magnificent opportunities available in Nepal for harnessing and developing the water resources of the tributaries of the Ganges emanating from this country, only a few projects had been undertaken in Nepal. The vast hydropower potentials (about 80,000 MW according to some) in Nepal still remain untapped.

THE ISSUE OF SHARING THE DRY SEASON FLOWS OF THE GANGES

Although the annual flow of the Ganges is 446 MAF (550132 mcm), the dry season (January through May) availability at Farakka, amounts to only 21 MAF

(25903 mcm). Because of extreme low flow in the Ganges during dry seasons when there is very little rainfall, there arises upstream-downstream conflict over the use of water of this river.

The issue of sharing the Ganges waters between Bangladesh and India arose when India Commissioned a 7,300 ft. (2225 m) long Barrage across the Ganges at Farakka only 11 miles upstream of the Bangladesh border. The stated purpose of the barrage was to divert dry season Ganges flows into the Bhagirathi-Hooghly river in the state of West Bengal for improving navigability of the port of Calcutta. The Governments of Bangladesh and India had discussed for more than 20 years to resolve the Ganges sharing issue but could not arrive at a long-term Agreement during those years.

Although the two countries did agree on short-term arrangements for sharing the dry season Ganges flows for five years (1978-82) under an Agreement signed in 1977 ; for two years (1983-84) under a Memorandum of Understanding (MOU) signed in 1982 and for three years (1986-88) under another MOU signed in 1985, the Ganges issue has irritated the relations between India and Bangladesh quite often.

In 1996, new Governments came to office both in India and Bangladesh. Intense and bold efforts by both the new Governments ultimately resulted in the signing of a thirty year Treaty between Bangladesh and India on sharing of the Ganges waters at Farakka on December 12, 1996.

According to the Treaty of 1996 the sharing will be for thirty years and the quantum of waters agreed to be released by India to Bangladesh will be at Farakka (in India). The sharing between India and Bangladesh of the Ganges waters at Farakka will be in 10-day periods from January 1 to May 31 every year and shall be with reference to the following formula :

Availability at Farakka	Share of India	Share of Bangladesh
70,000 cusec or less	50%	50%
70,000-75,000 cusec	Balance of flow	35,000 cusec
75,000 cusec or more	40,000 cusec	Balance of flow

Note : *Cusec means cubic feet per second and 35.3147 cusec equals to 1 cubic metre per second* (m^3/s)

Subject to the condition that India and Bangladesh each shall receive guaranteed 35,000 cusec (991 m^3/s) of water in alternate three 10-day periods during the period March 11 to May 10.

For the period of this Treaty, in the absence of mutual agreement or adjustments following reviews, India shall release downstream of Farakka Barrage, water at a rate not less than 90% of Bangladesh share according to the formula mentioned above, until such time as mutually agreed flows are decided upon.

The sharing of Ganges waters between Bangladesh and India under the 1996 Treaty commenced from January 1, 1997. A Joint Committee set-up by the two Governments as per provisions of the Treaty has successfully implemented the arrangements for sharing contained in the Treaty during the dry seasons of 1997 and 1998. The Joint Committee has formulated detailed procedures and guidelines for sharing the Ganges flows at Farakka in India and monitoring at Hardinge Bridge in Bangladesh which the Joint Observation Teams posted at the two sites are following strictly. No major difficulty in implementing the sharing arrangements has arisen as yet.

The Ganges Treaty has now opened opportunities for Bangladesh to undertake projects like the long-awaited Ganges Barrage project for restoration of the Ganges dependent area of Bangladesh because of its critical situation. This area, mostly located in the Southwest of the country was once generously watered by the Ganges and a diverse range of eco-systems evolved as a result. Past reductions of fresh water flows into the area has caused widespread degradation of the environment, primarily due to salinity ingress from the Bay of Bengal which together with the pressures of a growing population, has had detrimental impact on social and economic development. Health, nutrition and the well-being of the population, particularly amongst women, have been put significantly at risk. Bangladesh is now trying its utmost to make best use of the opportunities derived from the Treaty, so that the dry season flows of the Ganges secured by Bangladesh under the Treaty as its share can be used to nurture the region that has suffered so much social and environmental damages since their diminution.

AUGMENTATION OF DRY SEASON FLOWS OF THE GANGES

The present dry season availability of the Ganges at Farakka is not enough to meet the requirements of both Bangladesh and India. The dry season flows of the Ganges being received by Bangladesh now are only half of those which formerly entered the country before commissioning of the Farakka Barrage. Bangladesh needs more waters in the Ganges during dry seasons to support the socio-economic development for present and future generations. As such there is an urgency for initiating a process of cooperation amongst the co-basin countries for augmenting the dry season flows of the Ganges. In Article-VIII of the 1996 Treaty, both Bangladesh and India have recognised the need to cooperate with each other in finding a long-term solution to the problem of augmentation of dry season Ganges flows.

Plenty of water is available in the Ganges during the monsoon and there is ample scope to harness from the monsoon flows. A portion of the monsoon floods of the Ganges which cause widespread damages in the co-basin countries could be conserved in the upstream storage sites, particularly in Nepal to mitigate flood intensities downstream. This in turn would enable significant augmentation of the dry season flows of the Ganges satisfying the reasonable water needs of all the co-basin countries.

FUTURE NEED

The area constituting the Ganges basin is one of the poorest in the world. But this should not have been the case in view of the basin's rich endowments. In fact the fate of the entire basin could have been changed dramatically through meaningful and effective cooperation amongst all the co-basin countries for harnessing, development and management of the water resources of this river and its tributaries. The desired development of this common resource however remained neglected with inadequate appreciation of the fact that every year lost meant the loss of a productive multiplier through the creation of wealth and employment that would otherwise have been at work. According to many, a number of social, political and historical inhibitions had been at work obstructing meaningful regional cooperation for development and management of common water resources of the Ganges.

In the Ganges basin area today, humanity faces two overriding realities relating to fresh water. First, the use of water has increased dramatically during the past century and will continue to do so as the number of human beings using and relying upon it continues to multiply at an alarming rate. This implies the complexity of issues related to ensuring food scarcity, providing adequate and safe drinking water and sanitation services, stimulating the economy, and preserving the environment. Satisfying these needs would no doubt be a challenging task.

It needs to be realised that water would be the most important vector of development that would shape the future of millions of people living in the Ganges basin area. Their future would depend on collective and individual choices and action. At the brink of a new century, taking a long view would be an appropriate exercise for all concerned in this region. The vision should address water sector transcending issues such as seasonal water scarcity and its overall effect on life and living of the people and environment ; flooding and the cost to society in terms of public health and the loss of economic assets; water pollution and the links to public health, the loss of essential environmental functions. This vision would help development and management of the water resources of the Ganges in the next millennium.

DEVELOPMENT AND MANAGEMENT OF WATER RESOURCES IN THE GANGES BASIN

Basinwide development and management of water resources should be the major option for future development of the Ganges area. Conservation of waters would no doubt be the only way for tackling the huge problems of alternative flooding and water scarcity during wet and dry seasons and meet the expanding water and power needs for sustaining a rapidly growing economy and population. Side by side, conjunctive use of surface and groundwater and its equitable distribution, controlled flooding through scientific catchment management and water management would be the other important elements which would play crucial roles. Again, development of waterway transportation could make a significant contribution to the economic integration of the region with investments in various navigation improvement programmes.

The option and measures envisaged above would undoubtedly need large projects with major investments. Moreover, the way towards formulation, implementation, operation and maintenance of the projects envisioned, would not be devoid of complications. Firm political commitment from the Governments of India, Nepal and Bangladesh to undertake effective joint actions would be the essential prerequisite to launch a programme for integrated development and management of water resources of the Ganges. A congenial atmosphere in the relations amongst the three countries shall therefore be crucial. With signing of the Ganges Water Sharing Treaty between India and Bangladesh in 1996 and the Mahakali Treaty between India and Nepal, a new climate of trust and confidence in the region has emerged. All concerned may, therefore, take advantage of this new climate.

Development and management of water resources would involve various components and wide ranging issues. Some of the major components and important issues are described below :

WATER CONSERVATION

Although there is scarcity of surface water in the basin area during dry season, plenty is available in the rivers during the monsoon (the proportion of lowest and highest flows is about 1:70 for the Ganges in Bangladesh). Portions of monsoon flows of the Ganges which cause widespread flood damage can be conserved in the upstream storage sites available in Nepal and India to mitigate flood intensities downstream. This in turn would enable significant augmentation of the dry season flows of these rivers satisfying the reasonable water needs of the co-basin countries. In addition, generation of large amounts of hydropower from the storage dams could ease the energy crisis in the region and create more job opportunities by facilitating rapid industrialization in different parts of the region. More hydro-power would reduce the tremendous pressure on fuelwood in the region as an energy source and the forest resources and thereby environment shall be saved. The upstream storages would also help improvement of navigation in the region, check salinity intrusion in the lower deltaic areas and control pollution by increasing fresh water supplies during dry seasons. The potentials of the reservoir sites in the Gandaki, Mahakali, Kosi, Karnali basins in Nepal and remaining sites in the Ganges basin in India offer bright prospects for water conservation.

According to a Bangladesh-Nepal Joint Study on Flood Control (1989), there are about 30 potential storage reservoir sites in Nepal in the Ganges basin. The study highlighted the following regarding the potential Nepalese storage reservoirs :

- all the five reservoirs identified in the Sapt Kosi basin, after full development could have potential to store 50.4 percent of the total monsoon flow for dry season use.
- the nine reservoirs identified in Gandak basin could similarly store 54.7 percent of the total monsoon flow for dry season use.

- the reservoirs identified in Karnali basin are capable of total regulation of monsoon flow.
- the two reservoirs in the border river Mahakali together will be able to hold 43.2 percent of the monsoon flow.
- reservoirs on southern smaller rivers are capable to store the monsoon flow of their catchments from 60 to 100 percent.

The Bangladesh-Nepal Joint Study Report stated as follows ,

> "In general, however, it could be said that among thirty identified sites for reservoir creation, the more effective sites in terms of flow regulation will be Sapta-Kosi, Tamur-1, Sun Kosi-II, Burhi Gandaki, Marsyangdi, Seti-I (central), Kali Gandaki-I and II, Andhi-Khola, Mainachuli, Bagmati, Bhalubang, Naumuri, Pancheswar and all the reservoirs in the Karnali basin. The dry season (December-May) flow augmentation potential of these reservoirs taken together is in the vicinity of 4,950 cumec (174,800 cusec). This constitutues more than 170 percent of average dry season natural flow".

These reservoirs when created would provide benefit for irrigation navigation and hydro-electricity generation and other consumptive and non-consumptive use. According to the Joint Report, the total hydro-power installation potential at different capacity factors is in the order of 36,600 MW.

The proposed water conservation projects shall definitely be large projects and would have their implications. There may be valid arguments in favour of small dams, water harvesting techniques, micro and mini hydel schemes or run-of-the river hydropower generation, all of which would reduce or avoid human displacement and encroachment on or damages to wildlife habitats. These are well intentioned but not alternatives to storage dams for the most part of the region and, where they are feasible, are additional to rather than substitutes for dams. It needs to be appreciated that the condition in the Ganges basin is different where it may not be possible to abandon or limit the conservation and harnessing its water resources in an increasingly water short situation during dry season. Large water storage projects are, therefore, difficult to be ruled out. Moreover, one should appreciate that the proposed storages are nothing but rain water harvesting projects - but of course on a mega scale. However, there is need to assess the environmental, ecological, human and social implications and impacts of such projects. In case of those projects which would be found acceptable, adequate machinery and procedures will have to be devised in each case to ensure the proper formulation and full implementation of remedial and ameliorative measures ; and in each case there will have to be the fullest measure of consultation with and participation by the people concerned.

FLOOD MANAGEMENT AND FLOOD FORECASTING

The aforementioned storage reservoirs would no doubt reduce flood intensities in the Ganges river in the downstream reaches. But that might not be enough.

Besides the main Ganges there are many other tributaries, distributaries and smaller rivers in the basin which cause localised flood havocs. For mitigation of floods caused by such rivers appropriate flood management strategies are to be chalked out and practiced. Watershed management through extensive soil conservation, catchment area treatment, preservation of forests and increasing the forest area and the construction of check dams would have to be promoted to reduce the intensity of floods. The possibilities of flood by-pass or diversions shall need to be investigated more intensively through joint efforts. Uncontrolled and indiscriminate development of flood plains under the false sense of security due to pressure of population has been responsible for increasing flood damages in some areas of the basin despite substantial investments in flood sector in the past. The concept of flood plain zoning would therefore, need to be more vigorously practiced in a concerted manner by all the co-basin countries to avoid dangerous, undesirable and unwise use of flood plains.

Flood forecasting and Warning plays and shall continue to play a very important role in saving lives and properties from flood damages. Meaningful cooperation and co-ordination amongst the co-basin countries can improve the flood forecasting and warning system in the Ganges basin. There exists limited cooperation on Flood Forecasting amongst the countries of the region on bilateral basis. These cooperations need to be further strengthened, expanded and made multilateral. To that end, the co-basin countries may decide expeditiously all aspects of data requirements for effective and early flood forecasting and warning in the river basin and ensure free flow of data relevant to flood forecasting on a real time basis.

WATER QUALITY

Another priority concern for water management in the Ganges basin should be water quality. With the increase of population, more and more often the use of water will be limited by its quality rather than the quantity available. Poisoning of water by arsenic and other toxic chemicals and related chronic effects are the most recent public health concerns to arise over water quality. Strict water quality measures would need to be undertaken to avoid or reduce contamination of water that results in the degradation of drinking water quality and quantity, contamination of food resources and increasing incidence of infectious diseases and in the substantial biological impoverishment and impairment of basic ecological functions and services.

FREE FLOW OF DATA AND INFORMATION

The success of integrated water resources management in the Ganges basin will depend greatly on free flow of relevant data and information amongst the co-basin countries. Mistrust, fear, misperception and myth had so long impeded free flow of data amongst the countries concerned. In the brink of a new century, such mistrust and fear need to be removed totally for the sake of a better future of millions of people. The co-basin countries, through mutual agreement, would need to establish a system of free flow of all water related data and information amongst them as early as possible. In today's world, with revolutionary advancement in global communication, establishment of such a system would not take much time if the political will is there. With regard to data management and long-term data needs the following initiatives require to be envisaged :

- mapping of all governmental and non governmental agencies, Institutions, Research Centres and etc. connected with water resources development, management and use in the Ganges basin area ;
- analysis of technological and institutional bottlenecks in basic data acquisition and dissemination mechanisms ;
- evaluation of options for rehabilitation, harmonization and standardization, and integration of data collection, processing and exchange mechanisms on basin scale ;

EFFECTIVE COOPERATION

The management of water resources of a river basin like that of the Ganges is a matter of regional concern because it is a transboundary resource. In the past, isolated and unilateral actions for development and utilization of waters of the Ganges in one co-basin country have caused adverse impacts in another country. This has resulted in irritations in the relations between the concerned countries. When one country is adversely impacted because of another's action in the same basin, it becomes the collective obligation of all the co-basin countries to take corrective measures in a concerted manner. The development, sharing and management of the Ganges water resources must not be a zero-sum game. The key to future development of the Ganges basin area is effective cooperation amongst the co-basin countries. Such cooperation should necessarily be multilateral as the number of co-basin countries of the Ganges is more than two.

So long whatever negotiations or actions regarding development, sharing and management of waters of the Ganges and its tributaries have taken place had been purely on bilateral basis between India and Bangladesh; between India and Nepal; and between Nepal and Bangladesh. This principal of bilateralism has already created confusion and even mistrust amongst the co-basin countries. Enough time has already been wasted. It is time now that all concerned breaks this myth of Bilateralism. For the sake of teeming millions of the basin area, all the co-basin countries should act in unison. Without effective cooperation from all, the desired objectives of water conservation, flood management, water quality management, free flow of data and information in the Ganges basin area would remain only illusions. All concerned should, therefore, make sincere efforts to create the required atmosphere of mutual trust and confidence to commence the journey towards such cooperation.

CONCLUSION

Water of the Ganges is too precious a resource to waste when there are millions of people dependent on it. The waters of this basin can really be turned into wealth. What is needed, is the will and commitment of the Governments and people of all the co-basin countries. Effective cooperation will be the key to future development and management of the Ganges water resources. This however would require a different mindset and a long-term view of the political and social leaders of the Gangetic region. In the interest of all, the political and conceptual problems now need to be more purposefully addressed especially as the underlying commonality of interests in the Ganges is overwhelming. Waters of the Ganges must be seen as a potential source, not of conflict but of peace and prosperity in the region.

REFERENCES

K.L. Rao (1979) *Indias Water Wealth*, Orient Longman Limited, New Delhi

Tauhidul Anwar Khan (1987), *The Water Resources situation in Bangladesh* in "Water Resources Policy for Asia", A. A. Balkema, Rotterdam, Boston.

Government of the People's Republic of Bangladesh and His Majesty's Government of Nepal (1989), *Report on Flood Mitigation measures and Multipurpose Use of Water Resources* by Bangladesh - Nepal Joint Study Team Dhaka.

B.G. Verghese & R. Iyer Ramaswamy (eds. 1993), *Harnessing the Eastern Himalayan Rivers,* Konark Publishers Pvt. Ltd., New Delhi.

Tauhidul Anwar Khan (1996), *Management and Sharing of the Ganges,* in "Natural Resources Journal - International River Basins, Part-2", The University of New Mexico School of Law, New Mexico.

Agreement between the Government of the People's Republic of Bangladesh and the Government of the Republic of India on Sharing of the Ganga/Ganges Waters at Farakka singed on December 12, 1996 at New Delhi.

DEVELOPING A NEURAL NETWORK MODEL FOR PREDICTING THE NILE RIVER INFLOW

Mohamed Rami Mahmoud[1] Hesham Mostafa Ali[2]

ABSTRACT

Egypt is facing a major challenge to manage its limited water resources to satisfy future demand. Nile River inflow is satisfying more than 85% of the total demand. Accurate prediction for yearly inflow is essential for planning and management of the water resources. The inflow of the river exhibits large variation due to many natural phenomena. The prediction of inflow rate has been under continuous study. Different approaches have been used to fit observed data. However, some of these approaches may not adequately predict the river inflow because they are based on many simplifying assumptions about the natural phenomena that influence the inflow. This paper demonstrates how a neural network can be used as an adaptive model synthesizer as well as a predictor for inflow to Nile River. Historical data for stations along the river has been used. Issues such as selecting an appropriate neural network architecture and a correct training algorithm are addressed as well. A Neural Network Model for Nile Rainfall-Runoff process (NNMNRR) has been developed in an attempt to overcome the difficulties faced in predicting the inflow. The main issue discussed in this research is training the network to map rainfall patterns into measures of the runoff. Our preliminary results show that the neural networks are capable of adapting their complexity to match changes in the flow history. Moreover the NNMNRR model has the capability to predict the river inflow.

TRADITIONAL METHODS

Prediction of streamflow provides a warning of impending flood during the times of flood. It also assists in regulating reservoir outflows during the low flows. The need for accurate stream flow predication has been emphasized by the recent devotion of an entire scholarly journal issue to the subject (Journal of Hydrology, Vol. 133, April, 1992). Prediction of streamflow and is a difficult task because of varieties of parameters like watershed topography, vegetation cover, soil types,

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channel characteristics, rural and urban activities, and precipitation distribution. Continuous predication of streamflow can be made by indirect or direct methods (Thirumalaiah and Deo, 1998). The indirect method is based on runoff either through a rainfall-runoff model or by routing the flow observed at an upstream gauge to the desired location downstream (Kitanidis and Bras, 1980a,b). For direct prediction of stream inflow, statistical correlation techniques have been employed (Devore, 1991).

For indirect methods, different techniques of relating the temporal and spatial history of precipitation to corresponding streamflow discharge at a point of interest, have been developed (for extensive reviews see; Bras, 1990, and McCuen, 1989). Most of these methods assume a uniform rainfall distribution in space, or a coarse subdivision of watershed area into sub-areas within which the rainfall can be assumed to be uniform in a piecewise fashion. These methods are typically used in runoff models since the standard source of rainfall measurement are widely scattered point measurement gauging stations. The rainfall-runoff models require knowledge of underlying hydrology and establishment of many rain gauges together with a good telemetry system.

Direct methods require a comprehensive exogenous input and involve some type of model along with certain assumptions. The occurrence of streamflow, being uncertain, may not always be amenable to any specific modeling.

USING NEURAL NETWORKS FOR PREDICTION

Flood and Kartam (1994a,b) published research that illustrates using neural networks in solving general civil engineering problems. They concluded that neural networks offer a powerful means of solving poorly defined problems that have eluded computational digital computing techniques. Also, The success of the neural network implementation depends not only on the quality of the data used for training, but also on the type and structure of the neural network adopted, the method of training, the way in which both input and output data are structured and interpreted, and ensuring that a network is used only for problems that fall within the training domain.

Karunanithi et. al. (1994) used neural network model to predict the inflow of the Huron River in Michigan. Empirical comparisons between the predictive capabilities of neural network model and analytic nonlinear power model in terms of accuracy and convenience of use have been preformed. The analysis showed that the neural networks are capable of adapting their complexity to match changes in the flow history. Furthermore, model developed by the neural network approach are more complex than the power model. Moreover, the authors note that the neural network approach is a new approach for this application and further research is needed to fully understand its modeling capabilities and limitation.

Smith and Eli (1995) implemented a neural network to map rainfall patterns into various measures of runoff. The neural network was trained to predict the peak discharge and the peak time resulting from a single rainfall pattern. The authors concluded that the difficulty to predict peak discharge and peak time is due to insufficient information content to properly characterize the functional relationship between input and output or the training set being too small. The authors recommended further research to answer some questions including:

- Do neural network configurations and their weight space solutions have some identifiable relationship to the physics of the rainfall-runoff process?
- Does the neural network approach offer significant advantages as compared to traditional rainfall-runoff modeling?

Tawfik et. al. (1997) trained a neural network for modeling rating curves. A simple three-layer back propagation neural network is introduced for developing rating curves at two Nile gauging stations for two historical periods. The results for three out of four cases analyzed show that the neural network approach was more accurate than the commonly used techniques for modeling rating curves. The authors recommended testing several sophisticated neural network structures for more accurate results.

Thirumalaiah and Deo (1998) presented an approach for using neural network for real time river stage forecasting. Three methods were used to train the neural network: error back propagation, cascade correlation, and connective gradient. They stated the following advantages of neural network which can be usefully exploited in river forecasting:

- Neural networks are useful when the underlying problem is not clearly understood.
- Their application does not require prior knowledge of the underlying process.
- Neural networks are most suitable for dynamic forecasting problems because the weights involved can be updated when fresh observations are made available.
- Due to their inherent distributed processing, neural networks are fairly stable. A small amount of errors in the input does not produce significant change in the output.
- They do not require any exogenous input other than a set of input-output vectors for training purpose.

They concluded that continuous forecasting of river stage in real-time sense is possible through the use of neural networks.

Pham and Xing (1995) presented an application of predicating the Amazon River at Iquitos. The multi-layer perceptron and Group Method of Data Handling (GMDH) neural networks (Hecht-Nielsen, 1990) structure was used. They showed that even though only 11 data points were used for training and selection, the GMDH networks produced reasonable predictions.

STUDY AREA

Our study area include part of Lake Victoria basin. The Basin, which feeds this lake, lies between latitude 3° 30" south of Equator and latitude 0° 30" north of Equator and between longitude 30° 0" and 36° 0" east (Fig. 1). Lake Victoria itself lies between longitude 32° 35" and 34° 30" east and between latitude 3° 30" south of equator and latitude 0° 30" north of equator. Lake Victoria is fed by different tributaries that flow into it from the north, south, and west. The area of Lake Victoria basin is about 262,000 square kilometers while the surface area of the lake is about 67,000 square kilometers. The average intensity of rainfall on the basin per year is about 1.190 meters while the average on the lake is about 1.150 meters. The average quantity of water entering the lake is about 95,000 million m^3/year while the average evaporation losses on lake surface is about 75,000 million m^3/year. The basin is the major source for contributing inflow to the White Nile River. Knowing the inflow from Lake Victoria will assist to estimate the inflow in the Nile River. Namasagali is a location on the outlet river of Lake Victoria. Predicating yearly and monthly river inflow to Namasagail is important for predicating the flow in the White Nile River and monitoring water rights. Rainfall measuring stations are located on the area of Lake Victoria basin which is shared between Uganda, Kenya, and Tanzania. The rainfall measurement stations have monthly records since 1913 until 1972. Also inflow in Namasagail is measured monthly for the period between 1913 to 1972. There are some missing records for both rainfall and inflow measuring stations at that period. Moreover, after 1972 all these measuring station have been closed for several reasons. Measuring rainfall for the area of study could be determined through satellite images and image processing models. With the drawback of using traditional methods and missing data and information for the studied area, a neural network model is implemented in an attempt to predict the inflow to Namasagail. The historical records have been used to train and test the neural network model.

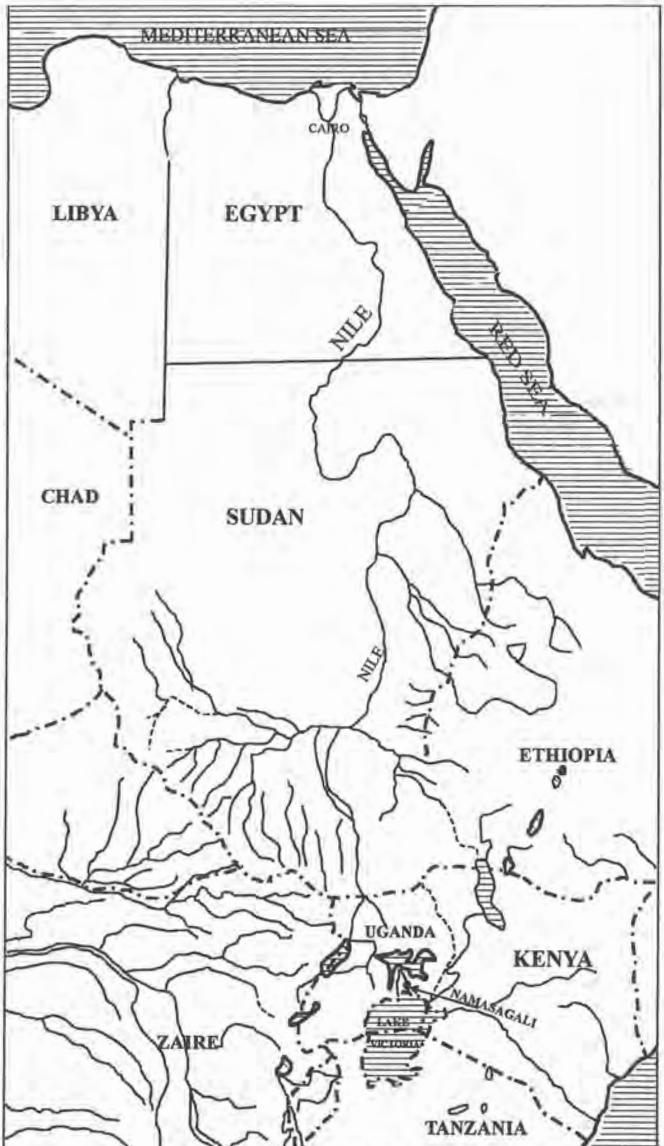

Fig. 1. Study Area and The Nile River

NEURAL NETWORKS THEORY

Artificial neural networks can be characterized most adequately as computational models with particular properties such as the ability to adapt or learn, generalize, cluster or organize data. Neural networks are massively parallel systems, as illustrated in Fig. 2, composed of the following elements (Muller et. al., 1995):

- A set of operating processors termed neurons, cells, or units.
- A set of activations (a_i) for every unit, which also determines the output of the units.
- Connections between the units, each connection has a weight (w_{ij}).
- A propagation rule (i_i).
- An activation function (F_i).
- An external input or offset θ_i for each unit.

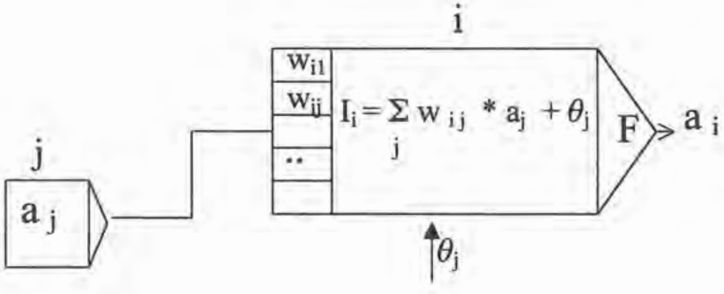

Fig. 2. Neural Network Elements.

Each unit perform to tasks: 1) receive input from neighbors or external sources and use this to compute an output signal which propagate to other units; 2) adjusting the weights. There are three types of units: input (receive data from outside the system); output (send data outside the system); and hidden (the input and the output signals remain within the system). During operation, units can be updated either synchronously or asynchronously. Often, the activation function is non-decreasing sigmoid function of the total input of the units:

$$a_i = F(i_i) = 1 / (1 + e^{-i_i}) \tag{1}$$

where is the propagation rule i_i is:

$$i_i = \sum_j w_{ij} \bullet a_j + \theta_i \tag{2}$$

The training algorithm adjusts how the inter-neuron connections and the nature of the connections are arranged. This adjustment is designed to achieve a desired overall behavior of the network. In the learning process, often called the training process, large numbers of input-output pattern pairs are presented to the network in a repetitive fashion designed to provide iterative corrections to the weights. Each iteration, called an "epoch", is a single pass through all training pattern pairs. To train the network, an input pattern p presenting to the network, making prediction as to the output O_{pk}, and then comparing this predicted output to the input pattern's actual output T_{pk}. The total error E_p is computed as:

$$E_p = \sum_{k=1}^{N} (T_{pk} - O_{pk})^2 \tag{3}$$

The global error E is equal to

$$E = \sum_{k=1}^{C} E_p \tag{4}$$

Where

C is the number of unique input-output pattern pairs presented in an epoch.

The training process is accomplished by a suitable methodology for iterative correction of the interconnection weights to produce a final set of weights that minimize the global error E (for extensive reviews see Smith, 1993). Neural networks can be classified according to their structure and learning algorithms.

NEURAL NETWORK MODEL FOR NILE RAINFALL-RUNOFF

A Neural Network Model for Nile Rainfall-Runoff process (NNMNRR) has been developed to map rainfall patterns into measures of the runoff. The model is developed using the C++ computer language. Various types of neural networks were tested. These included standard back-propagation (Lippman, 1987), cascade-correlation algorithm (Fahlman and Lebiere, 1990), conjugate gradient (Fletcher and Reeves, 1964), and genetic reinforcement learning (Holland 1975; Goldberg, 1989). The tests were carried out using a part of the input data. The best performing networks were the standard back-propagation network and the cascade-correlation networks. Both methods have been implemented in NNMNRR.

The back-propagation method involves minimization of the global error by using the gradient descent approach. The network weights and biases are adjusted by moving a small step in the direction of the negative gradient of the error function during each iteration (Fig. 3). The iterations are repeated until either a specified convergence is reached or a prescribed number of iterations is exceeded. Application of this algorithm in the present case starts with normalization of the input values and initialization of all weights and biases to random values within the range of -0.8 to 0.8. Then, the activation value a_i for each unit in the hidden layer is determined. Each output node interacts similarly with the hidden nodes and produces the network output. The difference between this network output and the target output gives the error gradient. The gradient descent is used to evaluate of new weights and biases with respect to a given training pattern. One iteration is over when all training patterns are finished. The iterations are continued until the overall mean squared error ($E^{\Box}$) for all output nodes and training patterns reaches a minimum. In the back-propagation method, no general methodology is available for determining the number of hidden layer neurons. In our case study, the model starts with a sufficient large number of units in the hidden layer and progressively reduces this number until training statistics indicate optimum performance.

The cascade-correlation method is an efficient constructive training algorithm that combined the idea of incremental architecture and learning in its training procedure (Fig. 4). Training starts with a minimal network consisting of an input and an output layer. Then, the training is developed until iterations fail to reduce the residual error. Then it stops this phase of training, and enters the next phase for training a potential hidden unit. The potential hidden unit has associated weights from the input layer and all preexisting hidden units, but not toward the output layer. Weights associated with the potential hidden units are optimized by a gradient ascent method. When a potential hidden unit is trained, weights associated with output layer are kept unchanged. Once a potential hidden unit is added to the network, it becomes a new hidden unit and its incoming weights are frozen for the rest of the training period. After installing a hidden unit, the training updates weights of all connections that directly feed the output layer. This dynamic expansion of the network continues until the problem is successfully learned.

The inputs of the NNMNRR are rainfall amount for the selected stations and the output is the river inflow at Namasagail. The model determines the monthly and the yearly inflow depending on the input using both methods.

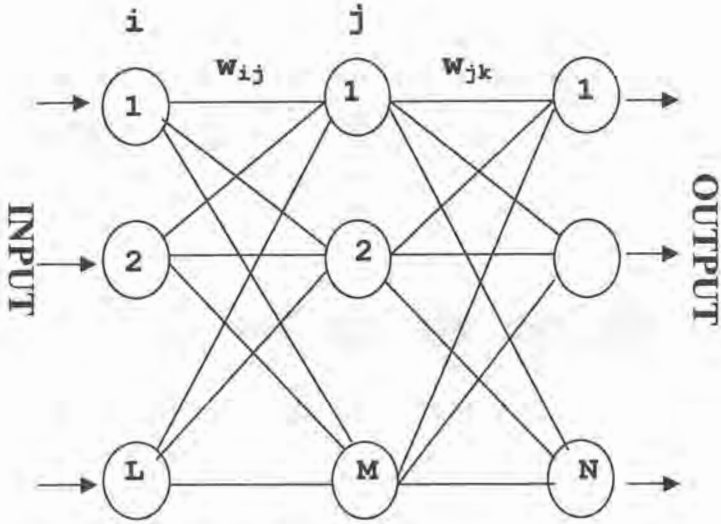

Fig. 3. The Back-propagation Method

RESULTS

All rainfall measuring stations enclosing Lake Victoria have been studied. Stations with missing records have been neglected. The correlation between yearly inflow Namasagail and yearly rainfall of each of selected stations have been determined for the period between 1913 and 1969. Only data for 43 years have been considered since there are a lot of missing data in that period. The results of the correlation coefficient test are illustrated in Table 1.

Only rainfall stations with a correlation coefficient greater than 0.39 were selected as input to the NNMNRR. Therefor the inputs are rainfall amount for the stations MASINDI, MONIKO ESTATE, MASAKA and BWAVU at Uganda. Moreover, the correlation coefficient between monthly inflow at Namasagail and monthly rainfall for each selected station were determined for the period between 1913 and 1972. These correlation coefficients are illustrated in Table 2. For monthly prediction, MASINDI Port, MASINDI and MASAKA were considered for their complete records and high correlation coefficient. The yearly and monthly input data for each period have been shuffled for better training of the NNMNRR. Moreover, extreme values for rainfall and river inflow were included in training set for NNMNRR to avoid extrapolation effect for prediction.

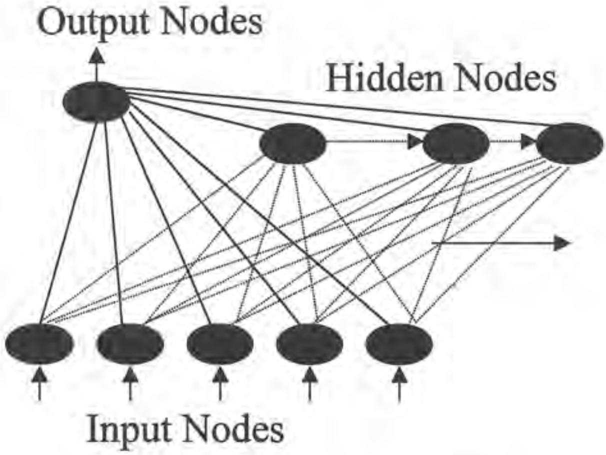

Fig. 4. Cascade-Correlation Networks

Table 1: The Correlation Between Yearly River Inflow At Namasagail And Yearly Rainfall For Selected Stations.

Station Name	Correlation
MASINDI (Uganda)	0.418
MONIKO ESTATE (Uganda)	0.487
BWAVU (Uganda)	0.394
Fort Port (Uganda)	0.115
Gulu (Uganda)	0.091
BUDO (Uganda)	0.288
MASAKA (Uganda)	0.385
KERICHO D.C. (Kenya)	0.17
LONDIANI (Kenya)	0.187
KISUMU (Kenya)	0.065

Table 2: The Correlation between monthly River Inflow at Namasagail and yearly Rainfall for Selected Stations.

Station Name	Correlation
KITGUM (Uganda)	0.144
MASINDI Port (Uganda)	0.454
MASAKA (Uganda)	0.222
BWAVU (Uganda)	0.136
MBARARA (Uganda)	0.131
MASINDI (Uganda)	0.189

For yearly prediction, 35 records were used to train the NNMNRR and 8 records were used for testing. The results for yearly inflow using cascade-correlation method are illustrated in Fig. 5. The correlation coefficient between target and predicted river inflow equal to 0.825. By applying the back-propagation method, prediction for the river inflow was performed with correlation coefficient between target and predicted river inflow equal to 0.56. The predicted values are illustrated in Fig. 5. The optimal size units in the hidden layer for the back-propagation method was found to be 2 units.

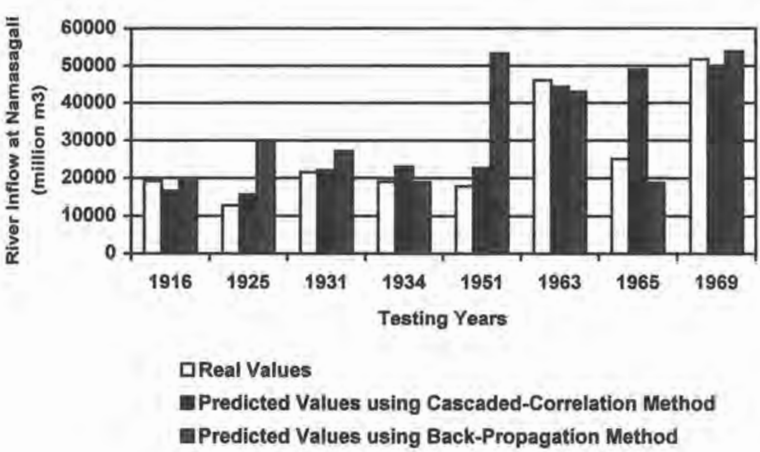

Fig. 5. The yearly inflow prediction using cascade-correlation and back-propagation methods.

For monthly prediction, 202 records were used to train the NNMNRR and 31 records were used for testing. The results for yearly inflow using cascade-correlation method are illustrated in Fig. 6. The correlation coefficient between target and predicted river inflow equal to 0.16. By applying the back-propagation method, prediction for the river inflow was performed. The predicted values are illustrated in Fig. 6. The optimal size units in the hidden layer for the back-propagation method was found to be 2 units.

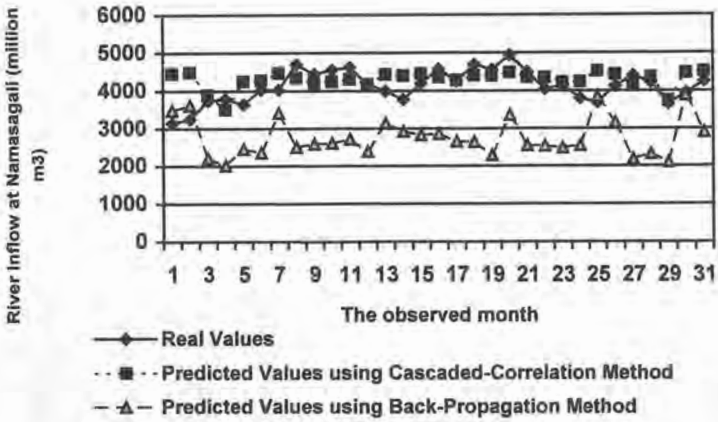

Fig. 6. The monthly inflow prediction using cascade-correlation and back-propagation methods.

CONCLUSIONS

The forgoing studies indicated that predicting inflow from rainfall pattern is possible through the use of NNMNRR. A good correlation between the observation and the corresponding model output (prediction) is found to be dependent on the training algorithm. A proper choice of the training algorithm can give good prediction for yearly inflow. Moreover the cascade training algorithm provided faster learning than back propagation method in yearly prediction. The back propagation may reach the same results of cascade-correlation method if more iteration processed. The NNMNRR is a black-box tool and the user need not know much about the flow process. The back propagation method is easy to use but the corresponding solution converges slowly and may exhibit oscillatory behavior because of the fixed step size.

For predicting the yearly inflow, the cascade-correlation method gives better results than the back-propagation method. Therefor, the model can be used accurately for monitoring water rights when measured data for inflow is not applicable. For predicting monthly inflow, the back propagation method performed better than the cascade correlation. The non-accurate output of the model, for both methods, in monthly case resulted in the hypothesis that there was insufficient information content in this predicted output variable. Including information as infiltration and evaporation loses as input variables in the model will probably increase the performance of the model for monthly inflow prediction. Also information as time lag between rainfall and effective runoff for different rainfall stations could enhance the model performance of model for monthly inflow predication.

REFERENCE

Bras, R.L., 1990, Hydrology: an Introduction to Hydrologic Science, 1st Edition, Addison-Wesley Publication Co., Reading, Massachusetts.

Devore, Jay L., 1991, Probability and Statistics for Engineering and Sciences, 4th edition, Duxbury Press, Belmont, California, pp. 371-558.

Fletcher, R., and Reeves, C. M., 1964, Function minimization by conjugate gradients, Computer journal, Vol. 7, pp. 149-153.

Fahlman, S. E., and Lebiere, C., 1990, The Cascade Correlation Learning Architecture, Advances in neural engineering processing system 2, D.S. Touretsky, ed. Morgan Kaufman Publishers, Inc., San Mateo, Calif, 524-532.

Flood, I., and Kartam, N., 1994a, Neural Networks in Civil Engineering. I: Principles and Understanding, Journal of Computing in Civil Engineering, ASCE, Vol. 8, No. 2, pp. 131-148.

Flood, I., and Kartam, N., 1994b, Neural Networks in Civil Engineering. II: Systems and Application, Journal of Computing in Civil Engineering, ASCE, Vol. 8, No. 2, pp. 149-162.

Goldman, D., 1989, Genetic Algorithms in Search, Optimization and Machine Learning, Reading, Addison-Wesley, MA.

Holland, J. H., 1975, Adaptation in Natural and Artificial Systems, Ann Arbor, University of Michigan Press, USA.

Karunanithi, N., Grenney, W. J., Whitley, D., and Bovee, K., 1994, Journal of Computing in Civil Engineering, ASCE, Vol. 8, No. 2, pp. 201-219.

Kitanidis, P. K., and Bras, R. L., 1980a, Real Time Forecasting with a Conceptual Hydrological Model. 1- Analysis of Uncertainty, Water Resources Research, Vol. 16, No. 6, pp. 1025-1033.

Kitanidis, P. K., and Bras, R. L., 1980b, Real Time Forecasting with a Conceptual Hydrological Model. 2- Application and Results, Water Resources Research, Vol. 16, No. 6, pp. 1034-1044.

Lippman, R., 1987, An Introduction to computing with neural nets, IEEE ASSP Magazine, Vol. 4, pp. 4-22.

Masters, T., 1995, Advanced Algorithms for Neural Networks: A C++ Sourcebook, John Wiley and Sons Inc., New York.

McCuen, R. H., 1989, Hydrologic Analysis and Design, 1st Edition, Prentice-Hall, Englewood Cliffs, New Jersey.

Muller, B., Reinhardt, J., and Strickland, 1995, Neural Networks An Introducation, Springer-Verlag Berlin Heidelberg, Germany.

Pham, D.T., and Liu, X., 1995, Neural Network for Identification, Predicition and Control, Springer-Verlag, London.

Smith, J., and Eli, R. N., 1995, Neural Network Models of Rainfall- Runoff Process, Journal of Water Resources Planning and Management, ASCE, Vol. 121, No. 6, pp. 499-508.

Smith, M., 1993, Neural Networks for Statistical Modeling, Van Nostrand Reinhold, New York.

Tawfik, M., Ibrahim, A., and Fahmy, H., 1997, Hysteresis Sensitive Neural Network for Modeling Rating Curves, Journal of Computing in Civil Engineering, ASCE, Vol. 11, No. 3, pp. 206-211.

Thirumalaiah, Konda and Deo, M.C., 1998, River Stage Forecasting Using Artificial Neural Networks, Journal of Hydrologic Engineering, Vol. 3, No. 1, pp. 26-32.

Walley, W. J., and Fontama, V. N., 1998, Neural Network Predictors of Average Score Per Taxon and Number of Families at Unpolluted River Sites in Great Britain, Water Research, Elsevier Science, Vol. 32, No. 3, pp. 613-622.

A NEW DIRECTION FOR ALLOCATING WATER OF THE NILE RIVER IN EGYPT

John E. Priest[1]

ABSTRACT

The Egyptian philosophy of water use is that of an agrarian society even though perhaps only 50 % of foodstuffs are produced domestically. The Egyptian Government is now implementing a plan of action that will spread water over vast new areas of the Western Desert and the Sinai. The objective is to transfer within 20 years as many as 7 million persons from the Nile Valley and the Delta to intensively irrigated areas of the Western Desert. This diversion of Nile River water is to be accomplished even as the nine upstream riparians are demanding more water.

A paradigm shift is required. Those guiding irrigation development in the Western Desert must accept and embrace a model of mixed development based on: 1) the eventual minimization of irrigation of field crops, 2) the identification and filling of now dry water-table aquifers through diversion of excess river flows in wet years, and 3) exploitation of minerals and other important resources of the Western Desert to support the new communities.

Clearly, during the initial stages of New Valley developments, the government needs to divert the entire excesses of wet year flows for over-irrigation of reclamation crops and the filling of pre-identified underground reservoirs. Integrated ground-water-surface-water systems should be established, successively along the path of development, to supply municipal and industrial water and for the irrigation of vegetables and fruit trees. A large component of the water required for creating shaded communities and wind breaks should be derived from reuse of treated wastewater effluents and the pumping of mildly brackish ground water. Thus, through the establishment of water-table aquifers along the route of development and the careful husbanding of the water resource, extensive settlements can be realized in the western Desert without substantial diminishment of the productive capacity of the agriculture of the Nile Valley and Delta.

Sustainability of the colonization will depend equally on the exercise of care in protecting the fragile desert environment in every zone of development and the equitable collection of water user fees from the start of project operations.

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INTRODUCTION

Three aspects of allocation of the water of the Nile River, and its management, are crucial to the water users of Egypt – a) the division and utilization of water and water rights among the ten riparian nations of the Nile River Basin, b) the internal allocations within Egypt, the most downstream riparian, and c) utilization of the flood water excesses. The focus of this paper is the allocation and management of water within Egypt and more specifically the allocation and utilization of excess surface water for environmentally sound and financially sustainable colonization of the Western Desert.

Egyptian Philosophy of Water Use

The Egyptian philosophy of water use is rooted in the achievement of food self-sufficiency through irrigation and the cultivation of cotton for domestic industry and for export. There still is not general recognition that the population of Egypt not only has exceeded the carrying capacity of the agricultural lands of the Nile Valley and the Delta Region but requires quantities of municipal and industrial water which render obsolete the notion of expanded pursuit of traditional flood-irrigated agriculture. The Egyptian Government is now struggling to evolve new policies and a plan of action that recognizes two important truths. First, Egypt must supply water to vast new areas of the Western Desert and the Sinai if the ever-growing population is to be accommodated outside the Nile Valley and the Delta. Secondly, the upstream riparians, particularly Ethiopia and Sudan, increasingly are claiming their heretofore unused rights to the flow of the Nile River.

Required Change of Philosophy

Required is a paradigm shift relative to the design and emphasis of the Egyptian program now under implementation to expand irrigated agriculture. There is adequate river water to service the Nile River Valley and Delta within the 1959 treaty allocation to Egypt of 55.5 billion cubic meters. It is doubtful, however, that even with contemplated changes of the cropping pattern, increased reuse of drainage water from irrigation, and development of ground water of the Western Desert, that the vast areas being planned for irrigation can be adequately watered for intensive agriculture.

Thus, the first of two propositions of this paper posits that, the government needs to consider the duty of water required for creating a *favorable living environment* in the desert instead of the establishment of new exclusively *agricultural communities*. Irrigation water should be used to irrigate vegetables, fruit trees, and date palms for food production and for creating shaded communities. Only through careful husbanding of the water resource can extensive settlements, largely based on non-agricultural pursuits, be realized without substantial diminishment of the productive capacity of the Delta.

Best Use of Flood Water Which Is Excess to the Treaty Allocation

The second philosophical point of this paper is technical in nature. It relates to utilization of the extra-ordinary floods that originate in the upper basin and which are as yet uncontrolled by the upstream riparians. For example, some 110 billion cubic meters of flow occurred from August to October of 1998. Such flows present an ephemeral opportunity to divert the large quantities of water needed to establish the vast new settlements of the western Desert. It is essential, for the realization of sustainable development of the Western Desert that such high-volume, uncontrolled flows from upstream be used for the charging of new water-table aquifers and to improve the quality of recharge to existing, ground-water reservoirs.

Supporting decisions and policies are needed to assure that any excess water available during the coming decade is used to achieve the high multiplier effect that can be achieved through the development and use of water-table aquifers as reservoirs and as underground transmission systems.

VISION AND OBJECTIVES

The government of Egypt long has recognized that the population of the Nation, which has quadrupled over the past forty years, can not continue to be domiciled exclusively in the area of the Nile Valley and the Delta without extensive sacrifice of fertile lands. Even now these lands produce only about 50% of the nation's requirements for foodstuffs. The resulting crisis, which may be viewed in terms of national survival and economic independence, has prompted national leaders to articulate a vision with objectives of expanding irrigation to the Sinai and to the Western Desert to support the transfer of population away from the Delta.

The extension of irrigation to the Sinai is based on use of water at the tail of the existing irrigation system where reuse of irrigation return flows and treated municipal and industrial return flows from the Metropolitan Cairo area potentially are major components of the required water resources.

By contrast irrigation of the Western Desert requires: 1) the division of Nile flows at Lake Nasser into a new river flowing to the Western Desert, and 2) the maintenance of flows through the hydro-power plant at Aswan and on down river to service the Valley, Delta, and Sinai. Important to the establishment of colonies and irrigation in the Western Desert is the extent and quality of the developable deep ground water reservoir that underlies most zones of the area. And as emphasized in this paper, the establishment of a series of shallow ground-water reservoirs that extend along the alignment-for-development, from Lake Nasser northwesterly toward the Qatarrah Depression.

Thus, it is the vision of the government that relates to the Western Desert that requires scrutiny and re-articulation. Determinants of the review should be the water resource base that may appropriately be mobilized to support extensive colonization and the water consuming nature of those colonies.

Vision

Current Vision: *The Government of Egypt is programming and working toward agriculture-based colonization of the Western Desert on an alignment extending from Lake Nasser toward the Qatarrah depression, incorporating the oases of Kharga, Dakhla, Farafra, and Bahariya, Figure1.*

Limitations of the Vision: The current vision anticipates the successive development of a chain of traditional agricultural based settlements extending ever farther away from Lake Nasser. While Egypt may initially divert enough water to create one or two agricultural communities, the flow of the Nile River will, in the future, be inadequate to sustain a whole chain of new communities dedicated to intensive irrigated agriculture in a very hot desert climate.

Objectives

Objective: *The current objective of the government of Egypt is to convince excess population of the Delta and Valley to migrate to the Western Desert and the Sinai to relieve further decline of the agriculture of the traditional areas.* The goal is to encourage some seven million citizens to settle in the Western Desert during the next two decades.

Discussion: It is recognized that no desert civilization can arise without ample water resources. To achieve this objective, it is planned to pump water from Lake Nasser, as a first stage, and to convey it over the western escarpment of the reservoir to irrigate agricultural crops on the sandy soils of the New Valley including the East Uwainat and Toshka areas. The initial areas were selected to minimize pump lift, to serve the most suitable nearby soils, and to attract non-governmental investment.

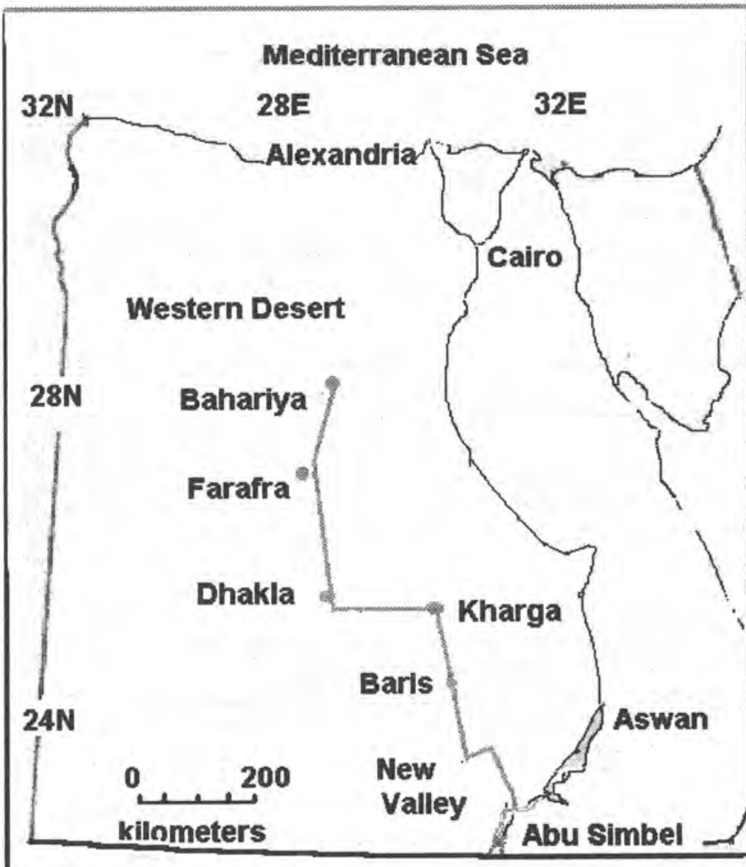

Fig. 1. Alignment for Settlement of Western Desert

Required Paradigm Shift

If Egypt is to succeed in the colonization of the Western Desert, while still maintaining the high levels of agricultural production of the Nile Valley and Delta, it is essential that the model of developing agricultural communities in the desert be modified to emphasize colonization based on strengths other than extensive, intensive irrigated agriculture.

Deficiencies of Current Vision and Objectives -- The current vision and objectives represent only the broadest societal framework. The vision is far ahead of technical analyses that might justify sustainable, extensive, traditional agriculture in the deserts

Considering the finite quantities of future surface water availability and the uncertainties associated with development of exploitable deep ground water, it is clear that communities should be located only in areas where rechargeable ground water reservoirs can be established. Thus, it is critical that areas which are to be irrigated have proved extensive potential for the establishment of water table aquifers. These presumably dry aquifers would undergo a deliberate program of charging through initial over-irrigation with diverted excess flows of the Nile River.

Besides the need for a change in the concept for selection of areas for development, a paradigm shift is required in the vision that foresees traditional agricultural developments extending across the desert. Required is a commitment to build infrastructure and to allocate surface water adequate to support communities with just enough agriculture to create an environment adequate to the attraction of settlers.

Thus, *the development paradigm will of necessity shift from one of extensive irrigated agriculture to the establishment of communities with water resources adequate to support a mix of industrial and commercial enterprises and limited water-efficient agriculture.*

Possibly with the exception of mining, only industrial enterprises that consume minimal quantities of water should be permitted, and irrigation mostly should be dedicated to productive date palms that shade streets and parks and to vegetables, fruit, and other high value crops adequate to supply local markets.

GEOGRAPHY AND SETTING

Nile River

Source: The Nile River rises in nine countries that lie to the south of Egypt. Two major tributaries, the White Nile and the Blue Nile, join at Omdurman outside Khartoum, Sudan. The Atabara is tributary some 200 kilometers downstream. The Blue Nile and the Atabara rise in the Ethiopian Highlands, where the summer monsoons contribute flood flows in Egypt from July to October.

Tropical rains that maintain a relatively constant flow originating in the lake districts of Burundi, Zaire, Tanzania, Kenya and Uganda feed the White Nile. The White Nile branches into a series of channels in the Sudd, an extensive marsh in the southern Sudan. The Sudd regulates not only the upland flows but also the flood flows of the rainy season of the savanna of central Sudan.

Egyptian Conditions: The flow of the Nile River is almost totally regulated as it enters Egypt through Lake Nasser. The river channel of the Nile Valley and the channels of the Delta have been, essentially, canalized since construction of the Aswan High Dam during the 1960s.

Treaties: In 1929 the Nile Water Agreement, to apportion use, was sponsored by Great Britain. During 1959 Egypt and Sudan signed a bilateral utilization agreement that stipulated an increase of Sudan's share from 4.0 to 18.5 billion cubic meters per year and that of Egypt was fixed as 55.5 billion cubic meters per year. The 1959 agreement freed Egypt to build Aswan Dam, Sudan to develop the Rosieres Dam, and Egypt and Sudan to carry out the Jonglei Canal channelization of the Sudd, a project designed to conserve large quantities of water lost to evaporation in the swamps.

Lake Nasser

An evaluation of the potentials for water conservation within the present day Nile River system, requires a full appreciation of the huge size of Lake Nasser and its geographic and geological setting. The surface area of the lake when the water level is at the crest of the emergency spillway, is some 5600 km2.and the annual evaporation is approximately two meters of water depth. Thus the evaporation loss approximates 11 billion m3/yr during periods the lake is full. Besides, there are subsurface losses from the reservoir.

Western Desert

Features of the Western Desert that are key to extensive development there include: 1) the deep Nubian aquifer, probably a glacial remnant that is not recharged. It underlies much of the Western Desert extending from the oases south to Sudan and west to central Libya, 2) the presence of sands and gravel strata at shallow depths along the approximate alignment of development, 3) rechargeable aquifers as indicated by the springs at the oases, and 4) exploitable mineral deposits.

The topography of the Western Desert is such that a gravity-feed canal can be built to carry water from diversion at Lake Nasser toward the Toshka Depression and then along an alignment extending successively to the oases of Baris, Kharga, Dakhla, Farafra, and Bahariya.

INDICATED INVESTIGATIONS AND STUDIES

To achieve effective development and the financing and settlement of millions of citizens in the Western Desert, the government will have to carry out field investigations, compile and analyze data and information, and study and model expected outcomes for a series of scenarios of water availability, water use, and water-user charges. These analyses will require updating on a periodic basis as development progresses. Only through such an approach will water and financial resources be mobilized and allocated on a timely basis. Timely mobilization of adequate resources will persuade the populace that settlement is the correct option It also will assure that the fragile desert environment can be protected and that it will sustain the ever growing numbers of settlers. Among actions required are the following:

1) Conduct of extensive field investigations at the reconnaissance level to: a) determine topography along the development alignment, b) identify potentials for developing shallow, water-table reservoirs along the development alignment, c) identify the source of spring water at oases, d) identify deep ground water potentials, e) identify potential reservoirs of usable brackish ground water, and f) survey all resources of the area including minerals, tourism and health spa potentials, soil suitability for agricultural and community developments, and quality of ground water, both brackish and sweet.
2) Conduct of office investigations and studies to: a) prepare and disseminate records of Nile River flows entering Lake Nasser, b) define appropriate allocations to canal commands of the Nile Valley, Delta, and Sinai, and c)

assess evaporation, seepage and leakage from Lake Nasser over a range of water surface levels.

3) Development of scenarios for the modeling of water supply factors which are key to successful colonization of the Western Desert, including: a) a time based scenario of developments and water use by upstream riparians considering political stability and consequent capacity of those riparians to mobilize domestic and international financing, b) time-based scenarios for developments in the Western Desert and concomitant water and financing requirements, and c) requirements for wastewater treatment for reuse for agriculture and for greenbelt development.
4) Integration of studies and investigations for the modeling of water available, considering: a) exploitable deep ground-water contribution, b) differing levels of Lake Nasser and effects on water availability and hydro-power production, c) impacts of upstream developments over several time horizons, d) salt balances of the several aquifers, e) reuse potentials of wastewater and irrigation return flows, and f) the quality of water required for mining and other industrial activities.
5) Integration of water availability, over time and space, with development scenarios for the Western Desert communities. Postulate potential developments in the Western Desert considering sequenced developments with respect to distances along the alignment of colonization and the efficacy of filling and utilizing water-table reservoirs.
6) Determine water-user fees for immediate implementation. There should be no forgiveness. If it is necessary initially to provide incentives, then subsidies or other means should be used rather than the provision of free water. A civilization, based on costly water that is available in limited quantities, can not sustain itself if the commodity is provided without cost or accountability. Sustainability can be achieved only if the user must pay a fair share.

PROPOSED NEW APPROACH TO SETTLEMENT OF WESTERN DESERT

Non-nomadic civilizations rise in the desert where adequate, exploitable water resources are available. Thus, any approach to settlement of the Western Desert will be driven by the quantity, quality, and timing of water availability. Further, the population that may be supported is dependent on the total resource base rather than just agriculture.

Water Demand

Irrigated agriculture, industry and population will drive the demand for water. Diversion requirements from the Nile River will be driven by quantities of ground water available; early implementation of measures to treat and reuse municipal and industrial water; capacity to capture irrigation waste and return flows; and the adaptation of agriculture, forestry, and industry to use brackish water.

Gross Estimate of Water Demand: If seven persons can be fed from the produce of one hectare of land irrigated year round, then some one million hectares of land must be cultivated to support a populace of seven million. And, if two meters of water per year is required to flood-irrigate land year-round in the desert, irrigation use will total 20 billion cubic meters. Some two billion cubic meters per year likely will be required for municipal and industrial demand. Thus, if flood irrigation were used some 22 billion cubic meters of high quality water must be pumped from ground water and diverted from the Nile River to provide food self sufficiency and to support domestic, commercial, and light industrial uses of the settlers.

Although it is doubtful that such a large quantity of water could be allocated to the Western Desert, demand could be met from a number of sources, and the demand also could be reduced through implementation of various measures if programmed from the beginning of development.

Measures to Reduce Demand: There is little that can be done to reduce the municipal and industrial demand short of reducing the population. Thus, it is in the sphere of irrigation that demand-reducing measures should be taken. An obvious effort should be made to implement drip irrigation, but only after land reclamation is completed through flood irrigation, hopefully, using major flood flows as they occur. There is a tradeoff to be explored, however. With flood irrigation of lands overlying shallow ground water reservoirs, the multiplier effect of successively re-pumping groundwater throughput can approximate 30%. Thus, there is available to flood irrigation some 130% of surface water input and deep ground water pumpage.

Water Availability

Water demand can be met from diversion of the Nile River, by ground water pumping, and through reuse.

Surface Water Availability: Constant or maintenance flow from the Nile River should be diverted from Lake Nasser at such a rate that agriculture along the Nile Valley and in the Delta will not be degraded. Depending on allocations to the Sinai Region, there should be several billion cubic meters per year available on average. Savings additional to those to be achieved in the Nile Valley and Delta, could be realized by lowering the level of Lake Nasser to reduce annual evaporation by, say, one to two billion cubic meters. This measure should likely be implemented only after floodwaters entering Lake Nasser are reduced by new upstream developments and diversions, perhaps one to two decades in the future.

It is the large volume floods in wet years that provide the best opportunity for establishing colonies in the Western Desert. It should be determined at what level Lake Nasser may be operated in future, and flood flows should be diverted through deep-cut canals and tunnels at that operational level. With a facility adequate to divert high-rate flood flows by gravity, the pumping facility now under construction could be used to pump maintenance water when the reservoir is below the gravity offtake.

Diversion of flood flows likely will not occur every year, but the diversions should be regulated to the extent possible. The objective of high-rate diversion of flood flow is to reclaim lands and to simultaneously fill any shallow aquifers identified. A shift to sprinkler or drip irrigation can follow as areas are successively reclaimed.

Ground Water: The Nubian sandstone aquifer is mostly confined deep below the desert. It underlies essentially the entire area planned for development. This aquifer is said to be non-rechargeable, although investigators during the 1970s and 1980s, were divided regarding whether there is a recharge area in the southern most reaches of the Sahara Region to the south of Libya. There exists a body of reconnaissance level ground-water data that derives from oil exploration that may be used to reanalyze whether there are possible recharge zones.

Wells have been in operation in the areas of the oases at least since the 1950s. During that period investigators of the U S Geological Survey studied the corrosive electro-chemical properties of the water and the effects on well screens and materials. The fact that the springs of the oases have flowed for millennia without the benefit of mechanical pumps indicates that there may be recharge in some zones of the Western Desert. Considering the low average annual rainfall, wadis must flow infrequently.

There undoubtedly are or will be shallow brackish water reservoirs. These should be exploited by pumping from relatively low-cost, shallow wells to grow windbreaks and to create greenbelts near settlements. This approach was employed near Basrah, Iraq to establish plantations of tamarisk through the pumpage of highly saline ground water for just a few years, Afterwards the tamarisk rooted to 15 meters of depth and thrived on the saline aquifer water.

The purpose of this discussion is intended to highlight three points. First that there is a considerable ground water resource underlying the Western Desert, second it is not certain if there is recharge to part or all of the aquifer, and third fairly high cost wells will be required for pumping deep water. The ground-water situation currently is being studied by the Ministry of Public Works and Water Resources. That ministry should be funded to carry out the above specified reconnaissance level investigations.

Population Support

Should the water resource be adequate to intensively cultivate a million acres year round, then some 150,000 farm families or, say 500,000 people will be directly engaged in agricultural production. If another 150,000 persons are engaged in governmental and non-governmental services to farmers, maintaining wells, and in maintaining green belts, parks, etc, then agriculture will support a population of one million. It therefore will be necessary to employ another 1.5 million workers in food processing, tourism, transport, mining, manufacturing, schools and universities, health care, communications, and government service. Thus it is essential that institutions and infrastructure be created in parallel with water development to attract not only farmers but also professionals from all walks of life.

SUMMATION

It is crucial that the government promptly re-articulates its vision, reexamines its objectives, and formulates a detailed plan that defines water availability and the means to achieve sustainable, environmentally friendly colonization of the Western Desert. A key element of success will be early government definition of the availability, over time, of Nile River flows considering probable upstream uses. All future flows of the Nile River entering Egypt in excess of the treaty allocation should no longer be delivered to the Valley and Delta. There now is over watering in these areas especially during periods of high flow. Water in excess of the treaty allocation should be turned to the desert where the benefits will be measurably greater.

An objective will be to divert these large volumes of floodwater to reclaim lands for irrigated agriculture and to simultaneously fill any water table reservoirs available. This program of aquifer creation and land reclamation will require the early construction of large canals to carry water to as many of the predefined development areas as possible during the next two decades. It will not be necessary to line these transmission canals along reaches where water losses seep to water table aquifers targeted for filling.

Structures designed for intermittent high-rate gravity diversions from Lake Nasser also may be required. This diversion capacity would be in addition to the pumping plants now being built.

Once the lands are reclaimed, through flood irrigation of rice and other field crops, highly efficient irrigation delivery systems may be installed. Further decisions may be taken regarding which reclaimed areas may be dedicated to green belts and community uses. Any newly established ground water reservoir may be maintained by the application of leaching water during periods of high Nile River flows.

Protection of the quality of ground water will be fundamental to the maintenance of the desert communities in perpetuity. It will be necessary to export salts to undeveloped desert areas or down basin at a rate equal to the input of salts from the Nile River and the salts accumulated during leaching operations. Further the aquifers will have to be protected from overuse of fertilizers, herbicides and pesticides. Industrial developments will have to be limited to those with low water use. From the outset no discharge of pollutants to canals, streams, and aquifers should be permitted.

The vision will have to be supported by carefully defined investment schedules, public and private, and identifiable bench marks. Policies will have to be devised to maximize private inputs even though massive government inputs of capital will be essential to initially catalyze adequate infrastructure construction in all sectors. All infrastructure will have to be adequate to protect water quality and the environment. Foremost among the measures required will be those which provide for the proper control, collection, treatment, recycling, and disposal of human and industrial wastes.

An inviolate policy of water charges will have to be implemented from the beginning of each development. The schedule of charges will have to account for whether water is totally government developed or whether the user has invested in wells or other facilities.

Sustainability of the colonies will depend equally on the twin pillars of maintenance of the environment and generation of water user revenues that are adequate to fully perform operation, maintenance, rehabilitation and replacement of facilities.

WATER MANAGEMENT IN THE SHARED DANUBE SECTION WITH RESPECT TO HYDRO POWER PLANT CONSTRUCTION

Andrej Šoltész[1]

ABSTRACT

Contribution deals with hydrological aspects of construction of Danubian hydropower plant Gabčíkovo on surface and ground water level regime in adjacent area, concretely in the left-hand side floodplain area of the Danube river. The authors thematically upgrade previous scientific works which have been done in this region (Šoltész,A.-Benetin, J., 1992, Burger, F.-Šútor,J., 1990, Szolgay, J.jr., 1988, Skalová,J.-Klementová,E.-Novák,V.,1996, Rehák,Š.-Šútor,J.,1996) and extend this problem with new knowledge about possible regulation of unfavourable ground water level regime by means of water supply from the branch system which is situated in the floodplain area of the Danube river. The solution utilizes a numerical modelling method of ground water flow for the evaluation of several scenarios of distributing the discharges between the river bed of the Danube and the upstream canal of hydropower plant Gabčíkovo.

INTRODUCTION

The Gabčíkovo Project was originally designed and constructed as a part of hydropower system Gabčíkovo-Nagymaros located on the Danube river, roughly between 1860 rkm at Bratislava and 1696 rkm at Nagymaros. Hungary unilaterally decided to abandon the construction of Nagymaros and to suspend the work to be carried out on the Gabčíkovo-Nagymaros waterworks. After this decision , in order to minimize economic and ecological damages, former Czechoslovakia decided to put nearly ready Gabčíkovo part of the system into operation, constructing necessary technical structures on their own territory. These technical structures are known as Variant C. This variant is situated inside the area of the original project, replaces the function of the Dunakiliti weir in Hungary. The Gabčíkovo hydropower was put into operation by damming of the Danube river in Čunovo profile in October 1992.

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METHODICAL PROCEDURE AND RESULTS EVALUATION

Hydrological regime of the Danube river before the damming influenced directly the hydrological regime in river branches as well as the ground water regime in the floodplain area. In pre-dam conditions the increase of water level in the river bed of the Danube caused a synchronous increase of water level in the branch system. At discharges about 3500 - 4000 $m^3.s^{-1}$ in the river bed there was a direct fulfilling of the branch system with water and the branches created together with Danube a complicated hydraulic surface water system and at 4500 $m^3.s^{-1}$ came to flooding of the area. The left-hand side floodplain area is situated between the old river bed of the Danube and the power canal of Gabčíkovo hydropower plant and its area is about 62 km^2. In this region there is about 4000 ha of productive floodplain forest.

Most important for surviving of floodplain forest and improvement of hydrological conditions in this area is a favourable ground water regime. The only data about measured ground water levels before damming were available from the time period 1987-1992. These gave the base for the following monitoring of the whole area. Illustration of the ground water level regime in floodplain area is shown for hydrological years 1991 and 1992 on Fig.1. and Fig.2. The ground water level course for three different boreholes (S-5, S-6 and S-8) with distances of 650 m, 750 m and 1050 m from Danube, are shown. From these figures is apparent that the fluctuation of ground water level during the vegetation period in pre-dam conditions reached the value 2,5-3,0 m. However, the ground water table was all the vegetation period in cover layers representing the root zone of the floodplain forest and never decreased into gravel layer, wherefrom no capillary rise is available. The lowest ground water levels are in winter and the highest are in summer. In august 1991 there was a flood in floodplain and the ground water was over the terrain.

For the analysis and the following prognosis of ground water regime we have used a numerical boundary element method. The software product BEFLOW is solving two-dimensional ground water flow at different hydrogeological properties. Its advantage is that after twofold application of Green´s theorem for transformation of the basic equation of ground water flow in two-dimensional space, the integration equations are composed only for the boundary of the solved region. The consequence of it is the dimension decrease of the problem, i.e. we used one-dimensional elements for division of the boundary at solving a two-dimensional problem. The boundary conditions for the solution were the water levels in the Danube and from the other side the seepage channel of the Hrušov reservoir.

The analysis consisted of series of numerical calculations for several discharge scenarios in old river bed of the Danube from the range of 50 up to 3000 $m^3.s^{-1}$. Results of the ground water flow modelling can be seen on Fig.3. where are shown the isolines of ground water table at discharge in the Danube Q_D = 350 $m^3.s^{-1}$ and the corresponding field of velocity vectors. Conclusions of the results obtained by modelling are as follows:

- for discharges Q_D = 50 - 350 $m^3.s^{-1}$ there is a large drainage effect of the Danube apparent which causes ground water decrease more than 4 m,
- the drainage effect is vanished at discharges of Q_D = 800 - 1000 $m^3.s^{-1}$ and the ground water table is stabilised 2,5 - 3,0 m bellow the terrain,
- for higher discharges in the Danube there is an infiltration effect apparent and the Danube supplies the floodplain system.

The evaluation of mean ground water levels (GWL) at different discharges in the Danube (Q_D) on several localities of the floodplain are shown in Table.1., where PT is the average altitude of terrain and HPRK and HTK are minimum and maximum altitudes of boundary between cover soil layer and the gravel (Burger, F.-Šûtor, J.,1990).

One of the possibilities how to regulate in sufficiently natural manner the ground water level regime in the floodplain area of the Danube is by water supply from the branch system placed in this area and artificially filled with water from inlet structure situated on the upstream power canal. This structure is dimensioned up to discharge Q_R = 234 $m^3.s^{-1}$, which quantity would serve not only for water supply in the branch system and for ground water regulation but for securing of regulated floods in the floodplain area, as well. These regulated floods have to serve for refilling of cover layers with water necessary for floodplain forest vegetation.

The base for determination of surface water level regime in the branch system the results of research group from Water Research Institute managed by Sikora (Sikora, A.-Slota, R., 1992) were used. This group was concentrated in physical modelling of surface water level in branch system at different discharges. From these results follows that the floodplain area was divided into separate flooding checks created by system of weirs and sluices at the main branch of the Danube in accordance with the suggestion of Szolgay, J.,sr.,1991. Authors determinated by modelling the water levels in the main branch at supply discharges of Q_R = 28.2, 50, 75, 99.9, 120, 150 and 234 $m^3.s^{-1}$. Evaluating the influence of the branch system on ground water level regime we concentrated on first six mentioned supply discharges, where is no overflow from branch system. The influence of the branch system was investigated for discharges in the Danube river Q_D = 50, 100, 350, 500, 800 $m^3.s^{-1}$, etc., because this interval of discharges would occur most often at waterworks operation. This selection was confirmed by fact that for higher discharges in the Danube river bed the influence of water levels in the branch system as a boundary condition looses its sense. It results in simplification of data input and in decrease of the equation number, as well. The main deficiency of this method (requirement for homogenity of region) was solved by introducing of "per partes homogeneous areas," i.e. subareas which can be taken into account as sufficiently homogeneous and the boundary element method is applied for each of them. Interconnection of these subareas is solved by introducing of compatibility conditions on the interface of individual subareas.

The solution procedure consists of inputing the so called internal elements which create the main branch of the system in the floodplain and make possible to add the internal boundary conditions. In our case there were boundary conditions of the first order, i.e. water levels in the branch system. The prepared problem with defined boundary conditions was solved for several discharges in the Danube and in the branch system. Some of the results are shown in Table 2. and the entire results of the solution are documented in Šoltész, A., 1995.

Table.1.

Locality	Q_D	PT	HPRK	HTK	GWL
No.	$m^3.s^{-1}$	m o.s.	m o.s.	m o.s.	m o.s.
	50				116,80
	100				117,10
	350				117,50
	500				117,60
9	1000	120,50	117,30	119,20	118,00
	1300				118,40
	1500				118,75
	2000				119,00
	2500				119,40
	50				114,00
	100				114,20
	350				114,70
	500				115,15
19	1000	119,00	115,70	118,65	115,50
	1300				116,00
	1500				116,50
	2000				116,90
	2500				117,20
	50				113,30
	100				113,40
	350				113,65
	500				113,80
31	1000	117,00	112,50	116,10	114,00
	1300				114,20
	1500				114,70
	2000				115,00
	2500				115,20
	50				110,50
	100				110,80
	350				111,00
	500				111,10
49	1000	114,00	108,55	112,00	112,20
	1300				112,60
	1500				112,90
	2000				113,20
	2500				113,60

Table 2.

Loc.	PT	HPRK	HTK	Q_R	GWL at Q_D (m o.s.)			
No.	m o.s.	m o.s.	m o.s.	$m^3.s^{-1}$	350	500	800	1000
9	120,5	117,3	119,2	28,2	118,5	118,7	118,8	118,9
				50,0	118,8	118,9	119,0	119,1
				75,0	119,2	119,3	119,4	119,5
				99,9	119,6	119,6	119,7	119,8
				120,0	119,8	119,8	119,8	119,9
				150,0	120,0	120,0	120,0	120,0
19	119,0	115,7	118,7	28,2	117,0	117,0	117,1	117,2
				50,0	117,2	117,2	117,3	117,4
				75,0	117,8	117,9	117,9	118,0
				99,9	118,0	118,0	118,1	118,2
				120,0	118,1	118,1	118,2	118,3
				150,0	118,2	118,2	118,3	118,4
31	117,0	112,5	116,1	28,2	115,5	115,7	115,8	115,9
				50,0	115,9	115,9	116,0	116,1
				75,0	116,0	116,0	116,1	116,2
				99,9	116,4	116,4	116,5	116,6
				120,0	116,4	116,5	116,6	116,7
				150,0	116,5	116,6	116,7	116,8

Considering the great extent of the solved research work and the little space for this contribution we decided to quote for comparison the graphical illustration of ground water isolines course for discharge in the Danube $Q_D = 350\ m^3.s^{-1}$ and for supply discharge in the branch system $Q_R = 50\ m^3.s^{-1}$ on the Fig.4. This figure illustrates evidently the character change of the isolines course in the floodplain area, especially at low discharges in the Danube when full extent of the water supply from the branch system is demonstrated. In these cases the water levels in branch system dominate in the floodplain area, especially in the upper part and they create a "roof," wherefrom the water flows to adjacent ground water aquifer. This phenomenon is apparent already at the lowest supply discharge in the branch system and it causes around the branches an increase of ground water level of 1.5 m at supply discharge $Q_R = 28.2\ m^3.s^{-1}$ and of 2.5 m at $Q_R = 150\ m^3.s^{-1}$. This influence is decreasing gradually with the increasing distance from the branch system. Measured course of ground water level in years after damming the Danube due to monitoring programme is illustrated on Fig.5.

CONCLUSION

This analysis of ground water level regime in the floodplain area, where the natural ground water level regime at different discharges in the Danube with the ground water level regime influenced by water supply from the branch system is compared, is the evidence for the fact that the water regime in the given region is controllable and by convenient technical measures a desirable ground water level can be achieved. This is important with respect to capillary rise of water into the root zone of the vegetation cover of floodplain forest in the river zone of the Danube.

REFERENCES

Burger, F., Šútor, J., 1990. Soil moisture potential of soil cover layers in conditions of ground water table fluctuation. Vodohosp. Čas., 38, pp.3-20.

Rehák, Š., Šútor, J., 1996: Evaluation of interaction of the aeration zone in soil and ground water table from the point of soil and water protection in the area influenced by Water Work Gabèíkovo. In: Proceedings of the conference "Water in Landscape" Brno, p.75-88.

Sikora, A., Slota, R., 1992. Research of discharge and water level regime in left-hand side branch system of the Danube by method of physical modelling. WRI, Bratislava, 42 p.

Skalová, J., Klementová, E., Novák, V., 1996. Parametrization of the empirical equation applied to the estimation of steady water flow from the ground water to soil root zone. Slovak Journal of Civil Engineering. STU Bratislava, pp.1-4.

Szolgay, J. Jr., 1988. Danubian discharge regime before and after starting the operation of Gabčíkovo waterworks. IHH SAS, Bratislava.

Šoltész, A., Benetin, J., 1992. Dependence of design parameters of floodplain forest water regime regulation on hydrophysical properties of the soil. Vodohosp. Čas., 40, No.3, pp.316-330.

Šoltész, A., 1995. Interaction of surface and ground water in the floodplain of the Danube. Habilitation Thesis, FCE STU, Bratislava, 116 p.

Fig.1 Ground water level course on the locality Kráľovská lúka (Royal Meadow) in hydrological year 1991

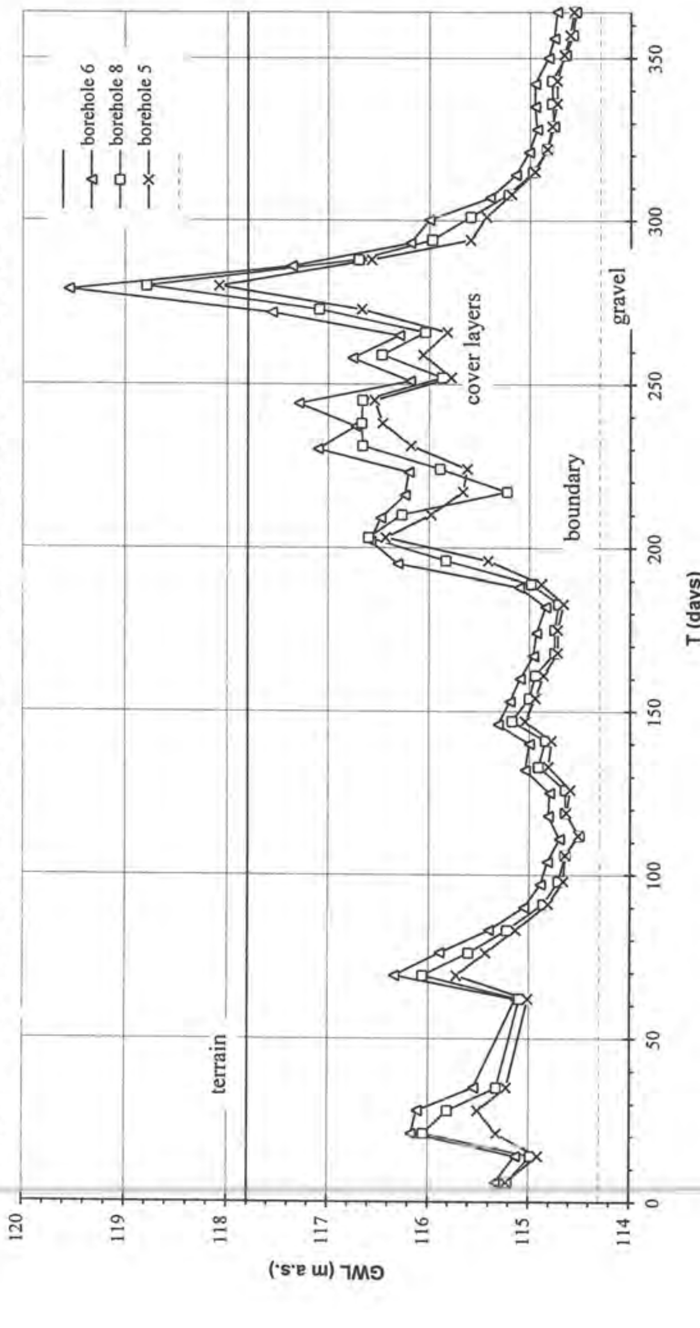
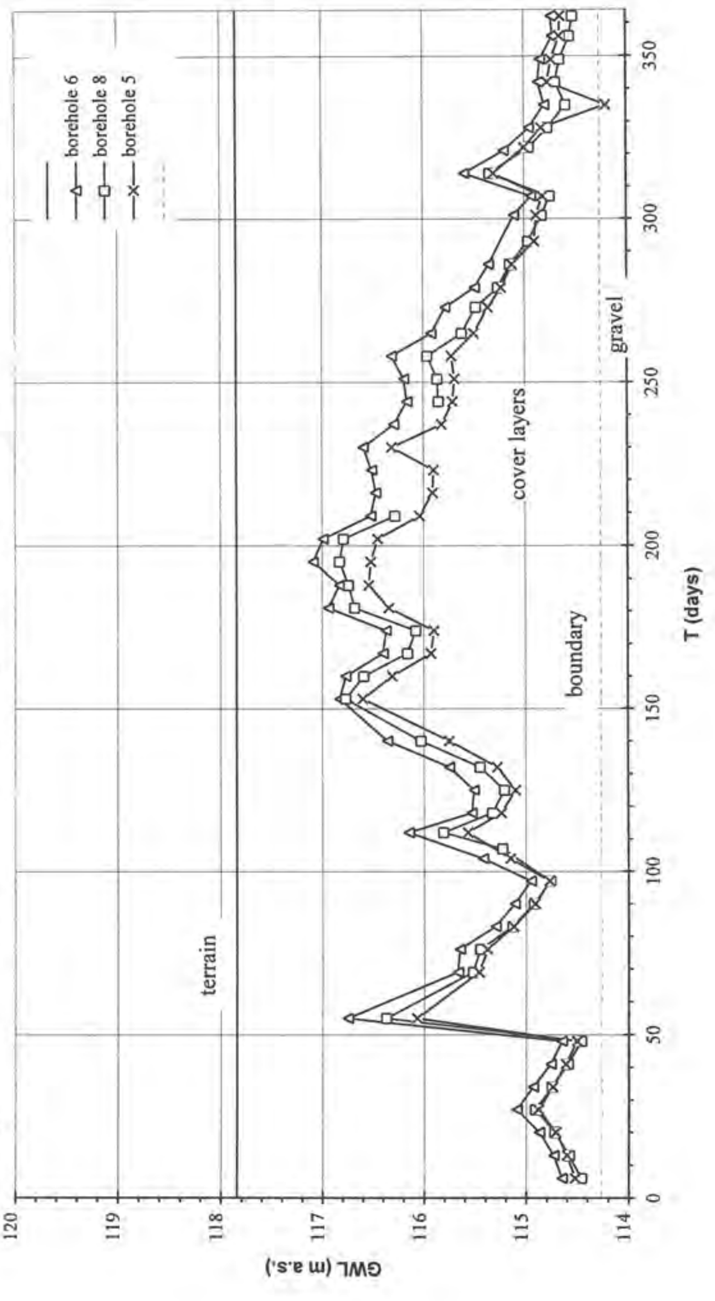


Fig.2 **Ground water level course on the locality Kráľovská lúka (Royal Meadow) in hydrological year 1992**



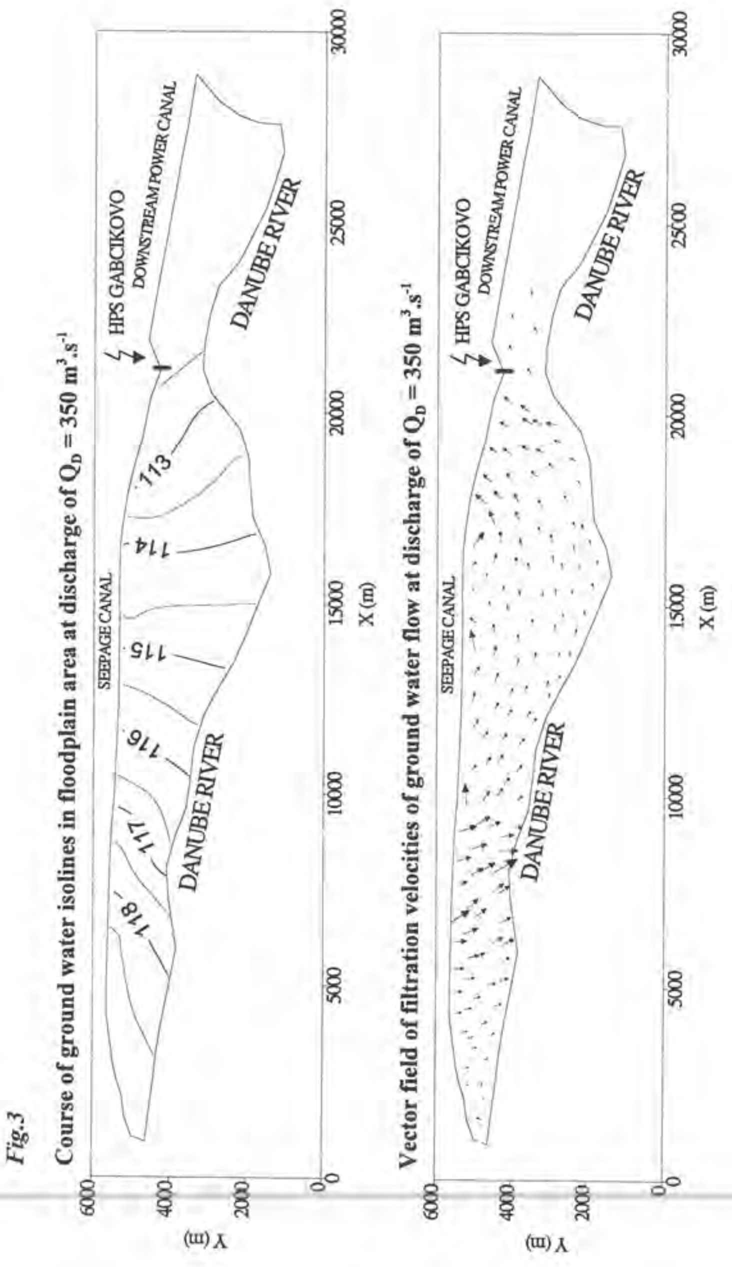


Fig.3
Course of ground water isolines in floodplain area at discharge of $Q_D = 350\ m^3.s^{-1}$
HPS GABCIKOVO
DOWNSTREAM POWER CANAL
DANUBE RIVER
SEEPAGE CANAL
113
114
115
116
117
118
DANUBE RIVER
Y (m)
X (m)
0
2000
4000
6000
0
5000
10000
15000
20000
25000
30000
Vector field of filtration velocities of ground water flow at discharge of $Q_D = 350\ m^3.s^{-1}$
HPS GABCIKOVO
DOWNSTREAM POWER CANAL
DANUBE RIVER
SEEPAGE CANAL
DANUBE RIVER
Y (m)
X (m)
0
2000
4000
6000
0
5000
10000
15000
20000
25000
30000

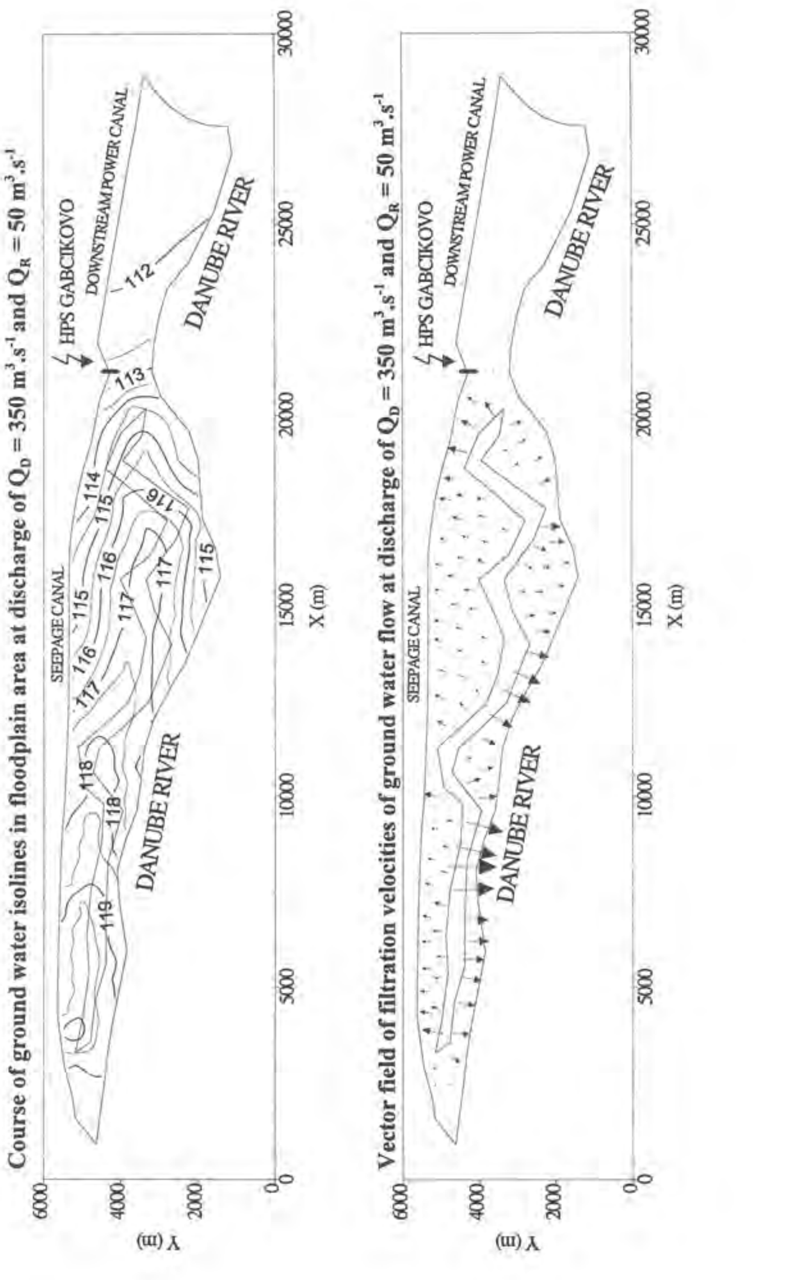
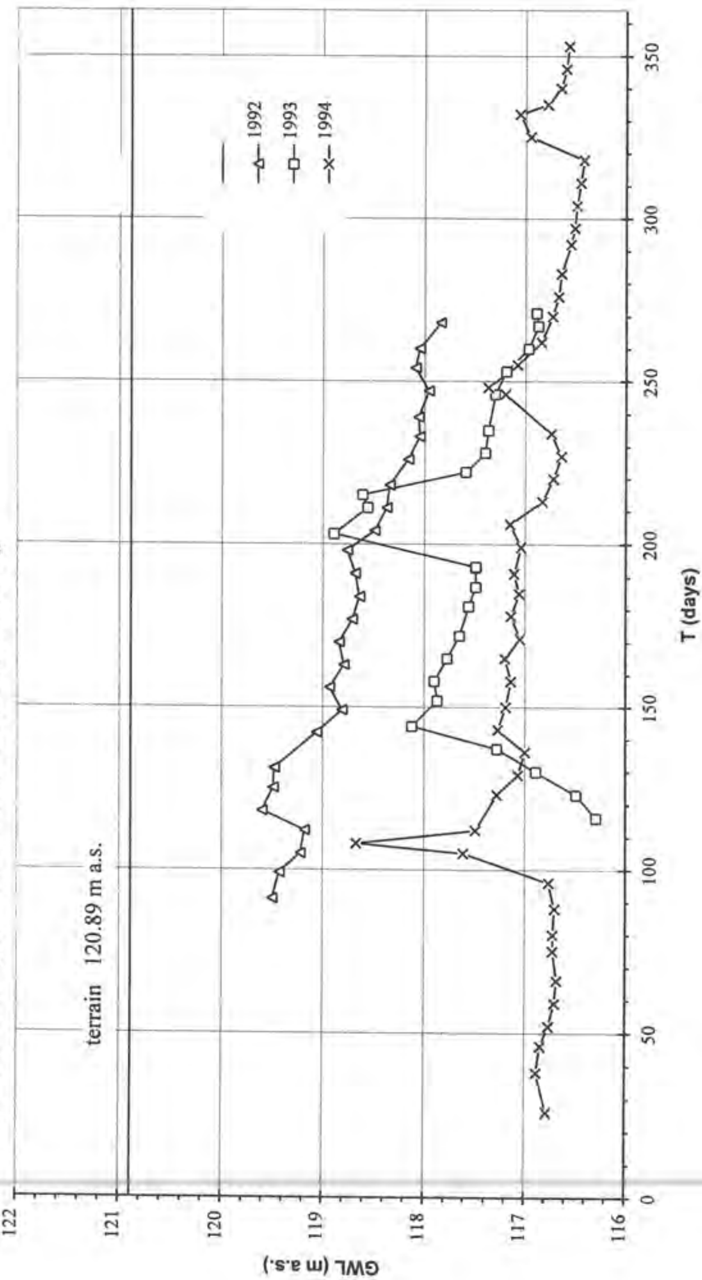

Course of ground water isolines in floodplain area at discharge of Q_D = 350 $m^3.s^{-1}$ and Q_R = 50 $m^3.s^{-1}$
HPS GABCIKOVO
DOWNSTREAM POWER CANAL
SEEPAGE CANAL
DANUBE RIVER
DANUBE RIVER
112
113
114
115
116
117
118
119
Y (m)
X (m)
Vector field of filtration velocities of ground water flow at discharge of Q_D = 350 $m^3.s^{-1}$ and Q_R = 50 $m^3.s^{-1}$
HPS GABCIKOVO
DOWNSTREAM POWER CANAL
SEEPAGE CANAL
DANUBE RIVER
DANUBE RIVER
Y (m)
X (m)

Fig.4

Fig.5 **Measured ground water level course in borehole L_{10}**



SPILL AND DISSOLVED GAS MANAGEMENT

ON THE COLUMBIA/SNAKE RIVERS

Bolyvong Tanovan [1]

ABSTRACT

Spill is a major component of the salmon recovery program in the Pacific Northwest. In addition to being costly, the relatively high spill amounts needed to achieve an acceptable fish passage level at Columbia and Snake Rivers mainstem dams also create high total dissolved gas saturation levels that often exceed state standards and federal criteria. Starting in the mid-1990's, spill on the Columbia River mainstem has been closely controlled, directly and indirectly, in order to minimize harmful impacts to fish and other aquatic life forms.

BACKGROUND

Spill in the Columbia River Basin occurs for a variety of reasons. Firstly, storage reservoirs are not large enough to keep the runoff within the installed hydraulic capacities of the lower river powerhouses. The total active storage in all Columbia River projects is slightly over 60 million acre-feet (maf), of which about 40 maf can be effectively used to control floods. This represents only about 30 percent of the average annual runoff of the Columbia River at The Dalles, and less than 23 percent of the April-September volume of the maximum flood of record, that of 1984. When flows exceed powerhouse capacity of mainstem dams, involuntary excess spill often ensues on a system-wide basis. Secondly, powerhouses cannot always operate up to their full installed capacities, as turbine units regularly undergo scheduled and unscheduled outages. Also, turbines can only be operated when power loads, which vary by the hours and by the day of the week, are there to be met. Spill caused by temporary lack of power load or reduced powerhouse capacities can be controlled to some extent and therefore is referred to as voluntary spill. In addition to excess capacity spill, spill is also scheduled to increase fish passage past Columbia and Snake River dams. Relatively large amounts of water are spilled every day to increase the survival of migrating juvenile salmon on their way to the Pacific Ocean as part of the Snake River salmon recovery program made possible by the Endangered Species Act (ESA). Spill for-fish-passage is entirely voluntary.

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Construction in the early 1970's of the Dworshak and Libby Reservoirs provided an additional 9.4 maf of storage that is available for use in controlling runoff. Turbine units were added during 1973-1981 to increase powerhouse capacity at The Dalles, Ice Harbor, Lower Granite, Lower Monumental and Bonneville. Skeleton bays were also used to pass more water through the powerhouses without having to install additional turbines. Flood control rule curves were updated that provide some flexibility in minimizing spill.

Spillway deflectors were also installed to produce a more horizontal spill flow and limit the plunge depth of water over the dam spillway, thus reducing the amount of entrained TDG. A multi-year, multi-million dollar Gas Abatement Study was launched in 1994 to evaluate operational and structural alternatives at Corps of Engineers dams located in the main fish migration corridor (see Figure 1). The study is still in progress, aiming at a 1999-2000 decision-making date.

Figure 1. Columbia River Dams Location Map

Regardless of the causes, spill has many associated risks. Spilling water entrains air and raises the levels of gas supersaturation that can be lethal to both adult and juvenile fish. Although the current state standards and federal criteria for TDG are 110%, actual TDG levels in the 130-140% range sometimes prevail all the way to the estuary. Because of the slack water movement between reservoir pools, little dissipation in TDG occurs naturally. TDG levels may even slightly increase if any of the dams were to spill additional water. Figures 2 and 3 show the spill and TDG levels at selected mainstem Columbia River sites during 1997, one of the relatively high runoff years of recent past.

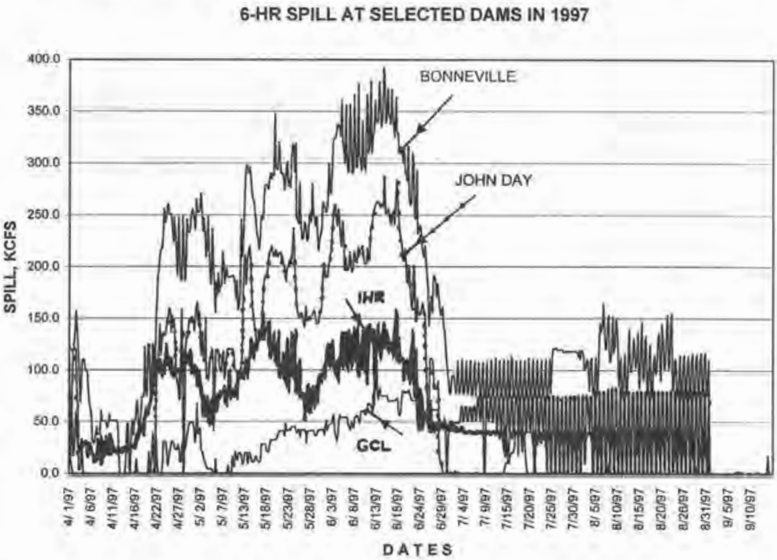

Figure 2. Spill Levels at Selected Mainstem Columbia River Dams

Many public and private regional interests are extending great effort to abate high TDG levels, while balancing the requirements of the Endangered Species Act (ESA) with those of the Clean Water Act (CWA). The National Marine Fisheries Service (NMFS) is the Federal agency charged with implementing the ESA. NMFS, along with other state, tribal and federal fishery agencies are the proponents of the spill for-fish-passage program to the extent allowed by the State water quality standards. The U.S. Environmental Protection Agency (EPA) monitors the TDG levels for compliance with the CWA. EPA and the State environmental quality departments have granted temporary waivers for TDG standards (from 110% to 120% saturation) and have pushed for an expedited implementation of permanent solutions.

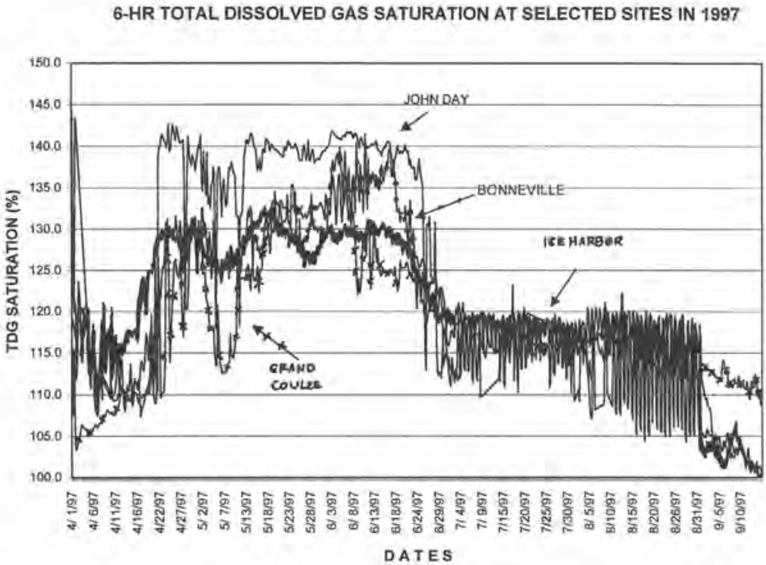

Figure 3. Total Dissolved Gas Levels below Selected Mainstem Columbia River Dams

These improvements will have to be made by the project owners and operators, as effectively and economically as possible, to comply with existing environmental regulations and/or Federal Energy Regulatory Commission licensing requirements. Many issues need to be resolved, including relevance of the current standards, limited TDG reduction potential, and the extremely high costs of the required fixes.

Because of the environmental risks involved, TDG levels are being monitored very closely and spill adjusted as much as possible while long-term solutions are being developed through regional forum. The overall spill and TDG management goal applies to both involuntary and voluntary spill although, by definition, only voluntary spill (e.g. spill for-fish-passage) can be practically managed on real-time. The Corps' Reservoir Control Center (RCC) is charged with meeting this goal. It is also responsible for flood control in the Columbia River Basin and. hence, indirectly manages involuntary spill as well.

SPILL FOR-FISH-PASSAGE

A special mention has to be made about the voluntary spill for-fish-passage, an operation that poses additional TDG problems. During the juvenile fish migration season, from late March until fall, flows in the river are augmented by releases from upstream reservoirs, and water is spilled at the dams to improve juvenile migration conditions. Spill diverts fish that approach the dam away from the turbines and forces the juvenile fish migrants to go over the safer (according to fish biologists) dam spillways. In this context, fish passage efficiency (FPE) is defined as the percent of the smolts that pass the dams via other than the turbine routes.

In the early 1980's, the minimum recommended FPE level was 50 percent for spring migrants and 70 percent for summer migrants. In its 1995 Biological Opinion, NMFS called for an FPE of 80 percent for both spring and summer migrants. Depending on the efficiency of the fish screens that prevent fish from entering the turbines, spill ranging from 27 to 86 percent of the instantaneous flows was needed to achieve this 80 percent fish passage efficiency level. Some projects were meeting the 80 percent FPE goal, but others were not, due to TDG limits. In its 1998 Supplemental Biological Opinion, NMFS called directly for spill at all projects up to the 120 percent TDG cap (rather than setting an FPE goal). The required spill in percent of the outflow prescribed now ranges from 27 to 81 percent at lower Snake River dams, and from 33 to 100 percent at lower Columbia River dams (see Table 1).

Table 1. Summary of the 1998 Spill For-Fish-passage Requirements

Projects	Rivers	Spill Hours	Spill Start/ End Dates	Spill Cap (Kcfs) for 120% TDG (or max. spill %)
Lo. Granite	Snake	1800-0600	4/10-6/20	45
Little Goose	Snake	1800-0600	4/10-6/20	60
Lo. Monumental	Snake	1800-0600	4/10-6/20	40
Ice Harbor	Snake	0-2400	4/10-8/31	75
McNary	Columbia	1800-0600	4/10-6/30	140
John Day	Columbia	1800-0600	4/20-8/31	180 (or 60% of the flows)
The Dalles	Columbia	0-2400	4/20-8/31	230 (or 64% of the flows)
Bonneville	Columbia	0-2400	4/20-8/31	120 (and 75 kcfs daytime max.)

It is often argued that short-term increased passage survival at the dams as a result of spill may not always outweigh long-term fish mortality in reservoir pools supersatured with dissolved gas. Also, spill is expensive; its resulting power losses cost millions in foregone revenues to power marketing agencies. At some strategically located projects such as The Dalles, spilling water beyond a certain level adversely affects power transmission stability of the north-south regional intertie.

MANAGEMENT GOAL AND OPTIONS

The overall goal is to maintain TDG conditions uniformly across the entire river basin at or below the State standards as much as possible. Hot spots, especially at sites where ESA-listed fish are present, must be avoided. Exceedence of the TDG standards, if any, will be minimized in absolute terms in time and space. To achieve this goal, management options are operational as well as structural in nature.

Operational options mainly involve flow management, and powerhouse and spill operations. At the system level, upstream storage reservoirs are operated to store maximum volume of runoff, consistent with flood control rule curves, so that the risk for spill in the lower river is minimized. This is practically the only way to effectively deal directly with involuntary spill; all other measures only provide an indirect solution. At the individual project level, powerhouses are operated at full capacity through careful and selective unit outage scheduling to ensure maximum unit availability. Special unit operations (e.g., speed-no-load or operation outside the 1% peak efficiency) are implemented to artificially maintain a high powerhouse hydraulic capacity during low power load hours.

When spill is unavoidable, TDG level can still be controlled to some extent by limiting some lack-of-load spill to a preset cap at a few projects and transferring the rest to other more TDG-friendly projects. A spill priority list establishes the order in which projects will start spilling and the maximum amount of water these projects are allowed to spill. Spill caps are assigned to each project to limit TDG to the State standards. Even for the same amount of spill, the resulting TDG level may still be reduced depending on which spillway bays are being used and how the entire spill is distributed to the individual bays as a whole. This may entail such options as changing the spill from a crown to a uniform pattern, and/or avoiding the use of spillway bays without deflectors.

Structural options rely on powerhouse expansions to increase capacity, and on spillways and stilling basins improvements to reduce air entrainment. By and large, powerhouse expansions are very costly and hard to justify in economical terms, leaving only spillway deflectors as the most effective and affordable solution under the current situation. As a result, new spillway deflectors have been added at two Corps dams --Ice Harbor and John Day-- in 1997-1998. A few innovative and more comprehensive TDG abatement measures have also been developed recently, including raised tailraces and/or stilling basins, side-channel spillways, and submerged spillways. It may be a while before actual construction of any of these new designs is started, pending satisfactory resolution of issues involving cost, fish injuries, and expected TDG reduction. Removal of mainstem Snake River dams, now under regional forum discussion, may remove the need to spill at those projects and subsequently provide an indirect, albeit partial, solution to high TDG problems in the lower Snake River.

Operational flexibility is assessed in general terms early in the season based on runoff forecasts. The analysis involved a wide range of runoff shapes while the system is operated to meet customary requirements for flood control, power, fish flow augmentation, and the impact of special operations, if any. Projected spill and TDG levels are made public and all interested parties are given an opportunity to comment on their preferred system operations. The proposed operations potentially impact the environment, fish survival and other reservoir regulation requirements to a varying degree. Some of them must be implemented early enough in the season to be fully effective.

Any changes in the spill for-fish-passage are based on actual TDG readings, a product on a real-time system-wide monitoring network covering the entire Columbia and Snake Rivers. Spill changes are made in full consultation with members of the Technical Management Team (TMT), an inter-agency work group created by NMFS to recommend week-to-week reservoir operations in support the Salmon Recovery to the operating agencies.

REAL-TIME MANAGEMENT

A plan to control TDG is developed annually along with a water management plan, based on the runoff forecasts and the spill predicted for that year. Obviously, it is a lot more difficult to manage involuntary spill than voluntary spill. Therefore, the plan applies mostly to voluntary spill (for-fish-passage) up to the state standards waivers and within the main fish migration season (April 10 through August 31).

To maintain uniformly low TDG conditions or to avoid spill in river reaches where the greatest number of fish is actively migrating, spill is distributed to various other projects in a pre-planned sequence. The distribution starts with projects with the least propensity for developing high TDG level or those located outside the fish migration corridor. In the case of spill for-fish-passage, there is no spill priority list to follow except for minor adjustments to take best advantage of the 120% TDG limits. For example, to account for cumulative impacts, some spill reduction may be needed at upstream projects so that some meaningful spill can still occur in the lower river within the stated 120% TDG limits. The decision on

where to cut or increase spill is highly fish-dependent, and will be based on salmon managers' recommendations.
Spill caps are assigned to each project, and adjusted in-season based on actual TDG readings below each project. When TDG cannot be managed to 120% saturation, the river is to be managed in the best interest of listed and proposed salmon stocks.

In 1998, the Plan was much dictated by the relatively low runoff forecasts. Storage reservoirs were operated to follow flood control rule curves, while providing some cushion to minimize involuntary spill. No preemptive reservoir drafting below flood control elevation was attempted, as the fishery agencies were concerned about reservoir refill. In essence, the basic Plan was as follows:

1. Implement spill for-fish-passage at all mainstem-federal dams as specified in the 1998 Biological Opinion up to the spill caps for 120% TDG. Adjust spill as needed, based on real-time TDG data, and fish movement and biological conditions in that order.
2. Operate hydropower units within 1% of peak efficiency;
3. Limit daytime spill at Bonneville to 75 kcfs to avoid adult fallback;
4. Accommodate special spill requirements/restrictions for research, adult passage, etc. that have the full endorsement of all concerned parties. Also, continue to implement fish transportation program as agreed to and using calculation method endorsed by NMFS (or an equivalent method agreed to at TMT);
5. If system-wide TDG exceed 120%, update and implement the spill priority outlined below, with incremental system TDG control objectives. Spill will normally start from the lower river and work its way upstream;
6. Discontinue or postpone field research and non-critical unit service and maintenance schedules that create (or have potential for creating) high localized TDG levels, especially when and where high numbers of listed fish are present;
7. Operate turbines outside their respective 1% peak efficiency flow range;
8. Store water at lower Snake reservoirs above their respective minimum operating pools, if this would result in a measurable (3% or more) reduction in TDG levels;
9. Experiment with promising, new spill patterns;
10. Implement other operations or measures recommended by the TMT or the Implementation Team.

The Spill Priority List generally lists projects in a sequential order, placing first priority on spilling at mainstem Columbia projects before spilling at projects outside the fish migration corridor (Hungry Horse, Willamette, Libby, etc). When system-wide TDG is at or below 120%, provide the spill for-fish-passage up to the 120% TDG spill caps in the following order:

1. Spill up to the 120% TDG spill caps at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite;
2. Spill up to the 110% TDG spill caps at projects outside the fish migration corridor: Priest Rapids, Rocky Reach, Wells, Rock Island, Wanapum, Chief Joseph, Grand Coulee, Dworshak in that order. The priority order for the mid-Columbia projects is as recommended for the period beyond 15 April by the Mid-Columbia Coordinating Committee;
3. Spill up to the 120% TDG spill caps at projects where state standards waivers have been granted: Priest Rapids, Rocky Reach, Wells, Rock Island and Wanapum in that order;
4. Spill up to the 120% TDG spill caps at Dworshak if release from Dworshak for use in maintaining 100 kcfs flow at Lower Granite, and
5. Spill up to the 110% TDG spill caps at Hungry Horse and Willamette Projects.

When systemwide TDG exceeds 120% TDG, then try to control systemwide TDG to 125%, then to 130% and so on by spilling up to the spill caps indicated for those TDG levels, at lower Columbia, mid-Columbia, Snake, Hungry Horse, Willamette Projects, and Libby in that order. See Figure 4. Spill caps for various applicable TDG levels are updated as needed based on real-time TDG information and actual fish movement and conditions.

Many players are involved in this entire process. The TMT provides the general recommendations on the spill priority, and ensures that fishery needs are met with minimal adverse impacts. The Corps issues the appropriate teletypes instructions, including spill priority and spill caps, to the affected projects for implementation. Its RCC staff develops the annual management plan, coordinates the operation of the TDG monitoring network, issues revised spill caps and spill priority list, and reports on the spill and TDG changes at the weekly TMT meetings. They also maintain a real-time and widely accessible database on the TMT Internet web-pages and ensure that teletypes instructions are fully implemented.

Bonneville Power Administration (BPA) dispatchers and individual project staff actively participate in this real-time activity. BPA is the Federal agency that markets and sells the hydropower generated at Federal dams. As part of their power dispatch, BPA follows spill instructions very closely, looking for maximum flexibility in distributing their generation and spill requirements to the projects. BPA enjoys considerable discretionary power to distribute and transfer spill on an hour-by-hour basis, 24 hours a day, and seven days a week. The role of

BPA is crucial in successfully implementing the Spill and TDG Management Plan endorsed through regional forum for maximum fish benefit and minimal impact on regional power sales. All project owners and operators are ultimately responsible for any and all operations, including spill, at their projects.

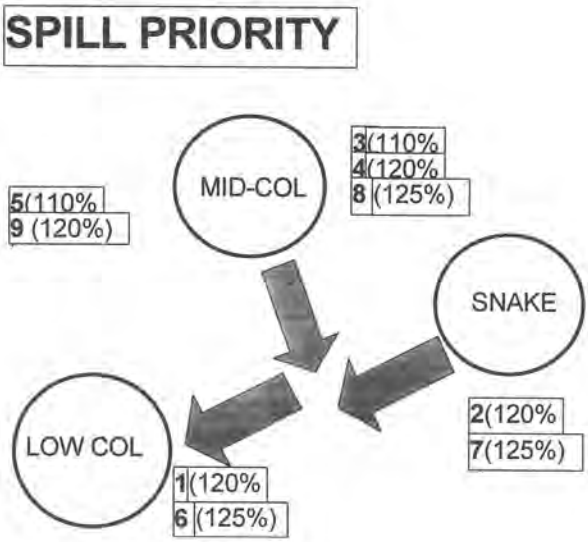

Figure 4. Schematic of the Spill Priority Concept

CONCLUSIONS

Despite the difficult task of physically managing spill and TDG management along the Columbia and Snake Rivers' mainstem, all those involved have made a "best effort" attempt to maintain TDG at or below the state standards and federal criteria. Since 1984, this effort has also hopefully provided better migration conditions to both juvenile and adult anadromous fish. Although the cost of spill for-fish-passage runs into the millions, early signs of fish recovery are still far and few. Real-time management and monitoring activities are nevertheless going to continue, as they are an integral part of sharing the River with all the water users --fish, insects, aquatic life forms, and humans.

ENLIBRA: A NEW SHARED DOCTRINE FOR ENVIRONMENTAL MANAGEMENT

Kathleen Clarke[1]

QUESTIONS AND ANSWERS

What is the name of the new shared doctrine for environmental management?

Enlibra, a newly created word meaning balance and stewardship. The authors of the new doctrine believe Enlibra will become a symbol for a balanced approach to successful environmental management.

What is the history of the new shared environmental doctrine Enlibra?

As Western governors have struggled with a range of environmental problems, it has become evident that there are common principles underlying the most promising approaches and successful solutions they have developed. These principles form the basis of a new shared doctrine for environmental management. The doctrine speaks to greater participation and collaboration in decision making, focuses on outcomes rather than just programs, and recognizes the need for a variety of tools beyond regulation that will improve environmental management. Utah Governor Mike Leavitt and Oregon Governor John Kitzhaber took the lead in developing this shared set of principles that were agreed upon as policy of the Western Governors' Association.

The Governors gravitated to this new doctrine because they rarely see environmental improvements coming out of polarized situations. However, when communities, states or regions are able to identify shared goals, progress is made.

They believe the principles can help the West successfully deal with increasingly complex environmental problems. This complexity is a function of both the global economy we are a part of and its ability to dramatically influence our economy and communities, as well as the many dimensions to environmental problems that were not well understood or anticipated when many of the environmental laws were written nearly 25 years ago.

The governors recognize that to succeed at environmental management we need to empower people to do the right thing. This requires good information;

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inclusive processes that respect different values and provide individuals a role in designing and implementing solutions; and meaningful incentives to complement existing laws.

The Governors believe the principles that they came up with, when taken together, offer the best promise for solving environmental problems today and tomorrow.

What is the purpose of the new shared environmental doctrine Enlibra?

While the last 25 years of environmental management have seen some major environmental successes, the easy targets are gone and there is a growing emotion and polarization among interested parties. People generally agree about the need to protect the environment and its natural resources. Unfortunately groups representing extreme positions have largely shaped environmental management and the environmental debate. Today there is no symbol for the middle, for the majority of citizens who believe that the environment and its natural resources can be protected while at the same time providing recreational and employment opportunities for citizens. Enlibra will be that symbol for the middle.

The Governors believe that the principles espoused in this shared doctrine, developed through their personal experiences and the collective experiences of others over the past 25 years, provide a collection of tools that, if employed, will result in improved and expedited environmental decision-making and implementation. They believe that the doctrine, though created largely based on experiences in the West, can serve as a tool for environmental management across the nation.

What Enlibra is not:

1. Enlibra does not represent a rejection of the goals and objectives of Federal environmental laws such as the Endangered Species Act or Clean Water Act.

2. It is not a rejection of the need for national environmental standards.

3. This shared doctrine does not represent a rejection of the legitimate role of the Federal government in regulation and enforcement.

What are the principles that form the doctrine Enlibra?

- National Standards, Neighborhood Solutions – Assign Responsibilities at the Right Level

- Collaboration, Not Polarization – Use Collaborative Processes to Break Down Barriers and Find Solutions
- Reward Results, not Programs – Move to a Performance-Based System
- Science for Facts, Process for Priorities – Separate Subjective Choices from Objective Data Gathering
- Markets Before Mandates – Replace Command and Control with Economic Incentives
- Change a Heart, Change a Nation – Environmental Understanding is Crucial
- Recognition of Costs and Benefits – Make Sure Environmental Decisions are Fully Informed
- Solutions Transcend Political Boundaries – Use Appropriate Geographic Boundaries for Environmental Problems

What do the governors hope will come of the new shared doctrine Enlibra?

1. It becomes part of the American political lexicon, giving people a symbol for balance and stewardship in environmental management.
2. It becomes a widely used framework for solving difficult environmental problems.
3. It becomes a philosophic foundation for balanced environmental legislation.
4. It becomes a road map for discussions between regulators and stakeholders.

What are some examples of the new shared doctrine Enlibra?

There are numerous excellent examples from Western states, some of which were highlighted during the Western Governors' Association's Annual Meeting in Alaska. A few examples, listed by type of issue, are included.

Air Quality – *Grand Canyon Visibility Transport Commission*

Species Protection – *Oregon Coastal Salmon Restoration Initiative, Desert Tortoise Habitat Conservation Planning*

Land Issues – *Utah Schools and Federal Land Exchange*

Species Protection – *High Plains Partnership*

Water Planning – *Texas Regional Water Supply Planning Process*

Recreation – *Trails and Recreational Access for Alaska*

Open Lands – *Wyoming Open Lands Initiative.*

Note: More information on the Shared Environmental Doctrine and links to related web sites may be found on the Governor's page of the State of Utah web site at www.state.ut.us.

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