designed for the shutoff head of the pumps, which would be higher than the normal operating pressure in the piping.

General unit costs per square foot have been utilized to estimate the cost of the building based on the floor space developed in the conceptual plan.

The control system would be typical of municipal water pumping stations, consisting of instrumentation such as pressure transmitters and a flow meter to measure the total station flow. A programmable logic controller would be utilized to control the pumps and monitor status and alarms. The pumping stations would likely need to be controlled or at least monitored from a central facility, possibly the treatment plant. This would require some type of communication system either hard wired or transmitted such as radio. Since cabling could be efficiently installed along the pipeline route, this type of system has been assumed in the cost estimate.

As with most large pumping stations, a method for mitigating hydraulic transients will be required. It is likely that hydraulic transient mitigation measures would best be accomplished through the use of flywheels on the pumps used to store energy to be used during a power failure and/or surge chambers.

Maintenance and replacement costs were estimated at 2% per year of initial construction cost. Operations costs are primarily comprised of power costs. Assuming the pumping station operates for a total period of 50 weeks per year, 24 hours per day, the total kWh was calculated and a cost of $0.05/kWh was used to calculate the power costs for each pumping station.

Preliminary engineering evaluations of construction along each of the three conveyance corridors were prepared. The evaluations include geologic reconnaissance based on literature review, construction methodology, and preliminary cost estimates for tunnel sections.

Initial evaluations were made of 35 tunnels (7 tunnels in the North Corridor, 13 tunnels in the Central Corridor, and 15 tunnels in the South Corridor). Key elements of each proposed tunnel are summarized in Table 6-5 located at the end of the chapter. These initial tunnel layouts were later expanded with a second set of tunnels that involved longer and deeper alignments as a means of reducing pumping requirements at select locations (Table 6-6 located at the end of the chapter). Some of these subsequent tunnels would replace tunnels within the initial set of tunnels.

Upon initial review and discussion, the anticipated geologic conditions along the alignments were developed using, as a basis, information obtained from a review of published geologic maps (Tweto, 1976), geologic columns and descriptions of individual geologic units in the project area. In general, the tunnels located on the western slope of Colorado are expected to be situated in weak to moderately strong sedimentary rocks. These materials are predominantly shale and sandstone, with some siltstone, claystone, limestone and evaporate deposits. Tunnels that cross beneath the continental divide (eastern portion of corridors) are expected to encounter relatively strong igneous and metamorphic rock. Rock types include gneiss, schist, granite and intrusive igneous rock.

A rock classification system was developed to help characterize the anticipated geologic conditions for further assessment of tunneling conditions, ground support and associated costs. Three rock strength classes were selected for the geologic characterization:

- Class 1: Strong rock including gneiss, schist, granite, metamorphic rock and intrusive igneous rock.
- Class 2: Moderately strong rock including sandstone, limestone and shale.
- Class 3: Weak rock including shale, interbedded sandstone/siltstone/shale, volcanic ash and tuff.

Estimates were made to assess the percentage of each rock class anticipated to be encountered along each tunnel alignment. A review was also made to obtain additional relevant geologic information pertaining to geologic structure or other conditions that may impact tunnel construction. These conditions include faults, folding, intrusive contacts, paleo valleys, hot water, potential squeezing ground, etc. The rock classification and other relevant geologic information for each tunnel are summarized in Table 6-5 and Table 6-6.

Approximate tunnel lengths, range in tunnel elevations, and maximum and average ground cover were computed for each of 50 aforementioned tunnels. Tunnel lengths for the initial set of tunnels (35 tunnels) ranged between 0.75 and 16.7 miles and averaged 3.5 miles. Maximum ground cover ranged between 250 and 2,800 feet. Specific information for each tunnel is summarized in Table 6-5. Tunnel lengths for the second set of tunnels (15 tunnels) ranged between 4.5 and 32.8 miles and averaged 15.5 miles. Maximum ground cover is between 1,200 and 5,100 feet. Table 6-6 provides a summary of the information developed for this set of tunnels.

Preliminary Design Criteria

Tunnel geometries were set to accommodate final inside pipe diameters of 8.5 to 15 feet for either pressurized or gravity flow.

Anticipated Ground Conditions

A review of the anticipated geologic conditions and range in overburden cover indicates that a wide range in ground behavior can be expected. Rock types are expected to range from weak sedimentary rock (qu=500 to 1,500 psi) to strong metamorphic and igneous rock (qu=20,000 to 30,000+ psi). Furthermore, faulted/sheared ground is anticipated at some locations. Average overburden cover ranges between 150 and 2,070 feet, with maximums reaching 5,000+ feet.

Ground behavior during tunneling operations will be a function of the mass rock strength, nature and extent of rock mass, discontinuities (faults, shears, rock joints), in-situ stress conditions and groundwater conditions. Anticipated ground behavior may range from firm ground requiring no initial support to squeezing ground requiring significant and prompt support. Faulted/sheared ground may contain materials exhibiting raveling, flowing, squeezing or swelling behavior. Other post-tunneling ground behavior considerations may include the propensity for slaking and swelling of weaker clayey rocks.

The presence of weak shales and sandstones under high stress conditions for this project may present difficult ground conditions for tunneling. Overload factors (ratio of average tangential tunnel stress to vertical overburden stress, Deere, 1969) can be used to predict the potential for squeezing ground conditions in ductile rock. Overload factors between 1 and 3 are typically associated with mildly squeezing ground, while factors exceeding 3 often present moderately to highly squeezing behavior. Simple calculations suggest that the weakest rocks (qu=500 psi) could exhibit moderately squeezing conditions with ground cover around 1,000 feet and highly squeezing ground around 1,500 feet. Case histories of squeezing/raveling ground conditions in similar sedimentary rocks include the Navajo Tunnel 3 in New Mexico and the Stillwater Tunnel in Utah. In the Navajo Tunnel No. 3, extensive cracking, slabbing and spalling was observed in the 21-foot diameter tunnel, excavated in weak sandstone, siltstone, and shale (Sperry and Heur, 1972). The estimated overload factor was in the range of 1 to 2.5. Significant problems were encountered in the Stillwater Tunnel, where thinly bedded and sheared shale exhibited raveling and squeezing behavior (Phien-wej and Cording, 1991). Overburden cover for this tunnel was reported to be about 2,700 feet.

Overstressing of relatively moderate to strong rocks that exhibit brittle behavior can result in spalling or slabbing conditions. This can occur when overload factors exceed 1; however, Cording (1984) indicates that minor stress slabbing can occur in sedimentary rocks when the overload factor is as low as 0.5.

Excavation Methods

The tunnels on this project will generally require use of a Tunnel Boring Machine (TBM). TBMs utilizing a full-face rotating cutterhead are commonly being used in the tunneling industry today to excavate rock tunnels at relatively high advance rates through many types of rock. There are open TBMs and shielded TBMs. Open TBMs are used primarily for excavating hard rock formations with good stand-up time. The cutterhead of the open TBM is thrust forward with hydraulic rams supported by grippers which are mounted on either side of the frame of the machine and bear against the tunnel walls.

In weak rock or fault zones, the rock is not strong enough to withstand the bearing pressure of the grippers and a shielded TBM with thrust jacks may be better suited. A shielded TBM has a full circular shield that provides temporary ground support while the initial support system is erected in the tail of the shield. Shielded TBMs typically advance by thrusting against the tunnel's initial internal support system with hydraulic jacks. Such an approach requires an initial support system that can withstand both ground loads and TBM thrust forces. The cutterhead of either type of TBM can be equipped with disc cutters for excavating rock or drag teeth for excavating soil and soft rock. Squeezing ground and large groundwater flows are important factors to consider when selecting a TBM system.

TBM performance is critical when considering tunneling schedules and cost, particularly for long tunnels with difficult ground conditions. Other key factors include machine utilization and work schedule. Penetration rates are generally a function of tunnel geometry, rock mass characteristics, ground behavior and machine parameters.

Pressure Grouting

Tunnel construction for this project may require use of pressure grouting to reduce large groundwater inflows to manageable levels in fault/shear zones or other highly permeable formations. Probe holes drilled in advance of a tunnel excavation are often used as a means of checking the potential for large groundwater inflows and to identify where pre-excavation grouting is needed. Pressure grouting can be implemented depending on the amount of water encountered in the probe holes.

Initial Support Systems

Requirements for initial support/stabilization systems are a function of anticipated ground behavior and loads, potential hydrostatic loads, compatibility with TBM excavation, design life and corrosion resistance, and timing of installation. Stabilization systems for rock tunnels generally consist of a number of elements, including rock dowels, welded wire fabric, shotcrete, steel sets and lagging. Massive to moderately blocky ground may only require spot rock dowels, while blocky and seamy ground may require pattern rock dowels and shotcrete. Faulted/sheared ground as well as squeezing ground often requires installation of steel sets on relatively tight spacing. Thick/robust stabilization systems (as well as final lining needs) must be considered when establishing the required excavated tunnel diameter.

Sequence and timing of initial support installation is critical, particularly for overstressed rock exhibiting raveling or squeezing behavior. Without timely installation of support, the rock can experience rapid deterioration and deformation, which in turn can result in unstable conditions and/or tunnel convergence.

Final Lining Systems

Final lining requirements for water conveyance tunnels are typically established based on hydraulic, groundwater infiltration/exfiltration, and erosion and corrosion protection criteria. Key hydraulic criteria impacting liner selection include internal pressures that must be resisted to avoid hydraulic fracturing or undue water loss into the surrounding rock mass. Conversely, watertight liners may be required to limit infiltration of groundwater into the tunnel and associated impacts to groundwater levels. Where potentially erodible rock conditions are present (soft sedimentary rock), liner systems will be required to prevent scour as a result of the anticipated maximum flow velocities.

Depending on the design criteria ultimately adopted, final lining systems for tunnels may include unlined, shotcrete, cast-in-place concrete, and/or welded steel or gasketed segmental lining systems with cast-in-place concrete. Welded steel lining is often employed in pressure tunnels where internal hydraulic pressures cannot be resisted by in-situ ground stresses (e.g. vicinity of portals or valley crossings). Gasketed, precast concrete segments are a one-pass system in which the liner is installed behind the TBM without the need for other primary stabilization methods. This system is generally employed where a watertight liner system is required and high external groundwater pressures are anticipated. State of the practice suggests that the liner system is capable of resisting external hydrostatic pressures up to 600 psi (about 1,400 of groundwater head).

Long Tunnels

Several of the proposed tunnels (especially those studied in Table 6-6) exceed 15 miles in length. As indicated in Table 6-5 and 6-6, these tunnels include, NCT06 (18.2 miles), NCT07 (24.2 miles), NCT12 (30 miles), CCT08 (16.7 miles) NCT13 (21.6 miles), CCT15 (18.9 miles) and SCT16 (32.8 miles). Drive lengths could be reduced substantially by implementing two drives from either end; however, tunnel lengths exceeding 15 miles will present several key issues that would require special consideration:

- Ability to meet ventilation requirements;
- Efficient muck removal to maintain desired TBM production rates;
- Groundwater removal under high inflows;
- Efficient transport of tunnel crews, equipment and construction materials to and from the heading; and
- Ability to provide the necessary large electric power sources in remote areas.

Extensive planning and detailed studies would be required to address the challenges presented by tunnel drives of this magnitude.

Cost Estimates

Tunnel cost estimates were developed to provide unit costs (per foot of tunnel) for use in developing the overall construction cost estimates for alternative pipeline alignments. The unit costs are intended to be used for reconnaissance level planning and screening of alternatives and will require more rigorous efforts upon selection of preferred conveyance corridors and pipeline alignments.

The unit costs were developed based on information obtained from a review of actual costs of previously constructed U.S. water conveyance tunnels. Cost information for several rigorous contractor estimates for proposed tunnels that involved long tunnel drives and high stress conditions were also included.

As a means of providing some level of consistency in the cost estimates, the following assumptions were made with respect to tunnel engineering considerations and assumptions:

- All tunnels will be constructed using a hard rock Tunnel Boring Machine (TBM);
- Initial support and final lining systems will be installed employing a two-pass system;
- Initial support will consist of rock reinforcement/welded wire fabric/shotcrete or steel sets and lagging;
- Final lining will consist of shotcrete or cast-in-place concrete; and
- Total lining thickness will range between 9 and 18 inches thick.

Although the following issues will be relevant for more detailed studies, estimated unit costs did not address the following:

- Provisions to accommodate high groundwater inflows during TBM operation (i.e. groundwater conditions and primary/secondary rock hydraulic conductivities are not known at this time);
- Requirements to limit long-term inflows into tunnels to avoid undesirable drawdown of groundwater levels (i.e. need for installing water-tight lining systems or grouting in advance of the TBM); and
- Employing steel lining in low-cover areas where internal pipeline pressures approach or exceed in-situ stresses.

Once the baseline range in unit costs was set, each proposed tunnel was assigned a unit cost based on a review of the following specific criteria:

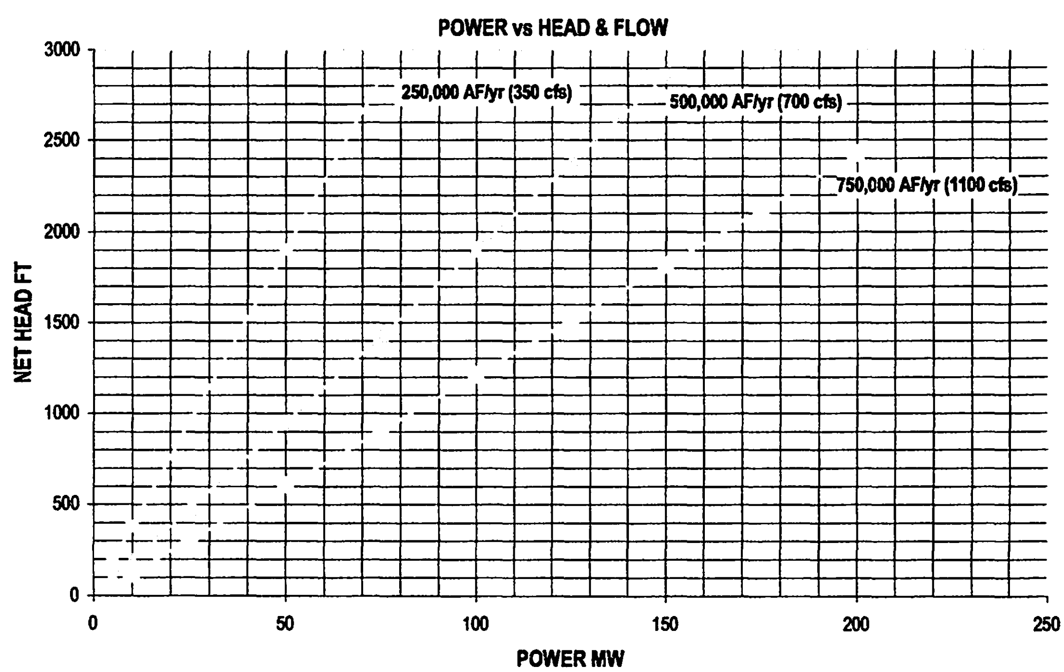
- Excavated diameter;
- Tunnel length;
- Geologic conditions; and
- Anticipated ground behavior under the range in overburden cover (i.e. requirements for initial support).

Estimated unit costs and total costs for each tunnel are presented on Tables 6-5 and 6-6.

Hydroelectric powerhouse cost is governed largely by the physical size of the structure and the equipment cost which in turn are dependent on the dimensions of the power generating equipment, the turbine(s) and generator(s). Most of the installations being evaluated for the CRRRS will have a vertical shaft directly connecting the turbine and generator. In these arrangements the dimensions of the turbine water-passageways usually control the powerhouse foundation dimensions and strongly influence the footprint and powerhouse height. The turbine dimensions are governed by the water flow rate. The cost of the powerhouse is therefore also a function of flow rate, which is directly proportional to capacity and inversely proportional to head.

Figure 6-10 shows the potential installed capacities of the hydroelectric plants as a function of the three flow rates corresponding to the three project delivery capacities and available heads.

Figure 6-10: Hydropower Generation



Because power is directly proportional to head, when head increases, the turbine dimensions decrease with a constant capacity, and because the turbine speed increases, the generator also gets smaller. The powerhouse correspondingly decreases in size. Therefore powerhouse cost can be shown to be a function of Capacity/Head.

Reconnaissance-level cost estimates for hydroelectric power plants typically use generalized cost curves or formulas which have been developed based on actual costs of existing hydro plants. A sufficiently accurate expression has been developed using US Department of Energy and other, more recent, cost data from existing plants. Applying this approach and escalating costs to 2003 values yields these estimated costs for a range of potential hydro plants being considered at various flows and heads, as shown in Table 6-7.

Table 6-7: Hydropower Facility Costs

	1	2	3	4
FLOW cfs	**250,000 af/yr (350 cfs)**		**750,000 af/yr (1100 cfs)**	
HEAD ft (m)	100 ft (30.5m)	2500 ft (762m)	100 ft (30.5m)	2500 ft (762m)
CAPACITY MW	2.3 MW	66 MW	8.3 MW	208 MW
COST	$4,150,000	$19,500,000	$12,500,000	$46,200,000

Operation and maintenance cost for a hydro plant can have many variables such as whether or not the plant is fully automated, the type and quality of equipment installed, the frequency of operation, frequency of overhaul etc. Statistical studies have been performed of some or all aspects of operation & maintenance costs. For example the USBR has developed the 'Replacements' Manual which predicts the service life of a large selection of hydroelectric equipment components and structures and assigns a relative cost to replace them. Another statistical study is that performed by Ontario Hydro using annual cost data published by the US Department of Energy entitled 'Historical Plant Cost and Annual Production Expenses for Selected Electric Plants. The data base was the 430 hydro plants regulated by the FERC and included as separate items maintenance, operation and capital expenditures. The cost items included; powerhouse mechanical, hydraulic and electric equipment; all structures; reservoirs, dams and waterways; supervision and engineering. The database included plant ages of up to 85 years. The operator cost would be significantly reduced for a hydro plant constructed today because it would be fully automated and there would be no need for operators in the plant. In the database there is a mix of fully attended, fully automated and semi-automated plants.

Future studies should consider this detailed analysis for operations cost, including revenue generation potential based on project power sales rates. However, to maintain consistency with other components of the study annual operations and maintenance costs have been assumed at 2% of construction costs. Power sales are assumed at $0.05 kwh. The following efficiencies are assumed in order to calculate power generation revenue, which are typical of similar facilities.

- Pelton turbine 91% at full load
- Generator 98% at full load
- Transformer 99% at full load

Typical layouts for the range of hydropower facilities are shown in Figures 6-11 through 6-14.

The electricity demands for the CRRP are a result of pumping a large volume of water (250,000 to 750,000 af per year) over major elevation changes (7,000 to 9,000 feet) and over a substantial distance (180 to 250 miles). There are, however, opportunities for hydroelectric generation along the corridors that would potentially offset a portion of the power requirements.

To complete this study, the following were addressed with respect to power:

- Pumping needs and related power generation requirements.
- Magnitude of power generation capacity available, and how the CRRP would procure this generation.
- Transmission lines to the pumping stations and from the hydrogeneration facilities into the existing power grid.
- Costs associated with providing power for the CRRP.

Total net power requirements range from 260 MW to 1164 MW depending on project delivery capacity and alignment. The CRRP's net pumping capacity requirements and annual energy needs for each alternative are projected in Table 6-8 as pumping requirements net the hydroelectric generation resulting from the project. This study assumes that all of the hydrogeneration coming out of this project will be used to help offset the power requirements so that net generation requirements by corridor and by delivery scenario become the focus of this evaluation. The number of pump stations and hydropower facilities for each alignment are listed in Tables 6-9 through 6-11.

Table 6-8. Net CRRP Pumping Capacity Requirements and Annual Energy Needs

	Annual Deliveries		
	250,000 af	500,000 af	750,000 af
Northern Alignment (NO1)			
Net Capacity Requirements	396 MW	779 MW	1,164 MW
Net Energy Requirements	3.3 BkWh*	6.5 BkWh*	9.8 BkWh*
Central Alignment 1 (CO1)			
Net Capacity Requirements	318 MW	630 MW	944 MW
Net Energy Requirements	2.7 BkWh*	5.3 BkWh*	7.9 BkWh*
Central Alignment 5 (CO5)			
Net Capacity Requirements	339 MW	689 MW	1,026 MW
Net Energy Requirements	2.8 BkWh*	5.8 BkWh*	8.6 BkWh*
Southern Alignment 1 (S01)			
Net Capacity Requirements	268 MW	520 MW	777 MW
Net Energy Requirements	2.3 BkWh*	4.4 BkWh*	6.5 BkWh*
Southern Alignment 2 (SO2)			
Net Capacity Requirements	261 MW	503 MW	751 MW
Net Energy Requirements	2.2 BkWh*	4.2 BkWh*	6.3 BkWh*

* BkwH=Billion Kilowatt hour (the use of one Billion Kilowatts of power for one hour duration

To place the power requirements of the CRRP in perspective, the 500,000 af delivery scenario would represent approximately 20 to 25 percent of current annual energy sales of Xcel Energy in Colorado and is roughly comparable to the combined annual sales of Fort Collins and Colorado Springs Utilities.

The CRRP will need to obtain or contract for electric generation capacity ranging from approximately 300 to 1,200 megawatts, depending upon the delivery scenario and the corridor chosen. To put the generation capacity requirement in perspective, all Colorado residents and businesses together used slightly more than 8,000 megawatts of total generation capacity from all sources in 1999.[1] The 500,000 af delivery capacity would represent roughly six to eight percent of total generation capacity in the state.

As of Autumn 2003, there was not enough available generation capacity in western Colorado to supply this power, but initial research indicates that this amount of power could be obtained elsewhere within the Rocky Mountain Power Area or through the construction of a new plant. Substantial increases in generation capacity are planned in the near future; Xcel Energy is planning to increase capacity in the Rocky Mountain Power Area by more than 1,500 megawatts between 2000 and 2004, and other utilities are planning large increases as well. Regardless, no utilities are planning for the capacity load to serve CRRP at the present time, and a major effort would need to be undertaken collaboratively with area utilities to plan for such an addition to regional generation capacity.

From an efficiency standpoint, the project might be best served with the construction of a new base load facility in western Colorado. [2] Assuming the 500,000 af delivery scenario, such a plant might be about half the size of the Craig Generation Station.

Planning for new electricity generation of this magnitude will require a considerable period of time; perhaps 10 years or more may be needed to bring this base load generation capacity on line.[3]

The three prospective pipeline corridors generally follow major electric transmission corridors. The Southern Corridor pipeline alignments are generally proximate to the 230 kV and 115 kV lines along the Gunnison River owned by the Western Area Power Administration. The Central Corridor alignment is, for the most part, proximate to the 230 kV line owned by Xcel Energy that follows the Colorado River. Much of the Northern Corridor alignment is parallel to the 230 and 345 kV lines owned by Western and Tri-State, though the transmission lines follow the Yampa Valley, approximately 10 to 20 miles north of the proposed pipeline alignment.

These major, high-voltage transmission lines are also likely to have available capacity to serve the 250,000 af and 500,000 af capacity delivery scenarios without major upgrades. The larger delivery scenario will probably require upgrading the high-voltage lines that transmit power in and out of these regions of Colorado.

Transmission lines will need to be constructed from the pumping stations and from the hydrogeneration facilities to the high-voltage transmission lines. Based upon an examination of the facility locations and the transmission lines, it is assumed that an average of 10 miles of transmission line will be needed for each pumping station, with the exception of the Northern Pipeline Alignment. For that alignment, between Meeker and Kremmling, it is assumed that the average transmission line connection would be about 20 miles.

Based upon this preliminary evaluation, CRRP's power requirements can be met from a physical and technical standpoint. Environmental and permitting issues have not been addressed, and these might obviously be considerable, affecting feasibility, timelines and costs. Order of magnitude and environmental assessment costs

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[1] U.S. Department of Energy, Energy Information Administration, 2003.

[2] Inez Dominguez, Engineer, Colorado Public Utilities Commission, October 1st, 2003.

[3] Inez Dominguez, Ibid.

were incorporated into the CRRP cost estimates. Without further study of alternative electricity supply approaches, a ten-year lead time should be assumed.

Costs associated with meeting the CRRP's electric power requirements would include the capital and annual costs of the pumping stations and hydroelectric generation facilities, the costs of transmission lines and other power features required to connect the project to the electric grid, and the annual energy costs used by the project. Capital and operating costs to build and maintain the pumping stations and hydroelectric generation facilities have been included in the overall project cost estimates.

Rough estimates of the costs of constructing lines needed for transmission can be derived using an assumed transmission line construction cost per mile. Guidelines developed by the Electric Power Research Institute and updated to current dollars using the Engineering News Record Cost Indices indicate a range of costs from about $215,000 to about $540,000 per mile for constructing single circuit, 230 kV transmission lines.[4] More recent guidelines, from the U.S. Department of Energy, indicate costs of about $440,000 to $650,000 per mile (updated to 2003 dollars) for 230 kV lines with rated capacities of 398 MW and 796 MW, exclusive of right of way costs.[5] Recent major transmission line construction projects, including the Navajo Transmission Project from the Four Corners area to Las Vegas and the Bonneville Power Administration's Shultz-Hanford Project have experienced or estimated costs of between $1 million and $2 million per mile, though both of these examples involve 500 kV lines that would likely not be required to provide power to individual CRRP pumping stations.

Factoring in the difficult terrain along much of the CRRP pipeline alignments, plus right-of-way costs, this study assumes an average cost of $1 million per mile for the necessary transmission connections. As shown in Tables 6-9, 6-10, and 6-11, general estimates of transmission line construction costs range from about $140 million for the Central Corridor pipeline alignment to about $250 million for the Northern Corridor pipeline alignment.

Electric utilities might recoup the costs of building generation capacity and the annual energy costs through a composite charge per kilowatt hour (kWh) of energy consumed by the CRRP. Ranges of kilowatt hour prices were obtained from the U.S. Department of Energy and the Western Area Power Administration for Colorado and for the Rocky Mountain Power Region. Price ranges were found from 3.9 cents per kWh to 5.6 cents per kWh; the most recent industrial electric price data for Colorado (1999) indicate 4.4 cents per kWh price. This study assumes 5 cents per kWh, recognizing the uncertainty of future fuel prices and other variables. Applying this assumption, estimated annual CRRP energy costs are included in the operations costs shown in Table 6-9, 6-10, and 6-11.

Based upon preliminary research, it appears that sufficient electric power can be provided for the CRRP. The 750,000 af delivery capacity scenario might be problematic from both a transmission line and generation standpoint. Hydrogeneration from the project can be used to partially offset power requirements. New generation capacity will likely be needed in western Colorado or elsewhere in the Rocky Mountain region to provide the base load power requirements for the CRRP. Transmission lines will need to be built from the project to nearby high-voltage transmission lines that currently cross western Colorado.

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[4] Electric Power Research Institute, Technical Assessment Guide: Electric Supply, 1989, Vol. 1, Revision 6, p. B-4. Updated to current dollars by BBC Research & Consulting using ENR Index.

[5] *Upgrading Transmission Capacity for Wholesale Electric Power Trade*. U.S. Department of Energy, Energy Information Administration. Table FE2. Accessed by Internet, file last updated on June 6, 2003.

Capital costs will be required to construct transmission lines from the pipeline to the high-voltage transmission lines that already exist. These costs are anticipated to range from $140 million to $250 million in up-front 2003 dollar requirements. Annual energy costs to pay for generation capacity and production will range from $110 million to $490 million, depending upon the alignment corridor and the water delivery scenario.

The size of such a project is not unprecedented. The annual pumping energy requirements for the California State Water Project are roughly comparable with the range of the CRRP pumping energy requirements.

Land purchases will be required for facilities such as the water treatment plants, pumping stations, hydropower facilities, and storage reservoirs. Easements will also be needed for the pipeline

Advertisements for undeveloped land on the west slope of 5 acres or more ranged from $2000 to $20,000 per acre. This data was used to develop an average land value of $13,000 per acre that is used in the cost estimates for the water treatment plant, pump stations and hydropower facilities. Easement costs assumed to be 30% of the value of the land. Further studies would require additional research on land value that could result in modification of the alignments.

The costs of constructing and operating ancillary facilities not specifically discussed above including, but not limited to, access roads and their maintenance, are provided by the 30 percent cost contingency applied to all project configurations.

The components of the CRRP can be grouped in five broad categories: 1) Diversion; 2) Operational storage; 3) Water treatment; 4) Conveyance; and 5) Energy recovery. The largest cost component of the CRRP is the conveyance system, including pipe, tunneling and pump stations. The conveyance system is also the largest contributor to annual operating costs, primarily due to pumping. Evaluation of the costs and benefits of these three components were conducted together because the sizing and operational characteristics of one component affects the sizing and operational requirements of the rest of the components in the system. It was determined during the layout of the alternative pipeline alignments that the cost and performance of the CRRP could be significantly affected by the length and depth of the tunnels (longer tunnels can reduce the magnitude of pumping along any given alignment) and the velocity of the water in the pipeline (the higher the velocity of flow, the smaller the pipe diameter will need to be, but more pumping energy is required). Therefore, analyses were made to test how sensitive the construction and operating costs are to the following two issues:

- Utilization of longer and deeper tunnels
- Reductions in pipeline diameter

By incorporating longer tunnels with greater overburden, the total pumping lift can be minimized, resulting in lower capital and operating cost for pumping and reduced pipe costs due to lower operating pressures. However, the unit cost of these tunnels is higher than shorter, shallower tunnels and may result in higher total capital costs.

To characterize the net effects of longer and deeper tunnels, they were incorporated into two of the alignments, one in the Central Corridor (C01) and one in the Southern Corridor (S02). Compared to the original C01 alignment, the net increase in capital (including tunneling, pipe, pump stations, and hydropower) after the inclusion of longer tunnels is on the order of $180 Million, with a net annual operating savings of $16 Million. This would offer direct pay back in a period of approximately eleven years. A greater benefit was seen in the sensitivity analysis for the southern alignment S02. With the inclusion of longer and deeper tunnels in alignment S02, the capital costs decrease by approximately $35 Million due to the decrease in amount of high pressure pipe. The annual operating costs are smaller as well, by approximately $42 Million. Should further studies be performed on the CRRP, the concept of longer and deeper tunnels should be considered.

A reduction in pipe diameter reduces the unit cost of the pipeline, but increases the velocity in the pipeline. Increased fluid velocity results in higher friction along the pipe walls requiring higher head pumping pressures which increase the pumping station capital and operations cost. A cursory evaluation was performed to characterize the effect of a change in pipeline diameter on the Central Corridor alignment (C01) for the middle project delivery capacity of 500,000 af/yr.

The pipe diameter was reduced from 12-feet to 8.5-feet, approximately doubling the velocity in the pipe. It is recognized that the resulting velocity is on the higher end of the acceptable range, but was chosen to bracket the lowest potential pipe cost, and thus the greatest potential for savings. This resulted in a greater pumping capital cost, higher annual operating costs, and reduction in hydropower recovery. The net reduction in capital costs including pipe, pump stations, and hydropower is on the order of $400 million. The increase in net annual operating costs in on the order of $75 million. In this case the capital savings is utilized in a period just over 5 years, which is probably not justified. However, there may be some benefit to a smaller pipeline diameter reduction that should be evaluated further if future studies are conducted.

The two sensitivity analyses presented above are only starting points to consider in any future improvements in the layout of the CRRP alternatives. If further studies are conducted, these and other sensitivity studies should be performed including, but not limited to, the following:

- Utilization of longer and deeper tunnels
- Optimization of pipeline diameter
- Multiple pipes installed in the same trench instead of single large diameter pipe
- Additional pump stations and hydropower facilities along the alignment
- Use of above ground pipelines for portions of the alignment

- Use of gravity-flow canals to reduce project cost (note this concept may have water quality constraints if treatment facilities are sited ahead of the canal sections)

- Use of cast in place concrete conduits for portions of the alignment

The data discussed in previous sections was used to compile opinions of probable costs for 31 alignments representing all three corridors. The results for each of the three delivery capacities are shown on Tables 6-9 through 6-11.

Total capital costs including construction, easements, engineering, administration and contingencies for the least costly alternatives are as follows:

- For 250,000 af/yr – approximately $3.7 billion or about $14,700 per acre foot[6]

- For 500,000 af/yr – approximately $6.0 billion or about $12,000 per acre foot[6]

- For 750,000 af/yr – approximately $8.7 billion or about $11,600 per acre foot[6]

For purposes of comparison, Colorado-Big Thompson Project water purchases are currently $21,000 to $24,000 per af of firm yield.

Total annual operation and maintenance costs including net energy purchases and operation of physical facilities are as follows:

- For 250,000 af/yr – approximately $220 million or about $890 per acre foot

- For 500,000 af/yr – approximately $420 million or about $840 per acre foot

- For 750,000 af/yr – approximately $620 million or about $820 per acre foot

The following general conclusions were reached:

1. Economy of Scale – for all 31 alignments, the estimated capital cost of per acre-foot of water delivered decreases with increasing delivery capacities, that is, at 750,000 af/yr, the CRRP is more cost effective per unit of water delivered than for 500,000 or 250,000 af/yr.

2. Most Cost-Effective Alignments within each Corridor - at this reconnaissance level of study, there are no significant differences in costs between the alignments in each corridor. Therefore, there is flexibility in future selection of specific alignments.

3. Most Cost-Effective Corridors – at this reconnaissance level of study, there are no significant differences in capital costs between the Central and South corridors. There is, however, a significant difference (approximately a 50% capital cost penalty) between the North Corridor and the other two corridors due to the increased length of pipe. Annual operating costs are also higher for the North Corridor. Comparing the least cost alignments in each corridor based on annual costs indicates that the North Corridor is

[6]Cost per acre foot is equal to the project cost divided by the project delivery capacity. Operating costs are discussed in Chapter 7.

almost 20% more expensive than the Central and almost 40% more expensive than the Southern. Environmental impacts and the differences between each corridor are discussed in the next chapter.

The affordability of the capital and annual operating costs, and their competitiveness with other sources of supply are discussed in the financial and economic sections of the next chapter.

Table 6-9 - Total Project Costs - 250,000 acre-feet per year Delivery Capacity ($ in Millions)

	Capital Costs																						Annual Operations			
	Infrastructure											Contingencies		Land								Summary				
Alternative	Pipe	Appurts.	Const. Cond.	Tunnels	Pump Stat.	Hydro	Diver. Struc.	Water Treatment	Storage	Power Trans	Total Capital	General 30%	E&A 20%	WTP Land Cost	# of PS	PS Land Cost	# of Hydro	Hydro Land Cost	Pipe Length (miles)	Pipe Ease. Cost	Total L & E Costs	Total Project Cost	Pump & Hydro	WTP	Pipeline	Total O&M
N01	$ 2,090	$ 104	$ 313	$ 147	$ 355	$ 87	$ 0.9	$ 605	$ 75	$ 250	$ 4,027	$ 1,208	$ 805	$ 92	14	$ 0.4	7	$ 0.09	260	$ 26	$ 118	$ 6,159	$ 175	$ 68	$ 13	$ 257
N02	$ 1,997	$ 100	$ 300	$ 147	$ 365	$ 88	$ 0.9	$ 605	$ 75	$ 250	$ 3,929	$ 1,179	$ 786	$ 92	15	$ 0.4	7	$ 0.09	253	$ 25	$ 118	$ 6,011	$ 178	$ 68	$ 13	$ 259
N03	$ 2,054	$ 103	$ 308	$ 147	$ 357	$ 87	$ 0.9	$ 605	$ 75	$ 250	$ 3,986	$ 1,196	$ 797	$ 92	14	$ 0.4	7	$ 0.09	257	$ 26	$ 118	$ 6,098	$ 175	$ 68	$ 13	$ 257
N04	$ 2,015	$ 101	$ 302	$ 147	$ 341	$ 75	$ 0.9	$ 605	$ 75	$ 250	$ 3,912	$ 1,174	$ 782	$ 92	14	$ 0.4	6	$ 0.08	253	$ 25	$ 118	$ 5,986	$ 194	$ 68	$ 13	$ 275
N05	$ 2,051	$ 103	$ 308	$ 147	$ 371	$ 104	$ 0.9	$ 605	$ 75	$ 250	$ 4,015	$ 1,204	$ 803	$ 92	15	$ 0.4	9	$ 0.12	260	$ 26	$ 118	$ 6,140	$ 178	$ 68	$ 13	$ 259
N06	$ 2,108	$ 105	$ 316	$ 147	$ 363	$ 103	$ 0.9	$ 605	$ 75	$ 250	$ 4,073	$ 1,222	$ 815	$ 92	14	$ 0.4	9	$ 0.12	264	$ 26	$ 119	$ 6,229	$ 175	$ 68	$ 13	$ 256
N07	$ 2,146	$ 107	$ 322	$ 147	$ 361	$ 102	$ 0.9	$ 605	$ 75	$ 250	$ 4,116	$ 1,235	$ 823	$ 92	14	$ 0.4	9	$ 0.12	268	$ 27	$ 119	$ 6,293	$ 175	$ 68	$ 13	$ 256
N08	$ 2,070	$ 104	$ 311	$ 147	$ 347	$ 90	$ 0.9	$ 605	$ 75	$ 250	$ 3,999	$ 1,200	$ 800	$ 92	14	$ 0.4	8	$ 0.10	260	$ 26	$ 118	$ 6,118	$ 173	$ 68	$ 13	$ 254
C01	$ 734	$ 37	$ 110	$ 392	$ 244	$ 33	$ 0.9	$ 605	$ 75	$ 140	$ 2,371	$ 711	$ 474	$ 92	11	$ 0.3	3	$ 0.04	184	$ 18	$ 111	$ 3,667	$ 140	$ 68	$ 13	$ 221
C02	$ 738	$ 37	$ 111	$ 403	$ 235	$ 29	$ 0.9	$ 605	$ 75	$ 140	$ 2,374	$ 712	$ 475	$ 92	11	$ 0.3	3	$ 0.04	184	$ 18	$ 111	$ 3,671	$ 139	$ 68	$ 13	$ 220
C03	$ 816	$ 41	$ 122	$ 377	$ 256	$ 36	$ 0.9	$ 605	$ 75	$ 140	$ 2,469	$ 741	$ 494	$ 92	11	$ 0.3	3	$ 0.04	193	$ 19	$ 112	$ 3,815	$ 143	$ 68	$ 13	$ 224
C04	$ 725	$ 36	$ 109	$ 223	$ 287	$ 63	$ 0.9	$ 605	$ 75	$ 200	$ 2,336	$ 701	$ 467	$ 92	15	$ 0.4	5	$ 0.07	168	$ 17	$ 109	$ 3,613	$ 150	$ 68	$ 13	$ 231
C05	$ 730	$ 37	$ 110	$ 260	$ 295	$ 63	$ 0.9	$ 605	$ 75	$ 200	$ 2,375	$ 713	$ 475	$ 92	15	$ 0.4	5	$ 0.07	168	$ 17	$ 109	$ 3,672	$ 149	$ 68	$ 13	$ 230
S01	$ 961	$ 48	$ 144	$ 150	$ 258	$ 78	$ 0.9	$ 605	$ 75	$ 180	$ 2,500	$ 750	$ 500	$ 92	12	$ 0.3	6	$ 0.08	195	$ 19	$ 112	$ 3,862	$ 120	$ 68	$ 13	$ 201
S02	$ 1,078	$ 54	$ 162	$ 74	$ 226	$ 46	$ 0.9	$ 605	$ 75	$ 150	$ 2,472	$ 741	$ 494	$ 92	11	$ 0.3	4	$ 0.05	217	$ 22	$ 114	$ 3,821	$ 115	$ 68	$ 13	$ 196
S03	$ 973	$ 49	$ 146	$ 155	$ 275	$ 78	$ 0.9	$ 605	$ 75	$ 180	$ 2,537	$ 761	$ 507	$ 92	12	$ 0.3	6	$ 0.08	198	$ 20	$ 112	$ 3,918	$ 118	$ 68	$ 13	$ 200
S04	$ 1,001	$ 50	$ 150	$ 127	$ 278	$ 73	$ 0.9	$ 605	$ 75	$ 180	$ 2,537	$ 761	$ 507	$ 92	13	$ 0.3	5	$ 0.07	202	$ 20	$ 113	$ 3,918	$ 121	$ 68	$ 13	$ 202
S05	$ 990	$ 49	$ 148	$ 121	$ 277	$ 72	$ 0.9	$ 605	$ 75	$ 180	$ 2,519	$ 756	$ 504	$ 92	13	$ 0.3	5	$ 0.07	199	$ 20	$ 112	$ 3,891	$ 121	$ 68	$ 13	$ 203
S06	$ 1,027	$ 51	$ 154	$ 100	$ 248	$ 63	$ 0.9	$ 605	$ 75	$ 180	$ 2,502	$ 751	$ 500	$ 92	11	$ 0.3	5	$ 0.07	202	$ 20	$ 112	$ 3,866	$ 112	$ 68	$ 13	$ 194
S07	$ 1,057	$ 53	$ 158	$ 71	$ 247	$ 58	$ 0.9	$ 605	$ 75	$ 180	$ 2,505	$ 751	$ 501	$ 92	12	$ 0.3	4	$ 0.05	206	$ 21	$ 113	$ 3,870	$ 114	$ 68	$ 13	$ 195
S08	$ 1,001	$ 50	$ 150	$ 119	$ 217	$ 48	$ 0.9	$ 605	$ 75	$ 150	$ 2,415	$ 725	$ 483	$ 92	11	$ 0.3	4	$ 0.05	215	$ 21	$ 114	$ 3,737	$ 107	$ 68	$ 13	$ 188
S09	$ 979	$ 49	$ 147	$ 141	$ 220	$ 53	$ 0.9	$ 605	$ 75	$ 150	$ 2,421	$ 726	$ 484	$ 92	11	$ 0.3	5	$ 0.07	216	$ 22	$ 114	$ 3,745	$ 108	$ 68	$ 13	$ 189
S10	$ 997	$ 50	$ 150	$ 126	$ 272	$ 89	$ 0.9	$ 605	$ 75	$ 150	$ 2,514	$ 754	$ 503	$ 92	12	$ 0.3	8	$ 0.10	214	$ 21	$ 114	$ 3,886	$ 119	$ 68	$ 13	$ 200
S11	$ 1,016	$ 51	$ 152	$ 97	$ 267	$ 86	$ 0.9	$ 605	$ 75	$ 150	$ 2,500	$ 750	$ 500	$ 92	12	$ 0.3	8	$ 0.10	218	$ 22	$ 114	$ 3,864	$ 119	$ 68	$ 13	$ 200
S12	$ 1,059	$ 53	$ 159	$ 98	$ 228	$ 52	$ 0.9	$ 605	$ 75	$ 150	$ 2,479	$ 744	$ 496	$ 92	11	$ 0.3	5	$ 0.07	218	$ 22	$ 114	$ 3,832	$ 114	$ 68	$ 13	$ 195
S13	$ 1,078	$ 54	$ 162	$ 81	$ 280	$ 88	$ 0.9	$ 605	$ 75	$ 150	$ 2,573	$ 772	$ 515	$ 92	12	$ 0.3	8	$ 0.10	216	$ 22	$ 114	$ 3,974	$ 125	$ 68	$ 13	$ 206
S14	$ 1,097	$ 55	$ 165	$ 52	$ 275	$ 86	$ 0.9	$ 605	$ 75	$ 150	$ 2,560	$ 768	$ 512	$ 92	12	$ 0.3	8	$ 0.10	220	$ 22	$ 114	$ 3,954	$ 125	$ 68	$ 13	$ 207
S15	$ 1,030	$ 52	$ 155	$ 120	$ 206	$ 42	$ 0.9	$ 605	$ 75	$ 150	$ 2,435	$ 731	$ 487	$ 92	10	$ 0.3	4	$ 0.05	213	$ 21	$ 114	$ 3,767	$ 105	$ 68	$ 13	$ 187
S16	$ 1,013	$ 51	$ 152	$ 142	$ 210	$ 48	$ 0.9	$ 605	$ 75	$ 150	$ 2,447	$ 734	$ 489	$ 92	10	$ 0.3	5	$ 0.07	214	$ 21	$ 114	$ 3,785	$ 107	$ 68	$ 13	$ 188
S17	$ 1,032	$ 52	$ 155	$ 126	$ 264	$ 84	$ 0.9	$ 605	$ 75	$ 150	$ 2,544	$ 763	$ 509	$ 92	11	$ 0.3	8	$ 0.10	212	$ 21	$ 114	$ 3,929	$ 119	$ 68	$ 13	$ 200
S18	$ 1,053	$ 53	$ 158	$ 98	$ 258	$ 81	$ 0.9	$ 605	$ 75	$ 150	$ 2,531	$ 759	$ 506	$ 92	11	$ 0.3	8	$ 0.10	217	$ 22	$ 114	$ 3,911	$ 119	$ 68	$ 13	$ 200

Table Heading Legend and Descriptions (for a more detailed description of the assumptions see the Chapter 6 Text)

Alternative - alternative name

Capital Costs

- **Pipe** - the baseline installed construction cost for the pipeline
- **Appurts.** - allowance for pipe appurtenances such as valves and misc. items (5% of the baseline pipe cost)
- **Const. Cond.** - allowance for difficult construction conditions such as rock, limited access, etc. (15% of baseline)
- **Tunnels** - total construction cost for all of the tunnels included in the alternative
- **Pump Stat.** - total construction cost for all of the pump stations included in the alternative
- **Hydro** - total construction cost for all of the hydropower facilities included in the alternative
- **Diver. Struc.** - construction cost of the diversion structure
- **Water Treatment** - Construction cost of the water treatment plant
- **Storage** - construction cost of the operational storage include in the alternative
- **Power Trans** - Construction cost of installing power transmission
- **Total Capital** - total cost of construction for the infrastructure items listed above

General 30% - allowance of the 30% of the Total Capital cost for unaccounted for items and contingency

E&A 20% - allowance of 20% for engineering, legal, administration and permitting

Land

- **WTP Land Cost** - cost of land required for the treatment plant
- **# of PS** - number of pump stations included in the alternative
- **PS Land Cost** - cost of the land required for all of the pump stations
- **# of Hydro** - number of hydro power facilities included in the alternative
- **Hydro Land Cost** - cost of the land required for all of the hydropower facilities
- **Pipe Length (miles)** - total length of pipe
- **Pipe Ease. Cost** - cost of the pipeline easement
- **Total L & E Cost** - total cost of the land purchases and easement acquisition

Total Project Cost - Includes the total Capital Cost, Contingency, E & A, and Land and Easement Acquisition

Annual Operations

- **Pump & Hydro** - total operations cost for pump stations and hydropower facilities (including hydropower revenue)
- **WTP** - operations cost for the water treatment plant
- **Pipeline** - maintenance cost of the pipeline and tunnels (0.5% of the total pipeline and tunnel construction cost)
- **Total O&M** - total annual operations cost for the above items

Colorado River Return Reconnaissance Study

Prepared for:
State of Colorado
Colorado Department of Natural Resources
Colorado Water Conservation Board
1313 Sherman, Room 721
Denver, CO 80204

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ERO Resources Corporation
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Water Consult

November 14, 2003

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Chapter 6.
Construction and Operating Costs

Cost estimates are based on typical reconnaissance level procedures focusing the greatest attention on the largest cost components of the CRRP. For example, preliminary schematic drawings were prepared for water treatment alternatives, pumping stations, hydroelectric power plants and pipelines. These schematic drawings were used to generate cost estimates reflecting the size and complexity of the facility construction. Major cost items and constructability issues were reviewed with contractors specializing in construction of these facilities. In addition, manufacturers and local, state, and federal agencies provided data or commentary on the likely magnitude of electro-mechanical equipment prices and for power purchases and sales, materials, and equipment. Components of the alternative project configurations contributing small percentages of the total cost were estimated using data from other projects and industry cost estimating summaries. Presented below are the methods used to prepare cost estimates, including both the capital cost of construction and annual operating costs. Allowances for land acquisition, contingencies, and future planning, design, and administrative costs are as indicated in the cost summary section. All costs are based on 2003 US dollars.

The selection of the type of diversion structure to be used if the CRRP advances will involve detailed consideration of the environmental effects of constructing a structure in a particular reach of the river. The most cost-efficient and reliable type of structure from an engineering perspective would likely be a low-head diversion dam across the river to create a pool from which the water would be diverted into a forebay reservoir for the first pumping station. Considering that the reach of river being considered is designated as critical habitat for four endangered fish species, this type of structure would need to incorporate appropriate fish passage features such as those that have been, or are being, constructed on existing diversion dams on the Colorado and Gunnison Rivers. The reach of river downstream of currently used diversions is an area adjoined by a wilderness study area, a national conservation area, and a state wildlife area. Therefore, while it may be possible to design some type of diversion dam with the requisite fish passage details, this study assumed that other types of diversion structures are preferable.

Infiltration galleries, consisting of perforated pipe buried in the river alluvium would eliminate any cross-channel barrier to fish migration. Unfortunately, high sediment loads, variable flows in the river and overall channel stability horizontally and vertically, do not lend themselves to this type of diversion, especially of this size.

A special type of infiltration gallery, known as a radial collector was also considered. Here, the perforated pipes extend radially outward under the river channel from a large diameter wet well. This type of structure should be considered further in future studies, if conducted.

The fourth type of diversion structure considered is a side channel inlet consisting of a concrete levee along one side of the river. The levee would contain covered screened inlets to exclude fish larger than the openings in the screens. The size of screen openings greatly affect the performance and annual maintenance costs. Screens with 3/32-inch openings have been installed in existing canals in the Grand Valley with similar flows. Since the structure's design is so dependent on the conditions in the specific reach where it would be constructed, and the overall cost is small in relation to the total cost of the CRRP, no design sketches were prepared for this study. Based on costs incurred on similar structures in the area, an allowance of $3,000/cfs (equal to the upper end of the cost range experienced to date) of diversion capacity was used. An additional contingency of 30% was also included since this is a specialty structure that would likely require hydraulic model studies, would have to be tailored to specific conditions at the site finally chosen, and would likely have special construction constraints given the environmental sensitivity of the area.

Water storage can be an important component of long-distance water conveyance systems. It is especially important when there is great variability in the timing of water supplies available for diversion. Storage near the diversion point, or source of the water supply, allows the rest of the system, consisting of treatment plants, pumping stations, pipelines, and tunnels to be sized for flows approximately equal to the long-term average flow instead of short-term peak flows. Storage also provides operational flexibility. For example, if for an unexpected reason, there is a problem being able to divert water from the river, stored water can be delivered through the system instead of having to shut the system down until problems are resolved. For the purposes of this reconnaissance study, it is assumed that storage equal to five percent of the average annual deliveries is provided near the diversion point and that an additional five percent is distributed along the pipelines, likely near the pumping stations and hydropower facilities. Detailed layouts of these facilities were not prepared since the cost of this storage is estimated at less than 2 percent of the total construction costs. A cost allowance of $3,000 per acre-foot of storage was included based on a review of cost estimates for more than 100 new off-channel water storage sites prepared by Boyle Engineering in the past four years.

Equipment cost data from manufacturer's representatives, and other literature were used to develop opinions of probable costs. Costs were developed for the 230-MGD, 460-MGD, and 690-MGD treatment plants for the four alternative treatment processes presented in the previous chapter. Tables 6-1 and Table 6-2 present reconnaissance-level opinions of probable capital and annual operations costs, respectively. These tables present costs for process equipment, buildings, electrical, instrumentation/controls, yard piping, basic site/civil work including roadways and stormwater retention. Operating costs include allowance for labor, chemicals, and power consumption ($0.05/kWh). Land costs are included in the overall project configuration summary costs.

Site considerations and plant hydraulics must be taken into account before any alternative is selected to ensure the required facilities can be constructed on-site. Some of the unit processes may require transfer pumps rather than the assumed gravity flow.

TABLE 6-1: Conceptual Water Treatment Alternatives Capital Cost Opinion

Treatment Alternative - 230 MGD				
PARAMETER	1	2	3	4
	UF/NF/UV	C/S/LS/F/UV	C/S/F/NF/UV	LS/F/UV
Pretreatment	$90,000,000	$21,000,000	$62,000,000	--
Advanced Treatment	$120,000,000	$92,000,000	$100,000,000	$65,000,000
Post Treatment	$29,000,000	$29,000,000	$29,000,000	$29,000,000
Residuals Handling	$1,000,000	$63,000,000	$21,000,000	$52,000,000
Facility Buildings	$9,000,000	$9,000,000	$9,000,000	$9,000,000
Yard Piping (10%)	$25,000,000	$21,000,000	$22,000,000	$16,000,000
Site Civil (15%)	$37,000,000	$32,000,000	$33,000,000	$23,000,000
Instrumentation & Controls (15%)	$37,000,000	$32,000,000	$33,000,000	$23,000,000
Electrical (15%)	$37,000,000	$32,000,000	$33,000,000	$23,000,000
Residuals Storage	$220,000,000	$4,000,000	$220,000,000	$4,000,000
SUBTOTAL	***$605,000,000***	***$335,000,000***	***$562,000,000***	***$244,000,000***
$/GPD*	***$2.63***	***$1.46***	***$2.44***	***$1.06***
Treatment Alternative - 460 MGD				
	1	2	3	4
	UF/NF/UV	C/S/LS/F/UV	C/S/F/NF/UV	LS/F/UV
Pretreatment	$160,000,000	$38,000,000	$120,000,000	--
Advanced Treatment	$200,000,000	$180,000,000	$180,000,000	$130,000,000
Post Treatment	$57,000,000	$57,000,000	$57,000,000	$57,000,000
Residuals Handling	$2,000,000	$117,000,000	$41,000,000	$103,000,000
Facility Buildings	$9,000,000	$9,000,000	$9,000,000	$9,000,000
Yard Piping (10%)	$43,000,000	$40,000,000	$41,000,000	$30,000,000
Site Civil (15%)	$64,000,000	$60,000,000	$61,000,000	$45,000,000
Instrumentation & Controls (15%)	$64,000,000	$60,000,000	$61,000,000	$45,000,000
Electrical (15%)	$64,000,000	$60,000,000	$61,000,000	$45,000,000
Residuals Storage	$440,000,000	$8,000,000	$440,000,000	$8,000,000
SUBTOTAL	***$1,103,000,000***	***$629,000,000***	***$1,071,000,000***	***$472,000,000***
$/GPD*	***$2.40***	***$1.37***	***$2.33***	***$1.03***
Treatment Alternative - 690 MGD				
	1	2	3	4
	UF/NF/UV	C/S/LS/F/UV	C/S/F/NF/UV	LS/F/UV
Pretreatment	$230,000,000	$48,000,000	$172,000,000	--
Advanced Treatment	$290,000,000	$271,000,000	$250,000,000	$190,000,000
Post Treatment	$85,000,000	$85,000,000	$85,000,000	$85,000,000
Residuals Handling	$3,000,000	$170,000,000	$54,000,000	$154,000,000
Facility Buildings	$9,000,000	$9,000,000	$9,000,000	$9,000,000
Yard Piping (10%)	$62,000,000	$58,000,000	$57,000,000	$44,000,000
Site Civil (15%)	$93,000,000	$87,000,000	$86,000,000	$66,000,000
Instrumentation & Controls (15%)	$93,000,000	$87,000,000	$86,000,000	$66,000,000
Electrical (15%)	$93,000,000	$87,000,000	$86,000,000	$66,000,000
Residuals Storage	$660,000,000	$12,000,000	$660,000,000	$12,000,000
SUBTOTAL	***$1,618,000,000***	***$914,000,000***	***$1,545,000,000***	***$692,000,000***
$/GPD*	***$2.34***	***$1.32***	***$2.24***	***$1.00***

* *$/GPD is the* cost in dollars per gallon per day of treatment capacity

Routt and Moffitt Counties in Colorado (Yampa and White Rivers) and Uintah and Duchesne Counties in Utah (Green and Duchesne Rivers); by Howe and Ahrens (1988) for the Yampa and White Rivers and the Green River above the Colorado; and by Oamek (1990) for this entire "Northern region" (his "PA 82"). Weighted averages (based on consumptive use) are used to aggregate sub-regional estimates of Howe and Ahrens (1988) and of Gollehon *et al.* (1981) to the regional level, while estimates from Anderson (1973) and Oamek (1990) are used directly.

Colorado Front Range. Irrigated production on Colorado's eastern plains makes use of transmountain water exports from the Colorado River Basin. Demand for agricultural water was estimated from a minor revision of the model of northern Colorado agricultural production presented in Michelsen (1989). Crop flexibility constraints were modified in order to allow estimates of damages from up to 50 percent reductions in water use.

California. Estimates from a programming model developed by Booker and Young (1991) are used as the basis for water demand functions for California users of Colorado River Basin water. This model focused on irrigated production in the Imperial Valley, the major user of Colorado River water in southern California.

Arizona. Water demand functions for three distinct users in Arizona (Yuma, Colorado River Indian Reservation, and Central Arizona) were derived from the farm-level programming results obtained by Peacock (unpublished manuscript, Dept. of Agricultural and Resource Economics, University of Arizona, 1993). Two representative farms in the Yuma region were modeled, one with field crops only and one with both field and vegetable crops. A third representative farm, growing mostly cotton, was modeled using the enterprise budget given in Wilson (1992).

Net benefit functions were derived from point estimates of benefits in each of the three models. A portfolio of the three farms which best matched county acreages (minimized the sum of squared deviations from estimated crop acreages) of cotton, wheat, alfalfa, and vegetables was then constructed. A programming model of water allocation within each region was developed to estimate regional benefits from water use. Effective markets within regions were assumed, allowing reallocations among the three farm types when diversions were less than 100 percent. The resulting regional net benefit point estimates were then re-estimated to give a continuous function representing regional benefits.

Municipal Demand Functions

Municipal demand estimates were derived for major southwestern cities, including Phoenix/Tucson, Denver/Front Range, Salt Lake City, Las Vegas, Albuquerque, and the Metropolitan Water District (MWD) service area in southern California. A single cross-sectional study of seasonal household water demand (Griffin and Chang, 1991) was used as the basis for deriving the set of unique but methodologically consistent benefit functions for each municipal region. The approach was based on the observation that the proportion of outdoor to indoor uses varies across regions as a result of climate differences and socioeconomic factors. Summer and winter elasticities of -0.41 and -0.30 reported by Griffin and Chang (1991) for their generalized Cobb-Douglas estimate were used. Following Howe (1982), these are converted to indoor and outdoor elasticity estimates of -0.30 and -0.58. For example, using this procedure with data on indoor and outdoor use in Phoenix and Tucson gives average annual elasticities of -0.43 and -0.39, respectively. These are similar to the range of average elasticities (-0.27 to -0.70) reported in several studies by Billings and Agthe (1980) and Martin and Kulakowski (1991) for Tucson, and Planning and Management Consultants (1986) for Phoenix, as well as the range reported in the numerous other studies on this topic. Municipal demand functions were then estimated using the *average* water prices and use levels for 1985. Table 2 summarizes marginal and total benefit function estimates for Basin municipal uses.

Thermal Energy Demand Functions

Water is used for cooling water in thermal electric generation throughout the Southwest. A single benefit function for cooling water at thermal electric power generating facilities was re-estimated from data on costs of alternative cooling technologies presented in Booker and Young (1991). Actual long-run benefits may tend to be overestimated using this approach, given the possible availability of local ground water for use in cooling. The avoided cost approach may underestimate short-run damages from water shortages, however, given the necessary capital investments for use of water conserving cooling technologies. The estimated benefit function for cooling water use is $V(x) = x_0 v_0 (x/x_0)^{\beta}$, where v_0 = \$222/af, $\beta = -.070$, and $0 < x \leq x_0$. The benefit function implies a marginal water value of \$155/af and price elasticity of demand equal to -0.59 at full delivery.

TABLE 2. Estimated Municipal Benefit Functions,* Elasticities,** and Marginal Water Values at Full Delivery for Each Use (1992 dollars).

Agricultural Region	v_0 ($/af)	β	Proportion of Non-Colorado River Water Used $x_n/(x_n + x_0)$	Marginal Value at Full Use p_0 ($/af)	Price Elasticity of Demand
Denver	–373	–1.22	0.602	455.1	–0.45
Central Utah Project	–369	–1.23	0.884	453.9	–0.45
Albuquerque	–298	–1.61	0.495	479.8	–0.38
Las Vegas	–318	–1.27	0.050	403.9	–0.44
Central Arizona	–277	–1.31	0.626	362.9	–0.43
MWD (South California)	–211	–1.63	0.608	343.9	–0.38

*Use of parameters v_0, β, x_n, x_0, and p_0 in the total benefit function is described in the text.

**Because non-Colorado River supplies are available, elasticities given are at full water delivery.

Consumptive Use Depletion Requests

Full economic demand functions for consumptive use of Colorado River water are found using the demand estimates presented above together with USBR (1991) depletion data. The USBR data set gives the legal entitlements for consumptive use and is used to define a "full" delivery depletion schedule for each Basin use. This is the only source for spatially disaggregated estimates of Basin depletions, and it is the starting point for the consumptive use inputs in the modeling of drought impacts by Harding *et al.* (1995), Booker (1995), Henderson and Lord (1995), and Sangoyomi and Harding (1995), all reported in this issue.

The actual depletion schedule used in these studies modifies the USBR schedule by holding agricultural depletions constant at 1992 levels and shifting the Central Arizona Project (CAP) schedule back six years (from 1992 to 1986) to reflect recent low deliveries. CAP deliveries in excess of 1,248 thousand acre-feet (kaf) per year (surplus deliveries) are not included because there is little evidence of demand for these deliveries (Wilson, 1992). The Las Vegas depletion schedule is allowed to increase with population, irrespective of Nevada's limited Colorado River Compact entitlement. The total adjusted increase in depletion schedules for the period 1992 to 2030 is approximately 10.5 percent (1,350 kaf). Synthetic fuel development accounts for 233 kaf of new depletions. The annual growth rate in depletions is less than 1 percent, in contrast to U.S. Bureau of the Census (1990) projections of population growth of 1.2, 1.8, and 0.9 percent annually from 1990 to 2010 for California, Arizona, and Colorado, respectively.

Derivation of Total Benefit Functions

Estimation of total (direct) economic benefit functions for consumptive uses requires scaling demand functions to the level (scheduled depletion x_0) of each use, treatment of alternative water supplies, and use of additional data where demand functions are not defined for very low use levels. If the (inverse) demand function given in Equation (1) holds for $0 < x \le x_0$ (and the price elasticity is not inelastic), then the total benefit V(x) of water use x is found directly by integration of Equation (1), giving

$$V(x) = x_0 \, v_0 \, (x/x_0)^{\beta} \qquad (2)$$

where $v_0 = p_0 / (\alpha + 1)$ and $\beta = \alpha + 1$. Equation (2) is typically an oversimplification, however. First, most water users (particularly municipal and energy) have available an alternative water supply source (e.g., ground water). For simplicity, it is assumed that this alternative source is the inframarginal source and that a fixed amount is always utilized. Second, for agricultural water uses, Equation (2) holds only for $x/x_0 \ge 50$ percent of total requests because of limitations in the underlying data. In this case, additional data is needed to complete the integration.

Adjustment for Non-Colorado River Water. If a particular use has water available from a non-Colorado River source, then Equation (2) describes not the benefit from Colorado River use, but instead the benefit from all use. This is shown in Figure 1 where (a) shows the total benefit function V(x) from all sources; the solid line in Figure 1 is a total benefit function for Colorado River use alone, assuming that other supplies are inframarginal. It is desirable to set the total benefit $V_c(x')$ from use of Colorado River water x' to zero for $x' = 0$, as shown in Figure 1(b). Mathematically, the benefit $V_c(x')$ from use of Colorado River water x' is then given by

$$V_c(x') = (x_n + x_0)\, v_0\, \{((x_n + x')/(x_n + x_0))^\beta - (x_n/(x_n + x_0))^\beta\} \quad (3)$$

where x_n is the consumptive use of non-Colorado River water which serves as the inframarginal supply and x_0 is the maximum use (the depletion schedule) for Colorado River water. Note that the total benefit from Colorado River use $V_c(x_0)$ is now implicit in Equation (3) and is given by $V(x_0 + x_n) - V(x_n)$. The demand for Colorado River water is more elastic than the demand from all sources and is non-constant.

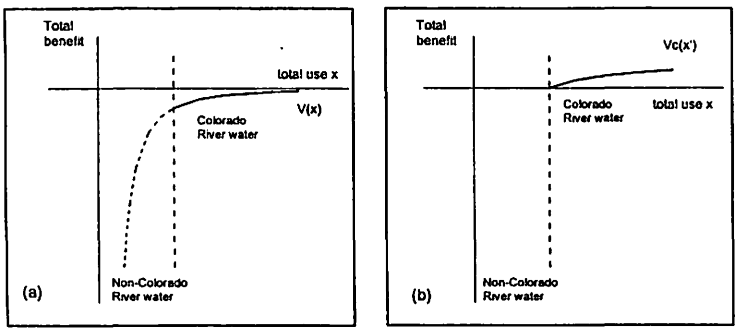

Figure 1. Benefit Function V(x) When Demand is Inelastic for Consumptive Use x from All Sources (a). In (b), $V_c(x')$ is the Benefit Function for Colorado Water Only.

Use of Average Water Use Benefits. It is useful to have an estimate of the total benefit from Colorado River water where (economically feasible) alternatives are not available. Because the agricultural benefit functions given in Table 1 hold only for $x/x_0 \geq 50$ percent, total benefit functions cannot be found solely from Equation (2). For agricultural users, the average benefit of water use $\bar{v}$ in \$/af is available, however. The total benefit $V_a(x)$ of use x can then be expressed as

$$V_a(x) = x_0\bar{v} - x_0 p_0 \int_x^{x_0} (x'/x_0)^\alpha dx' \quad (4)$$

where $x_0\bar{v}$ is the total benefit at full requests x_0, and the integral gives the loss suffered by the irrigator from deliveries below x_0. Evaluating the integral gives

$$V_a(x) = x_0\, (v_0\, (x/x_0)^\beta + \bar{v} - v_0) \quad (5)$$

The marginal benefit functions (Equation 2) and elasticities are not altered by addition of the constant $x_0\, (\bar{v} - v_0)$ to Equation (3).

RECREATION DEMAND

Water-based recreation is an important part of many Westerners' leisure activities, and water-related recreation opportunities draw visitors and tourism dollars to the western United States. Instream flows are vital in preserving fish and wildlife habitat in the arid West and in endangered species restoration. As diversions of water for offstream irrigation and for industrial and residential deliveries have increased, flow levels on many stream systems have decreased to the detriment of instream water uses. The droughts of the 1980s focused further attention on the negative effects of depleted streams and lake levels for recreation, fish, and wildlife.

Measuring Economic Impacts of Instream Flow Protection

Policy makers can make more informed decisions about stream and reservoir management and water allocation if they know the economic benefits provided by a stream system for various activities such as angling and whitewater rafting. Information on the effects of specific changes in water levels also is desirable when considering the economic impacts of drought-induced changes in stream flows and reservoir levels. Since there is limited direct-market evidence on willingness to pay for water-based recreational opportunities and for fish and wildlife preservation, a variety of valuation approaches have been applied to estimate the value of water for these purposes. Marginal benefit functions for recreation can be estimated using information on recreationists' expenditures to travel to and enjoy a water-based recreation site by using the travel costs method (TCM). Alternatively, data can be elicited from recreationists regarding their willingness to pay for recreational use of a river at differing flow levels by using the contingent valuation methods (CVM). The TCM has been used for decades to infer the value that visitors to a recreation area put on the site. The CVM has been refined and applied widely during the past decade to estimate benefits associated with site use and changes in site quality, including changes in flow levels. CVM also is used to measure willingness to pay for preservation that is not associated with actual [illegible] of an area. These non-use values arise as people experience benefits from preserving a site or a species that are not associated with a visit to the site or with viewing the species. Estimation of non-use values, which may be quite large, is outside the scope of this research (see Brookshire *et al.*, 1986; Cummings *et al.*, 1986; and Sanders *et al.*, 1990; for discussions of CVM and non-use values). Cummings and Harrison (1995) discuss the components of non-use values.

Reservoir Recreation Benefits

Although water-based recreation resources provide substantial non-market benefits to users, reservoir recreation has received little attention relative to other water uses. Reservoir operations have been primarily aimed at meeting water demands for consumptive uses and power generation, and few studies have attempted to assess the impacts of reservoir level fluctuations on water-based recreation opportunities.

Use of Basin reservoirs is believed to be a declining function of reservoir content or area. Little empirical work has been done in this area, however. One study by Ward and Fiore (1987) of visitation to New Mexico reservoir sites used the square root of reservoir area as an explanatory variable for observed differences in visitation at different reservoirs. No attempt was made to examine the impact of changes in reservoir levels over time with changes in visitation, however. Simple models of Colorado River Basin visitation data for 1980-1992 did not provide a basis for adopting any specific functional relationship, perhaps because of inadequate representation of substitute sites or because of limited reservoir fluctuations over a time period of increasing demand for recreational opportunities (and changes in reporting procedures). We have assumed, for purposes of this study, that visitation at each Basin site declines as the square root of the volume of each reservoir but that use benefits for each visitor are unchanged as reservoir level changes.

Annual visitation to seven Colorado River Basin reservoirs is estimated at 17 million visitor days, based on data provided by the Glen Canyon National Recreation Area (Gediman, personal communication, 1993) and the Lake Mead National Recreation Area (Warner, personal communication, 1993) and supplemented by the Upper Colorado River Commission (1992). Visitors typically engage in boating, fishing, and swimming. The economic benefits received by visitors to Basin reservoirs were estimated using existing studies of use values at specific Basin reservoirs supplemented by a literature summary (Walsh *et al.*, 1988). An average visitor day value for each reservoir was developed using separately calculated values for fishing and all other uses. The average recreational value per visitor day at each reservoir was then found as the weighted sum (weights based on data from Gediman and Warner) of values from each activity. Data sources and recreation visitor day values at Basin reservoirs are summarized in Table 3. In many cases alternative estimates of visitor day values are available for specific sites [e.g., Johnson and Walsh (1987) for Blue Mesa reservoir] which give similar values per visitor day to those reported here. In all cases the final estimated values are similar to the averages reported by Walsh *et al.* (1988).

Free Flowing Reach Recreational Benefits

Recreational use for fishing, boating, and hiking on free flowing reaches (defined here as those not impounded by reservoirs) of the Colorado River mainstem and tributaries also provides economic benefits to users. Because comprehensive data on the dependence of use levels and economic benefits to users on river flows is limited, this study only provides benefit estimates for use between Glen Canyon Dam and Lake Mead.

Recreation below Glen Canyon Dam is dominated by day users rafting and fishing in the relatively calm reach 15 miles below the dam and above the Lees Ferry boat launch, and by multi-day whitewater rafting trips through the Grand Canyon. A study commissioned by the Department of Interior (Bishop *et al.*, 1989) as a part of the Glen Canyon Environmental Studies (a multi-agency study effort providing information on the impacts of Glen Canyon Dam operations) indicates that benefits generated by whitewater rafting and fishing (day use) are significantly influenced by river flow levels. The study used the CVM and found that benefits per fishing day reach their peak of $51/visitor day at a constant flow level near 10,000 cubic feet per second (cfs) and that fluctuations in flows (which occur when peaking hydropower is generated) cause a decrease in fishing benefits. For comparison, Richards and Wood (1985) found fishing benefits at Lees Ferry of $170/visitor day in a TCM study. Fluctuations in flow levels also have a negative impact on benefits experienced by whitewater rafters, with relatively high steady flows (around 30,000 cfs) generating maximum benefits of $122/visitor day for whitewater boaters. Using the findings of Bishop *et al.* (1989) quadratic equations with total benefits V (in $/visitor day) expressed as a function of river flows Q (in kaf/year) were fit to the point estimates of use values:

TABLE 3. Annual Economic Benefits of Flatwater Recreation at Basin Reservoirs (1992 dollars).

Reservoir	Visitation (million/year)	Fishing ($/day)	Weight	Other ($/day)	Weight	Total ($/day)
Flaming Gorge	1.65	12.04[1]	0.5	21.21[2]	0.5	16.63
Curecanti Unit	0.78	29.22[3]	0.4	21.21[2]	0.6	24.41
Navajo	0.59	29.22[3]	0.4	21.21[2]	0.6	24.41
Powell	3.20	29.22[3]	0.2	24.21[4]	0.8	25.21
Mead	6.76	30.17[5]	0.2	36.16[6]	0.8	34.96
Mohave	2.05	30.17[5]	0.2	36.16[6]	0.8	34.96
Havasu	1.99	30.17[5]	0.2	36.16[6]	0.8	34.96

[1]Oster *et al.* (1989).
[2]Average of picnicking and swimming values (Rocky Mountains and Southwest) reported by Walsh *et al.* (1988) (Table 4).
[3]Average of flatwater fishing values reported by Gordon (1970), Sorg *et al.* (1985), and Ward and Fiore (1987).
[4]Average of motorized boating values for California given by Wade *et al.* (1988) and picnicking and swimming values reported by Walsh *et al.* (1988).
[5]Value for general anglers at Lake Mead reported by Martin *et al.* (1982).
[6]Motorized boating values on Lake Havasu given by Wade *et al.* (1988).

$$V_{fishing}(Q) = 23.6 + 5.76 \times 10^{-3} Q - 2.69 \times 10^{-7} Q^2 \quad (6)$$

$$V_{rafting}(Q) = -12.3 + 11.4 \times 10^{-3} Q - 2.41 \times 10^{-7} Q^2 \quad (7)$$

R^2 for Equations (6) and (7) were 0.99 and 0.98, respectively. Total benefits in each activity are found by multiplying the per visitor day benefits by 15,000 and 169,000 annual visitor days for day use fishing and multi-day rafting, respectively.

The focus on this single reach (located mostly within Grand Canyon National Park) likely results in a serious underestimation of the total instream use values in free flowing reaches. For example, visitor days on the single reach for which we estimate benefits total about 175,000 annually, while data provided by Rosene (Bureau of Land Management, Upper Colorado River District Office, Kremmling, personal communication, 1993) and Von Koch (Bureau of Land Management, Moab District Office, personal communication, 1993) identify over 130,000 visitor days on raft trips in the Westwater, Desolation Canyon, San Juan River, and Upper Colorado River reaches, half as part of multi-day trips. Day trips to raft Westwater Canyon on the Colorado River mainstem are valued at over $200 per trip by using TCM (Bowes and Loomis, 1980). Fishing and shoreline uses are also important throughout the region. For example, an individual's willingness to pay ranges up to $60/day [estimated by Daubert and Young (1981) using CVM] for fishing on the Cache la Poudre, an eastern Colorado mountain river affected by Basin water exports. Flow levels are important: anglers' and shoreline users' aggregate marginal benefits from additional flows range from $23 and $6/af, respectively, at relatively low flow, but are negative at high flow levels. Because such data on the relationship between instream flows and recreation values in Basin reaches is very limited, however, no further benefit functions are developed.

HYDROPOWER

Instream flows, largely from reservoir storage, produce hydroelectric power at a number of Basin dams. Estimates of the marginal value of generated hydropower were prepared based on the avoided cost of alternative thermal energy production. Hydropower production occurs during base and peak load periods, displacing base load (primarily coal and nuclear) facilities and peak load (primarily gas turbine) facilities, respectively. Because the cost of peaking production is typically significantly greater than for base load production, hydropower plants are often operated to maximize total production during peak periods.

Hydropower production in the Lower Basin during peak load periods is largely constrained by plant capacities. The physical effect of marginal decreases in water flow is then dominantly a decrease in base load production, with peaking production unchanged. The marginal value of Lower Basin hydropower is conservatively valued at the avoided cost of base load production at thermal facilities.

Upper Basin hydropower production is modeled after the preferred alternative given in the 1995 Final

Environmental Impact Statement on operation of Glen Canyon Dam (U.S. Bureau of Reclamation, 1995). Under the "Modified Low Fluctuating Flow Alternative," base and peaking releases are effectively constrained by a maximum allowable daily flow fluctuation. Marginal reductions in total flow thus reduce both base and peaking production. Because base and peaking periods are roughly equal in length (Harpman *et al.*, 1994), Glen Canyon hydropower can be valued at the mean avoided cost of base and peaking period alternatives. Other Upper Basin hydropower is valued similarly.

Generation costs for base and peaking periods for each Basin are taken from Booker and Young (1991). Only operations and maintenance costs were used given the presence of substantial underutilized thermal capacity serving the market for Basin hydropower. As an approximation to modeling operation of generation and transmission through a complex, interconnected grid in replacing hydropower generation (U.S. Department of Energy, 1994), the most costly 50 percent of total installed capacity serving the Upper and Lower Basins was used as the basis for these avoided cost calculations. Costs of operating Basin hydropower facilities were not determined, though they are both small (e.g., maintenance costs for investor-owned utilities reported by U.S. Department of Energy (1992) are 2.8 mills/kwh) and to some extent independent of the total level of hydropower production (and hence do not contribute to marginal costs). Net marginal benefits of hydropower production based on avoided cost and operating expenses were estimated at 52.4 and 46.9 mills/kwh for the Upper and Lower Basins, respectively.

Net benefits in units of instream flow (i.e., $/af) are found by calculating total energy production using

$$E = k\,h\,Q\,\eta \qquad (8)$$

where h is the hydropower head (in feet), k is a constant 1.02353 kwh/af/foot of head, Q is the total instream flow (excluding spills, in af), and η is the system efficiency for electric generation. Efficiency was estimated at 0.9 for all Basin reservoirs, while the hydropower head depends directly on reservoir conditions. Table 4 gives the net marginal benefits of instream flows estimated under the typical Basin conditions characterizing the first nine years of a particular drought sequence (Booker, 1995).

CONVEYANCE COSTS

Marginal conveyance costs are dominated by the energy costs of pumping lifts required to deliver Basin water to southern California municipal uses, Central Arizona, and several smaller users. Energy costs are estimated by the marginal costs of Basin electrical energy production. Following the approach to valuing hydropower production, the operation and maintenance cost of thermal sources is used to value energy usage. Again, the most costly 50 percent of installed capacity is used as the appropriate measure of marginal costs. Flow-related maintenance expenses estimated for hydropower production are utilized for non-energy marginal operation and maintenance costs. Such expenses would result primarily from maintenance of pump motors and turbines. Valuing conveyance costs from such a national economic perspective gives marginal costs for pumping of water for agricultural uses ranging from $10/af for Navajo Indian Irrigation Project users to $87/af for CAP. Municipal conveyance costs were estimated at $107/af for MWD users and an average $123/af for CAP users.

TABLE 4. Annual Economic Benefits of Instream Use at Basin Dams and Reservoirs. Year 1 of severe and sustained drought simulation (Booker, 1995) (1992 dollars).

Dam and Reservoir	Hydropower Benefits: Total ($ million)	Hydropower Benefits: Marginal ($/af)	Recreation Benefits: Total ($ million)	Recreation Benefits: Marginal (annual $ per af of storage)
Flaming Gorge	18	19.8	23	8.7
Curecanti Unit*	109	45.2	17	19.5
Navajo	24	17.0	12	10.0
Glen Canyon Dam/Lake Powell	223	26.3	71	3.7
Hoover Dam/Lake Mead	201	23.6	199	10.4
Davis Dam/Lake Mohave	46	5.8	72	39.6
Parker Dam/Lake Havasu	23	3.3	70	112.4

*Composite of Morrow Point, Blue Mesa, and Crystal Dams.

SALINITY DAMAGES

Colorado River salinity first became a major issue when irrigation return flows from the Wellton-Mohawk division of the Gila Project in Arizona resulted in water deliveries to Mexico with concentrations as high as 2,700 mg/l (Miller *et al.*, 1986). Construction of a drainage canal to the Gulf of California reduced concentrations in Mexican deliveries to near those used by Arizona and California irrigators, but drainage water could no longer be included in the 1.515 million acre-feet delivered annually to Mexico. Salinity in Colorado River water is believed to cause substantial damage to United States municipal and agricultural water users as well. Indeed, with the recent completion of the Central Arizona Project delivering municipal supplies to Phoenix and Tucson, an additional 2.5 million water users are now potentially affected by Colorado River salinity.

Damage estimates are problematic, however, given the differing composition of mineral constituents at different locations and the long time period over which damages are believed to occur. One set of damage estimates presented by Booker and Young (1991) is used here to provide an estimate of salinity damages to municipal and agricultural users. Constant marginal damages over time are assumed. The municipal damage estimate is based on the single household damage estimate of $0.26 per mg/l (1989 dollars) given in Booker and Young (1991). Assuming two households per acre-foot of water use, damages are $0.558/mg/l/af expressed in 1992 dollars. Municipal damages are assumed for Las Vegas, CAP (municipal), and MWD users. Agricultural damages are based on producer income differences in linear programming models of Imperial Valley (California) agriculture at 800 mg/l and 1100 mg/l salinity (Booker and Young, 1991). Salinity damages from full water deliveries to 50 percent reductions are within 10 percent of the average value of $0.0378/mg/l/af (1992 dollars). The latter is used to estimate damages to agricultural water users in Arizona and California.

While these damage estimates are typical of those used by other researchers, they should be regarded as preliminary. For example, the municipal damage estimate suggests damages of $130/af from use of Colorado River water based on salinity concentrations of 675 mg/l in Colorado River water and 415 mg/l in an alternative supply. Coupled with high conveyance costs for some uses, this suggests small net marginal benefits from Colorado River water use in several cases. The recent negative public reaction to introduction of Colorado River water in Tucson supports this view, as does the reluctance of central Arizona farmers to use CAP water. Nevertheless, unabated efforts to secure additional Colorado River supplies by southern California and southern Nevada suggest that water providers will accept salinity damages when they lack alternative cost effective water sources.

CONCLUSION

The economic benefit and cost estimates for offstream and instream water use provided in this article encompass all major water uses in the southwestern United States. The estimates provide a basis for policy decisions affecting southwestern United States water users and for policies governing the Colorado River, which currently are the subject of intense political negotiations and debate. In providing benefit estimates across a wide variety of competing uses, the inevitable tradeoffs in allocating water resources across the Southwest are clarified. The economic impacts of drought reported by Booker (1995) and Henderson and Lord (1995) elsewhere in this issue explicitly address tradeoffs exacerbated by the presence of drought.

Despite our focus on the dominant economic impacts of regional water use, these benefit estimates do not include non-use values. Hence significant environmental values not based on direct resource use (e.g., protection of endangered species) are not addressed. Second, indirect economic impacts of water use are not considered. Total regional economic impacts could thus significantly exceed the direct economic impacts calculated based on our benefit estimates. Finally, benefit estimates in every offstream and instream use contain large uncertainties and are subject to continued refinement as additional data becomes available. Nonetheless, the estimates given here are based on detailed research covering the value of water in both offstream and instream uses, and they provide a reasonable starting point for reconciling the competing needs of these alternative water uses.

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CARP

p .82 "Pumping energy is used in transporting surface water, and in lifting groundwater and pressurizing distribution systems. According to physical principles the minimum amount of work (energy) required to lift one acre-foot of water a height of one foot is 1.024 kwhs. the actual requirements in practice are more like 1.7 to 2 kwhs." For surface water projects the actual cost of pumping alone exceeds the price of water which is economical for forage, small grain, and irrigate pasture.

Source: Mark N. Christensen, Glenn W Harrison, and Larry J. Kimbell (1982) Energy in Competition For California Water; Alternative Resolutions, (Ernest A. Engelbert and Ann Foley Scheuring, eds., (1982); pp. 76 - 97, University of California Press, Berkekey, California, 208 pages.

Alternative Resolutions
E. Engelbert and A. F. Scheuring Eds

(wind-electric) or small incremental amounts of water (industrial co-generation, small-scale hydro-power at existing dams).[11]

While debate on energy policies for California has been bitter and divisive for a number of years, a new and very different perception of the problem and tentative consensus on general directions for both private choices and public policies has emerged. Given the magnitude of the implications of that change, the shift has come about in a remarkably short time. With a slow rate of increase in demands and emphasis on diverse sources (in smaller increments that have short lead times to put in place), supplies can be adjusted to demands as they develop. The former strategy (increases in supply in large increments to satisfy rapid increases in demand) required major political and economic commitments (e.g., power plant siting) to be made decades in advance. It was then thought that a set of inexorable and inevitable increases *must* be planned for. It is now clear that there has never been an adequate methodology for long-range forecasting of demands—that the seemingly urgent imperatives of those anticipated increases in demand reflected the conventional wisdom and subjective preferences of the experts and institutions doing the planning, rather than the actual dynamics of the economy and society. Long-range planning for water, rooted in long-range forecasts of demand, rests on similarly shaky ground. Under changing circumstances, especially rising costs of new supplies, demands are very likely to depart from patterns of the past.

Energy Used in Water Supply

Energy is used to move water, to treat water prior to use, and to treat wastewater prior to discharge. The energy requirements of these processes have been described previously.[12,13,14] Average energy requirements for California water supply systems are listed in Table 2. Here we briefly review salient results and then focus on implications for costs in particularly sensitive sectors.

Pumping energy is used in transporting surface water, and in lifting groundwater and pressurizing distribution systems. According to physical principles the minimum amount of work (energy) required to lift one acre-foot of water a height of one foot is 1.024 kwh. Actual requirements in practice are more like 1.7 to 2 kwh. Average pumping requirements, and expected costs, of various water projects are shown in Table 2. For surface water projects the anticipated costs of pumping energy alone exceed the price for water that is economical for forage crops, small grains, and irrigated pasture in 1980.[15] Declining-block pricing structures for electricity formerly created an incentive for groundwater overdrafting because it was then cheaper per unit to lift larger quantities of water. New inverted-block rate structures for electricity will remove that incentive and should help mitigate the problem of groundwater overdraft.

The importance of energy costs for the extent of groundwater overdraft has been emphasized recently by Noel and others,[16] who constructed an optimal control model of the allocation of groundwater and surface water among agricultural and urban uses. Applying their model to Yolo County, California, they show that:

> Energy costs can have an important influence on whether the model indicates a groundwater basin with an increasing or decreasing water table. For example, Upper Cache-Putah basin would be mined under a 2.6 cents [per kwh] energy cost assumption but would have a rising table under the 8 cents [per kwh] energy cost assumption. The

← Energy in pp. 76-97
Christensen M. N.
Harrison G. W.
Kimbell L. J.

Table 2

Energy Requirements for California Water Supply

Estimated average energy requirements per acre-foot for California water supply in 1972, and anticipated costs under alternative energy cost projections (in 1981 dollars).

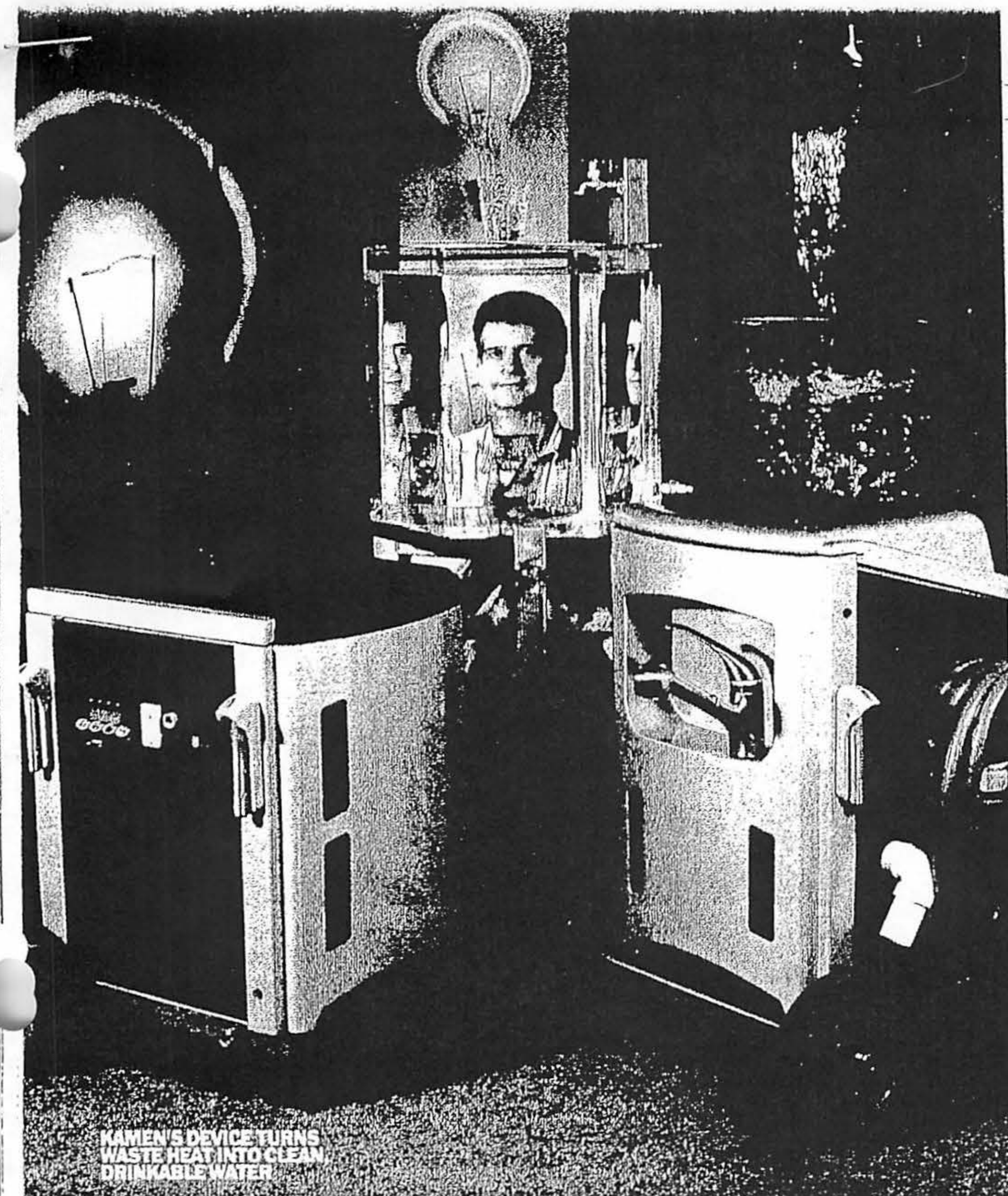
		$/Acre-Foot at	
	kwh/Acre-Foot	8¢/kwh	16¢/kwh
Pumping Energy			
Total water supply	270 (+)	$20 (+)	$40(+)
State Water Project	1600	128	256
Central Valley Project	350 (+)	28 (+)	56 (+)
Colorado River Aqueduct	2075	166	332
Groundwater	275	22	44
Water supply to farms			
State Water Project	625	50	100
Central Valley Project	340	27	54
Colorado River Aqueduct	2075	166	332
Groundwater	225	18	36
Municipal Water Treatment			
Prior to Use	30-135	2.40-11	5-22
Wastewater Treatment			
Municipal			
Primary and secondary	250 (+)	20	40
Tertiary	1000 (+)	80 (+)	160 (+)
Agricultural	various	?	?

> remaining basins [in Yolo County] move in the same direction . . . at alternative energy cost assumptions. In those basins where groundwater use exceeds recharge under a 4.5 cents energy cost, the effect of higher energy costs is to slow down the rate of mining.

These results illustrate the possible role of energy costs in California's water situation.

Municipal water treatment uses energy in the course of aeration, flocculation-sedimentation, filtration, chlorination, and softening, and increasingly will use treatments by activated carbon. Wastewater treatments use energy for pumping and chemicals. Anticipated energy costs for tertiary treatment of municipal wastewater are comparable to the cost of supplying the water in the first place. Agricultural wastewater treatment projects for the San Joaquin Valley and the Imperial Valley will also use substantial quantities of energy.

In addition to energy used in operating water treatment processes, outlined above, energy is also embodied in the facilities for supplying and treating water. Rising costs of energy are a significant factor not only in operating water supply systems, but also in constructing new facilities. The costs for construction of facilities for storage, transport, and treatment are soaring. The rising energy costs


KAMEN'S DEVICE TURNS WASTE HEAT INTO CLEAN, DRINKABLE WATER

JASON GROW FOR TIME

RUNNER-UP

water purifier

Thousands die every day for lack of clean water. Can the man who invented the Segway save them?

BY LEV GROSSMAN

AT THIS POINT DEAN KAMEN IS used to being called naive. "I'm getting neurotic about people overhyping things," he says, "so let me tell you what it *doesn't* do." Kamen's caution is understandable. He invented the overpublicized, underperforming superscooter known as the Segway—and was responsible for some of that hype. So when it comes to his latest invention, a low-cost, low-power water purifier designed for the Third World, he wants to be clear: he has no idea how to market it or get it to the people who need it. He just knows it works.

What it does is simple. A few years ago, Kamen was working on an electric generator for use in underdeveloped villages when he noticed that it produced about 1,000 watts of waste heat. Kamen decided to try to use that heat to make clean water. There are 6,000 deaths from contaminated water every day, according to the U.N., and safe water is one of the world's more urgent problems. Kamen's device uses that extra heat to distill water—boil it and condense it. Nothing new about that—Kamen has invented lots of things, but he didn't invent distillation. The trick is to do it using as little energy as possible. However, 1,000 watts of heat won't boil much water, so Kamen developed a closed system, powered by whatever fuel is at hand, that traps the energy released when the boiled water vapor recondenses. Essentially, he's recycling heat. Result: a low-power, low-maintenance device that will cost around $1,000 to manufacture and makes 10 gal. of drinkable water an hour.

Kamen knows major health organizations probably won't buy into unproved technology, so he's taking his invention on the road. He's exploring distribution strategies in Bangladesh, and later this month he'll head to Africa to meet with Rwanda's President. He knows he has a lot to prove. "I have no credibility," he admits. "We have to get them in the field and document that they work." He believes, perhaps innocently, that he can save a lot of lives. Sometimes when you want to change the world, it helps to be a little naive. ■

No page number - about page 65

engines cost about $3,000 to manufacture and more research is needed to bring the cost of fuel cells down to that level.

Can I use a fuel cell to power my home?

Fuel cells are ideal for power generation, either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines. Since fuel cells operate silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be used to provide hot water or space heating.

There are three main components in a residential fuel cell system - the hydrogen fuel reformer, the fuel cell stack and the power conditioner. Many of the prototypes being tested and demonstrated extract hydrogen from propane or natural gas. The fuel cell stack converts the hydrogen and oxygen from the air into electricity, water vapor and heat. The power conditioner then converts the electric DC current from the stack into AC current that many household appliances operate on. Fuel Cell Technologies Ltd. (FCT) estimates the expected pay back period on a residential fuel cell for a typical homeowner to be four years. The initial price per unit in low volume production will be approximately $1,500 per kW. Once high volume production begins, the price is expected to drop to $1,000 per kW, with the ultimate goal of getting costs below $500 per kW. Fuel cell developers are racing to reach these cost targets.

H Power is joining forces with energy companies all over the world, and has signed an $81 million contract with Energy Co-Opportunity (ECO), a consortium of rural electric cooperatives, to market its fuel cells exclusively through more than 900 cooperatives. ECO has agreed to buy 12,300 of H Power's 10kW fuel cells for $10,000 each, with installation to start in the second half of 2001. The two companies are working to manufacture and ship units to power-starved California within the next several months, for about $8,000 per unit. Prices are expected to drop to between $3,000 and $4,000 in seven years.

Plug Power and GE MicroGen have joined to form GE Fuel Cell Systems, LLC, and are building a network of qualified regional distributors to market, install, and service their residential fuel cell. A public utility has already agreed to purchase 75 of Plug Power's first fuel cell systems, a $7 million agreement, commencing this summer. The HomeGen 7000 is capable of serving an entire household's energy needs. Several different commercial models are going to be introduced that can operate on natural gas, propane, or methanol and are expected to achieve 40% electrical efficiency. Excess heat generated by the fuel cell can be captured and used for hot water or heating, increasing overall efficiency to over 80%. GE has signed an exclusive distribution agreement with New Jersey Resources for deployment of the fuel cells in New Jersey and DTE Energy Technologies will distribute these units in Michigan, Illinois, Ohio and Indiana. KeySpan Technologies has signed on as well to purchase and test 30 fuel cells at selected locations in New York City and Long Island.

Global Thermoelectric Inc., a solid oxide fuel cell (SOFC) manufacturer, has developed a 2.3 kW residential fuel cell system that is designed to cover the base load of an average North American home. The first prototype, running on natural gas, has been delivered to Enbridge Inc., who will be testing the system to evaluate performance characteristics including heat recovery to meet residential hot water needs. The results of the testing will be incorporated into subsequent prototype designs.

A1 pt. Negotiations between New Mexico and Texas over NM pay back of ~~326,000 ac ft~~ 340,100 ac ft of water not delivered to Texas over 10 year period.
N.M. made cash offer of between 3.4^m and 10.2^m
Texas feels water priceless
Water debt established by water referee are violations of Pecos River Compact over 34 years
A3 N.M. offer is between $10 and $30 per ac ft. to be paid from irrigation works account
Range is difference of opinion on value of water to Texas $10 and to N.M. $30.
Delivery of water would devastate agriculture
N.M. says cause is natural - 170 ft NM [illegible] it says.
Source: Ward, Leah B. (1986) ~~Give U.S.~~ Give Us Water, Not Your Cash Texas Tells N.M.
Albuquerque Journal (North) Nov 11, 1986, pp. A1 and A3

p19 City of Santa Barbara building municipal desalinization plant (biggest municipal desalinization plant in the country) to be completed in 1992, to deliver 2,500-10,000 acre feet yearly (city to decide how much in 1991). Water will cost $1900 an acre-foot. Currently City paying $200-300 per ac-ft. During 1st 5 years price of water to be cut in half. Then reduced further when City owns plant. Plant being built by Ionics of Watertown, Mass.
Metropolitan Water District [L.A. area] agreed to pay 100^m to Imperial Irrigation District to line more than 300 miles of main and secondary canals. In exchange MWD for 35 years will keep 100,000 ac ft that will be lost to seepage
Source: Mitchell Gordon (1990) How Dry They Are; Effects of California's Drought Ripple Far and Wide, Barrons, November 26, 1990, pp 18, 19, 43.

from over

p.19 Aim is to offset almost 650,000 ac ft of Colorado River water MWD to relinquish to Arizona

To take effect in 2 years; MWD uses 1.2 m ac ft of water each year now.

Los Banos Grandes near Modesto - 2.0 m ac ft reservoir for $800 m to yield 260,000 ac ft per year.

Kern Water Bank project - percolation ponds for underground storage - add up to 300,000 ac ft at cost of $85 m

B of Rec - Central Valley Project water still at $3.50 per ac ft - a subsidy. 40 year contracts being renegotiated in 1980's for $16.50 per ac ft.

CARP → Even with pumping farmers are not paying over $90.00 an ac ft compared with $400 per ac ft commonly charged urban users.

• 10% cut in ag water use results in 50% increase of urban supply.

Source - Barrons 26 Nov 90 p 19 over

Consumptive Water Use Totals in acre inches for Arizona Crops 1982

Alfalfa 74 — Late Grapes 20

Cotton 41 — Late Cantaloupe 20

Lettuce 9

Bermuda Grass Lawn 44 — from Conservation Research Report 29 USDA, Ag Research Service May 1982

Sorghum 25

Barley 25

from: Gerri Miller and Bradley R. Cardon
What Farmers Can Do For Themselves
in Water Scarcity, Engelbert E.A. Ed. (1984) U. of Calif. Press

Good book

p 8 Ventura Calif. dateline for San ~~Buenavista~~ Buenaventura coastal town northwest of Los Angeles asked in vote its citizens whether to (1) hook up to State Water Project at $823 per acre foot or (2) construct desalination plant at $1,924 per acre foot. Voted for desal. project to maintain independence. Size of project is 7,000 ac ft. per year. Ventura now uses 24,000 acft. – reclaims waste water for golf course, commercial landscapes, medians on highway
Source: U.S. Water News, Anon 1993 January, "Ventura Seeks Desal[?] Independence", p8.

C. Ariz. Project may require a 2nd mortgage

PHOENIX, Ariz. — With some unsolicited help from a Congressional oversight committee, active participants in the beleagured Central Arizona Project (CAP) are grappling with the tough issues of what to do with surplus Colorado River water delivered by the canal, and how to pay to the federal government the $4.7 billion cost of the project, the most costly ever built by the Bureau of Reclamation.

After a one-year reprieve, users of the CAP began making payments on a 50-year mortgage for the project in January. But serious questions have been raised by the General Accounting Office over whether Arizona users will be able to pay their $2-billion share of the project's cost. Usage of CAP is running only about a third of the canal's capacity of some 1.5 million acre feet a year, largely because irrigators are continuing to use groundwater that is available for about half the cost of CAP water.

New report cites less urgency for desalination

VENTURA, Calif. — A proposal by this coastal city to build a seawater desalination facility attracted considerable attention a couple of years back, but a recent report concludes that Ventura will not need a supplemental water supply source in the foreseeable future. Water conservation and groundwater banking have forestalled the need for the desalination plant, the report says, while a water supply model suggests that Ventura might need an additional water supply sometime beyond the year 2010.

"Water conditions have changed since the last water supply overview was prepared two years ago," said Glenn McPherson of Boyle Engineering Corp., which prepared the water supply forecast for the City of Ventura. Water demand is returning to non-drought levels slower than anticipated, said McPherson, due largely to the community's ongoing commitment to water conservation programs. In addition, he noted, groundwater supplies have risen significantly over the past two years, with the city's Fox Canyon Aquifer Groundwater Management Agency bank providing a drought reserve of some 10,000 acre feet.

"Perhaps the most positive conclusion is that the city, in all probability, won't need a supplemental water source in the immediate future, meaning the next 15-plus years," McPherson stated. While modeling indicated that Ventura won't need a supplemental water source in the near term, "it is possible there will be a demand for a drought-proofing supplemental water supply of up to 7,000 acre feet sometime beyond 2010," he added.

Despite the lack of immediate urgency, the report recommends that Ventura continue to pursue its plans for a seawater desalination facility together with Southern California Edison. Boyle Engineering determined that the city's ocean outfall could be rehabilitated for use as an intake facility, and that brine generated by desalination could be conveyed to an existing Southern California Edison outfall.

The estimated cost of the desalinated supply ranges from $1,700 to $1,800 per acre foot, McPherson pointed out. "Compare that to constructing a 3,000 acre feet per year facility within the city," he said, "which would take an estimated capital outlay of $36 million, with a total unit cost of $2,400 per acre foot."

SCE also ← involved

:ven more impressive is r's ability
:twork a Mac with Wind s or serv-
This capability doesn't require Rendez-
, which isn't used today by Windows.
:ad, Apple built into Jaguar a key tech-
gy Microsoft uses for networking in Win-
s and made it work simply, without re-
ing a user to know about networking.
tested this by placing the iMac, the
erBook and a Toshiba laptop running
dows XP on a table within range of my
e wireless network. After less than 10
utes of fiddling with file-sharing and net-
king settings on the three machines,
popped up on the other's lists of avail-
computers on the network.

ITH THE MACS, I was able to peer into the Toshiba hard disk, open fold-
and copy or use files—all without addi-
al software. I opened, on the Mac, a coin-
graphics file stored on the Toshiba hard
. I opened, on the Toshiba, Microsoft
d documents stored on both Macs. Using
Windows PC, I played a song stored on
iMac. I copied files in every direction. It
worked quickly and smoothly.
This is a big deal, because it should
ke life much easier for people who use
cs in workplaces dominated by Windows.
Also in Jaguar is a new kind of Internet
gram that directly accesses information
want on the Web without requiring you
se a browser. Called Sherlock 3, this pro-
m allows you to check out stock prices,
ht schedules, movie show times and
ghborhood businesses quickly, and with-
having to navigate Web pages.
It fetches the information automatically
l displays it in a rich manner. For exam-
, flights en route are illustrated with maps
wing their general progress. Movie show
es include a video trailer. Local business
ings include maps and driving directions.
Finally, Jaguar's built-in e-mail program
v contains an intelligent, automated anti-
m feature you can train over time to
k very well. In my tests, it wasn't per-
t, but it caught about 95% of the spam
t came in during a week. Not bad.
Oh, and one other thing: In stark con-
st to Microsoft's practice with Windows,
ple is introducing family pricing for Jag-
. The company will sell for $199 a family
sion that can be legally installed on up
five computers.
Jaguar is a big step forward for the Mac,
l continues the effort to differentiate Ap-
's operating system from Windows XP. In
view, it's worth the price.

E-mail me at mossberg@wsj.com.

By STEPHANIE FAYLER

WILL A LITTLE PRIVACY lure big spenders back to Vegas?

Two top Las Vegas casinos are readying luxurious closed-door gaming rooms, the first such private areas since Nevada legalized gambling in 1931. The casinos are betting these salons will bring back celebrities and international high rollers, who have recently shunned the Strip.

MGM Mirage Inc.'s MGM Grand and Park Place Entertainment Corp.'s Caesars Palace each plan to open private gambling rooms in the fall. Such salons had been illegal in Nevada, where state law requires gambling to be public and accessible to regulators. But in 2001, the Nevada legislature heeded the cries

... require private salons to o around-the-clock video surveillance cameras, so that regulators in their offices can observe the play in real-time.

Private gambling is the most deliberate effort so far by U.S. casinos to harpoon more "whales," players with $500,000 in cash or credit who fuel casinos' lucrative high-end games, where betting starts at $500. The Strip has been losing international whales for years to private casinos in burgeoning gaming markets such as Macau, Australia and elsewhere in Southeast Asia. For Caesars Palace and the MGM casinos, where high-end play contributes as much as 25% of revenues, overseas competitors have made the game even more volatile and risky.

Whales nearly disappeared from the Strip after Sept. 11 brought travel complications; with the stock market sputtering, they are staying away. Bear

Undaunted, the MGM Grand is still hunting whales. It is remodeling its Mansion Casino wing and expects to start offering private gambling there in September. Among the changes: thick doors to keep oglers out. (Casino executives note, however, that even in high-roller rooms open to the public, ordinary patrons have usually felt too intimidated to drop in and watch.) The area will have a hallway leading directly from high-roller hotel suites to private gambling rooms—eliminating the need for big spenders to pass through public spaces on their way to play.

Caesars Palace, meanwhile, expects to win approval next month for private salons. It plans to add doors to rooms in a high-roller tower that it opened late last year, in anticipa-

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family photo albums, ne messages and offer-ing services such as free e-mail and friendly betting pools. Although Web access and literacy is limited in many of Mexico's small towns, Internet activity is starting to catch on because it is such a fast and cheap way for people to stay connected.

"People use this as a way of keeping in touch with their roots," says Mr. Durán, who taught himself computer programming to launch Jalpazac.com two years ago.

Totatiche.com, centered on a town in the Jalisco state of the same name and created by José de Jesús Félix, a building-maintenance worker in Mill Valley, Calif., keeps its natives in the U.S. abreast of their village's latest projects, including a 19-foot-high statue of San Cristóbal Magallanes, the town's patron saint. At

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From Toilet to Tap: California Project Purifies Sewage Water

Backers Concede a 'Yuck Factor' But Call Process Safe, Essential; Critics Cite Cost, Quality Concerns

By JIM CARLTON

FOUNTAIN VALLEY, Calif.—Engineers in this arid region have a controversial solution for water shortages: Reuse the water that is flushed down toilets.

"There is a yuck factor, but we explain to people the quality of water will end up being actually higher than what we already use," says Ron Wildermuth, spokesman for the Orange County Water District. That agency is collaborating with the Orange County Sanitation District to build a $600 million sewage-purification system. When completed over the next 20 years, the system is expected to be the largest of its kind in the world.

Boosters of the project for Orange County, a suburban metropolis in the shadow of Los Angeles, say the new system will bring the waste water up to drinking-water standards. After treatment, the sewage water will be pumped into an immense groundwater basin that serves the drinking and household needs of about two-thirds of the county's three million residents. Orange County officials say the treated water is likely to be enough to slake the thirst of the 600,000 new residents projected for the area over the next two decades.

Proponents of the project say the timing couldn't be better: Water supplies imported into Southern California are set to decline precipitously over the same

A Growing Need

Supply and demand for the Metropolitan Water District of Southern California, in millions of acre-feet:

Note: Demand data assume conservation goals are met. The service area includes Los Angeles and Orange, Riverside, San Bernardino and Ventura counties.

*Includes water only from Colorado River and Northern California.

Source: Metropolitan Water District of Southern California

time, as Arizona and other states take a higher share from the Colorado River under court agreements. "This is indeed state-of-the-art and will make another resource available for a water-short area," says Harvey Collins, former chief of drinking water for the California Department of Health Services.

Underpinning the project is a technology called reverse osmosis, which passes unclean water through a porous, plastic membrane filter that removes viruses and other materials. Reverse osmosis is already being used on a much smaller scale to treat sewage water for limited drinking and industrial use in Los Angeles, Scottsdale, Ariz., and Singapore.

In other locales, sewage-purification projects have been stymied by opposition. Three years ago, San Diego killed a plan to use reverse osmosis to upgrade sewage to drinking water after critics worried about quality. More recently, in the suburban Castro Valley near San Francisco, environmentalists and their supporters derailed a plan to pump treated sewage water into a local groundwater basin. Opponents argued the extra potable water would help fuel runaway growth in the area.

In Orange County, critics have pilloried the so-called groundwater-replenishment system over both quality and cost concerns. The quality issue was highlighted earlier this year when water-district officials discovered trace amounts of the chemical 1,4-dioxane, a suspected carcinogen, in water that the agency had already run through reverse osmosis. That process has been used for some time in a separate operation to cleanse sewage water intended to be reinjected in the ground as a buffer against ocean water. But agency officials say somehow the dioxane got through—ironically, from a maker of plastic membranes used for reverse osmosis situated farther upstream.

"The episode just reinforced my concern that the water officials need to be sure they cover all chemicals going through this system to prevent any surprises," says Jack Skinner, a retired internist who serves on a scientific advisory panel evaluating the county's water quality.

The dioxane levels turned out to be too low to warrant any cleanup action. But water-district officials say they resolved to prevent any future problems by adding more decontaminant chemicals to their cur-

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INSIDE

The Wall Street Journal 15-Aug 2002 /B1

[illegible] Jalpazac.com and an attorney [illegible] Manatt, Phelps & Phillips LLP in Los Angeles.

Jalpa's mayor, Mr. Diaz, takes this as part of the territory. He says he has received criticism—much he considers unfounded—from Web site users. "The disadvantage is that [through the Internet] they have more freedom to speak without proving what they are saying," he says. Still, he adds, Jalpazac.com has helped him get a better sense of what his constituents abroad want and need.

The Web sites also provide less crucial information, such as betting scores. At Juchipila.com, Joel Rodriguez created a virtual betting pool for Juchipilans near and far to bet on the World Cup and on regular Mexican soccer-league games. "We don't really put down any money but just do it for the pleasure of participating," he says.

Mr. Rodriguez is a Web-site designer and in Juchipila.com has created a site far slicker than many of the others. Mike's Garden Center and Lawn Mower supply in Arieta, Calif., and Century 21 real-estate agent Jorge Haro advertise there. Mr. Haro, a native Juchipilan who has lived in Los Angeles for 15 years, says his ad has resulted in a number of calls.

Businesses back in Juchipila, such as the town's dry goods store and Priscila's Plata, a jewelry store, also advertise on the site, mainly because their livelihood depends on the dollars Mexicans in the U.S. send to and spend in Juchipila. In fact, with so many towns heavily dependent on the dollars sent home, the Web sites can be just as important to those back home as they are to homesick Mexicans in the U.S.

Mario Tejeda, creator of Sanmartinjalisco.com, is raising money through the site to buy computers for schools in the village. And the creators of Tulcingo.net have a project in the works to take a $50,000 computer server to the village of 5,154 people, thereby providing it with a resource even unavailable in much bigger and richer towns. The Chávez family of Jalpa has gone a step further by creating an Internet service provider to tape into the growing Web ties between the U.S. and Mexico.

Through technology, the sites also are preserving the history and tradition of towns that, with migration, have changed radically in the past 50 years. "People are willing to leave their traditions to get ahead in life," Mr. Tejeda says. "Now with the Web site it is like a return to what was there before."

Analysts suggest it will take more than privacy to bring back whales. Both MGM Mirage and Park Place say they are actively courting international high rollers, relying more than ever on marketing agents to work connections overseas. When wealthy gamblers do visit, they can expect the royal treatment. MGM flies its best customers in on private jets. Park Place hosts cultural events and throws celebrity-studded parties. When big-name entertainers come to town, big gamblers often get free tickets.

The perks are hurting profits. A whale's high-end hotel room can cost up to $20,000 to build and stock, calculates Ashley Craig, an analyst with Morgan Stanley. Today's big spenders get more than monogrammed bathrobes: They often receive in-room dining with a private chef, unlimited wine and drinks, money for shopping, discounts on losses, promotional chips and cash incentives, Ms. Craig says.

In fact, the high-end game has become so competitive that the Rio, a unit of **Harrah's Entertainment** Inc., dropped out of the running last year. "Several quarters in a row we just didn't come close to making our projected numbers," a Harrah's spokesman says. "You [illegible] unit of Las **Vegas Sands** Inc., says [illegible] has become more "selective" about pursuing high rollers.

Large companies with several properties catering to high rollers—such as MGM with its MGM Grand, Bellagio and Mirage casinos—have fared the best, Morgan Stanley's Ms. Craig says. If a high roller feels unlucky at one hotel, he or she can move to another owned by the same company. The longer a casino can keep a player betting, the greater its odds of winning.

The companies are starting to show restraint. Caesars Palace officials say they are saying "no" to high rollers' demands for extravagant bets or excessive discounts on losses. Caesars' President John Groom attributes the casino's second-quarter profit rise to "being attentive to profitability in high-end play."

"I won't say we've never made a bad decision," he adds. But while trying to give high-end customers a fair shot at winning, the casino also is being mindful of the bottom line. Caesars Palace now follows guidelines when dealing with such customers. "You can be willing to pay no more than what the play is worth to you," Mr. Groom says. "That's where people got off track a bit."

eral counsel, John Raposa.

Meanwhile, both sides are gearing up for a showdown next week in Florida. It may be a tough fight for AT&T and Comcast: Miami officials say they plan to push for conditions ranging from customer-service guarantees to a promise that the new company will license its channels to competitors at fair rates.

California Project Purifies Sewage

Continued From Page B1

rent sewage treatment. When the sewage-to-tap system becomes operational, they add, the reverse-osmosis process will be further refined using a three-step cleansing process.

Here's how it will work: First, the sewage water will be run through a microfilter to remove suspended particles. Then it will be squeezed through a reverse-osmosis membrane to ferret out any remaining microscopic contaminants such as viruses and bacteria. Finally, it will be exposed to ultraviolet light to destroy anything else that might have slipped through, before being piped back into the ground.

At a demonstration plant for the technology in the water-district headquarters, the water is so devoid of minerals that it lacks almost any taste. Some minerals will be added for taste before reaching consumers' taps, officials say.

Whatever the taste, the cost is too high in the view of other critics. With the project estimated to cost $600 million over its life, the treated sewage water will cost around $420 an acre-foot to produce. (An acre-foot of water—the volume that would cover one acre to a depth of one foot—is the average amount used by a family of five over the course of one year.) Existing groundwater supplies cost only about $150 an acre-foot, while imported supplies cost from $200 to almost $500.

Critics say further that ample water supplies exist for the foreseeable future. "This project is way ahead of its time," says Peer Swan, a former member of the sanitation district's board who joined a minority of directors in voting against the sewage-purification system last year. Both the water- and sanitation-district boards gave final approval to the project at that time. "To me," Mr. Swan says, "this is egos running amok."

But officials of the two districts say that without the project the county faced having to pay as much as $170 million to build a new sewage pipe to handle increases in urban runoff. So far, the agencies have raised from local, state and federal sources about $93 million of the $370 million needed to complete the first phase of the project, set to be operational in 2006.

CARP (Colorado Aqueduct Return Project) July 2002
Ralph (Butch) Clark

Some concepts similar to CARP:

* In the early 1960's the California Water Plan called for some 10,000 cubic feet per second of flow (7.2 million acre-feet per year at full capacity) to be sent from northern California to southern California. The plan included "a few hundred reservoirs," 5,000 miles of canals, 600 miles of tunnels, 100 hydroelectric plants, 75 pumping stations, and a lift of 3,300 feet over the Tehachapis Mountains. This project would be built over 50 years at a cost estimated at $12 billion dollars. (Kuiper E. (1965) Water Resources Development: Planning, Engineering, and Economics, Butterworth and Co., London, pp. 26 and 395 - 396).

* Libya is water stressed. Major underground water resources were discovered in the 1970's beneath the desert in the southeastern part of Libya, the Nubian Aquifer in the Al Kufrah region. A few years later another major aquifer, was found in the southwestern part of Libya, the Marzug Basin. The proposed plan was to build pipelines to bring water from the south of the country northward to the rapidly developing coast along the Mediterranean. The plan was called the Great Man Made River. Stage I was to construct a 1,900 kilometer pipeline, 4 meters in diameter, linking two water well fields in the southeast to the coast. The pipeline would carry 700 million cubic meters a year (about 860,000 acre-feet). Stage Two of the project was for two pipelines with 2.5 times this capacity. Both stages were brought in under time and under budget for $6.4 billion. Three more stages are planned. (de Villers M. (2000) Water: The Fate Of Our Most Precious Resource, Houghton Mifflin Co., New York, New York, pp. 147 - 154).

* A group in Canada is reported to be planning for a 30 foot diameter pipeline from the shore of Hudson Bay in Canada to the Southwest of the United States, about 2,100 miles to reach the upper part of the Upper Colorado River Basin. The location for the start of the pipeline is very close to the shore of Hudson Bay to minimize upstream environmental impacts. The amount of water sent back through the pipeline would be 3 days worth of the annual inflow into Hudson Bay. The project would cost $34 billion (U.S.) and would deliver 1.3 trillion gallons a year (almost 4 million acre feet). If sold at $.50 to$ .75 a gallon, the expected profit for promoters would be $2.9 to $5.9 billion a year. The water price would be $1,630 to $2,445 per acre-foot. This price is noted to be far above the subsidized price of water to U.S. farmers which is $50 to $100 per acre-foot. (Owens D. (2001) Water, Water Everywhere, but Canada Won't Sell It, The Wall Street Journal, August 31, p. A9)

* Exxon Corporation planned to move 1.1million acre-feet a year from Oahe Reservoir on the Missouri River and eastern border of South Dakota some 680 miles to the Piceance Basin in western Colorado. This water was for oil shale development. Three 1,000 megawatt electrical power plants would be required to send this amount of water through three pipelines each 9 feet in diameter. (Gulliford A. (1989) Boomtown Blues: Colorado Oil Shale, 1885 - 1985, University of Colorado Press, Niwot, Colorado, pp. 126 - 130).

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DAILY SENTINEL
Grand Junction, CO
(Mesa County)

80 CARP

Officials consider diversion of water

By MARIJA B. VADER
The Daily Sentinel

GLENWOOD SPRINGS — The Colorado River Water Conservation District is researching the idea of shipping Western Slope water through the Continental Divide from Ruedi Reservoir to Aurora and Colorado Springs.

Taking water from Ruedi Reservoir would be more of an environmentally friendly and politically palatable alternative to the Homestake II reservoir, which would have dried up wetlands in the Eagle River drainage, said Kerry Sundeen, an engineer hired by the river district to study the option.

As a result of six years of litigation, Homestake II proponents Aurora and Colorado Springs have the right to take up to 20,000 acre-feet of water a year from the Eagle River, roughly enough water to supply 20,000 families annually, but where the water should come from remains in question.

In 1993, the river district agreed to gather water users on both sides of the Continental Divide in an attempt to answer that question and reach a workable solution for all parties.

By 1997, the water users had identified four alternatives — all which would take water from the Eagle River Basin.

Later, someone conceived the idea of taking water from outside that basin and using Ruedi Reservoir.

On the Fryingpan River east of Basalt and west of the Eagle River Basin, Ruedi Reservoir was originally built for Western Slope storage and now supports a gold-medal fishery below the dam.

With the Ruedi diversion concept, six pumping stations would push 20,000 acre-feet of water 12 miles and 2,300 vertical feet uphill during winter months to Nast. The water would then flow into an existing Front Range collection system, Sundeen said.

Because the plan would involve no new reservoirs, would not dry up wetlands and would take water only during the winter when the reservoir is typically drawn down, it is less intrusive environmentally and less expensive as well, Sundeen said.

Sundeen estimated the project could cost $136 million, 20 percent less than the other alternatives identified.

Noticeable impacts would include a significant reduction in the amount of water flowing through the Fryingpan River during the winter, said Sundeen, who suggested studying that issue before the river district makes a decision.

Because the river district owns the water rights in Ruedi, it has veto power over the concept, Sundeen said.

While the river district does not endorse the idea, said Manager Eric Kuhn, "we're just asking if we should bring this up to alternative status," along with the four other alternatives. "The environmental aspects are so much less than the other alternatives."

The river district board has not formally voted on the concept. Kuhn said he would discuss it with water and government officials from the Front Range and the Western Slope and report on its status at the January board meeting.

The ill-fated Homestake II project would have drawn billions of gallons of water from the Holy Cross Wilderness Area near Vail and shipped it to Aurora and Colorado Springs.

The project was killed by state courts in the mid-1990s after years of protests from environmentalists and water officials on the Western Slope, who feared it would drain wetlands and jeopardize their water supplies.

Eagle County had denied permits to the Front Range cities to build Homestake II.

In 1997, Colorado Springs and Aurora, which hold rights to 60,000 acre-feet of Eagle River water, agreed to limit their take to 20,000 acre-feet after a ruling by the U.S. Supreme Court.

■

Marija B. Vader can be reached via e-mail at mvader@gjds.com.

Utah looks for ways to turn surplus water into cash

By The Associated Press

SALT LAKE CITY — State officials studying the possibility of leasing Utah's share of undeveloped Colorado River water have found that the idea may not produce the windfall lawmakers had hoped.

In a projection of Utah's water needs over the next 50 years, about 110,000 acre-feet of Colorado River water goes unused — about 8 percent of the state's 1.4 million acre-foot annual share.

There are no guarantees against the state needing that excess, so "we are looking at leasing the water, not marketing it," Larry Anderson, director of the Utah Division of Water Resources, told lawmakers last month. "There will come a time when we need that water."

State officials, at the direction of the legislature and Gov. Mike Leavitt, are studying the feasibility of leasing a portion of Utah's Colorado River water to thirsty downstream states such as Arizona and California.

Anderson said the state has a valuable resource that is flowing to downstream users with no compensation to the state. Just how much that water is worth is anybody's guess.

Developed water delivered to users sells for $400 to $800 an acre-foot. An acre-foot is the standard measure of water and considered enough to serve a family of four for a year.

Anderson said questions remain whether downstream states would pay for undeveloped water they get for free now or if buyers would invest in the dams, pipelines and other facilities to deliver 110,000 acre-feet.

The downstream states of California, Arizona and Nevada are guaranteed a minimum of 7.5 million acre-feet of Colorado River water.

Anderson said those states could be pressured to negotiate a deal only if Utah planned to develop and use its unused portion.

"The agreement (with downstream states) could be a kind of forbearance whereby the state agrees not to pursue certain (water development) projects for the next 50 or 100 years and agrees to continue to let that water go downstream," Anderson said.

Utah's water also could be made more marketable if other upper basin states and various Indian tribes with water rights all agreed to bank their shares of unused water and then lease the water to downstream states.

Utah uses about 857,000 acre-feet of Colorado River water a year, with 512,000 acre-feet going downstream unused. Anderson told the legislature's Energy and Natural Resources Committee that long-range water plans call for the state to increase its use of the river water by almost 50 percent.

Among the developments that would utilize Colorado River water over the next 50 years are a proposed pipeline from Lake Powell to the St. George area, oil and gas development in northeastern Utah, completion of the Central Utah Project and expansion of Utah power plants.

The Colorado River is the nation's sixth largest in terms of water volume at 17.5 million acre-feet per year. The river basin covers 224,000 square miles in Wyoming, Colorado, Utah, Nevada, New Mexico, Arizona, California and in northern Mexico. Twenty million people depend on Colorado River water, most of them in Phoenix, Denver, Los Angeles, Salt Lake City and Las Vegas, Nev.

Searching with checkbook rather than a divining rod

By SCOTT McCARTNEY

PHOENIX, Ariz. — A concrete canal ribbons its way 190 miles over red rock mountains and scorched sand, defying the laws of both gravity and economics, representing both the past and future of water in the West.

The umbilical cord called the Central Arizona Project carries water uphill at 4 mph from the Colorado River to bursting, thirsting cities. It is the last and most expensive of all the great federal water works, a $3.6 billion aqueduct conceived as a way to irrigate the desert and hailed as the final answer for Arizona's needs.

Yet the CAP will be neither when it begins regular delivery of high-cost water this fall — too expensive for farmers and, mammoth as it is, not big enough to quench the urban thirst for golf courses, ornamental lakes and million-gallon-a-day microchip plants.

Instead, water experts say the CAP has become an ominous example of how the cost of water in the West is being driven dramatically higher. Construction costs have been so high that CAP water will be many times more expensive than other sources.

At the same time, Arizona cities squeezed by growing demand and a law requiring the preservation of ground water are hunting with checkbooks rather than divining rods for new water that promises to be even more expensive.

The bottom line to consumers throughout the West: The days of cheap water are numbered; experts say water is going to cost more, a lot more.

"We're going to have to spend more and more and more for water — there's no question," said George W. Britton, the Phoenix water planner. "It's like oil — can you ever run out of oil? Probably not, as long as we're willing to spend more and more money for it."

As the era of giant federal projects like the CAP ends, a new economics is emerging, one of water trading and water marketing, competing for gallons and paying top dollar for a precious commodity.

Those in need have begun buying water rights on the open market, purchasing farms and their water rights, for example, to harvest the water rather than the crops. Urban demands are competing with rural interests, clashing with environmentalists, and raising the price of water to all users.

Scottsdale, Ariz., spent $11.6 million for a giant ranch with rich water rights near California, Mesa paid $30 million to 13 cotton farmers, and Phoenix is considering the purchase of an entire town.

"There will be significant social and environmental impact. It will eventually mean the elimination of agriculture as a way of life (in central Arizona), and we'll essentially make deserts out of farm communities," Britton said.

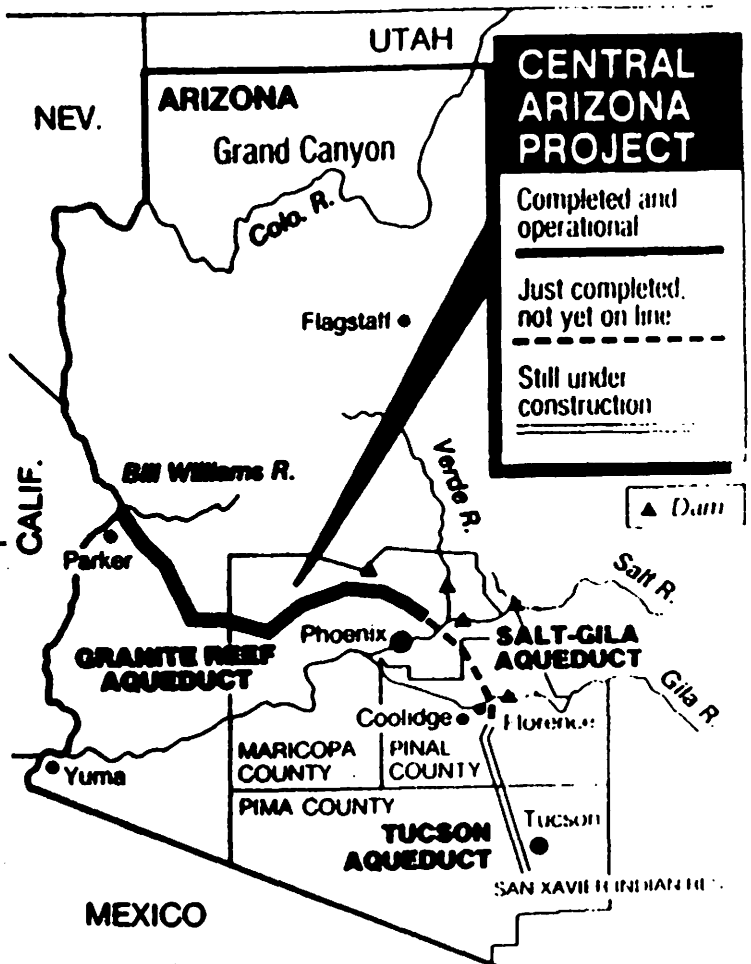
The new economics has its detractors. Farmers and rural businessmen worry about the loss of farm land, and conservationists question whether Arizona doesn't already have more than enough water — if farmers would only cut back or cities would abandon the wasteful "oasis mentality" of lush lawns and palm trees.

For decades, Phoenix had it easy when it came to water. The booming city and its suburbs relied on a combination of ground water and surface water from the Salt River Project, a federal dam and canal development built under President Theodore Roosevelt's administration.

It came cheap. For an acre-foot of SRP water, about 325,851 gallons, enough to supply an average family for two years, the Phoenix Water Department has paid about $8, so little it wasn't even factored into consumers' monthly bills.

But with the CAP coming on line, those days are numbered. Only 44 percent complete in terms of dollars spent, the CAP by 1991 will stretch 337 miles to Tucson. This year, budget-minded federal officials have required state and local governments to begin shouldering some of the cost up front, rather than spreading it out over 50 years.

CAP water will cost close to $200 an acre-foot to deliver to consumers, and water bills could jump a quick 15 percent. And over the next 10 years, Arizona consumers are likely to see water bills double or triple, officials said.



Source: U.S. Dept. of the Interior

Scott McCartney is the Associated Press Southwest regional reporter, based in Dallas.

SUNDAY TIMES CALL
SUNDAY, OCTOBER 5, 1986

WATER RESOURCES BULLETIN
VOL. 31, NO. 5 AMERICAN WATER RESOURCES ASSOCIATION OCTOBER 1995

also see Booker 890 and ... Colorado River Institutional Model

COMPETING WATER USES IN THE SOUTHWESTERN UNITED STATES: VALUING DROUGHT DAMAGES[1]

from Severe Sustained Drought publication

James F. Booker and Bonnie G. Colby[2]

ABSTRACT: Economic benefit functions of water resource use are estimated for all major offstream and instream uses of Colorado River water. Specific benefit estimates are developed for numerous agricultural regions, for municipal uses, and for cooling water in thermal energy generation. Economic benefits of hydropower generation are given, as are those for recreation on Colorado River reservoirs and on one free-flowing reach. Marginal and total benefit estimates for Colorado River water use are provided. The estimates presented here represent a synthesis of previous work, providing in total a comprehensive set of economic demand functions for competing uses of Colorado River water. Non-use values (e.g., benefits of preserving endangered species) are not estimated.

(KEY TERMS: water demand; drought; economic benefits; irriga- municipal water demand; recreation; hydropower, salinity.)

INTRODUCTION

Water resources provide critical services to a wide range of consumptive and non-consumptive users in the southwestern United States. Water is consumptively used for irrigation of crops, and for municipal and industrial purposes in cities and towns, including cooling water for thermal electric generation. Instream flows (derived largely from storage in regional reservoirs) generate hydropower, provide unique habitat, and are required for a variety of recreational activities. While total benefits from use of all regional water resources might possibly be estimated, our purpose here is more modest. We are concerned primarily with estimation of damages (lost economic benefits) resulting from a range of marginal or incremental reductions in water availability, and also with examining water users' incremental adjustments to drought-induced water reductions.

We focus on those activities in the southwestern United States which typically utilize water from the Colorado River Basin, the dominant water supply for the region. Basin water can be delivered to a population of over 25 million across seven states, from Wyoming to California. Total consumptive use exceeds 10 million acre-feet (maf), with an additional 1.5 maf used in northern Mexico. Hydropower sufficient for the electricity needs of 4 million residential users is generated by water released from Basin reservoirs. The same reservoirs are also major recreational attractions, with approximately 17 million visitor days per year. Fishing and rafting on the mainstem and tributaries provide further benefits.

We value these sometimes competing uses of Basin water by developing economic benefit functions for the major uses. Economic benefits of consumptive use in agricultural, municipal, and energy sectors at a number of locations are first estimated. Many of these uses are affected by high concentrations of dissolved minerals (salinity) in Colorado River water which cause damages to water-using appliances in municipal uses, and reduce crop yields in irrigation uses. Damage estimates from a prior study by one of the authors (Booker and Young, 1991) are used to value these salinity damages. Economic benefit estimates for instream, non-consumptive uses (hydropower and recreation) are also developed. While instream flows provide general and critical habitat for a rich spectrum of Basin wildlife, no attempt is made to place an economic value on habitat for endangered or other species. Similarly, other non-use values are not treated.

[1]Paper No. 95032 of the *Water Resources Bulletin*. **Discussions are open until June 1, 1996.**
[2]Respectively, Assistant Professor, College of Business, Alfred University, Alfred, New York 14802; and Associate Professor, Department of Agricultural and Resource Economics, University of Arizona, Tucson, Arizona 85721.

Specific approaches to measuring economic benefits for each use are developed here and applied to evaluate the foregone benefits (damages) during drought. The benefit estimates presented here are largely based on previously reported research. Our primary contribution is the synthesis of studies by numerous authors covering a variety of offstream and instream uses. The result is a complete set of economic benefit functions suitable for use in estimating economic damages of reduced water resource availability in the southwestern United States. All monetary values are given in 1992 dollars.

We identify only the direct economic damages from drought. Additional indirect damages will occur through reductions in regional purchases and employment resulting from drought. For example, shortages of irrigation water may result in a failure to produce an agricultural crop. The resulting income loss to the landowner is the direct economic damage of drought reported by this study. Lost wages to farm workers and lost income to regional businesses supplying (or purchasing from) irrigated farms are termed indirect or secondary economic impacts. While potentially significant to local and regional economies, indirect impacts to national economies are zero under conditions of full employment. Because regional links to the national economy are not identified here, only partial equilibrium analysis of direct economic impacts is possible [see Brookshire *et al.* (1993) for a discussion of indirect and general equilibrium impacts of regional water supply reductions].

DEVELOPING ECONOMIC DEMAND FUNCTIONS FOR CONSUMPTIVE USES

Consumptive uses include irrigated crop production, provision of household services such as showers and landscaping, and evaporative cooling in industrial processes such as electric power generation. Consumptive use of Colorado River water is assigned to one of three sectors: agricultural, municipal, or energy use. Within each sector a single methodology is followed in developing economic demand estimates for water use. Economic demand estimates for actual offstream diversions are developed by scaling each regional, sectoral demand estimate to depletion data originally developed for use in the U.S. Bureau of Reclamation (USBR) Colorado River Simulation Model (1991) and modified for this study.

Agricultural Demand Functions

Water demand functions which summarize the direct marginal economic benefits of utilizing irrigation water from the Colorado River are derived here from linear programming models of regional irrigated agricultural production. Several independent modeling efforts were utilized in developing the comprehensive set of benefit functions presented here. For consistency, all water use figures given in the original modeling efforts were converted to consumptive use figures, with benefit estimates updated to 1992 dollars using the GNP price deflator.

Linear programming models frequently require the use of ad hoc crop flexibility constraints to calibrate predicted crop acreage to observed crop acreage (as reported in state crop summary reports, for example). In several of the studies used here, lower bounds on crop acreage resulted in models giving unreasonably high predictions of damages from reductions in crop production caused by irrigation water shortages. Uncritical acceptance of such estimates would suggest unrealistically inelastic water demand functions, and hence unrealistically high marginal water values at large reductions from existing use levels. Because the underlying calibration constraints which cause this difficulty vary greatly between studies, an attempt was made to correct for this effect. First, an estimate of the average benefit of irrigation water use was developed to help identify artificially high damage estimates (e.g., greater than $100/acre-foot (af) in Upper Basin uses). Because agricultural land values implicitly reflect the average value of water in irrigated crop production, average benefits of irrigation water use were estimated from state land values (U.S. Department of Agriculture, 1990) using average irrigation water requirements for each state (U.S. Department of Agriculture, 1992). A 4 percent discount rate was used to calculate annualized irrigated land values. Reported marginal water values (shadow prices) which exceeded the average estimated water value by more than 20 percent at greater than 50 percent of full water supply were then excluded from the benefit function estimates reported here.

After adjustments for the programming artifacts described above, water demand (marginal benefit) schedules were developed from the reported programming solutions for each region. For any particular region, this initial demand schedule frequently included marginal values estimated from several studies. From this initial schedule a single marginal benefit, or (inverse) demand function of the form

$$p(x) = p_0 \, (x/x_0)^{\alpha} \quad (1)$$

for $0 < x \leq x_0$, was estimated by least squares regression. In Equation (1), x_0 is the maximum water delivery, p_0 is the willingness to pay for addition water at full delivery, and α is the inverse of the price elasticity of demand. The Cobb-Douglas form was chosen because it successfully fit most demand schedules constructed for this study; linear demand functions were particularly limited in capturing the nonlinearities in most schedules. The range of R^2 for the 11 estimated functions was 0.55 to 0.95; $R^2 \geq 0.8$ and 2 to 3 degrees of freedom were typical. The underlying demand schedules included meaningful marginal benefit values for use reductions to approximately 0.5 x_0. Use of the estimated demand functions for greater water use shortfalls would require extrapolating beyond any data available to this study.

Total benefit functions were also desired as a baseline from which to measure drought damages. Because the estimated (inverse) demand functions have little empirical content below 50 percent of full water delivery, however, simple integration of Equation (1) is inappropriate. Instead, the average water values described above were utilized to derive total benefit functions V(x) such that $V(x_0) = x_0 \bar{v}$, where $\bar{v}$ is the average benefit (in \$/af) from irrigation water use calculated from irrigated land values. By maintaining that the estimated demand functions do not hold for low water use, the problem of nonconvergence of an inelastic Cobb-Douglas demand function is also avoided. Table 1 gives estimated total benefit functions, average water values, elasticities, and marginal water values at full delivery, for 11 agricultural regions covering agricultural users of basin water.

Because the studies on which Table 1 is based were published over a broad time span (1973 to 1988), there was concern that real changes in agricultural water values might have resulted from changes in farm income due to trends in output versus input prices, and technological change. Our data showed no evidence of real changes in marginal water values, however: adjusting marginal water values for changes in reported farm income (U.S. Department of Agriculture, 1984, 1991) did not decrease variances across studies.

Central and Southern Region. The region includes uses in portions of Colorado, New Mexico, and Utah. Studies by Booker and Young (1991) for the Grand Valley; Oamek (1990) for the mainstem of the upper Colorado, the Gunnison, and the Dolores; and Howe and Ahrens (1988) (similar regions to Oamek) were utilized in part to develop the water demand functions. Irrigation uses in the San Juan River Basin are also included. Demand estimates for the region by Oamek (1990) and Howe and Ahrens (1988) were used, together with estimates at three sub-regional elevations by Gollehon *et al.* (1981).

Northern Region. The region includes uses in Wyoming (mainstem of the Green River) and portions of Colorado and Utah. Tributary uses on the Yampa, White, Duchesne, Price, and San Rafael Rivers are included. Four previous studies are available from which to estimate the water demand functions. Marginal values are given by Anderson (1973) for the Uintah Basin in Utah; by Gollehon *et al.* (1981) for

TABLE 1. Estimated Agricultural Total Benefit Functions.*
Average water values, elasticities, and marginal water values at full delivery for each use (1992 dollars).

Agricultural Region	v_0 (\$/af)	β	Proportion of Non-Colorado River Water Used $x_n/(x_n + x_0)$	Average Water Benefit $\bar{v}$ (\$/af)	Marginal Value at Full Use p_0 (\$/af)	Price Elasticity of Demand**
Western Colorado	–16.3	–0.75	0.000	30.6	12.2	–0.57
Colorado Front Range	–10.8	–1.24	0.873		13.4	–0.45
Wyoming	–23.6	–0.53	0.000	14.2	12.5	–0.65
Utah	–23.6	–0.53	0.000	37.8	12.5	–0.65
New Mexico	–16.3	0.75	0.000	51.2	12.2	–0.57
San Juan-Chama Export	–16.3	–0.75	0.800		12.2	–0.57
Nevajo IIP	57.8	0.93	0.000	51.2	53.9	–14.77
CAP	46.0	0.59	0.725		27.1	–2.44
Colorado River Indian Tribe	32.9	0.44	0.000	36.3	14.5	–1.79
Yuma	83.2	0.24	0.100		20.0	–1.32
California	–29.5	–0.92	0.000	39.4	27.2	–0.52

*Use of parameters v_0, β, x_n, x_0, $\bar{v}$, and p_0 in the total benefit function is described in the text.
**If non-Colorado River supplies are available, this elasticity holds only at full water delivery.

from over

p.17 Accs to offset almost 650,000 acft of Colorado River water MWD to relinquish to Arizona. To take effect in 2 years; MWD uses 1.2m acft of water each year now.

Los Banos Grandes near Modesto = 2m acft. reservoir for $800m to yield 260,000 acft per year.

Kern Water Bank project - percolation ponds for underground storage - add up to 300,000 acft at cost of $85m

B of Rec - Central Valley Project water still at $3.50 per acft - a subsidy. 40 year contracts being renegotiated in 1980's for $16.50 per acft.

CARP → Even with pumping farmers are not paying over $90.00 an acft compared with $400 per acft commonly charged in Tijuana.

• 10% cut in ag water use results in 50% increase of urban supply.

Source - Barnes 26 Nov 90 p.17 over

Consumptive Water Use Totals in acre inches for Arizona Crops 1982

Alfalfa 74 — Late Grapes 20
Cotton 41 — Late Cantaloupe 20
Lettuce 9
Bermuda Grass Lawn 44 — from Conservation Research Report 29 USDA, Ag Research Service May 1982
Sorghum 25
Barley 25

from Gerri Miller and Bradley P. Cardon
What Farmers Can Do For Themselves
in Water Scarcity, Engelbert E.A. (1984) U. of Calif. Press
Ed.
Earth books

Negotiations between New Mexico and Texas over NM
A1 pot. payback of ~~326,000 ac ft~~ 340,100 ac ft of water not
delivered to Texas over 10 year period.
N.M. made cash offer of between $3.4m and $10.2m
Texas feels water priceless
Water debt established by water referee are violations
of Pecos River Compact over 34 years
A3 N.M. offer is between $10 and $30 per af. to be paid
from irrigation works account
Range is difference of opinion on value of water to Texas
$10 and to N.M. $30.
Delivery of water would devastate agriculture
N.M. says cause is natural - Not NM farmers it says.
Source: Ward, Leah B. (1986) ~~Give Us~~ Give Us
Water, Not Your Cash Texas Tells N.M.
Albuquerque Journal (North) Nov 11, 1986, pp. A1 and
A3

p19 City of Santa Barbara building municipal desalinization plant
(biggest municipal desalinization plant in the country)
to be completed in 1992, to deliver 2,500-10,000 acre feet
yearly (city to decide how much in 1991). Water will cost
$1900 an acre-foot. Currently City paying $200-300 per ac-ft
During 1st 5 years price of water to be cut in half. Then
reduced further when City owns plant. Plant being built by
Ionics of Watertown, Mass.
Metropolitan Water District [L.A. area] agreed to pay $100m to
Imperial Irrigation District to line more than 300 miles
of main and secondary canals. In exchange MWD for 35
years will keep 100,000 acft that will be lost to seepage
Source: Mitchell Gordon (1990) How Dry They Are; Effects of California's Drought
Ripple Far and Wide, Barrons, November 26, 1990, pp 18, 19, 43.

engines cost about $3,000 to manufacture and more research is needed to bring the cost of fuel cells down to that level.

Can I use a fuel cell to power my home?

Fuel cells are ideal for power generation, either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines. Since fuel cells operate silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be used to provide hot water or space heating.

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for $0 < x \leq x_0$, was estimated by least squares regression. In Equation (1), x_0 is the maximum water delivery, p_0 is the willingness to pay for addition water at full delivery, and α is the inverse of the price elasticity of demand. The Cobb-Douglas form was chosen because it successfully fit most demand schedules constructed for this study; linear demand functions were particularly limited in capturing the nonlinearities in most schedules. The range of R^2 for the 11 estimated functions was 0.55 to 0.95; $R^2 \geq 0.8$ and 2 to 3 degrees of freedom were typical. The underlying demand schedules included meaningful marginal benefit values for use reductions to approximately 0.5 x_0. Use of the estimated demand functions for greater water use shortfalls would require extrapolating beyond any data available to this study.

Total benefit functions were also desired as a baseline from which to measure drought damages. Because the estimated (inverse) demand functions have little empirical content below 50 percent of full water delivery, however, simple integration of Equation (1) is inappropriate. Instead, the average water values described above were utilized to derive total benefit functions V(x) such that $V(x_0) = x_0 \bar{v}$, where $\bar{v}$ is the average benefit (in $/af) from irrigation water use calculated from irrigated land values. By maintaining that the estimated demand functions do not hold for low water use, the problem of nonconvergence of an inelastic Cobb-Douglas demand function is also avoided. Table 1 gives estimated total benefit functions, average water values, elasticities, and marginal water values at full delivery, for 11 agricultural regions covering agricultural users of basin water.

Because the studies on which Table 1 is based were published over a broad time span (1973 to 1988), there was concern that real changes in agricultural water values might have resulted from changes in farm income due to trends in output versus input prices, and technological change. Our data showed no evidence of real changes in marginal water values, however: adjusting marginal water values for changes in reported farm income (U.S. Department of Agriculture, 1984, 1991) did not decrease variances across studies.

Central and Southern Region. The region includes uses in portions of Colorado, New Mexico, and Utah. Studies by Booker and Young (1991) for the Grand Valley; Oamek (1990) for the mainstem of the upper Colorado, the Gunnison, and the Dolores; and Howe and Ahrens (1988) (similar regions to Oamek) were utilized in part to develop the water demand functions. Irrigation uses in the San Juan River Basin are also included. Demand estimates for the region by Oamek (1990) and Howe and Ahrens (1988) were used, together with estimates at three sub-regional elevations by Gollehon *et al.* (1981).

Northern Region. The region includes uses in Wyoming (mainstem of the Green River) and portions of Colorado and Utah. Tributary uses on the Yampa, White, Duchesne, Price, and San Rafael Rivers are included. Four previous studies are available from which to estimate the water demand functions. Marginal values are given by Anderson (1973) for the Uintah Basin in Utah; by Gollehon *et al.* (1981) for

TABLE 1. Estimated Agricultural Total Benefit Functions.*
Average water values, elasticities, and marginal water values at full delivery for each use (1992 dollars).

Agricultural Region	v_0 ($/af)	β	Proportion of Non-Colorado River Water Used $x_n/(x_n + x_0)$	Average Water Benefit $\bar{v}$ ($/af)	Marginal Value at Full Use p_0 ($/af)	Price Elasticity of Demand**
Western Colorado	–16.3	–0.75	0.000	30.6	12.2	–0.57
Colorado Front Range	–10.8	–1.24	0.873		13.4	–0.45
Wyoming	–23.6	–0.53	0.000	14.2	12.5	–0.65
Utah	–23.6	–0.53	0.000	37.8	12.5	–0.65
New Mexico	–16.3	0.75	0.000	51.2	12.2	–0.57
San Juan-Chama Export	–16.3	–0.75	0.800		12.2	–0.57
Nevajo IIP	57.8	0.93	0.000	51.2	53.9	–14.77
CAP	46.0	0.59	0.725		27.1	–2.44
Colorado River Indian Tribe	32.9	0.44	0.000	36.3	14.5	–1.79
Yuma	83.2	0.24	0.100		20.0	–1.32
California	–29.5	–0.92	0.000	39.4	27.2	–0.52

*Use of parameters v_0, β, x_n, x_0, $\bar{v}$, and p_0 in the total benefit function is described in the text.
**If non-Colorado River supplies are available, this elasticity holds only at full water delivery.

Specific approaches to measuring economic benefits for each use are developed here and applied to evaluate the foregone benefits (damages) during drought. The benefit estimates presented here are largely based on previously reported research. Our primary contribution is the synthesis of studies by numerous authors covering a variety of offstream and instream uses. The result is a complete set of economic benefit functions suitable for use in estimating economic damages of reduced water resource availability in the southwestern United States. All monetary values are given in 1992 dollars.

We identify only the direct economic damages from drought. Additional indirect damages will occur through reductions in regional purchases and employment resulting from drought. For example, shortages of irrigation water may result in a failure to produce an agricultural crop. The resulting income loss to the landowner is the direct economic damage of drought reported by this study. Lost wages to farm workers and lost income to regional businesses supplying (or purchasing from) irrigated farms are termed indirect or secondary economic impacts. While potentially significant to local and regional economies, indirect impacts to national economies are zero under conditions of full employment. Because regional links to the national economy are not identified here, only partial equilibrium analysis of direct economic impacts is possible [see Brookshire *et al.* (1993) for a discussion of indirect and general equilibrium impacts of regional water supply reductions].

DEVELOPING ECONOMIC DEMAND FUNCTIONS FOR CONSUMPTIVE USES

Consumptive uses include irrigated crop production, provision of household services such as showers and landscaping, and evaporative cooling in industrial processes such as electric power generation. Consumptive use of Colorado River water is assigned to one of three sectors: agricultural, municipal, or energy use. Within each sector a single methodology is followed in developing economic demand estimates for water use. Economic demand estimates for actual offstream diversions are developed by scaling each regional, sectoral demand estimate to depletion data originally developed for use in the U.S. Bureau of Reclamation (USBR) Colorado River Simulation Model (1991) and modified for this study.

Agricultural Demand Functions

Water demand functions which summarize the direct marginal economic benefits of utilizing irrigation water from the Colorado River are derived here from linear programming models of regional irrigated agricultural production. Several independent modeling efforts were utilized in developing the comprehensive set of benefit functions presented here. For consistency, all water use figures given in the original modeling efforts were converted to consumptive use figures, with benefit estimates updated to 1992 dollars using the GNP price deflator.

Linear programming models frequently require the use of ad hoc crop flexibility constraints to calibrate predicted crop acreage to observed crop acreage (as reported in state crop summary reports, for example). In several of the studies used here, lower bounds on crop acreage resulted in models giving unreasonably high predictions of damages from reductions in crop production caused by irrigation water shortages. Uncritical acceptance of such estimates would suggest unrealistically inelastic water demand functions, and hence unrealistically high marginal water values at large reductions from existing use levels. Because the underlying calibration constraints which cause this difficulty vary greatly between studies, an attempt was made to correct for this effect. First, an estimate of the average benefit of irrigation water use was developed to help identify artificially high damage estimates (e.g., greater than $100/acre-foot (af) in Upper Basin uses). Because agricultural land values implicitly reflect the average value of water in irrigated crop production, average benefits of irrigation water use were estimated from state land values (U.S. Department of Agriculture, 1990) using average irrigation water requirements for each state (U.S. Department of Agriculture, 1992). A 4 percent discount rate was used to calculate annualized irrigated land values. Reported marginal water values (shadow prices) which exceeded the average estimated water value by more than 20 percent at greater than 50 percent of full water supply were then excluded from the benefit function estimates reported here.

After adjustments for the programming artifacts described above, water demand (marginal benefit) schedules were developed from the reported programming solutions for each region. For any particular region, this initial demand schedule frequently included marginal values estimated from several studies. From this initial schedule a single marginal benefit, or (inverse) demand function of the form

$$p(x) = p_0 \, (x/x_0)^{\alpha} \qquad (1)$$

engines cost about $3,000 to manufacture and more research is needed to bring the cost of fuel cells down to that level.

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A1 pt. Negotiations between New Mexico and Texas over N.M. payback of ~~326,000 ac-ft~~ 340,100 ac-ft of water not delivered to Texas over 10 year period.
N.M. made cash offer of between $3.4m and $10.2m
Texas feels water priceless
Water debt established by water referee as violations of Pecos River Compact over 34 years
A3 N.M. offer is between $10 and $30 per ac-ft to be paid from irrigation works account
Range is difference of opinion on value of water to Texas $10 and to N.M. $30.
Delivery of water would devastate agriculture
N.M. says cause is natural - not N.M. fault it says.
Source: Ward, Leah B. (1986) ~~Give Us~~ Give Us Water, Not Your Cash Texas Tells N.M. Albuquerque Journal (North) Nov 11, 1986, pp. A1 and A3

p19 City of Santa Barbara building municipal desalinization plant (biggest municipal desalinization plant in the country) to be completed in 1992, to deliver 2,500-10,000 acre feet yearly (city to decide how much in 1991). Water will cost $1900 an acre-foot. Currently City paying $200-300 per ac-ft. During 1st 5 years price of water to be cut in half. Then reduced further when City owns plant. Plant being built by Ionics of Watertown, Mass.
Metropolitan Water District [L.A. area] agreed to pay $100m to Imperial Irrigation District to line more than 300 miles of main and secondary canals. In exchange MWD for 35 years will keep 100,000 ac-ft that will be lost to seepage
Source: Mitchell, Gordon (1990) How Dry They Are: Effects of California's Drought Ripple Far and Wide, Barrons, November 26, 1990, pp 18, 19, 43.

from over

p.17 Aims to offset almost 650,000 ac ft of Colorado River water MWD to relinquish to Arizona.
To take effect in 2 years; MWD uses 1.2m ac ft of water each year now.
Los Banos Grandes near Modesto = 2m ac ft. reservoir for $800m to yield 260,000 ac ft per year.
Kern Water Bank project - percolation ponds for underground storage - add up to 300,000 ac ft. at cost of $85m
By Rec - Central Valley Project water still at $3.50 per ac ft - a subsidy. 40 year contracts being renegotiated in 1980's for $16.50 per ac ft.
CARP → Even with pumping farmers are not paying over $90.00 an ac ft compared with $400 per ac ft commonly charged urban users.
• 10% cut in ag water use results in 50% increase of urban supply.
Source - Barrons 26 Nov 90 p.17 over

Consumptive Water Use Totals in Acre inches for Arizona Crops 1982

Alfalfa 74 | Late Grapes 20
Cotton 41 | Late Canteloupe 20
Lettuce 9
Bermuda Grass Lawn 44 from Conservation Research Report 29 USDA, Ag Research Service May 1982
Sorghum 25
Barley 25

from Cassi Miller and Bradley P. Cardon
What Farmers Can Do For Themselves
in Water Scarcity, Engelbert E.A. ed. (1984) U. of Calif. Press
Fast books

Punts on Cherry Creek
River
Platte Gateway Foundation will turn a portion of Cherry Creek into into navigable water way from Market Street to Confluence Park.
use 4x10' punts - with docks at Larimer, Union Station, Auraria
Cost for 1st part Market to Delgany is $1.5 M
will use rotatable leaf gate dams - small used to create "lakes" with embankments
down each night to provide normal flow
Dredge channel for depth, hand powered locks between lakes, stabilize the banks
Watch for "flash floods", - but no greater risk than joggers & bicyclers using bottom of creek
Launch in 1995
J.D. (1993) Boating on Cherry Creek Slated for '95, Up the Creek (Denver, Colorado), Jan 15, 1993 no page

p8 Ventura Calif. dateline for San ~~Buenavista~~ Buenaventura coastal town northwest of Los Angeles. asked in vote its citizens whether to (1) hook up to State Water Project at $823 per acre foot or (2) construct desalination plant at $1,924 per acre foot. Voted for desal. project to maintain independence. Size of project is 7,000 ac ft. per year. Ventura now uses 24,000 ac ft - reclaims waste water for golf course, commercial landscapes, medians on highway

Source: U.S. Water News, Anon 1993 January, "Ventura Seeks Desalted Independence", p8.

C. Ariz. Project may require a 2nd mortgage

PHOENIX, Ariz. — With some unsolicited help from a Congressional oversight committee, active participants in the beleagured Central Arizona Project (CAP) are grappling with the tough issues of what to do with surplus Colorado River water delivered by the canal, and how to pay to the federal government the $4.7 billion cost of the project, the most costly ever built by the Bureau of Reclamation.

After a one-year reprieve, users of the CAP began making payments on a 50-year mortgage for the project in January. But serious questions have been raised by the General Accounting Office over whether Arizona users will be able to pay their $2-billion share of the project's cost. Usage of CAP is running only about a third of the canal's capacity of some 1.5 million acre feet a year, largely because irrigators are continuing to use groundwater that is available for about half the cost of CAP water.

New report cites less urgency for desalination

VENTURA, Calif. — A proposal by this coastal city to build a seawater desalination facility attracted considerable attention a couple of years back, but a recent report concludes that Ventura will not need a supplemental water supply source in the foreseeable future. Water conservation and groundwater banking have forestalled the need for the desalination plant, the report says, while a water supply model suggests that Ventura might need an additional water supply sometime beyond the year 2010.

"Water conditions have changed since the last water supply overview was prepared two years ago," said Glenn McPherson of Boyle Engineering Corp., which prepared the water supply forecast for the City of Ventura. Water demand is returning to non-drought levels slower than anticipated, said McPherson, due largely to the community's ongoing commitment to water conservation programs. In addition, he noted, groundwater supplies have risen significantly over the past two years, with the city's Fox Canyon Aquifer Groundwater Management Agency bank providing a drought reserve of some 10,000 acre feet.

"Perhaps the most positive conclusion is that the city, in all probability, won't need a supplemental water source in the immediate future, meaning the next 15-plus years," McPherson stated. While modeling indicated that Ventura won't need a supplemental water source in the near term, "it is possible there will be a demand for a drought-proofing supplemental water supply of up to 7,000 acre feet sometime beyond 2010," he added.

Despite the lack of immediate urgency, the report recommends that Ventura continue to pursue its plans for a seawater desalination facility together with Southern California Edison. Boyle Engineering determined that the city's ocean outfall could be rehabilitated for use as an intake facility, and that brine generated by desalination could be conveyed to an existing Southern California Edison outfall.

The estimated cost of the desalinated supply ranges from $1,700 to $1,800 per acre foot, McPherson pointed out. "Compare that to constructing a 3,000 acre feet per year facility within the city," he said, "which would take an estimated capital outlay of $36 million, with a total unit cost of $2,400 per acre foot."

SCE also ← involved

Routt and Moffitt Counties in Colorado (Yampa and White Rivers) and Uintah and Duchesne Counties in Utah (Green and Duchesne Rivers); by Howe and Ahrens (1988) for the Yampa and White Rivers and the Green River above the Colorado; and by Oamek (1990) for this entire "Northern region" (his "PA 82"). Weighted averages (based on consumptive use) are used to aggregate sub-regional estimates of Howe and Ahrens (1988) and of Gollehon *et al.* (1981) to the regional level, while estimates from Anderson (1973) and Oamek (1990) are used directly.

Colorado Front Range. Irrigated production on Colorado's eastern plains makes use of transmountain water exports from the Colorado River Basin. Demand for agricultural water was estimated from a minor revision of the model of northern Colorado agricultural production presented in Michelsen (1989). Crop flexibility constraints were modified in order to allow estimates of damages from up to 50 percent reductions in water use.

California. Estimates from a programming model developed by Booker and Young (1991) are used as the basis for water demand functions for California users of Colorado River Basin water. This model focused on irrigated production in the Imperial Valley, the major user of Colorado River water in southern California.

Arizona. Water demand functions for three distinct users in Arizona (Yuma, Colorado River Indian Reservation, and Central Arizona) were derived from the farm-level programming results obtained by Peacock (unpublished manuscript, Dept. of Agricultural and Resource Economics, University of Arizona, 1993). Two representative farms in the Yuma region were modeled, one with field crops only and one with both field and vegetable crops. A third representative farm, growing mostly cotton, was modeled using the enterprise budget given in Wilson (1992).

Net benefit functions were derived from point estimates of benefits in each of the three models. A portfolio of the three farms which best matched county acreages (minimized the sum of squared deviations from estimated crop acreages) of cotton, wheat, alfalfa, and vegetables was then constructed. A programming model of water allocation within each region was developed to estimate regional benefits from water use. Effective markets within regions were assumed, allowing reallocations among the three farm types when diversions were less than 100 percent. The resulting regional net benefit point estimates were then re-estimated to give a continuous function representing regional benefits.

Municipal Demand Functions

Municipal demand estimates were derived for major southwestern cities, including Phoenix/Tucson, Denver/Front Range, Salt Lake City, Las Vegas, Albuquerque, and the Metropolitan Water District (MWD) service area in southern California. A single cross-sectional study of seasonal household water demand (Griffin and Chang, 1991) was used as the basis for deriving the set of unique but methodologically consistent benefit functions for each municipal region. The approach was based on the observation that the proportion of outdoor to indoor uses varies across regions as a result of climate differences and socioeconomic factors. Summer and winter elasticities of -0.41 and -0.30 reported by Griffin and Chang (1991) for their generalized Cobb-Douglas estimate were used. Following Howe (1982), these are converted to indoor and outdoor elasticity estimates of -0.30 and -0.58. For example, using this procedure with data on indoor and outdoor use in Phoenix and Tucson gives average annual elasticities of -0.43 and -0.39, respectively. These are similar to the range of average elasticities (-0.27 to -0.70) reported in several studies by Billings and Agthe (1980) and Martin and Kulakowski (1991) for Tucson, and Planning and Management Consultants (1986) for Phoenix, as well as the range reported in the numerous other studies on this topic. Municipal demand functions were then estimated using the *average* water prices and use levels for 1985. Table 2 summarizes marginal and total benefit function estimates for Basin municipal uses.

Thermal Energy Demand Functions

Water is used for cooling water in thermal electric generation throughout the Southwest. A single benefit function for cooling water at thermal electric power generating facilities was re-estimated from data on costs of alternative cooling technologies presented in Booker and Young (1991). Actual long-run benefits may tend to be overestimated using this approach, given the possible availability of local ground water for use in cooling. The avoided cost approach may underestimate short-run damages from water shortages, however, given the necessary capital investments for use of water conserving cooling technologies. The estimated benefit function for cooling water use is $V(x)= x_0 v_0 (x/x_0)^{\beta}$, where v_0 =\$222/af, $\beta = -.070$, and $0 < x \leq x_0$. The benefit function implies a marginal water value of \$155/af and price elasticity of demand equal to -0.59 at full delivery.

good cost data appended

RESTORATION ALTERNATIVES REPORT FOR THE UPPER ARKANSAS RIVER BASIN

December 31, 2003

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PUEBLO CHIEFTAIN
Pueblo, CO
(Pueblo County)
Daily, 51,408; Sun, 54,355

Colorado Press
Clipping Service

80

Drip irrigation: Aurora pays to keep fields in production

By KARL LICIS
THE PUEBLO CHIEFTAIN

ROCKY FORD — When brothers Don and Herbert Mameda decided to do more with less, they found a willing ally: the city of Aurora.

"We started thinking about it maybe four years ago," said Don Mameda, a partner in Mameda Farms of Rocky Ford. "We were looking at drip irrigation, mostly as a way of increasing our yield. It's simply more efficient."

Maybe so, but the start-up costs for state-of-the-art drip systems are significant. Before they can deliver precious water to the produce fields of the Arkansas Valley they must be installed, and that requires capital.

Enter Aurora.

With its most-recent purchase of Rocky Ford Ditch water decreed last winter, the city to the north faced the responsibility of revegetating an additional 2,800 acres. Why not keep at least a part of that in farm production?

Indeed, why not? With approval from its city council last month, Aurora formally began a pilot Continued Farming program. The city approached eligible farmers — those who had sold ditch shares in the most recent transaction — with an offer.

The city would pay $1,400 per acre for installation of a drip system. And with farmers' wells supplying the water for irrigation, Aurora would provide a half acre-foot of augmentation water per acre annually. (Augmentation is required to replace water the wells take from the river system.)

More than 900 acres already have been committed to the program, according to Gerry Knapp, Arkansas River Basin manager for Aurora and a native of Rocky Ford. The Continued Farming program has been authorized for five years, and could be extended to 10.

Gerry Knapp

To date, 11 farmers have signed up for the program, according to a spokesperson for the Arkansas Valley Range Project office. Individual acreages range from 2 to 273 acres. The Mamedas have 185 acres in the program.

"It's an arrangement where everyone wins," said Bob Plummer, irrigation manager for Mameda Farms.

For its part, by keeping the land in agricultural production, Aurora gets immediate use of water from the recent sale. Otherwise, the decree requires revegetation — in effect, a return to rangeland — to be complete before that water can be taken. That process would require three to five years. With 1¾ acre-feet per acre decreed by the recent sale, and one-half acre-foot going for augmentation, Aurora can begin using the remainder right away.

CHIEFTAIN PHOTO/ANTHONY MESTAS

Bob Plummer, irrigation manager for Mameda Farms in Rocky Ford, points to drip irrigation emitters.

Aurora also keeps a testing option on a small portion of the Continued Farming lands.

"There's nothing specific in mind at this time," Knapp said. "It's just an option for future testing of things like how much irrigation water is needed per acre."

Advantages to participating farmers are unmistakable as the bright-green new-onion fields on Mameda's farm.

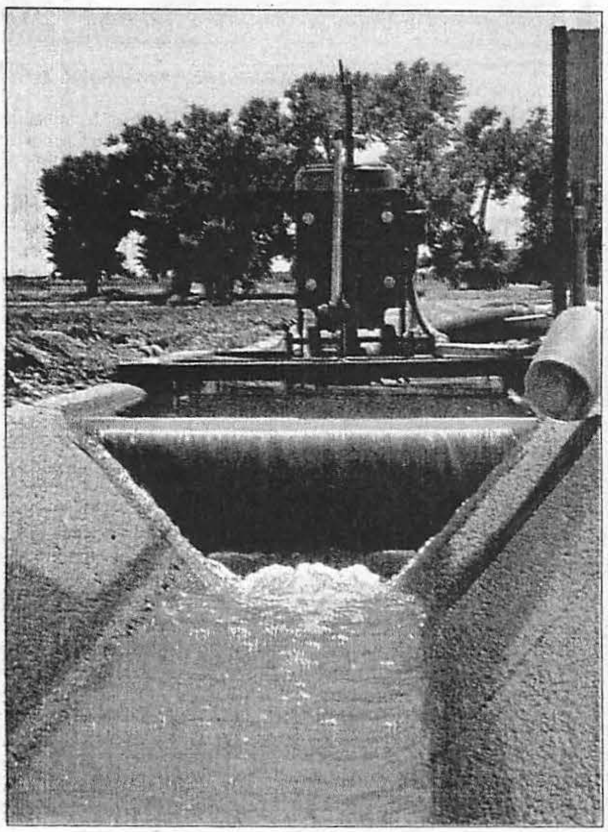
PLEASE SEE DRIP, 4B

Indeed, the drip system is a picture of efficiency. Unlike traditional furrow irrigation, water is delivered at the root level. The amount of water

Plummer reports yields per acre can double or even triple, with at least a 35 percent saving of water, alone.

"Uniformity translates to

...pays to keep fields in prod...



CHIEFTAIN PHOTO/ANTHONY MESTAS

A water pump for an irrigation system at Mameda Farms.

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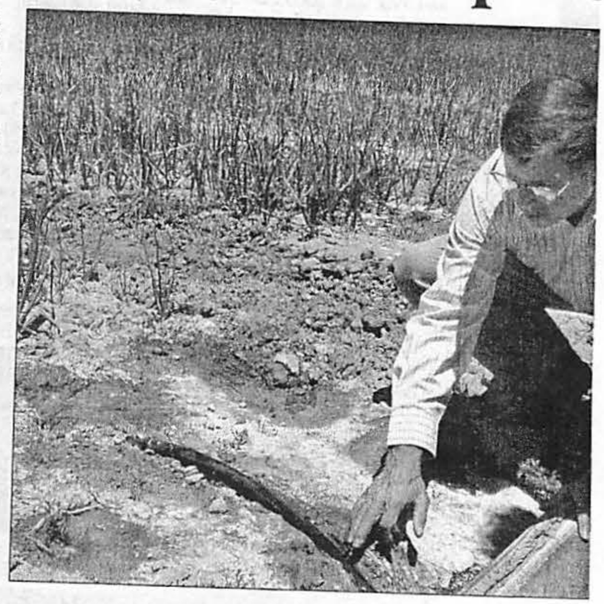

CHIEFTAIN

Bob Plummer, irrigation manager for Mameda Farms in Rocky Ford, ... irrigation emitters.

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DRIP / continued from page 1B

Indeed, the drip system is a picture of efficiency. Unlike traditional furrow irrigation, water is delivered at the root level. The amount of water required is calibrated daily. The system is largely automated, and fertilizers can be added directly to the irrigation water, making that process more efficient, also.

"If you don't see the water, you're saving it," Plummer said, noting drip irrigation sharply cuts evaporation losses.

The drip process has a side benefit of dramatically reducing return flows — water running off an irrigated field. That, in turn, can lessen the water-quality problems in the river associated with the return flows.

From a farming standpoint, the chief attraction remains improved production. Plummer reports yields per acre can double or even triple, with at least a 35 percent saving of water, alone.

"Uniformity translates to quality at harvest time," Plummer said, waving toward a virtual carpet of onion shoots.

Knapp believes the program will prove a benefit to the region.

"It can keep the land in production, and help keep farming in the Valley," he said. "Farmers can sell some of their water rights, change their cropping patterns and keep the melons going."

His drip system in place, Mameda agrees.

"With water becoming more scarce, another positive we can take from this is everyone working together for the benefit of all," he said. "That's going to be even more important in the future."

Main Identity

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75 of 125 DOCUMENTS

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HEADLINE: Compare costs of irrigation pumping

BYLINE: By Phil Tacker

BODY:

Crop harvest is the priority right now, but I hope this article will be helpful a little later as growers look at irrigation considerations for next year.

The irrigation pumping requirements for this season were generally less than we usually experience. However, comparing the pumping costs using different fuel and energy sources can be helpful in planning for next year.

The approach I am using considers only the seasonal operating costs associated with irrigation pumping. With increasing energy costs, the operating cost is usually at least 75 percent of the total irrigation cost over the life of an irrigation pumping plant.

Once you have a handle on the expected operating costs, you can compare the investment or fixed cost of the different options.

The information needed for the comparison is in three accompanying tables.

Table 1 shows what I feel are reasonable energy efficiency estimates for each fuel/energy source. In order to have a level playing field, the comparison uses the same horsepower load for each fuel/energy source. I am going to use "diesel" under a 50-hp load for an example and the numbers are highlighted in each of the three tables.

Using diesel in Table 2, divide the 50-hp load by an energy efficiency average of 18.5 hp-hr/gal to get the average fuel use of 2.7 gph gallons per hour .

Table 3 is used to calculate the average cost per hour based on the fuel/energy cost per unit. In this example the diesel is priced at $0.80/gal. and the operating energy cost is $2.16/hr 2.7 gph x $0.80/gal = $2.16/hr .

The cost of routine maintenance, like oil and filter changes for power units, is calculated as a percent of the operating energy cost. Using the 15 percent average for diesel units gets an additional $0.32 $2.16 x 0.15 = $0.32 to add to $2.16 for a total of $2.48/hr.

Table 3 also shows total cost calculations for the other fuel/energy sources at their respective cost per unit of fuel/energy. It may be difficult to nail down a unit cost for electric and natural gas since they usually have other charges to factor in. However, you can use different fuel/energy unit costs to determine how the variability affects the comparison.

In many cases comparing diesel to electric may be all that you do because that is all that is available. Electric may not be an option if the electric motor is bigger than 15 hp and three phase power is not available.

In some areas the propane company offers a summer power unit rental program that can be attractive from standpoint of less overhead and maintenance.

Vandalism problems in some locations and the distance to the field may make power units more of a problem to maintain than electric. Some growers may choose electric because it doesn't require fuel deliveries and the in-season oil and filter maintenance. However, most growers are more comfortable with trying to fix power units than they are with determining the problem with the electric.

The variable speed capability with power units can also be a significant comparison factor.

1. Energy efficiency estimates
Fuel/energy source
Energy
efficiency range Energy efficiency average
Diesel

17-20 hp-hr/gal 18.5 hp-hr/gal
Natural gas
9-11
hp-hr/ccf 10 hp-hr/ccf
LP propane
9-11
hp-hr/gal 10 hp-hr/gal
Gasoline
10-14
hp-hr/gal 12 hp-hr/gal
Electric-con
1-1.3
hp-hr/KWH 1.15 hp-hr/KWH
Electric-sub
1-1.1
hp-hr/KWH 1.05 hp-hr/KWH
hp-hr horsepower hours ; ccf 100 cubic feet , gal gallon ; KWH kilowatt hour .

2. Example for determining fuel/energy use - 50hp load
Fuel/energy source
Load
Energy efficiency average Fuel/energy use
Diesel
50 hp 18.5 hp-hr/gal 2.7 gph

Natural gas

50 hp 10 hp-hr/ccf 5.0 ccf/hr
LP propane

50 hp 10 hp-hr/gal 5.0 gph
Gasoline
50 hp 12 hp-hr/gal 4.2 gph
Electric-con

50 hp 1.15 hp-hr/KWH 43.5 KWH/hr
Electric-sub

50 hp 1.05 hp-hr/KWH 47.6 KWH/hr
ghp gallons per hour ; ccf/hr 100 cubic feet perhour ; KWH/hr kilowatt hours per hour .

3. Example for calculating operating cost per hour for 50-hp load

Routine maintenance
added as percentof operating energy cost
Fuel/energy source
Fuel/energy use Fuel/energy unit cost Operating energy cost Range
Average Total w/avg
Diesel 2.7 gph
$0.80/gal $2.16 10-20%
15% $2.48/hr
Natural gas 5.0
ccf/hr $0.70/ccf $3.50 10-15%
12.5% $3.94/hr
LP propane 5.0 gph
$0.90/gal $4.50 10-15%
12.5% $5.06/hr
Gasoline 4.2 gph
$1.30/gal $5.46 10-20%
15% $6.28/hr
Electric-con 43.5
KWH/hr $0.08/KWH $3.48 1-5%
3% $3.58/hr
Electric-sub 47.6
KWH/hr $0.08/KWH $3.81 3-10%
6.5% $4.06/hr
Electric: Con is conventional above-ground motorand Sub is submersible.

This is not the only way to compare pumping costs, and as I mentioned, you have investment costs and some of the other things I have listed to consider in making your decision.

Also, some may want to argue about some of the values I have used, but I feel this is a fair comparison method. I hope it is presented in a way that can be helpful.

This is one of several articles on drainage and irrigation water management. If you have questions or suggestions on topics please contact me: Phil Tacker, 501-671-2267 office , 501-671-2303 fax , 501-944-0708 cell , orptacker@uaex.edu e-mail .

Phil Tacker is an Arkansas Extension ag engineer.

LOAD-DATE: October 31, 2003

TECHNICAL

Wetland and Riparian Woodland Restoration Costs

by John Zentner, Jeff Glaspy and Devin Schenk

Three restorationists present detailed answers to the elusive question: How much will this wetland restoration cost?

A local non-profit recently asked us about the costs per acre for different types of wetland restoration. They were trying to determine how expensive it would be to implement regional wetland restoration goals, but could not find good information on costs. We told them that tidal marsh restoration would cost about $7,500/acre, assuming it was simply breaching a local levee; freshwater marsh would cost about $10,000 to $20,000/acre, depending on the amount of grading and planting densities; and riparian woodland would run about $40,000/acre, depending again on the extent of grading and planting densities but also on the extent of irrigation. When the non-profit sent out their report along with our cost estimates to a reviewing audience the reaction was startling, at least to us. Several people objected vehemently to what they felt were "absurdly high" cost estimates.

After this reaction, we also looked for information on costs in our library and on the Internet, either in the form of estimates or actual costs. Aside from some interesting projections or accounts for specific projects, almost the only work we found was a short article by Marylee Guinon (1989) noting that restoration costs were being grossly underestimated. The senior author of this paper then raised the issue at a SERCal conference and the reaction was informative. Not only did other restorationists feel that the true costs of restoration were rarely described, they felt that cost estimating was very poorly developed and that, for some projects, even the costs we quoted were low.

Project Costs

In this article, we provide costs for three different types of wetland restoration. Costs are initially presented as "baseline" costs (essentially, a private contractor-based estimate) with several variations following, based on likely construction options for these wetlands. At the conclusion, we note the differences that should be expected between these costs and those a non-profit or local public agency might expect to pay.

As noted elsewhere (Zentner 1999), the typical wetland restoration project is relatively small. This article will, accordingly, use as its examples a 10-acre (4-ha) salt marsh restoration and 1-acre (0.4-ha) freshwater marsh and riparian woodland restoration projects, all in the San Francisco Bay region. The costs described below are construction costs only, displayed in $US as of 2002. They do not include land acquisition; planning, permitting, and engineering (PP&E); or monitoring and maintenance (M&M).

Salt Marsh Restoration

Baseline Costs

We used to think that restoring salt marshes in the San Francisco Bay region was relatively simple. Almost two centuries of levee construction and farming has left many thousands of acres of "diked historic baylands" in the region, and restoration, at least early on, consisted simply of breaching the levees, watching the incoming tidal waters flood the site, and allowing sediment levels to increase to the point that marshes develop. Almost 20 years ago, Phil Williams, a local restorationist/hydrologist (see *R&MN* 17(4):202-209) navigated his kayak down the torrent into one such breech in south San Francisco Bay and, for many of us, captured the exhilaration of that period as 250 acres of diked lands were quickly (and cheaply) transformed into a productive estuary.

Since then, we have learned that most of these diked baylands have subsided, and that breaching a dike raises practical concerns from adjacent landowners who are not amused by plans to restore tidal action near their property, which is also below sea level. There is nothing like laying awake in bed at 2:00 a.m., listening to the rain coming down, knowing the tide is high and wondering if the wetland you just restored is going to flood the adjacent Interstate that 20,000 people expect to use the next day. Accordingly, the first order when doing such a restoration is the construction of a new perimeter levee that does not leak and will not breach in the first major storm. Figure 1 shows our hypothetical 10-acre salt marsh restoration project with the old levee and the tidal source on the west side of the site and a roughly square (for ease of calculation) border. In this case, the new perimeter levee would be 1,980 linear feet (LF) long (three sides of 660 ft each) along the southern, eastern and northern border. The baseline approach uses a levee with relatively steep sides (1.5:1; vertical:horizontal) built to +9.0 ft NGVD with a 10-ft wide top (Example 1 of Figure 2 shows the levee). Assuming the ground elevation is 0.0 ft, our levee contains about 7.8 cubic yards (CY) of dirt per LF for a total of 15,560 CY.[1] Levee construction includes moving the dirt (presumably from an on-site source), compacting it, and adding a clay core to stop seepage. The cost of levee construction currently averages about $3.20/CY. As a rule of thumb, we use a cost of $25/LF for levee construction in this region, which for this example is almost the same cost.

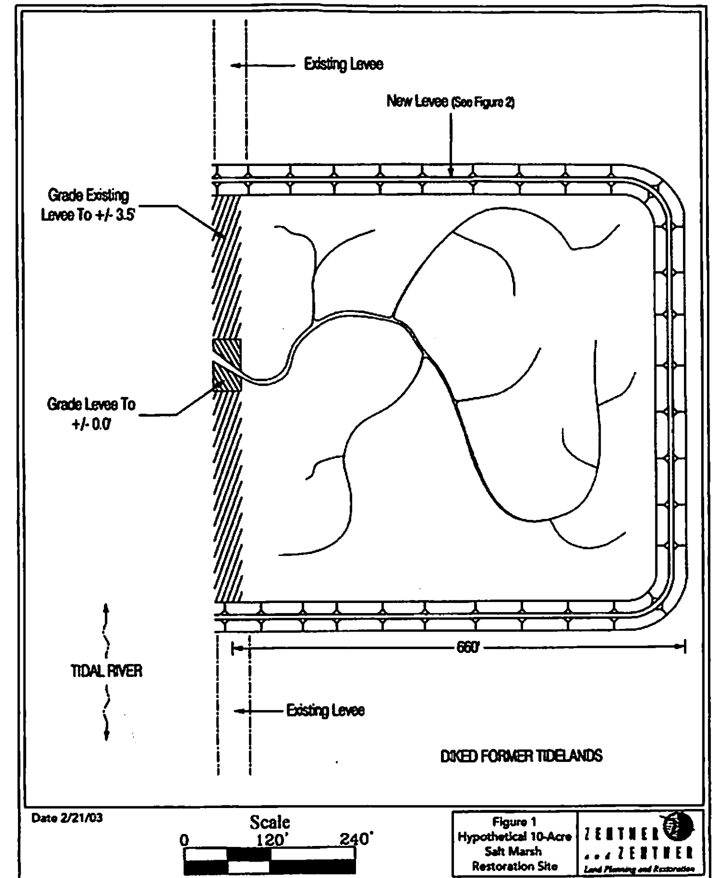

Figure 1. A diagram of a hypothetical 10-acre salt marsh restoration project with the old levee and the tidal source on the left side of the site. *All diagrams and photos courtesy of John Zentner*

Once the new perimeter levee has been built, the top 6 feet will be planted. The 6 feet on each side of a 1,980 LF levee translates to 23,760 square feet (SF) of planting, which is most commonly hydroseeded. We use a cost of $0.12/SF for hydroseeding. Costs will vary significantly for hydroseeding, though, depending on the seed used. An inexpensive erosion control mix (native wildflowers and non-native, fast-growing annual grasses) costs about $0.08/SF, while a predominantly native, perennial grass mix will cost $0.20/SF.

In this region, we generally don't plant the restored tidal marsh plain. Incoming tides provide sufficient plant material in the form of seeds and root material from other sites to rapidly colonize the new site once the elevations are appropriate. Additionally, the relatively few species of invasive tidal marsh plants found in this region are not spreading rapidly enough to warrant providing

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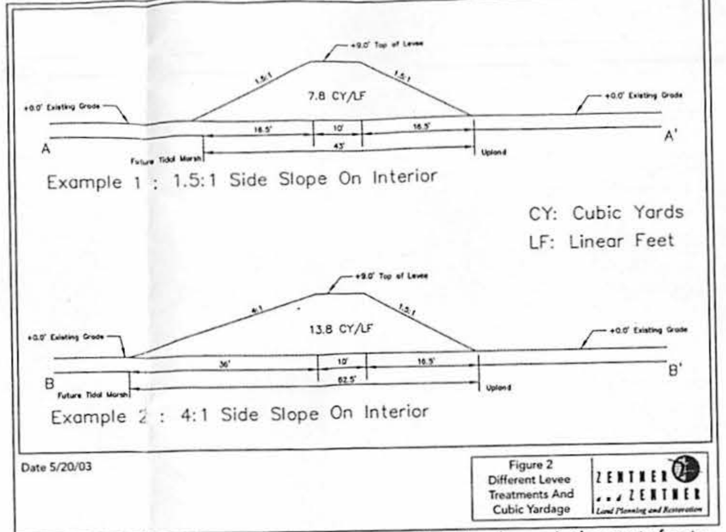

Figure 2. A diagram of two different levee treatments, including the required amount of material need to construct them. Variation 1 with 1.5:1 slopes (above) and Variation 2 with 4:1 front slope and 1.5:1 back slope (below).

Table 1. Baseline restoration costs for a 10-acre salt marsh site that has been restored by breaching a dike.

Element	Unit Cost	Extent	Total Cost	Assumptions/Comments
Levee Construction	\$25/LF	1,980 LF	\$50,000	Levee top 10 ft wide at +9 ft; ground elevation @0.0 ft; 1.5:1 side slopes (H:V), with clay core; all materials from on-site.
Hydroseed	\$0.12/SF	23,760 SF	\$3,000	Hydroseed the top 6 ft of both sides of the levee.
Exterior dike breech	\$5.50/CY	1,066 CY	\$6,000	Two 50-ft-wide breeches at -3.0 ft, sloped 1:1; heavy equipment can reach breech and deposit dirt on an adjacent area.
Totals			**\$59,000**	**\$6,000/acre**

immediate vegetation cover to reduce weed establishment.

Finally the old perimeter levee can be breached, letting the tides in. Table 1 includes the costs (rounded up to the nearest \$1,000) for this baseline process.

Variations

With 1.5:1 side slopes, our levee is not very well protected from the wave energy that can be generated on a 10-acre open pond (which is what a tidal marsh site is at high tide), and its sides will quickly erode after a few storms. To remedy this situation generally requires protecting two of the four sides of our hypothetically square restored wetland, or about 1,320 LF. Providing a rip-rap cover capable of withstanding erosive forces in the Bay Area adds about \$25 per linear foot to levee construction costs (another rule of thumb). This will add \$33,000 to the total.

Alternatively, increasing the interior levee slopes to an average 4:1 will accomplish much the same purpose (thanks to Dr. Peter Baye for that observation). Increasing the interior levee to 4:1 from 1.5:1 over the 9 feet of vertical height adds approximately 6 CY per linear foot of levee (see Example 2 of Figure 2). With a 1,980-ft levee, this adds about 12,000 CY, which at a cost of about \$3.20/CY (see previous levee grading assumptions) adds about \$40,000. This is more costly than the rip-rap, but ecologically more preferable.

Excavating to create the marsh, assuming the location is adjacent to a source of tidal water, is another option and generally does not have the potential to flood the neighbors or require building and maintaining levees.[2] However, it does require excavating the marsh basin and tidal channels and planting the upper rim of the basin (see Zentner and Micallef 2001 for a sample project). Assuming that the site is at +6.0 ft and the target elevation is +2.0 ft and that the side slopes are 3:1, the work can be done in dry conditions using large-volume scrapers that deposit the dirt nearby for a cost of \$2.00/CY. This results in a total excavation of almost 65,000 CY. Then, assuming that the tidal breach is excavated to -3.0 ft with 1:1 sides and that the tidal channels are similarly sized and about 1,500 ft long (\$4.50/CY), and that the excavated slopes are hydroseeded, the total project cost is about \$140,000.

In our experience, hydroseeding may provide a showy display of native wildflowers for one to two years, but non-native upland weeds take over thereafter. Planting a native tidal marsh fringe, dominated primarily by rhizomatous perennial grasses, such as creeping wild rye (*Leymus triticoides*) and salt grass (*Distichlis spicata*), is almost the only way we know to provide long- term native vegetation cover. Such a planting will cost about \$8,000 per acre (see freshwater marsh costs for more detail on this element).

Based on these examples, salt marsh restoration will cost from about \$6,000 to \$10,000 per acre for a dike breaching project, and \$14,000 per acre for excavation. As noted above, and will be the case for

Table 2. Baseline costs and three cost variations for a 10-acre salt marsh restoration where a dike has been breeched.

Element	Baseline	Variation 1	Variation 2	Variation 3
Grading	Levees with 1.5:1 slopes: \$50,000	1.5:1 levee with two rip-raped slopes: \$83,000	4:1 interior levee slopes: \$90,000	Excavate from upland: \$130,000
Planting: 0.54 acre	Hydroseed: \$3,000	Planting \$4,000	Planting: \$4,000	Planting: \$4,000
Final grading	Dike breach: \$6,000	Dike breach: \$6,000	Dike breach: \$6,000	Excavate channels: \$7,000
Total Costs; Costs/acre	**\$59,000; \$6,000**	**\$93,000; \$9,300**	**\$100,000; \$10,000**	**\$141,000; \$14,100**

the examples below, these costs do not include land acquisition, PP&E or M&M.

Freshwater Marshes

We divide marshes into three categories based on hydroperiod: perennial marshes, which are inundated for all or almost all of the year and dominated by open water, cattails (*Typha* spp.) and tules (*Scirpus* spp.); seasonal marshes, inundated for three to nine months to 1 to 2 ft and dominated by species such as spike rush (*Eleocharis palustris*); and wet meadows, which are primarily driven by saturation and are dominated by perennial graminoids like creeping wild rye, Santa Barbara sedge (*Carex barbarae*), and Baltic rush (*Juncus balticus*). These categories also reflect very different costs for restoration.

Perennial marshes

Perennial marshes are generally built by either excavating a basin and/or building levees; costs for both have been described above for salt marshes.[3] Due to our aversion to levees (remember, entropy happens!), the baseline case for perennial marshes is an excavated basin. For this example, we use a 6-ft deep basin of exactly 1 acre with square 209-ft long sides and 3:1 side slopes, resulting in the excavation of about 8,200 CY. Assuming this work is done in dry conditions, it will cost about \$2.00/CY.

Marsh basin construction is the opposite of levee construction since providing for gentler slopes results in less grading and, therefore, lower costs. However, this also reduces the extent of wetland. For example, gentler side slopes (averaging 8:1 as in Variation 1 below) reduce the amount of excavation to about 6,300 CY and provide a greater extent of upland-wetland transition zone, a topographic feature that is sorely lacking in most wetlands. For the 1-acre example, the 3:1 side slope basin contains about 0.90 acres of wetland, while the 8:1 side slope basin contains about 0.70 acres of wetland, assuming both wetlands reach to 4 ft in depth in our 6-ft basin. Without passing judgement on the ecological propriety, the difference between these two may be crucial for mitigation projects in relatively tight site conditions.[4]

As with tidal salt marshes in this region (unlike elsewhere), we generally do not plant the restored perennial marsh basin because natural revegetation by the native dominants is common and there are relatively few perennial marsh weeds. However, as with the tidal marsh restoration, planting of the wetland fringe will be needed and this can take the form of hydroseeding or planting, as noted above. This cost also varies depending on the slope; gentler slopes result in more upland transition which requires more planting. A 3:1 slope (using the same example from above) provides about 0.10 acres of planting zone in our 1-acre marsh, while an 8:1 slope results in about 0.30 acres of planting.

Some form of water control structure is generally required, typically either a pipe-gate (see *ER* 20(3):217 for a good photo of a self-regulating tide gate, which can also be adapted for freshwater conditions) or a weir. Table 3 provides a summary of costs for several options. Based on these examples, perennial marsh restoration will cost from about \$21,400 to \$33,300 per acre depending on the options chosen.

Seasonal marshes and wet meadows

Seasonal marshes and wet meadows are shallow basins or flats. Grading these sites is relatively simple—a rough outline is dug using high-volume scrapers followed by a smaller tractor to do the final contouring. Grading a 1-acre seasonal marsh basin, for example, to 2 ft in depth with 4:1 side slopes, and earthen entry-and-exit swales will cost about \$9,000 (3,000 CY at \$2.50/CY with about \$1,200 for final grad-

Table 3. Summary cost ranges for a 1-acre perennial marsh restoration.

Element	Baseline	Variation 1	Variation 2
Basin Construction	Excavated basin 6 ft deep, 3:1 side slopes; \$16,500	Excavated basin 6 ft deep, 8:1 side slopes: \$12,600	6 ft levee, 4:1 side slopes on interior, 2:1 on exterior, 10 ft top: \$30,000
Planting	Hydroseed 4600 ft² @ \$.12/ft²: \$600	Planting 0.3 acre @ \$8,000/acre: \$2,400	Planting 6000 ft² @ \$8,000/acre: \$1,100
Water control	2 rock weirs: \$6,400	2 rock weirs: \$6,400	2 Waterman slide/flap gates: \$2,200
Total Costs	**\$23,500**	**\$21,400**	**\$33,300**

Figure 3. A typical seasonal marsh restoration project, just after final grading.

Figure 4. A photo showing the difference in size between 1-gallon (left), tree-band (middle), and rose-pot (right) plant stock.

ing work). Figure 3 is a typical seasonal marsh project after grading and subsequent rainfall. Wet meadows are even shallower (0.9 to 1.0 ft deep) with corresponding reductions in grading costs to $6,000 for a 1-acre shallow flat.[5] This results in a higher per CY grading cost than with perennial marshes, but total grading costs are reduced relative to perennial marshes due to the shallow depth.

Unlike tidal salt marsh or perennial marsh in this region, these habitats require planting because the naturally dominant native plants do not readily invade the restored marsh basin. They are almost all perennial graminoids or similar species with low germination rates and/or slow colonization. Also, unlike tidal salt or perennial marshes, seasonal marshes and wet meadows are readily invaded by a host of non-native species that are well-established in this region. These factors all argue strongly, to us, for planting of rooted material at high densities. Others believe in hydroseeding or other seeding methods, which are much less expensive. In short, planting costs for these wetlands vary tremendously and there is no widely accepted approach to planting these habitats.

Hydroseeding costs have been addressed above. Planting of rooted material is a completely different effort. Typically, the species used for seasonal marshes and wet meadows, such as spikerush, Baltic rush and soft rush (*Juncus effusus*), come in a variety of stock sizes (Figure 4). Those most typically used in this region and their sizes are: plugs (very small, ½ inch x ½ inch x 3 inches), rose-pots (small, 2 inches x 2 inches x 3 inches), tree-bands (deep, 3 inches x 3 inches x 6 inches), or 1-gallons (large, 6 inches diameter x 8 inches deep).

Although the cost differential is significant, there is little hard data on the smallest (and, therefore, cheapest) size that will still provide good growth in field conditions. It is likely that this varies by species, but to our knowledge there have been no field tests of the various sizes for each species under controlled conditions. At this time, each restorationist in this region is making their best professional guess as to the appropriate sizes.

Complicating this issue is the matter of planting densities. As with plant sizes, little objective information is available on the appropriate densities at which these species should be planted. As shown in Table 4, density and plant size have significant cost implications. The difference between planting an acre with 1-gallon plants on 1-ft centers and another acre with plugs on 4-ft centers is enough to buy 60 acres of land suitable for conversion to wetland, even in California. As significant, though, is that we really do not know the appropriate middle ground. For seasonal marshes, with their mix of deep- and shallow-rooted species and moderate cover, we generally plant on 2- to 3-ft centers with a mix of plugs and rose-pots at a cost of $8,500/acre (Table 5). An alternative that we have rarely been able to do because of cost restrictions, would be the same density but using a mix of rose-pots and tree-bands, which would cost about $34,000/acre. Alternatively, we have reviewed seasonal marsh restoration projects that have been hydroseeded at a cost of about $4,000/acre and projects planted with plugs on 3-ft centers ($2,100/acre). Neither of these latter examples are what we would term successful, although they still are used because of price competition, lack of regulatory direction, and consultant acquiescence to parsimonious clients.

Native-dominated wet meadows are even more problematic. In the western United States, the drier it gets the more we have to face increasing competition from weeds. For wet meadows, we recommend and plan that the predominant species be planted as plugs on at least 18-inch centers ($8,000/acre) and preferably on 1-ft centers ($18,100/acre) or on 18-inch centers with 20 percent of the plants as rose-pots ($15,200/acre). Again, it is not difficult to understand why project managers might opt for less expensive solutions.

Salvaged topsoil application has also been used to restore native marsh and has been successful at providing good cover and introducing species diversity, although it also obviously requires a donor site. Topsoil salvaging is expensive by the cubic yard (plan for at least $10/cubic yard for salvage and re-application) but application can cost as little as $8,000/acre. In the best cases, it can be done by scraping 4 to 6 inches from the surface and transporting it with a scraper to a nearby site for immediate re-application with finish grading to a depth of 2 to 3 inches. Costs will go up dramatically when the topsoil must be transported more than 0.1 mile or when the work cannot be done with a scraper.

There are obvious differences in cost for these variations but little or no objective, verified information on the comparative differences and their progress at restoring naturalistic systems. Given the absence of comparisons, the near-absence of standard contract specifications, and the presence of competitive bidding, the variation most commonly selected is likely to be the least expensive.

Table 4. Planting densities and costs for marsh plants on sites greater than 1 acre.

Density (on-center)	Plants/ Acre	Plugs ($0.42 ea)	Rose-pots ($2.25 ea)	Tree-bands ($6.00 ea)	1-gallon ($14.00 ea)
4 ft	2,800	$1,200	$6,300	$16,800	$39,200
3 ft	5,000	$2,100	$11,300	$30,000	$70,000
2 ft	11,000	$4,600	$24,800	$66,000	$154,000
1.5 ft	19,000	$8,000	$42,800	$114,000	$266,000
1 ft	43,000	$18,100	$96,800	$258,000	$602,000

Riparian Woodlands

As described here, riparian woodlands consist of a channel, an overstory of trees and shrubs, and an understory of native herbs. The lateral extent of this area is greater than that typically defined as wetlands by the Corps of Engineers under its Section 404 authority but consistent with ecological understanding of riparian vegetation associations in California (Faber and others 1989). To make cost comparisons simple, this example assumes the reconstruction of a trapezoidal, 50-ft wide by 870-ft long channel, which provides a convenient 1-acre test.

Grading of the restored channel is relatively straightforward in this example as much, if not all, of the work can be done by scrapers at a relatively reasonable cost. The breadth and depth of the channel, however, require that about 3500 CY be excavated for a total cost of $14,500.

Planting for the riparian woodland involves significantly greater complexity and costs than any of the previous examples, primarily because the range of plant sizes and materials is so great and because, in this region, the trees and shrubs require irrigation. Again, there are no standard densities or plant sizes and the disparity in costs is greater than with marsh plants. Commonly used plant stock includes cuttings (bare root or salvaged from natural stands; not appropriate for many species aside from willows in this region), tree-pots (4 inch x 14 inch and preferred for deep rooting species, such as oaks), 5-gallon (12 inch x 14 inch, great for shrubs) and 15-gallon (18 inch x 24 inch, great for trees). Table 6 provides costs of the different plant material types at varying densities.

Typically, we plant the drier woodlands (above the mean annual flood [MAF] line) on 10-ft centers with a mix of tree-pots for the trees and 1- and 5-gallon stock for shrubs at a cost of $8,000/acre. Below the MAF, we use a mix of cuttings, tree-pots, and 1-gallon stock on 9-ft centers for a similar cost. These densities are based on our conception of planting densities required to produce relatively naturalistic systems in ten years.

Irrigation comes in many forms (see *ER* 20(1):23-30). We use drip systems (spray promotes summer-active weeds) with battery-powered (DC) controllers (an electrical connection is often not available). We irrigate all trees and shrubs with the exception of the cuttings. Typically this

Table 5. Baseline costs and two cost variations for a 1-acre seasonal marsh/wet meadow restoration.

Element	Baseline	Variation 1	Variation 2
Grading	1.5-ft deep basin or flat: $8,000	1.5-ft deep basin or flat: $8,000	1.5-ft deep basin or flat: $8,000
Planting	Plugs & rosepots @ 2-3 ft centers: $8,500	Rosepots & tree-bands @ 2-3 ft centers: $34,000	Hydroseeding: $4,000
Total Costs	**$16,500**	**$42,000**	**$12,000**

Table 6. Planting densities and costs for riparian trees and shrubs.

Density (on-center)	Plants/ Acre	Cuttings ($8.00 ea)	Tree-pots ($17.00 ea)	5-gallon ($25.00 ea)	15-gallon ($80.00 ea)
20 ft	100	$800	$1,700	$2,500	$8,000
12 ft	300	$2,400	$5,100	$7,500	$24,000
10 ft	430	$3,400	$7,300	$10,750	$34,400
8 ft	680	$5,400	$11,600	$17,000	$54,400

adds $18 per tree and shrub. Using our typical example from the preceding paragraph, this is 480 plants in one acre for a total cost of about $8,000 for irrigation.

The restoration of understory vegetation often receives short shrift in California riparian work. Typical dominants in the pre-Columbian period were creeping wild rye and Santa Barbara sedge. Optimally, these would be planted as plugs on 18-inch centers for a cost of about $9,000/acre (including a mow and herbicide spray to eliminate weeds).

Total riparian woodland cost for this one acre example are about $40,000. Obviously, the variations on this case are too numerous to consider.

Wetland and Riparian Restoration Costs for Non-Profits and Public Agencies

Of course, restoration can be done for less. Non-profits, especially those with large, volunteer labor pools can, in certain circumstances, decrease these costs significantly. For several of the wetland types noted above, grading and related construction are the primary costs. Most grading is done by heavy equipment with specialized labor that is not part of a non-profits constituency. On the other hand, some non-profits have had a good amount of work donated by construction companies.

Planting costs are very significant, however, and can be the predominant cost for some types of wetland and riparian projects. Planting is very labor-dependent (70 percent labor costs, 30 plant costs is a general rule of thumb) and the labor is mostly non-specialized. For example, assuming a non-profit can find free labor for planting the riparian woodland planting above, they would reduce the cost of the project by $5,600.

Irrigation installation is also labor-intensive and with a few hours from a good plumber to do the back-flow preventer or related points of connection, the remainder of the work is very simple and not beyond a non-profits' labor pool.

Public sector restoration, on the other hand, appears to have at least a 15- to 20-percent higher cost margin than private sector contracting in California. Based on our experience, public agencies have higher costs than the private sector due primarily to higher labor rates, "risk assumption," and materials specifications.

Higher labor costs have been a major issue in public contracting due to the payment of a "prevailing wage" to project labor. As a result, labor costs on a public sector job will typically be 100 percent more than for a private contracting operation, which increases total project costs by about 35 percent. For example, a laborer is generally charged out at $10/hr for landscape work by a typical private-sector job in this region. With a prevailing wage job, he or she is charged out at $30/hr. Without reference to the social equity issues, this represents a serious cost increase.

Second, public contracts are generally "risk-adverse." In other words, the public agency seeks to have the contractor assume all risks and, as a result, the specifications are very detailed with regards to the work. This avoids the constant problem of contractors pushing for change orders for every small variation. It also greatly increases bid prices. Private sector work, on the other hand, is generally "shared risk" work and the specifications are simpler and shorter.

Finally, public sector jobs tend to use much higher cost materials than are used in private sector jobs. As an example, we noted above the type of drip irrigation system we typically use, a relatively cheap system with battery-operated controllers. The public sector jobs we do typically have more elaborate irrigation systems, often with back-up power systems and satellite control capability.

Summary

First, ecological restoration of wetlands and riparian areas is expensive. Despite statements to the contrary, the contacts we made with other contractors and agency staff convinced us that much of the restoration work carried out in the San Francisco Bay region is even more expensive than detailed here. Moreover, the costs described above do not include the costs of land acquisition; planning, permitting and engineering; or monitoring and maintenance. Furthermore, even with the variations used in the costs described above, no unusual conditions (contaminated soils, movement of power transmission towers, or similar features) were included.

The Contra Costa County Public Works Department recently completed a survey of other public works agencies in the region about the costs of mitigation work. Of the nine responses received with wetland creation/restoration/enhancement cost estimates, three responses noted costs of $100,000 to $500,000 per acre, two responses cited costs of $50,000 to $100,000 per acre, three more were for $10,000 to $50,000 per acre, and one was for $1,000 to $10,000 per acre. County staff noted that the under $50,000 per acre costs were presumably for tidal marsh projects, meaning that freshwater wetland restoration costs for local public works agencies ranges from $50,000 to $500,000 per acre (Cece Sellgren, personal communication).

Second, there is still a large gap between wetland restoration designers and the contractors and others who restore wetlands. Furthermore, the research on wetland restoration appears to be largely focused on design problems, not the gritty, day-to-day real problems. Unlike engineering or architecture, ecological restoration does not have an entity comparable to AASHTO or similar organizations that seek solutions to practical engineering issues and develop applicable standards. It is at times difficult to be optimistic about the success of this field when so much attention is paid to ephemera while the basic building blocks of the field remain unexplored. Restoration planners must understand the physical characteristics, the opportunities, and constraints of restoration work. This does not mean that restoration planning requires a contractors' license, but it does mean coming to grips with horticulture, irrigation design, and construction equipment. We have found that it also helps immensely to include landscape contractors in the design team, require ecological monitoring during the construction phase (and require that the restoration planners be involved in that phase), and to recognize the physical limitations of construction and maintenance equipment and operations in the planning phase.

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Endnotes

1. Yardage estimates and costs are generally rounded up to the nearest appropriate place. In the example, the cubic feet we rounded-up from 418,770 to 420,000, which was then used to calculate the cubic yardage. Rounding up is also used to account for the uncertainties that plague cost estimating and restoration.
2. This paper does not include M&M costs but levee maintenance is a significant factor in these types of projects, both due to costs (as much as $1.00 to $2.00/LF/year) and the potentially horrendous affects of an unplanned levee breach.
3. These marshes can also be built by constructing dams or similar features. Construction of these marshes is not covered here because of the engineering effort required and the specificity of each dam to a particular location.
4. Of course, this effect will vary depending on the perimeter:interior ratio. Wetlands with relatively large perimeters (relative to the extent of the interior) and gentler side slopes will "lose" more available land to uplands, while wetlands with relatively small perimeters will not lose as much.
5. An important conversion factor: one acre-foot is 1,613 CY. We know, accordingly, that a 10-acre, 2-ft deep basin will require excavating about 32,000 CY.

Unit Costs

on zip disk drive

National Management Measures to Control Nonpoint Source Pollution from Agriculture

Draft 08/31/00

Prepared for

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Nonpoint Source Control Branch
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by

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Tetra Tech, Inc.
Fairfax, VA
George Townsend, Work Assignment Leader

U.S. EPA Contract # 68-C99-249
Work Assignment # 0-29

Table of Contents

Tailwater recovery may be required if surface chemigation is practiced, and backflow prevention is needed if sprinkler chemigation is used.

Cost and Savings of Practices

[EPA solicits additional information on costs.]

Costs

Costs to install, operate and maintain an irrigation system will depend on the type of irrigation system used. In order to efficiently irrigate and prevent pollution of surface and ground waters, the irrigation system must be properly maintained and water measuring devices used to estimate water use.

A cost of $10 per irrigated acre is estimated to cover investments in flow meters, tensiometers, and soil moisture probes (EPA, 1992a; Evans, 1992). The cost of devices to measure soil water ranges from $3 to $4,900 (Table 4f-11). Gypsum blocks and tensiometers are the two most commonly used devices.

Table 4f-11. Cost of soil water measuring devices.

Device	Approximate Cost
Tensiometers[a]	$50 and up, depending on size
Gypsum blocks[b]	$3-4, $200-400 for meter
Neutron Probe[c]	$4,900
Phene Cell[a]	$4,000-4,500
Tensiometers and soil moisture probes[d]	$10 per irrigated acre

[a] Hydratec, 1998.
[b] Sneed, 1992.
[c] Cambell Pacific Nuclear, 1998.
[d] Evans, 1992.

For quarter-section center pivot systems, backflow prevention devices cost about $416 per well (Stolzenburg, 1992). This cost (1992 dollars) is for: (1) an 8-inch, 2-foot-long unit with a check valve inside ($386); and (2) a one-way injection point valve ($30). Assuming that each well will provide about 800-1,000 gallons per minute, approximately 130 acres will be served by each well. The cost for backflow prevention for center pivot systems then becomes approximately $3.20 per acre. In South Dakota, the cost for an 8-inch standard check valve is about $300, while an 8-inch check valve with inspection points and vacuum release costs about $800 (Goodman, 1992). The latter are required by State law. For quarter-section center pivot systems, the cost for standard check valves ranges from about $1.88 per acre (corners irrigated, covering 160 acres) to $2.31 per acre (circular pattern, covering about 130 acres). To maintain existing equipment so that water delivery is efficient, annual maintenance costs can be figured at 1.5% of the new equipment cost (Scherer, 1994).

Tailwater can be prevented in sprinkler irrigation systems through effective irrigation scheduling, but may need to be managed in furrow systems. The reuse of tailwater downslope on adjacent fields is a low-cost alternative to tailwater recovery and upslope reuse (Boyle Engineering Corp., 1986). Tailwater recovery systems require a suitable drainage water receiving facility such as a sump or a holding pond, and a pump and pipelines to return the tailwater for reapplication (Boyle Engineering Corp., 1986). The cost to install a tailwater recovery system was about $125/acre in California (California SWRCB, 1987) and $97.00/acre in the Long Pine Creek, Nebraska, RCWP (Hermsmeyer, 1991). Additional costs may be incurred to maintain the tailwater recovery system.

The cost associated with surface and subsurface drains is largely dependent upon the design of the drainage system. In finer textured soils, subsurface drains may need to be placed at close intervals to adequately lower the water table. To convey water to a distant outlet, land area must be taken out of production for surface drains to remove seeping ground water and for collection of subsurface drainage.

The Agricultural Conservation Program (ACP) has been phased out and replaced by the Environmental Quality Incentive Program (EQIP) in the 1996 Farm Bill. However, the Statistical Summaries (USDA-FSA, 1996) from the ACP contain reliable cost-share estimates. The following cost information is taken from these summaries and assumes a 50% cost-share to obtain capital cost estimates. The ACP program has a unique set of practice codes that are linked to a conservation practice. The cost to install irrigation water conservation systems (FSA practice WC4) for the primary purpose of water conservation in the 33 States that used the practice was about $73.00 per acre served in 1995. Practice WC4 increased the average irrigation system efficiency from 47% to 64% at an amortized cost of $10.41 per acre foot of water conserved. The components of practice WC4 are critical area planting, canal or lateral, structure for water control, field ditch, sediment basin, grassed waterway or outlet, land leveling, water conveyance ditch and canal lining, water conveyance pipeline, trickle (drip) system, sprinkler system, surface and subsurface system, tailwater recovery, land smoothing, pit or regulation reservoir, subsurface drainage for salinity, and toxic salt reduction. When installed for the primary purpose of water quality, the average installation cost for WC4 was about $67 per acre served. For erosion control, practice WC4 averaged approximately $82 per acre served. Specific cost data for each component of WC4 are not available.

Water management systems for pollution control, practice SP35, cost about $94 per acre served when installed for the primary purpose of water quality. When installed for erosion control, SP35 costs about $72 per acre served. The components of SP35 are grass and legumes in rotation, underground outlets, land smoothing, structures for water control, subsurface drains, field ditches, mains or laterals, and toxic salt reduction.

The design lifetimes for a range of salt load reduction measures are presented in Table 4f-12 (USDA-ASCS, 1988).

Table 4f-12. Design lifetime for selected salt load reduction measures (USDA-ASCS, 1988).

Practice/Structure	Design Life (Years)
Irrigation Land Leveling	10
Irrigation Pipelines – Aluminum Pipe	20
Irrigation Pipelines – Rigid Gated Pipe	15
Irrigation Canal and Ditch Lining	20
Irrigation Head Ditches	1
Water Control Structure	20
Trickle Irrigation System	10
Sprinkler Irrigation System	15
Surface Irrigation System	15
Irrigation Pit or Regulation Reservoir	20
Subsurface Drain	20
Toxic Salt Reduction	1
Irrigation Tailwater Recovery System	20
Irrigation Water Management	1
Underground Outlet	20
Pump Plant for Water Control	15

Savings

Savings associated with irrigation water management generally come from reduced water and fertilizer use.

Steele et al. (1996) found that improved methods of irrigation scheduling can produce significant savings in seasonal irrigation water totals without yield reductions. In a six-year continuous corn field study, a 31% savings in seasonal irrigation totals was realized compared to the average commercial grower in the same irrigation district. Corn grain yields were maintained at 3% above average corn grain yields in the irrigation district.

- Know the livestock diet requirements in terms of quantity and quality to ensure that there are enough grazing units to provide adequate livestock nutrition for the season and the kind and classes of animals on the farm/ranch.
- Maintain a flexible grazing system to adjust for unexpected environmentally and economically generated problems.
- Follow special requirements to protect threatened or endangered species.

To speed up the rehabilitation process of riparian zones, seeding can be used as a proper management practice. This strategy, however, can be very expensive and risky. Riparian zones can be rehabilitated positively and at a lower cost through improving livestock distribution, better watering systems, fencing, or reducing stock rates. In areas where the desirable native perennial forage plants are nearly extinct, seeding is essential. Such areas will have a poor to very poor rating of forage condition and are difficult to restore.

Cost and Savings of Practices

[EPA solocits additional information on costs.]

[This section is incomplete. EPA solicits recent data on grazing management costs. The public is encouraged to submit studies detailing the costs and benefits of related management practices.]

[EPA solicits additional data on animal health as related to water quality improvements.]

[EPA solicits approximate lifespans of practices, as appropriate and available.]

Costs

Much of the cost associated with implementing grazing management practices is due to fencing installation, water development, and seeding. Costs vary according to region and type of practice. Generally, the more components or structures a practice requires, the more expensive it is. However, cost-share is usually available from the USDA and other Federal agencies for most of these practices.

The principal direct costs of providing grazing practices vary from relatively low variable costs of dispersed salt blocks to higher capital and maintenance costs of supplementary water supply improvements. Improving the distribution of grazing pressure by developing a planned grazing system or strategically locating water troughs, salt, or feeding areas to draw cattle away from riparian zones can result in improved utilization of existing forage, better water quality, and improved riparian habitat.

Principal direct costs of excluding livestock from the riparian zone for a period of time are the capital and maintenance costs for fencing to restrict access to streamside areas and/or the cost of herders to achieve the same results. In addition, there may be an indirect cost of the forage that is removed from grazing by the exclusion.

Principal direct costs of improving or reestablishing grazing land include the costs of seed, fertilizer, and herbicides needed to establish the new forage stand

and the labor and machinery costs required for preparation, planting, cultivation, and weed control (Table 4e-7). An indirect cost may be the forage that is removed from grazing during the reestablishment work and rest for seeding establishment.

Table 4e-7. Cost of forage improvement/reestablishment for grazing management (EPA, 1993a).

Location	Year	Type	Unit	Reported Capital Costs $/Unit	Constant Dollar[a] Capital Costs 1991 $/Unit	Constant Dollar[a] Annualized Costs 1991 $/Unit
Alabama[b]	1990	planting (seed, lime & fertilizer)	acre	84 - 197	83 - 195	12.37 - 29.00
Nebraska[c]	1991	establishment	acre	47	47	7.00
		seeding	acre	45	45	6.71
Oregon[d]	1991	establishment	acre	27	27	4.02

[a] Reported costs inflated to 1991 constant dollars by the ratio of indices of prices paid by farmers for seed, 1997=100. Capital costs are annualized at 8% interest for 10 years.
[b] Alabama Soil Conservation Service, 1990.
[c] Hermsmeyer, 1991.
[d] USDA–ASCS, 1991b.

Water Development

The availability and feasibility of supplementary water development varies considerably between arid western areas and humid eastern areas, but costs for water development, including spring development and pipeline watering, are similar (Table 4e-8). Additional cost data for watering troughs, piping, and holding tanks are given in Table 4e-10. These costs should be applied on a per-foot or per-gallon basis.

Use Exclusion

There is considerable difference between multistrand barbed wire, chiefly used for perimeter fencing and permanent stream exclusion and diversions, and single- or double-strand smoothwire electrified fencing used for stream exclusion and temporary divisions within permanent pastures. The latter may be all that is needed to accomplish most livestock exclusion in a smaller, managed, riparian pasture (Table 4e-9). Additional cost data for fencing are provided in Table 4e-10.

Overall Costs of the Grazing Management Measure

Since the combination of practices needed to implement the management measure depends on site-specific conditions that are highly variable, the overall cost of the measure is best estimated from similar combinations of practices applied under the Agricultural Conservation Program (ACP), Rural Clean Water Program (RCWP), and similar activities.

Table 4e-8. Cost of water development for grazing management (EPA, 1993a).

					Constant Dollar[a]	
Location	Year	Type	Unit	Reported Capital Costs $/Unit	Capital Costs 1991 $/Unit	Annualized Costs 1991 $/Unit
California[b]	1979	pipeline	foot	0.28	0.35	0.05
Kansas[c]	1989	spring	each	1,239.00	1,282.94	191.20
		spring	each	1,389.00	1,438.26	214.34
Maine[d]	1988	pipeline	each	831.00	879.17	131.02
Alabama[e]	1990	spring	each	1,500.00	1,520.83	226.65
		pipeline	foot	1.60	1.62	0.24
		trough	each	1,000.00	1,013.89	151.10
Nebraska[f]	1991	pipeline	foot	1.31	1.31	0.20
		tank	each	370.00	370.00	55.14
Utah[g]	1968	spring	each	200.00	389.33	58.02
Oregon[h]	1991	pipeline	foot	0.20	0.20	0.03
		tank	each	183.00	183.00	27.27

[a] Reported costs inflated to 1991 constant dollars by the ratio of indices of prices paid by farmers for building and fencing, 1977=100. Capital costs are annualized at 8% interest for 10 years.
[b] Fresno Field Office, 1979.
[c] Northup et al., 1989.
[d] Cumberland County Soil and Water Conservation District, undated.
[e] Alabama Soil Conservation Service, 1990.
[f] Hermsmeyer, 1991.
[g] Workman and Hooper, 1968.
[h] USDA–ASCS, 1991b.

Table 4e-9. Cost of livestock exclusion for grazing management (EPA, 1993a).

					Constant Dollar[a]	
Location	Year	Type	Unit	Reported Capital Costs $/Unit	Capital Costs 1991 $/Unit	Annualized Costs 1991 $/Unit
California[b]	1979	permanent	mile	2,000	2,474.58	368.78
Alabama[c]	1990	permanent	mile	3,960	4,015.00	598.35
		net wire	mile	5,808	5,888.67	877.58
		electric	mile	2,640	2,676.67	398.90
Nebraska[d]	1991	permanent	mile	2,478	2,478.00	369.30
Great Lakes[e]	1989	permanent	mile	2,100 - 2,400	2,174.47 - 2,485.11	324.06 - 370.35
Oregon[1]	1991	permanent	mile	2,640	2,640.00	393.44

[a] Reported costs inflated to 1991 constant dollars by the ratio of indices of prices paid by farmers for building and fencing, 1977=100. Capital costs are annualized at 8% interest for 10 years.
[b] Fresno Field Office, 1979.
[c] Alabama Soil Conservation Service, 1990.
[d] Hermsmeyer, 1991.
[e] DPRA, 1989.
[1] USDA–ASCS, 1991b.

Table 4e-10. Unit price of fencing, piping, watering trough and storage tank materials — 1997.

Material	Unit Price
Fencing	
Standard 6' Heavy T-posts	$2.40 each
Round Treated Wood Post:	
7' tall, 4" round	$6.10 each
8' tall, 5" round	$9.45 each
Electric Wire - 1/4 Mile Role	$38.95 each
Gallagher Plug In Controller/Charger	
15 Miles Power	$100.00 each
Parmak Solar Battery and Charger	$215.00 each
Ground Rod	$10.95 each
Insulators	$ .40–.60 each
Domestic Barbed Wire	
15 1/2 Gauge/1/4 Mile	$32.95 each
Piping	
PVC:	
1/2" sch 40 heavy/100 ft.	$13.29 each
1/2" class 315/100 ft.	$8.06 each
3/4" sch 40/100 ft.	$17.75 each
3/4" class 200/100 ft.	$9.90 each
Polyethylene:	
1/2" poly/100 ft.	$18.00 each
3/4" poly/100 ft.	$25.00 each
Holding Tanks	
Norwesco Plastic – 2,500 gallon	$1,100 each
Norwesco Plastic – 5,000 gallon	$2,200 each
Galvanized Steel – 2,500 gallon	$1,300 each
Galvanized Steel – 5,000 gallon	$2,000 each
Water Troughs	
Plastic Rubber Maid – 300 gallon	$175.00 each
Galvanized Round – 500 gallon	$200.00 each

Source: Farm Supply, San Luis Obispo, California, 1996.

Savings

[EPA solicits additional information on the benefits of improved grazing management.]

Table 4d-11. Costs for runoff control systems (DPRA, 1992; USDA, 1998).

Practice [a]	Unit	Cost/Unit Construction in 1997 Dollars [b, c, d]
Diversion	foot	2.38
Irrigation		
- Piping (4-inch)	foot	2.35
- Piping (6-inch)	foot	3.02
- Pumps (10 hp)	unit	2,350
- Pumps (15 hp)	unit	2,690
- Pumps (30 hp)	unit	4,030
- Pumps (45 hp)	unit	4,700
- Sprinkler/gun (150 gpm)	unit	1,180
- Sprinkler/gun (250 gpm)	unit	2,350
- Sprinkler/gun (400 gpm)	unit	4,300
- Contracted service to empty retention pond	1,000 gallon	3.68
Infiltration [e]	acre	2980
Manure Hauling	mile per 4.5-ton load	2.64
Dead Animal Composting Facility	cubic foot	5.96
Retention Pond		
- 241 cubic feet in size	cubic foot	3.08
- 2,678 cubic feet in size	cubic foot	1.48
- 28,638 cubic feet in size	cubic foot	0.72
- 267,123 cubic feet in size	cubic foot	0.37
Settling Basin		
- 53 cubic feet in size	cubic foot	5.08
- 488 cubic feet in size	cubic foot	3.27
- 5,088 cubic feet in size	cubic foot	2.04
- 49,950 cubic feet in size	cubic foot	1.29

a Expected lifetimes of practices are 20 years for diversions, settling basins, retention ponds, and filtration areas and 15 years for irrigation equipment.
b Table is derived from DPRA estimates presented in an earlier edition adjusted by USDA price indices.
c Table does not present annualized costs.
d Costs for pumps, sprinklers, and infiltration are rounded to the nearest 10 dollars.
e Does not include land costs.

Sources:
- DPRA. Draft Economic Impact Analysis of Coastal Zone Management Measures Affecting Confined Animal Facilities, DPRA, Inc., Manhattan, KS, 1992.
- United States Department of Agriculture (USDA), Agricultural Prices - 1997 Summary, National Agricultural Statistics Service, July 1998.

Table 4e-4. Grazing management influences on two brook trout streams in Wyoming (Hubert et al., 1985).

	Pete Creek (n=3)		Cherry Creek (n=4)	
Parameter	**Heavily Grazed (mean)**	**Lightly Grazed (mean)**	**Outside Exclosure (mean)**	**Inside Exclosure (mean)**
Width	2.9	2.2[a]	2.9	2.5[a]
Depth	0.07	0.11[a]	0.08	0.09[a]
Width/depth ratio	43	21	37	28[a]
Coefficient of variation in depth	47.3	66.6[a]	57	71
Percent greater than 22 cm deep	9.0	22.3[b]	6.7	21.0[a]
Percent overhanging bank cover	2.7	30.0[a]	24.0	15.3
Percent overhanging vegetation	0	11.7[a]	8.5	18.0
Percent shaded area	0.7	18.3[a]	23.5	28.0
Percent silt substrate	35	52	22	13[a]
Percent bare soil along banks	19.7	13.3	22.8	12.3[a]
Percent litter along banks	7.0	6.0	10.0	6.8[a]

[a] Indicates statistical significance at p<=0.05.
[b] Indicates statistical significance at p<=0.1.

Table 4e-5. Streambank characteristics for grazed versus rested riparian areas (Platts and Nelson, 1989).

Streambank Characteristic (unit)	Grazed	Rested
Extent (m)	4.1	2.5
Bank stability (%)	32.0	88.5
Stream-short depth (cm)	6.4	14.9
Bank angle (°)	127.0	81.0
Undercut (cm)	6.4	16.5
Overhang (cm)	1.8	18.3
Streambank alteration (%)	72.0	19.0

Kauffman et al. (1983a) showed that fall cattle grazing decreases the standing crop of some riparian plant communities by as much as 21% versus areas where cattle are excluded, while causing increases for other plant communities. This study, conducted in Oregon from 1978 to 1980, incorporated stocking rates of 3.2 to 4.2 ac/AUM.

Buckhouse (1993) did an extensive review of livestock impacts on riparian systems. Researchers documented many factors interrelated with grazing effects, primarily dealing with instream ecology, terrestrial wildlife, and riparian vegetation. Permanent removal of grazing will not guarantee maximum herbaceous plant production. Researches found that a protected Kentucky bluegrass meadow

Table 4c-3. Annualized cost estimates and life spans for selected management practices from Chesapeake Bay installions[a] (Camacho, 1991).

Practice	Practice Life Span (Years)	Median Annual Costs[b] (EAC[c])($/acre/yr)
Nutrient Management	3	2.40
Strip-cropping	5	11.60
Terraces	10	84.53
Diversions	10	52.09
Sediment Retention Water Control Structures	10	89.22
Grassed Filter Strips	5	7.31
Cover Crops	1	10.00
Permanent Vegetative Cover on Critical Areas	5	70.70
Conservation Tillage[d]	1	17.34
Reforestation of Crop and Pasture[d]	10	46.66
Grassed Waterways[e]	10	1.00/LF/yr
Animal Waste System[f]	10	3.76/ton/yr

[a] Median costs (1990 dollars) obtained from the Chesapeake Bay Program Office (CBPO) BMP tracking data base and Chesapeake Bay Agreement Jurisdictions' unit data cost. Costs per acre are for acres benefited by the practice.

[b] Annualized BMP total cost including O&M, planning, and technical assistance costs.

[c] EAC = Equivalent annual cost: annualized total costs for the life span. Interest rate = 10%.

[d] Government incentive costs.

[e] Annualized unit cost per linear foot of constructed waterway.

[f] Units for animal waste are given as $/ton of manure treated.

Savings

It is important to note that for some practices, such as conservation tillage, the net costs often approach zero and in some cases can be negative because of the savings in labor and energy. In fact, it is reported that cotton growers can lower their cost per acre by $24.32 due to lower fixed costs associated with conservation tillage (Zeneca, 1994).

Table 4c-2. Representative costs of selected erosion control practices.

Practice	Unit	Range of Capital Costs[1]	References
Diversions	ft	1.97 - 5.51	Sanders et al., 1991 Smolen and Humenik, 1989
Terraces	ft	3.32 - 14.79	Smolen and Humenik, 1989
	a.s.[2]	24.15 - 66.77	Russell and Christiansen, 1984
Waterways	ft	5.88 - 8.87	Sanders et al., 1991
	ac	113 - 4257	Barbarika, 1987; NCAES, 1982; Smolen and Humenik, 1989
	a.e.[3]	1250 - 2174	Russell and Christiansen, 1984
Permanent Vegetative Cover	ac	69 - 270	Barbarika, 1987; Russell and Christiansen, 1984; Sanders et al., 1991; Smolen and Humenik, 1989
Conservation Tillage	ac	9.50 - 63.35	NCAES, 1982; Russell and Christiansen, 1984; Smolen and Humenik, 1989

[1] Reported costs inflated to 1998 dollars by the ratio of indices of prices paid by farmers for all production items, 1991=100.
[2] acre served
[3] acre established

[Note: 1991 dollars from CZARA were adjusted by +15%, based on ratio of 1998 Prices Paid by Farmers/1991 Prices Paid by Farmers, according to USDA National Agricultural Statistics Service, *http://www.usda.gov/nass/sources.htm* 28 September, 1998]

For further information on controlling streambank erosion, refer to Chapter 6: "Management Measures for Hydromodification: Channelization and Channel Modification, Dams, and Streambank and Shoreline Erosion," in *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, EPA 840-B-92-002, 1993. *Stream Corridor Restoration: Principles, Processes, and Practices*, also contains valuable information on streambank erosion, as well as restoration.

Practice Effectiveness

[EPA solicits current information on effectiveness of practices.]

The available information shows that erosion control practices can be used to greatly reduce the quantity of eroding soil on agricultural land, and that edge-of-field practices can effectively reduce sediment transport. The benefits of this management measure include preservation of productive agricultural soils and significant reductions in the mass of sediment and associated pollutants (e.g., phosphorus, some pesticides) entering water bodies.

Although some sites are challenging, detailed local information combined with sound erosion control knowledge and experience should result in an effective system plan for erosion and sediment control.

The effectiveness of sediment control practices depends on several factors, including:

- The contaminant (e.g. sediment, phosphorus) to be controlled;
- The nature of the soil particles to be controlled;
- The types of practices or controls being considered;
- Site-specific conditions (e.g. crop rotation, topography, tillage, harvesting method); and
- Operation and maintenance.

Management practices or systems of practices must be designed for site-specific conditions to achieve desired effectiveness levels. Management practice systems include combinations of practices that provide source control of the contaminant(s) as well as control or reductions in edge-of-field losses and delivery to receiving waters. Table 4c-1 provides a gross estimate of practice effectiveness (i.e., "average" changes in runoff and pollutant loads due to the addition of the practice(s) at sites where erosion control practices are generally lacking) as reported in research literature. Even within relatively small watersheds, extreme spatial and temporal variations are common. Because of this variation, the actual effectiveness of practices at a specific site may differ considerably from the gross estimates given in Table 4c-1.

31 Aug 99/B2

Delta M3 Sells Unusual Technology in Unusual Way

Mobile Sewage Plants Demonstrate How Waste Water Becomes 'Snow'

By JOHN URQUHART
Staff Reporter of THE WALL STREET JOURNAL

OTTAWA—Entrepreneurs trying to sell new products often struggle to overcome skepticism. But few face Jeff White's problem: He turns sewage into snow and sprays it on open fields.

Mr. White says he devoted "literally 20 years of testing and testing and testing" to ensure the unusual technology meets safety regulations and saves money. At first, it didn't do a bit of good. Delta Engineering, a division of his closely held Ottawa company, Delta M3 Technologies Corp., sold only five of the systems in the past five years.

But lately, an unusual marketing strategy has changed Mr. White's luck. Three new orders are in hand, three others are close to signing and several others are in advanced stages of negotiations. All told, Delta Engineering expects to win 10 to 12 contracts in the next 18 months, he adds. "The cap is off the bottle," he says.

Gambling on a Pilot

Mr. White found that selling a controversial product often takes much more than ordinary marketing. When no amount of data alone would sell his technology, he gambled that building a working pilot plant on a prospect's own turf would show skeptics the process worked where it really mattered. So, he did just that, at a cost of $250,000 to $300,000 each.

Later, Mr. White built two mobile sewage plants, each mounted on 26 wheels, that he moves on-site for prospective customers of the systems, which typically cost $2 million to $3 million.

Using those demo machines, potential customers can see how Delta's machinery, called the Snowfluent system, blasts sewage through nozzles mounted on towers. The sewage freezes, killing bacteria, and drops to the ground as snow. Other components either dissipate in the air as gas or fall to the ground as new, harmless compounds, along with pure-ice crystals.

The "snow" melts, leaving a nutrient-rich residue for grass. Runoff into streams and lakes—a big problem for many sewage systems—is eliminated, Mr. White says. In the scenic village of Westport, Ontario, the system cut the cost of treating sewage by 50%, Delta says.

Ski-Hill Technology

The technology evolved from Delta's business of producing snow for ski hills. Delta started work in the 1970s on the sewage application of its snowmaking know-how, eager to tackle what has emerged as a massive potential market. Publicly owned U.S. waste-water treatment facilities are expected to spend $139.5 billion, the Environmental Protection Agency in Washington estimates. More than one-third of U.S. waters still are rated as too polluted for fishing or swimming, the EPA says.

Still, Delta didn't win its first order until it installed a pilot plant in Maine's Carrabassett Valley region six years ago. Skeptics warned if the project failed it could blight a major Maine tourist asset, the nearby Appalachian hiking trail, recalls David Keith, superintendent of the Carrabassett Valley Sanitary District.

The plant confirmed Delta's results for local regulators. The Carrabassett plant has six 37-foot towers, each with two snowmaking nozzles on top. The system produces snow piles as high as 60 feet and as long as a football field. The water melting off the piles is as high in quality as some drinking water, Mr. Keith says.

The plant's success opened the way for another Delta unit built in the area two years ago to treat the highly toxic waste water from a potato-processing plant.

Delta also wheeled one of its portable plants into Montana to perform pilot tests at the state's request. In view of the mounds of data on the process, using the mobile plants as pilot facilities for municipal waste water is "just reinventing the wheel," Mr. White says. But the pilot plants helped to persuade Montana to place an order.

Delta's system also requires far more extensive face-to-face promotion than most products need. For instance, Mr. White worked four years to crack the Idaho market. "I went around the state, maybe half a dozen times talking to the regulators and preaching and talking and preaching," he says. Finally, Idaho ordered a unit to be located in Island Park.

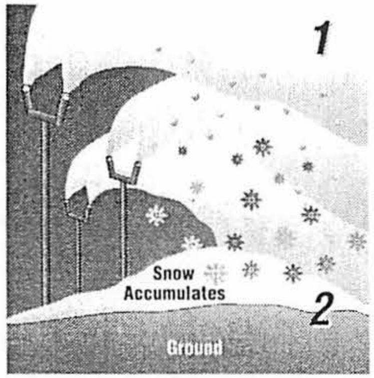
Local Regulators

Even with hard work, the bureaucracy sometimes can be demoralizing. "The regulatory system conspires against the success of new technologies because every time you cross a state or provincial boundary you have a whole new set of regulators and you have to start all over again," Mr. White says. For instance, it took three years to get the Westport plant online in 1995. Local regulators "threw every roadblock they could at us," he says.

Although Delta's market is limited somewhat by the system's efficiency only in cold climates, Mr. White says Delta Engineering has been profitable in the past year and will have an order backlog of $10 million to $12 million by the end of this year. Though most contracts have been in the $2 million to $3 million range, the company is negotiating for jobs valued at 10 times as much.

Mr. White believes the sewage world's resistance to change eventually will work in his favor, ensuring "a long shelf life" for his system. "We have persevered for 20 years on this thing," he adds. "It is going to be as hard for the next guy as well."

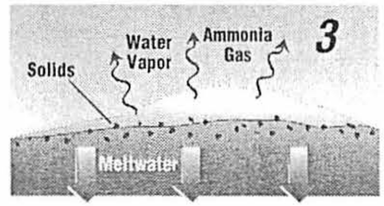
Delta's Treatment System



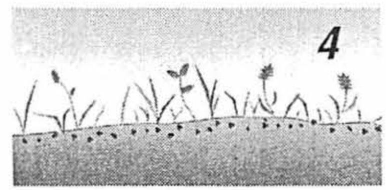
1. When temperatures go below freezing, waste water is pumped from holding lagoons to atomizing nozzles mounted on tall towers.

2. The nozzles spray the waste water into the air under high pressure. The rapid freezing kill bacteria and protozoa. Other contaminants either dissipate in the air as gas or fall to the ground as new harmless compounds, along with pure-ice crystals.

Source: Delta Engineering



3. As the snow pile ages, nitrogen is discharged as ammonia gas. Phosphorus from detergents and human waste combines with calcium, magnesium and/or iron to form insoluble phosphates–natural fertilizers. The melt water is highly polished.



4. When the snow finally melts into the ground, grasses planted on snow-deposit area take up the nutrient-rich residue almost immediately, limiting access of such contaminants to ground water.

110 ct
1998

$2 B for California reservoir near Riverside
being built by Metro Water Dis of Southern
Calif.
to hold 260 B of gallons
$1 B spent on pipeline to fill reservoir's

VK

Water, Water Everywhere, but Canada Won't Sell It

The Americas

By Dennis Owens

With an average annual rainfall of 33 feet, Link Lake in British Columbia sends enough water into the Pacific Ocean to meet all of California's water needs for the next 20 years, according to widely published estimates in the Canadian press.

This is but a small example of the comparative advantage Canada has in marketing water internationally. Yet, in July, when President Bush said he wanted to talk to Prime Minister Jean Chrétien about a pipeline to ship fresh Canadian water into the parched American Southwest, he was brushed off. This is because selling water to the U.S. is considered politically incorrect by Mr. Chrétien's important left-wing base. Nevertheless, it makes a lot of sense.

Canada has only a half percent of the world's population but it holds one-fifth of the planet's freshwater supply, half of which is renewable. It already sells an estimated 30 billion liters of water a year abroad, but only in containers no larger than 30 liters.

Bulk water sales could be a lucrative source of foreign exchange for Canadians, yet the government remains firmly opposed to it. Numerous ideas for bulk water marketing have been proposed in recent years, but almost all have been struck down either by the federal government, which forbids water sales from international boundary waters, or by provincial governments, which have jurisdiction over freshwater sales from their own provincial sources outside the Great Lakes.

This is a paradox for a country that hungrily seeks American markets for its comparatively finite petroleum resources. "Food, lumber and bulk water are all renewable resources, but we export only the first two, because water is sacred," comments Lee Morrison, a retired member of parliament. "Meanwhile, we merrily dispose of precious, non-renewable natural gas and oil. When it's gone, our lives will be much less comfortable, but we'll still have 20 times the water we need."

Even though most Canadians now approve of bulk water sales, nationalist groups like the Council of Canadians and their allies in the labor, environmental and aboriginal communities have mounted powerful campaigns against every proposal. "They're coming to take our water," intoned a recent poster campaign by Water Watch, a group of lobbyists patched together to fight against bulk exports. They insist wrongly—by most accounts—that under the North American Free Trade Agreement, once water has become a salable good, its sale cannot be stopped. Even if that were true, it's not clear why it would be a problem. Despite some ecologists' warnings of unforeseen dangers from water transfers, there is little detailed science to support such concerns.

Fortunately, there is some hope that the wisdom of water sales may eventually triumph over the left's emotionalism. Last spring the McCurdy Group, a Newfoundland company looking for permission to tanker 13 billion gallons a year from pristine Gisbourne Lake, received an unexpected endorsement from Newfoundland's Liberal Premier Roger Grimes. Mr. Grimes has promised to use the money the government gets from the deal to underwrite university tuitions in Canada's poorest province. A better plan would be to auction the rights and use the proceeds for much-needed tax cuts.

The McCurdy Group is still waiting for an official go-ahead but thanks to Canadian law, the federal government can't stop the province from granting the permit. "We don't want to sell water in bulk," says Mr. Chrétien, "But at the same time, we have to realize that we don't have absolute control of the water. We have control of navigable waters, but we don't have control of other types of water that are under the provincial jurisdiction." Ontario and British Columbia have already said "no" to companies that want to sell water by tanker but if Newfoundland has success in water marketing that might change.

Bulk water sales could be a lucrative source of foreign exchange for Canadians, yet the government remains firmly opposed to it.

Still, it is the pipeline debate that really matters. Consider a 30-foot pipe running from the mouth of the Nelson River in Manitoba near Hudson Bay to the American Southwest. (Placing the pipeline at the mouth of the river would allow the water to run its course nearly to the sea and thereby minimize environmental impacts.) It could carry an annual flow of 1.3 trillion gallons, only three days' worth of the fresh water now flowing into Hudson Bay annually. The cost would be about $34 billion to build, and if the water it carries was sold at only one-half to three-quarters of a cent per gallon, the province of Manitoba would garner $2.6 to $5.9 billion a year in profit.

The price of the pipelined water would be higher than what subsidized farmers in the U.S. now pay but lower than the desalinated water that is bound to become a staple in the thirsty Southwest. Pipelined water from Canada would be about $1,630 to $2,445 an acre-foot, far above the $50 to $100 rate now available to U.S. farmers who qualify for federal subsidies. But that bargain-basement rate has long been under attack by market economists, who dislike its concomitant resource distortions, and environmentalists, who decry the resulting waste. Moreover, if the Sun Belt continues to boom, current water sources will not be able to meet demand. The price of water from desalination plants then becomes the benchmark, and it is running at $2,000 per acre-foot. The pipeline option looks less whimsical when viewed from that perspective.

This economic potential makes for a compelling argument in a country with a standard of living 30% below the U.S., but logic has little power over religious fervor. "There is something about water that's part of our history, part of our soul, if you will," explains ultra-nationalist Maude Barlow. Western Canada's dustbowl experience was vicious and memories die hard. Alberta wrote a new Water Act about 10 years ago that allowed the commercial sale of water rights, but hamstrung the public by forbidding the transfer of water from districts with abundance to those with chronic drought problems. If Canadians can't sell to each other, it's unlikely that they will be allowed to send water over the border, even for a good price.

Mr. Chrétien's position is that Canada's water is not for sale. But this may change as more of his colleagues come to understand the opportunities presented by an intelligent and environment-friendly water export policy. Canada's freshwater advantage could help fund its stressed public healthcare system or, better yet, cut the country's high taxes.

Mr. Owens is a senior policy analyst at the Frontier Center for Public Policy in Winnipeg, Canada.

9-2-01

PUEBLO CHIEFTAIN
Pueblo, CO
(Pueblo County)
Daily, 51,802;Sun.,55,040

80

Otero County to assess value of major ditches

By MARY JEAN PORTER
The Pueblo Chieftain

Otero County isn't resigned to losing all its valuable water.

Equipped with a $30,000 Great Outdoors Colorado planning grant, the county hired a Denver firm to determine the value of six prominent ditches — Highline, Holbrook, Oxford, Nine Mile, Fort Lyon and Catlin.

Otero County also is using the grant money, which was approved in February and matched with $10,000 from the county, to begin developing conservation easements that will protect water rights.

The county stands to lose 5,000 acre-feet of water and the agricultural production it supports if the proposed sale of Rocky Ford Ditch water to the city of Aurora is approved by water court.

Barry Shioshita, Otero County administrator, said the appraisal of the water's value and the work toward conservation easements and a local land trust are part of a pro-active approach the county and its Water Works committee have taken.

"For over a year, we've been looking at alternatives to the sale of water rights," he said.

Shioshita said appraisers from the firm of Brown and Caldwell considered comparable water sales, facts and figures from the state engineer's office, consumptive use and cropping patterns in determining the ditches' value.

"It's based on the productive value of the land," he said. "We're trying to see what the municipal or development value would be compared to the historic ag value."

Shioshita said it's difficult for a county to determine what its water is worth, and that's precisely why Otero County sought the appraisal.

Although an appraisal is "a snapshot in time" because it is relative to the current water market, it does establish a baseline, Shioshita said.

Preliminary data from the appraisal will be presented Sept. 17 at the next Water Works meeting.

John Rose, Water Works coordinator, said the committee grew out of a forum in January 2000 sponsored by the West Otero/Timpas Soil Conservation District, in response to news of the proposed Rocky Ford Ditch sale.

Following the forum, the county decided to form the volunteer committee, which consists of city residents and officials, people living in rural areas of the county, irrigation company presidents and others. Rose is paid to coordinate the project, but is not a county employee.

"The premise is to find ways the farmers could get additional funds for their resources without selling the water permanently from the land," Rose said. "One of the ideas was conservation easements and the establishment of a land trust. We've just about got that finished. We've got a law firm from Denver helping us with it, and we've got a CPA helping us with the tax issues.

"The working name is the Arkansas Valley Preservation Land Trust."

Rose said there are several farmers who want to donate conservation easements to the trust. The easements would tie the water to the land in perpetuity.

"They will be trading the

Please see Water, Page 2A

Water

Continued from Page 1A

development rights to the land and water for a tax credit from the State of Colorado."

The Water Works committee also is pushing for the Arkansas Valley Conduit because water quality has become so poor in the lower Arkansas Valley, federal drinking water standards have become more stringent, and treating water has become so expensive.

Phase one of a feasibility study for the conduit should be complete by the end of the year. If no "fatal flaws" in the project are discovered, phase two would get under way.

Cost of the pipeline, which would deliver water from the Lake Pueblo to the lower part of the valley, is estimated at $230 million to $250 million.

"We have no choice," Rose said. "We have to do this. And we have to do it collectively. We have an economist who can tell us what money is available where — grants, low-cost loans. We're going to try to pick every pocket we can find."

Study of pipeline in Lower Arkansas Valley from Lake Pueblo to Lamar. The study to cost $200,000 with $100,000 from the Colorado Water conservation Board and rest from local entities. Purpose is to cope with increasing cost of water treatment for drinking water. Estimated cost for pipeline is $200 million and would take 20 years to build. First task is to collect information on water needs. Then examine a possible route and look for "fatal flaws," then compare feasibility of piping with treatment of raw water. Reference to pipelines for the Garrison Diversion Project in North Dakota. Half the funding came from the federal government. A pipeline in the original Frying Pan- Arkansas Project was not built because the cost was too high. If raw water was piped, an entity would be formed to maintain the pipeline. La Junta now chlorinates and distributes well water for residents at $1 to $1.15 per 1,000 gallons. With a new treatment plant, the treatment and delivery cost will double.
SOURCE: Mary Jean Porter (18 Sep 2000) Lake Pueblo - Lamar Pipeline Studied, The Pueblo Chieftain, pp. 1A and 2B.

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Aurora should be excluded from using the Pueblo Reservoir enlargement said manager for Southeastern Colorado Water Conservancy District. Aurora could not use the "if and when storage" to transfer new water out of the basin. In the future some type of water bank might be appropriate. Aurora would also pay more for use of the Fry-Ark project. Since 1986, Aurora has paid below market rates in relation to what Aurora pay the Pueblo Board of Water Works. Aurora pays the Bureau of Reclamation of $11 per acre-foot for exchange contracts and $23 an acre-foot for storage contracts. The District gets a $2 surcharge to pay for the Safety of Dams program. In the future that surcharge might be increased to $10 per acre-foot. An in-district entity pays $14 an acre-foot for storage in the project. The Pueblo Board fo Public Works contracts for exchanges with Aurora for up to 10,000 acre-feet at $52.50 per ac-ft for the first 4,000 ac-ft and over that at $63.00 per ac-ft. The first 4,000 or $210,000 a year must be paid whether or not Aurora exercises its rights. The Pueblo Board gives Aurora wet water upstream at Clear Creek, Twin Lakes or Turquoise and takes Rocky Ford water. SOURCE: Mary Jean Porter (17 Sep 2001) Arveschoug: Aurora should be excluded from reservoir project, The Pueblo Chieftain, pp. 1A and 2A.

The Southeastern Colorado Water Conservancy District has backed off wanting Aurora to participate financially in the enlargement of Pueblo Reservoir. Auror has been getting year to years storage contracts with the Bureau of Reclamation in reservoir but the District says the Bureau does not have the authority to make such contracts. Price paid by Aurora is very low. The District could charge a market price for the space. By limiting Aurora's storage space, the District could prevent Aurora's upstream exchanges. Cutting off Aurora's access to Arkansas water would make communities look elsewhere. SOURCE: Editorial 19 Sep 2001, Save The Arkansas, The Pueblo Chieftain, p. 4a.

The Southeastern Colorado Water Conservancy District and the City of Aurora appear close to an intergovernmental agreement on use of Fryingpan-Arkansas Project Facilities. It would allow Aurora to continue "if and when" storage of 5,000 to 10,000 ac-ft but subordinate to needs of District's entities. Aurora's water would be first spilled and limited to existing water rights and

Rocky Ford Ditch purchases. Contract is for 25 years. Aurora would pay $2.25 million with $1 million at beginning. Aurora would pay 10% of legislative, and lobbying costs and extra $10 per ac-ft for all water in "if and when storage" and a winter spill credit surcharge of $1 to $2 per ac-ft. An option for the District is to direct the $1 million to the Arkansas Valley pipeline. Annual payments of $50,000 a year by Aurora would go toward repayment of the Bureau of Reclamation. The whole project cost $400 million and the District has to repay $130 million. SOURCE: Mary Jean Porter (21 Sep 2001) Fry-Ark agreement on track, The Pueblo Chieftain, pp. 1B and 2B.

9·22·95
DURANGO HERALD
Durango, CO
(La Plata County)
M-F(PM), 9,704; Sun(AM), 9,117
Colorado Press
Clipping Service

A-LP a is hoax

By Ray Frost
Special to the Herald

PUBLIC PULSE

The U.S. Senate missed a golden opportunity this summer to stop the waste of over 700 million taxpayer dollars and protect important natural resources in New Mexico and Colorado. While the House voted to cut federal funding for the Animas-La Plata water project, the Senate did not. Not surprising, since Sen. Ben Nighthorse Campbell painted this project as an Indian water project, using a ceremonial pipe and eagle feathers to appeal to non-Indian guilt over hundreds of broken government promises to tribes. But this guilt is misplaced. Animas-La Plata is a hollow promise that will not provide the Southern Ute and Ute Mountain Ute tribes with their water. It merely allows non-Indians to hitch their wagon to the only vehicle that could have carried this boondoggle so far — Indian water rights. In reality, if federal funds are provided for Animas-La Plata, non-Indian irrigators will get their federally subsidized water, while Indians get water too expensive to use, stranded 10 miles from the nearest reservation lands.

Some Indians do support Animas-La Plata, but many do not. The Southern Ute Grassroots Organization (SUGO) represents more than 200 Southern Ute tribal members in Colorado and is strongly supported by much larger numbers. Our leadership includes elected tribal officials, many former elected officials, and most of the Southern Ute Tribe's most revered and respected elders. SUGO's primary objective is to bring about changes in tribal government and decision making that will make it more inclusive and responsive to the general membership. SUGO strongly opposes Animas-La Plata for a very simple reason: Animas-La Plata is a hoax that will not benefit our people. Instead, it will enrich a small number of non-Indian farmers and developers at taxpayer expense.

A-LP was designed in the 1960s with non-Indian irrigation in mind; not tribal water rights. If totally constructed, two-thirds of A-LP's water would go to non-Indians. Providing for the Ute tribes in a 1988 settlement agreement was an afterthought, with tribal delivery systems tacked on to Phase II of the project. Funding for Phase II is apparently an afterthought as well: This phase receives no federal funding. Consider the results of A-LP construction. About 64% of the water supplied by the project goes to non-Indian users, some of it to satisfy legitimate needs. However, of this non-Indian share, more than 42 percent will go to irrigators at a subsidy of $5,000 per acre, allowing them to grow low-value crops on land with a value of only $300 per acre. The average subsidy per farm totals $2 million. What do the tribes get? The Southern Ute and Ute Mountain Ute Tribes would receive about 62,000 acre-feet of water, but it would be stored 10 miles from the nearest reservation lands. There is no firm funding for a delivery system to deliver this water. Even project proponents have stated that it is unlikely that the delivery system will ever be built—another broken promise to Indians.

Even if a delivery system is ultimately built, delivered water would be too expensive for us to ever use. Current estimates place our costs for project water at $300 per acre-foot. This does not include delivery facilities to our reservations, which would be an additional expense. No uses available to us can generate enough revenue to pay these costs.

The outcome of Phase I also remains uncertain. Because of the massive depletions required, A-LP threatens the survival of two species of endangered fish. As a result, under federal law the federal government can only construct some, not all, of the facilities planned for Phase I, and must limit depletions from the Animas River to much lower levels than planned in the project design. Whether or not all of Phase I will ever be completed rests on the outcome of scientific studies to be completed years down the road. The small volume of water generated from this first — and only legal — part of the project is only one-half of what was promised under the settlement agreement. Another broken promise.

Under these circumstances, the tribes would have every justification to exercise their rights under the Colorado Ute Indian Water Rights Settlement Act to unilaterally void the agreement and reassert their water rights claims. The act provides this exit provision if the project is not substantially completed by the year 2000. Since the Interior Department has already stated that the project cannot be completed by that deadline, it is likely that American taxpayers will spend millions of dollars only to still face the water rights obligations that the project was supposed to resolve. This benefits neither the tribes nor the American taxpayer.

We believe that alternatives to A-LP can better serve the interests of our tribes. On February 23, 1995, SUGO presented an alternatives package of its own to the Interior Department's Bureau of Reclamation. The alternatives that we propose — such as using existing reservoirs, constructing smaller facilities, and allowing tribes to sell their water rights — would provide greater benefits to our tribes at less cost to taxpayers and the environment. But the Bureau of Reclamation has not evaluated any such alternatives. In fact, this failure to consider alternatives is one reason the Environmental Protection Agency recently found A-LP's Environmental Impact Study inadequate.

Without evaluating less costly alternatives, A-LP supporters are asking taxpayers to pay hundreds of millions of dollars for a project that will fail to satisfy tribal water claims. Moreover, according to the Bureau of Reclamation, for every dollar spent, the American people realize a benefit of only 36 cents. Normally, reclamation law requires at least a dollar for dollar return. And many of this project's costs can't be measured in dollars. ALP also would have massive impacts to the natural and cultural environment of our homeland by flooding wetlands and archaeological sites, destroying water quality in New Mexico, and jeopardizing endangered species. We oppose this waste of our taxes and environment.

In hunting buffalo, our ancestors often employed a strategy of stampeding a herd over a cliff. Once the herd was in motion, the pitfalls that would have stopped individual animals or groups of animals became invisible. In this era of fiscal constraints, Congress needs to stop blindly following the decades-old route of wasting taxpayer dollars on massive water projects to subsidize a handful of farmers. Instead of asking American taxpayers to foot the bill for a project doomed for failure, Congress should be requiring the Bureau of Reclamation to find alternatives that actually satisfy Tribal water claims, while addressing legitimate non-Indian water needs and complying with all federal environmental and reclamation laws.

We can do better than 36 cents return for every dollar spent, and we can design a project that isn't set up from the start for breaking promises. It's up to Congress to see that it happens.

Ray Frost is a Southern Ute tribal councilman and member of the Southern Ute Grassroots Organization.

Bruce - FYI
This sounds like what you need. The numbers can be changed. Butch

file: brs94 REC/[redacted]

WATER DEVELOPMENT PROPOSAL FOR THE UPPER GUNNISON BASIN

* Purchase of water out of Blue Mesa Reservoir from the Bureau of Reclamation.
* Instead of purchase, water held by right could be leased downstream.
* Allow water to flow downstream through Havasu Reservoir producing hydroelectric power.
* After water passes through Havasu Dam, it might be sold to Lower Colorado Basin water users.

Initial cost of water purchased from Bureau of Reclamation

price	$50 per acre-foot from Bureau of Reclamantion (Phase 1 Study (1989), p. 10-6)
quantity	110 cubic feet per second flow
conversion	60.18 conversion of cfs to acre-feet for one month
time	3 months

Givers the total quantity of water purchased as 19,859 acre-feet.
Total Cost of Purchase $992,970

Hydoelectric power generated on downstream flow:

Source: Brown T. C. and Harding B.L. (1987) A Preliminary Economic Assessment of Timber and Water Production in Subalpine Forests in MANAGEMENT OF SUBALPINE FORESTS: BUILDING ON 50 YEARS OF RESEARCH, General Technical Report RM-149, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, pp. 126-137)

Energy production for period in kilowatt hours is:
(head in feet at hydroelectric dam) * (flow in acre-feet) * (efficiency of .80) * (constant necessary to convert acre-feet flow to kilowatt hours of 1.0253)

	At Head in feet	Kilowatt Hours Produced
Blue Mesa	300	4,886,842
Morrow Point	380	6,190,000
Crystal	200	3,257,895
Powell	500	8,144,737
Mead	500	8,144,737
Mohave	100	1,628,947
Havasu	70	1,140,263

Total Kilowatt hours produced 33,393,422

Value at $.035 @ killowatt hour $1,168,770 (Intermediate load value)
Evaporation Loss of 10.00%
Proceeds from sale of power $1,051,893

Below Havasu Dam water can then be sold or leased to California users.
Water value per acre-foot $300.000
Evaporation Loss of 10.00%
Proceeds for sale of water $5,362,038

See also
Harding and Brown - A Preliminary Economic Assessment of Timber and Water Production in Subalpine Forests (1987) in Management of Subalpine Forests: USDA Gen Tech Report RM-149 RMFRES, Fort Collins

J. Booker
June 22, 1990

OPPORTUNITY COST OF UPPER COLORADO RIVER BASIN CONSUMPTIVE WATER USE

1. INTRODUCTION

The Colorado River is the dominant water supply for much of the southwestern United States, satisfying agricultural, municipal, and industrial needs. Recent drought in the Colorado River basin and California, and the start of significant diversions for the Central Arizona Project mean that not all current requests for basin water can be fully satisfied. With the resource essentially fixed and little opportunity for augmenting supplies at reasonable cost, the basin is characterized by a mature water economy.

Development of new consumptive uses of upper basin water, including out of basin exports, can occur only by foregoing existing uses of basin water. The institutional framework governing river allocation, founded on the 1922 Colorado River Compact, grants the upper basin rights to significant additional consumptive uses. The marginal lower basin use, from an institutional perspective, is "surplus" river flows presently delivered to the southern California coast for municipal use. Instream use of river flows for hydropower production, particularly at Glen Canyon and Hoover dams, would also be significantly affected. From a national economic perspective foregone benefits in these sectors represent an opportunity cost of upper basin water development.

The economic costs of reduced flows from the upper basin are developed below. Southern California municipal demand is estimated from cross-sectional data on rate structures and household water use in 21 area communities. Corrections for conveyance and treatment costs, and damages of Colorado River salinity levels which exceed alternative supplies are made. Upper and lower basin hydropower production estimates are based on historical and modeled generation; economic value of produced power is estimated as the avoided cost of alternative power production.

2. SOUTHERN CALIFORNIA MUNICIPAL WATER DEMAND FOR COLORADO RIVER WATER

The Colorado River is the largest single source of water for Southern California municipal uses, providing supplies for almost one third of the total area consumption. Up to 1.2 million acre-feet (maf) can be delivered annually to the coastal metropolitan areas through the Colorado River Aqueduct. Most of this capacity is used, with typical annual deliveries in excess of 1 maf.

The marginal value of Colorado River water in this use is derived from household water use patterns. Household demand functions are estimated from monthly consumption data provided by southern California water utilities. The estimates are then combined with California state estimates of total metropolitan area water consumption and population to give total benefits from municipal uses. Net benefits to Colorado River water are found by subtracting conveyance and treatment costs for raw water diverted at Lake Havasu.

<u>The data set</u>

The model presented below is estimated using cross-sectional data on total single family dwelling water consumption in 21 southern California communities for 1985. (A more complete description of the model and estimation procedures is given in Booker, 1990.) Water consumption and charges were determined from analysis of utility level data. Marginal and average prices (p_m and p_a respectively) were calculated at the average use level for each community. Household income was obtained from 1980 U.S. Census figures, adjusted to 1985 levels.

The price structure may be increasing, decreasing, or flat rate, but only communities where $p_a > p_m$ were included in the sample. The presence of service charges with otherwise increasing block rates allows $p_a > p_m$ This restriction on the sample requires a price difference variable $p_d = p_a - p_m > 0$. A summary of the data is presented in Table 2.

TABLE 2. Data Summary Statistics

	Mean	Standard Deviation	Max	Min
Monthly consumption Q (1000 gal.)	21.0	7.7	43.2	11.1
Marginal price p_m (\$/1000 gal.)	0.84	0.35	1.43	0.00
Average price p_a (\$/1000 gal.)	1.16	0.38	2.15	0.60
Price difference p_d (\$/1000 gal.)	0.32	0.28	1.14	0.10
Monthly service charge F (\$)	7.63	8.33	41.10	2.00
Annual income difference D (\$1000)	0.086	0.087	0.076	0.052
Annual income M (\$1000)	39.0	22.1	110	18.2
Conservation program dummy C	0.81	-	1	0

Model Specification

The model estimated here is

$$Q = \beta_0 + \beta_p p_m + \beta_F F + \beta_M M + \beta_C C \qquad (1)$$

where M is income and C is a dummy variable for existence of a water conservation program in the community. Price variables are marginal price p_m and the fixed service charge F.

Climate variables were found to be insignificant and are not included in the model specification. Similarly, a proxy for household size, population per water connection, had little explanatory power and is excluded.

Because p_m is jointly determined with Q, a simultaneous equations approach is also tested. This has been advocated by Chicoine, Deller, and Ramamurthy; Howe; Jones and Morris; and Nieswiadomy and Molina. Following Agthe et al., dummy variables were used as proxies for changes in rate structure between observations. The additional equation is

$$p_m = \alpha_{10} + \alpha_{11} D_1 + \alpha_{12} D_2 + \alpha_{13} D_3 + \alpha_{15} Q \qquad (2)$$

Because data on actual rate structures was unavailable, the vectors D_1, D_2 and D_3 in equations (2) and (3) were constructed by grouping actual marginal prices at the average consumption levels into four levels, from lowest to highest. If the first observation had a very low marginal price, then the first element of vectors D_1 - D_3 would be 1, 0, and 0, respectively.

Model Estimation

The model was estimated using ordinary least squares (OLS) and three stage least squares (3SLS). Parameter estimates are presented in Table 2. Coefficients for the models have the expected sign with the exception of the fixed service charge variable. The estimated coefficient for F is significant and positive, indicating that as service charges increase, water consumption increases. Inclusion of the service charge in the price specification is used for several reasons. First, use of an average price variable exacerbates simultaneity problems, while retaining a positive estimated coefficient. Such a result is very difficult to interpret. Using the service charge specification, one interpretation is that people believe that paying a large fixed charge gives them the "right" to high use levels. Second, a higher R^2 and lower standard errors are obtained with the model presented here than with alternative specifications.

Calculation of the municpal demand function will proceed using the OLS estimates presented in Table 2. This choice is suggested by the small sample; the 3SLS estimator is only asymptotically efficient. While the OLS estimator is biased, its mean square error is likely smaller given the limited sample size.

TABLE 2. Demand Function Estimates

Variable	Coefficient Estimates OLS	3SLS
constant	20.9	20.2
	(4.9)	(5.4)
P_m	-3.7	-3.1
	(1.0)	(1.0)
F	0.44	0.54
	(3.1)	(4.4)
M	0.161	0.145
	(3.2)	(3.3)
C	-7.9	-7.8
	(2.6)	(3.0)
R^2	0.709	0.695

Absolute values of t-statistics are in parentheses. Sample size = 21.

Total municipal demand

The household demand function estimated above is used to develop the municipal benefit function from use of Colorado River water. Household demand functions are first used in conjunction with population and water use estimates to develop aggregate municipal demand functions for the MWD service area in southern California. This should provide a lower bound for total benefits from municipal water use, since the value of commercial and industrial uses (not considered here) are typically greater than in household use. Demand for delivered Colorado River water is found by considering alternative water supplies presently used by southern California municipalities. Demand for untreated Colorado River water at the diversion point (Lake Havasu) is estimated by subtracting treatment and conveyance costs.

Population and urban use estimates for the south coast region of California (California Department of Water Resources, 1988) are used as the basis for constructing total municipal demand functions. The 1985 demand function is constructed using a 1985 net urban use estimate of 2.82 million acre-feet (maf), and a (population weighted) average consumption of 0.70 af/household determined from the survey data. Total municipal demand is then given by summing the estimated demand functions over the equivalent metropolitan area household number of 4.0 million for 1985.

Municipal demand for Colorado River water

Southern California relies on a number of supply sources in addition to Colorado River water. In 1985 only about 30% of supplies were derived from imports of Colorado River water. The balance came from imports of Owens Valley and Mono Lake Basin water, California State Project water, and local surface and groundwater development. Determination of municipal demand for Colorado River water must consider the opportunity costs of these alternative supplies. First, all supplies can be used for agricultural purposes; it will be assumed in this section that opportunity costs from foregone agricultural production are roughly constant across all supplies. Environmental and other third party costs will also be assumed constant. In practice, supplies are limited by aqueduct and reservoir capacity. Construction of new capacity would generally exceed the net benefits which are implicit here and will not be considered. Thus supply from the different sources is inelastic.

With these assumptions variations in energy costs are the predominate cost differences between supplies. Benefits from the various supplies are not equal, however, because of differences in water quality. In particular, calculation of salinity damages indicates that Colorado River water causes damages of about \$100/af. This figure is based on household damages of \$0.26 mg/l, a salinity difference of 260 mg/l, and 1.42 million affected households. This level of municipal damages is consistent with estimates given by Kleinman and Brown (1980). These damages are considered here as a cost of Colorado River water; thus costs of loss of dilution water are implicit in the municipal benefit estimates below. Costs of increased salinity to other lower basin municipalities and agricultural users is not considered.

Figure 1 shows the difference between 1990 MWD service area water demand and energy supply costs and salinity damages, assuming an energy cost of 40 mills/kwh. If supply sources are ordered by increasing cost, then the difference between total municipal demand and cost of supply of each source gives the marginal benefit to consumers from consumption of treated,

delivered water. In particular, the inclusion of salinity damages causes Colorado River water to be treated as the marginal supply source.

Conveyance costs

Colorado River water is delivered to southern California municipal users through the 242 mile-long Colorado River aqueduct. A total lift of 1,617 feet is required between the intake at Lake Havasu and its terminal reservoir near Riverside. Energy costs of moving water through the aqueduct are believed to be the dominant conveyance costs. In fiscal 1987-88, 2.55×10^9 kilowatt-hours (kwh) were required to transport 1.23 maf through the aqueduct (Metropolitan Water District, 1988.) The energy use is thus 2,070 kwh/af. Some energy recovery is made from hydroelectric power recovery plants located at metropolitan area storage reservoirs. This offsetting energy production is estimated at 200 kwh/af, giving net energy consumption of 1,900 kwh/af. Using an opportunity cost of 40 mills/kwh gives a net energy cost of \$76/kwh. should be per ac-ft err

Other operations and maintenance costs are also presumed important. An initial estimate of 20% of energy costs, or \$15/kwh is used.

Treatment costs

The Metropolitan Water District serves as a wholesaler of treated and untreated water in southern California. Contracts with local municipalities for all service classes in fiscal 1988-89 reflected a premium of \$33/af for treated versus untreated supplies (Metropolitan Water District, 1988.) This can be taken as a measure of treatment costs for Colorado River water.

Marginal net benefits

Assuming 9% population growth between 1989 and 1990 (California Dept. of Finance) in the MWD service area, and no increase in available supplies allows calculation of net benefits from use of Colorado River water in the

MWD service area. Using the above costs of conveyance and treatment, and damages from salinity gives marginal net benefits $1,040/af for initial deliveries to $374/af at the aqueduct capacity of 1.23 maf/year for 1990.

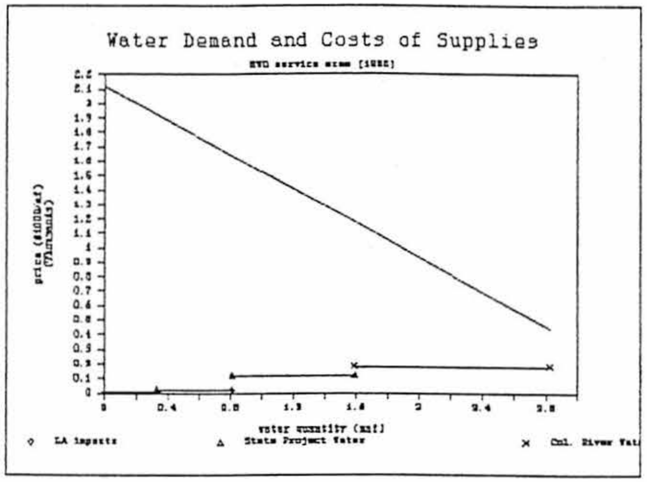

FIGURE 1. Demand and supply for South Coast region, 1985. Net benefit to use of Colorado River water is the difference between the downward sloping demand curve anbd the costs of using Colorado River water, in the rand 1.59-2.82 maf.

3. HYDROELECTRIC POWER GENERATION

Electric power generation from Colorado River hydroelectric plants produces significant economic value. The combined head of the mainstem dams is about 1800 feet, producing 1200 kilowatt-hours (kwh) per acre-foot. Electricity from upper basin power generation (primarily at Glen Canyon) is used in in all basin states. Lower basin generation (mostly at Hoover dam) is supplied to costumers in Arizona, Nevada, and California. The largest single customer is MWD, which consuming about 1.6×10^9 kwh annually (MWD, 1988) to pump Colorado River water through the Colorado River aqueduct to the southern California coast.

Economic Value of Hydropower Production

The economic value of Colorado River hydropower cannot be estimated by investigating market transactions. Most firm energy sales are fixed by long term contracts with the Bureau of Reclamation at highly favorable rates. The appropriate measure of economic value is the cost avoided by utilities in substituting hydropower from the best available alternative. This opportunity cost is presently measured by the operation and maintenance costs of alternative electrical generation capacity, minus the operation and mainteneace costs of hydropower generation. An additional penalty (or premium) is necessary if significant differences in transmission costs are incurred. If excess capacity does not exist in the future, then capital costs of constructing additional generation capacity must also be added. In this case, increasing the firm yield from hydopower supplies would be particularly beneficial. Such strategies are discussed for the Snake River basin in southern Idaho by Hamilton, Whittlesey, and Halverson (1989).

Tables 3 and 4 summarize most of the existing generation capacity, in the lower and upper basins, respectively (Department of Energy, 1988). Capacity factors (proportion of time the plant was generating electiricity) and operation and maintenance costs for 1986 are given. The most costly plants to operate tend to have the lowest capacity factors, indicating that (desireabley) that the least costly plants are used at the margin. Avoided cost in using hydropower for this study is defined as the capacity weighted average of the most costly 50% of total capacity, calculated separately for upper and lower basin states, respectively. While it coud be argued that the most costly utilized plant gives the avoided cost, at periods of low use less costly plants almost certainly constitute the marginal generation. The use of a broad average also addresses operational constraints imposed by transmission line capacity and other factors.

See application of this in Phase I Study for Upper Basin p. 8-52

TABLE 3. Lower basin electric generation plants ($1986). All plants are fossil fueled steam plants unless otherwise noted.

State	Plant	Rating (MW)	Factor (%)	O&M cost (mills/kwh)	Year
AZ	Springerville	420	23	68	1985
AZ	San Tan	414	22	40.1	1974
AZ	Navajo	2409	75	14.4	1976
AZ	Cholla	1105	32	23.8	1962
AZ	Coronado	822	59	32.4	1980
AZ	Palo Verde	2719	38	22.6	1986
AZ	Yucca[a]	192		63	1971
AZ	Saguaro[a]	106		73	1972
AZ	Phoenix[a]	106		74	1972
AZ	Ocotillo[a]	106		59	1972
CA	El Segundo	996	23	37.4	1955
CA	Alamitos	2120	24	35.4	1956
CA	Long Beach	586	20	36.6	1928
CA	Huntington Be	1008	14	37.8	1958
CA	Morro Bay	1056	21	51.3	1955
CA	Encina	982	24	37.7	1953
CA	Moss Landing	2175	23	40.7	1950
CA	Redondo Beach	1580	29	32.4	1948
CA	Pittsburg	2029	25	40.6	1954
CA	South Bay	714	29	36.9	1960
CA	Contra Costa	1291	16	42.5	1951
CA	Etiwanda	1049	15	38.1	1955
CA	Ormand Beach	1613	21	38.2	1971
CA	San Onofre[b]	2710	58	35.6	1968
CA	Diablo Canyon[b]	2376	59	19.8	1985
NV	Mohave	1636	66	19.8	1971
NV	Reid Gardner	636	50	41.3	1965
NV	Sunrise	82	18	40.6	1964
NV	Clark[a]	420		60.7	1973

[a] Gas turbine plant
[b] Nuclear plant

Source: Department of Energy, 1988.

TABLE 4. Upper basin electric generation plants ($1986).

State	Plant	Rating (MW)	Factor (%)	O&M cost (mills/kwh)	Year
Utah	Hunter(Emery)	1339	45	19.4	1978
	Huntington	893	58	19.5	1974
WY	Dave Johnston	750	62	14.6	1959
	Jim Bridger	2034	51	17.8	1974
	Wyodak	332	69	20.8	1978
	Naughton	707	46	20.8	1963
CO	Rawhide	255	79	16.6	1984
	Cherokee	804	46	19.1	1957
	Comanche	779	50	18.4	1973
	Pawnee	552	74	16.8	1981
NM	Four Corners	2270	61	17.6	1963
	San Juan	1779	61	23.4	1973
	Cunningham	265	43	39.1	1957

Source: Department of Energy, 1988.

Calculation of economic benefits from use of basin water for hydropower generation also includes operation and maintenance costs at hydropower plants, plus differences in transmission costs from hydropower sites and alternative sources to demand centers. Following Abbey (1979), transmission costs of 2.1 mills/kwh/100 miles are used. Alternative costs are weighted by the proportion of power serving upper and lower basins. Table 5 shows the disposition of power from upper and lower basin operations. Table 6 shows the benefit calculation for the base case. Using this apparoach, avoided costs are 44.2 and 26.0 mills/kwh in lower and upper basins, respectively.

TABLE 5. Disposition of power generated at main hydroelectric facilities, upper and lower basins.

State	Disposition (proportion) Upper	Lower
CA	0.009	0.648
AZ	0.151	0.176
NV	0.065	0.176
CO	0.267	
Utah	0.285	
WY	0.103	
NM	0.120	

TABLE 4. Calculation of net benefits to hydropower, upper and lower basins. Total net benefits are the sum of the weighted net benefits; totals are 44.2 and 26.0 for upper and lower basins, respectively.

State	Avoided Cost	Hydro O&M expense Upper	Lower	Transmission Cost	Weighted net benefit Upper	Lower
CA	47.8	1.2	1.2	2.9	0.40	28.30
AZ	47.8	1.2	1.2	2.9	6.60	7.69
NV	47.8	1.2	1.2	0.0	3.03	8.19
CO	24.4	1.2	1.2	2.3	5.57	0.00
Utah	24.4	1.2	1.2	4.3	5.37	0.00
WY	24.4	1.2	1.2	0.0	2.38	0.00
NM	24.4	1.2	1.2	1.4	2.61	0.00

Hydropower Production

Energy production estimates from basin dams are derived below from those used by the Colorado River Simulation Model (USBR, 1986a). The results of one study (USBR, 1986c) using this model gives average annual basin energy production and releases from Glen Canyon and Hoover dams for a variety of average annual flows. It was found that using a linear functional form these releases were very succesful in explaining predicted hydropower generation in the upper and lower basins, respectively. Estimated coefficients determined from the study data are used in to give power production as a function of river flows.

Figure 2 shows the data used and the least squares linear estimates of energy production. While reservoir level should influence power production levels, and is considered in CRSM, the effect is small compared to other factors. In Figure 1 the least squares estimates do not systematicaly overestimate power production for low flows, and hence low reservoir levels.

Upper basin energy production is given by

$$E = 93 + 0.616\,Q \qquad (R^2=0.99) \qquad (1)$$

where E is energy production in gwh, and Q is total volume leaving Glen Canyon dam in kaf. Lower basin production (using the same units) is

$$E = -14 + 0.724\,Q \qquad (R^2=0.99) \qquad (2)$$

where Q is the volume leaving Hoover dam.

Value of Upper Basin Water for Hydropower Production

The above analysis indicates that water originating in the upper basin water is used to produce 1,340 kwh/af. Valuing the production of 616 kwh/af at Glen Canyon at 24.4 mills/kwh, and lower basin production of 724 kwh/af at 47.8 mills/kwh gives a value of upper basin water for hydroelectric energy production of $49.6 /af. This should be viewed as a conservative estimate, as basin reservoirs are frequently used to provide (more valuable) peaking power. No attempt has been made here to determine the additional value added through operations designed to provide peak load generation.

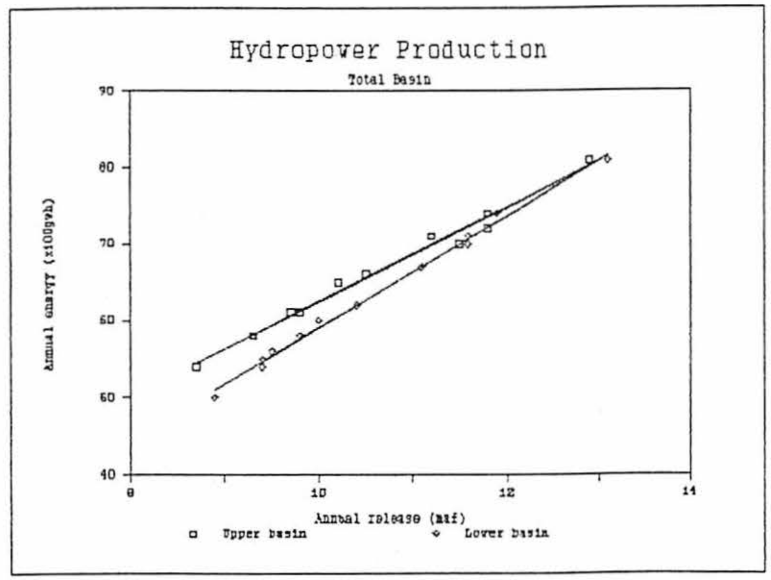

FIGURE 2. Upper and lower basin hydropower generation as a function of average annual flows.

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[a number of references are missing]

Western Slope gets $43m for new reservoir. Denver gets 40% permanently of Wolford Mountain Resevoir or 15,000 ac-ft or enough for 60,000 people. Denver pays $43m or all but $6m of building cost of 60,000 ac-ft reservoir on Muddy Creek near Kremmling. "A fast moving deal" others say when you make a $50m deal you should be extraordinarily careful. Two CRWCB members opposed but rest said delay could jeopardize deal. Interest rate changes and Two Forks decision made Denver backoff 25 year lease agreement and go for permanent at extra $10m. Denver was to pay $3m a year to lease. As part of new deal are settlement of law suits and half of $8.5m price of Clinton Gulch Res. paid by Denver for Summit and Grand Counties ski resorts.
Heather McGregor (1992) River District OKs Denver Water Pact, The Daily Sentinel (Grand Junction), July 22, pp. 1A and 7A.

City purchases of water have dried up 60,000 acres of Colorado crop land over the past two decades and 30,000 acres is underway. Appraised value in Crowley County has dropped 10% in 7 years. Increasing burden for schools and local gov. shifted to those remaining. No neighbors have enough cash to buy out those who want to sell. Farmers account for 2% of population and consume 92% of water and farming provided 3.25% of state's total economic output according to Colorado's office of state planning and budgeting.
Between 1980 and 1990, C olorado's farm population dropped 23.7% to 45,118 residents according to Census.
Ranchers say lucky to get $200 per acre gross raising beef and hay and then expenses. City will buy water for $5,000 per acre-foot. Can lease ranch for $2,500 per year or sell ranch in Lower Arkansas near Rocky Ford for water at $200,000 to Aurora and get $17,000 from CD's [not any more].
Anon. (1992) Cities Take Toll With Agricultural Water Purchase, Alamosa Valley Courier, July 21, n.p.

Ag use is 92% of water and 3.25% of total economic output in Colorado. Lots of water for little wealth production. Ag use wastes more water than entire metro area drinks. USGS reports leaky irrigation canals and ditches in Colorado annually lose 3.2m acre-feet - double flow of entire South Platte River in a year, or enough for 12.8 million people. Agriculture not concrened about waste. Over past two decades 60,000 acre dried up. Need way to have ag conserve water and sell to cities. Farmers soon to face competiton from Ukraine as soil, rain, transportation worse than Ukraine. Change needed.
Mark Obmascik (1992) Colo. Farmers Should Catch The Wave Of Water Conservation, The Denver Post, n. p.

LaSalle has nitrate problem with well water. Voters passed 1.5% sales tax to raise $82,500 annually for water purchases. Also committed $285,000 of reserve funds for immediate purchase of 192 units of Colorado-Big Thompson Project water which traditionally is .7ac-ft of delivered water per year. Loan / bond insurance also from CWRPDA and $300,000 impact assistance grant to install meters.

Objective is to own 120% of annual consumption.

Bill Jackson (1992) LaSalle Water Project Gaining Momentum, Greeley Tribune, June 15, n.p.

4,000 ac-ft of Windy Gap Project water available for Northern District users as a rental. Latest offer is $16 per ac-ft. Annon. (1992) NCWCD Freeing Up 4,000 Acre-feet For Users, Greeley Tribune, June 13, n.p.

Animas - LaPlata -- Drinking water already to be supplied by Deloris Project to Towaoc and Ute Mt. Utes. Only 2,058 Native Americans listed in Montezuma County (1990 census). Is there cheaper way? Souther Utes have Sky Ute Downs, high stakes bingo etc. They would be better off if A-LP built on their lands. Native American pop. in LaPlata and Archuleta combined is 1,709 (1990 census). Wonder whose 98,000 acres are to be irrigated.
Verna Forbes Willson (1992) A-LP Article Left Much Unanswered (letter to editor), Durango Herald, July 15. n.p.

Pine River Indian Irrigation Project near Durango uses Vallecito Res. (built in 19412) and Pine River Res. and need for repairs at about $700th.
"Today, ownership of Vallecito is divided between the PRIIP with one-sixth interest and the Pine River Irrigation District with five-sixths interest. Vallecito hold enough water to irrigate 54,000 acres. The PRIIP operated by the BIA, provides water for 12,000 acres of farmland and serves 225 Indian and 87 non-Indian water users. It has an annual budget of $100,000 for operations and maintenance paid by water users."
Annon. (1992) Repairs Planned On Irrigation Project, Durango Herald, July 19, n.p.

Farming on Great Plains affected by 26 bird species proposed for listing as T and Endangered, esp. because of loss of wetland base. $10 billion a year goes into ag. subsidy. 90% of farmers in plans are heavily dependent - esp. for wheat, corn, and other grain. [p. 8]. [p. 16>] Beef producers in trouble because of perception of beef as unhealthy food. Irrigation groundwater depletions. Population grew 40% form 1930 to 1990 but this was in urban areas of 10 states compared with 100% growth for U.S. as whole. Subtract urban areas and a 16% decline. Discussion of Poppers' Buffalo Commons.
John Brinkley (1992) Storm Clouds Darken Great Plains, The Rocky Mountain News, July 22, pp. 8 and 16.

Water treatment plants for Leadville. Leadville Tunnel Treatment plant at 1,150 gallons per day for $6.8m. Ph manipulation and polymer flocculent to pull out metals. Yak Tunnel Water Treatment plant at $12m plus superfund for 300 gallons per day. Up. Arkansas RiverInitiative coordinated by Karen Hamilton of EPA. $5913 per gallon
Tracy Harmon (1992) Yak, Leadville Water Treatment Plants Dedicated, The Pueblo Chieftan, July 23, pp. 1A and 2A.

Department of Natural Resources
Colorado Water Conservation Board

Colorado River Basin
Basic Facts

The following information reflects a very simplified presentation of Colorado River Basin data and facts and does not necessarily reflect the final position of the State of Colorado regarding these matters.

This presentation does not waive any position Colorado may take in the future concerning any aspect on the interpretation of the Law of the River.

Law of the River

1922 - Colorado River Compact
1928 - Boulder Canyon Project Act
1929 - California Limitation Act
1931 - California Seven Water Party Agreement
1940 - Boulder Canyon Project Adjustment Act
1944 - Mexican Water Treaty
1948 - Upper Colorado River Basin Compact
1956 - Colorado River Storage Project Act
1964 - Arizona v California - U.S. Supreme Court
1968 - Colorado River Basin Project Act
1970 - Long-Range Operating Criteria

Compact Apportionment

Lower Colorado River Basin States: 7,500,000 af of 75,000,000 per 10 yr. consumptive use per annum

California	4,400,000 af
Arizona	2,800,000 af
Nevada	300,000 af
	7,500,000 af

Upper Colorado River Basin States: 7,500,000 af* of consumptive use per annum; additionally the Upper Basin States will not deplete the flow of the Colorado River at Lee Ferry below 75 million af in any 10 year period.

Arizona		50,000 af
Colorado	51.75% -	3,079,000 af
New Mexico	11.25% -	669,000 af
Utah	23.00% -	1,368,000 af
Wyoming	14.00% -	833,000 af
		6,000,000 af

* 1988 Bureau of Reclamation Hydrologic Determination: Physical water supply available to Upper Basin States is only 6,000,000 af and this assumes that the Upper Basin is responsible for one-half of the Mexican Treaty obligation. The Upper Basin States do not agree with this assumption

4035E*

Mexican Treaty Ol gation

Mexico 1,500,000 af

Historic Consumptive Uses

Lower Basin States 1/ (1,000 a.f.)

	1987	1988	1989	1990
California	4,892	5,040	5,145	5,279
Arizona	1,755	1,923	2,230	2,316
Nevada	109	129	156	177
	6,756	7,092	7,531	7,772

Upper Basin States 2/ (1,000 a.f.)

Arizona	42
Colorado	2,300
New Mexico	443
Utah	793
Wyoming	415
	3,993

California Priorities - (1,000 af)

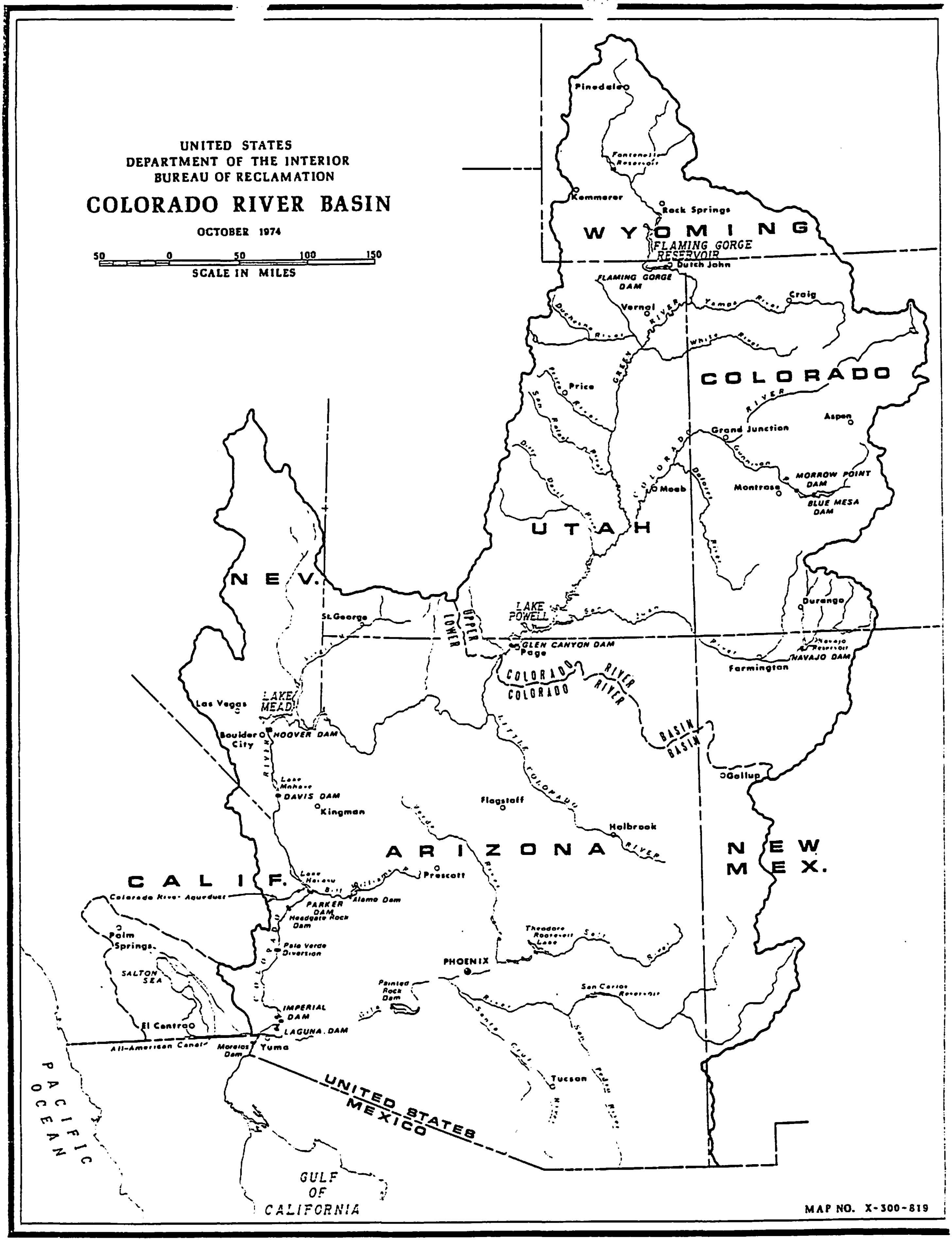
Agricultural Users (1-2-3)	3,850
Metropolitan Water District (4)	550
	4,400

Diversion Capacity (1,000 a.f.)	Max.	Aver.	1990
Metropolitan Water District	1,339	1,243	1,217
Central Arizona Project	2,171	1,500	779

1/ Most recent preliminary consumptive use values for the Colorado River Mainstem by the Bureau of Reclamation.

2/ Most recent preliminary consumptive use values by the Bureau of Reclamation for WY 1981-85, Average

EIJ/gl


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER BASIN
OCTOBER 1974
50 0 50 100 150
SCALE IN MILES
Pinedale
Fontenelle Reservoir
Kemmerer
Rock Springs
WYOMING
FLAMING GORGE RESERVOIR
Dutch John
FLAMING GORGE DAM
Vernal
Craig
GREEN RIVER
Duchesne River
White River
Yampa River
COLORADO
Price
Price River
San Rafael River
Grand Junction
Aspen
Gunnison
MORROW POINT DAM
BLUE MESA DAM
Montrose
Moab
COLORADO
Dolores River
Dirty Devil River
UTAH
NEV.
St.George
UPPER
LOWER
LAKE POWELL
San Juan
GLEN CANYON DAM
Page
Durango
Navajo Reservoir
NAVAJO DAM
Farmington
COLORADO RIVER
COLORADO RIVER
BASIN
BASIN
Las Vegas
LAKE MEAD
Boulder City
HOOVER DAM
RIVER
Lake Mohave
DAVIS DAM
Kingman
Flagstaff
LITTLE COLORADO
Holbrook
RIVER
Gallup
ARIZONA
NEW MEX.
Verde River
Prescott
CALIF.
Lake Havasu
Bill Williams
Alamo Dam
PARKER DAM
Headgate Rock Dam
Colorado River Aqueduct
Palm Springs
SALTON SEA
Palo Verde Diversion
Theodore Roosevelt Lake
Salt River
PHOENIX
Painted Rock Dam
San Carlos Reservoir
Gila River
IMPERIAL DAM
LAGUNA DAM
El Centro
All-American Canal
Morelos Dam
Yuma
Santa Cruz
San Pedro River
Tucson
UNITED STATES
MEXICO
PACIFIC OCEAN
GULF OF CALIFORNIA
MAP NO. X-300-819

London project to relieve growing need for water

50-mile water ring will replace deteriorating system

By Steven Prokesch
NEW YORK TIMES NEWS SERVICE

LONDON – What will be longer than the English Channel tunnel, deeper than the London Underground railroad and will insure that there are not a lot of thirsty, smelly Londoners in the 21st century?

The answer is the London Water Ring Main, a 50-mile tunnel being dug deep beneath metropolitan London. It is the biggest water project here since the Victorians built the sewers after the Great Stink of 1858.

The $500 million main is needed because the drinking-water system already has been stretched to the breaking point, literally. A major main breaks in metropolitan London every day on average, and 18 percent of the city's water leaks away. That is not surprising, since some mains are more than 100 years old.

While the area of London served by Thames Water Utilities Ltd. is only slightly larger than it was at the turn of the century, the daily demand for water has more than doubled, to 600 million gallons.

It is still growing by about 1 percent a year, mainly because of the proliferation of water-guzzling appliances," said Stephen Walker, project manager of the ring main at Thames Water.

The water company had kept up with demand by pumping more water through existing mains. But it dares not increase the pressure because the mains are so fragile.

One possible solution was ripping up the streets and replacing the mains. That would have risked provoking customers who are already less than thrilled by traffic and causing water-supply disruptions due to main bursts.

Wouldn't it be better, mused the people at Thames Water, to build a supplementary system so pressure in existing mains could be lowered? It would have to be deep to avoid the water, gas, phone, electrical and subway lines already packed into subterranean London. And why not let gravity move the water and reduce the need for energy-devouring pumps?

So they decided to build the London Water Ring Main.

When completed in 1996, the main will be a continuous loop capable of carrying 343 million gallons of water a day. Controlled by a system of fiber-optic cables and computers, the water will be drawn up to local networks through 12 giant shafts.

The tunnel will be an average of 8.3 feet in diameter, big enough for a London black cab should one lose its way. And it will be an average of 131 feet deep.

But in some places it goes nearly twice as deep, as visitors discovered recently as they stood 246 feet below Barrow Hill in Primrose Hill Park.

"We went under the insect house and passed by the lions in the London Zoo," said Kevin McManus, a Thames engineer, after a ride on one of the small trains that carry workers and construction material."

Since construction began in 1986, mechanical moles have dug slightly more than half of the main. There have been mishaps. An elaborate rescue had to be mounted to retrieve a mole trapped in a flood.

And four workers have been killed. One was electrocuted, another was crushed in a train accident and two suffocated when they ventured into a section surrounded by oxygen-absorbing sand without breathing devices.

Navajo Res DEIS 2002 3 gpd 3

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2002 CRSP M and I Rate is ~~$[illegible]~~ $68.57 per ac-ft

$600 per ac ft estimated suburban domestic rate in region

p III-40

p 128 of 323 Water use on reservation between 10 gpd and 100 gpd

p 166 of 323 p III-78 Replacement power costs for City of Farmington is ~~$~~ $60 per MWh

Ranged from $65 per MWh to $750 per MWh in 2002

p 209 of 323 Crop value per acre - Alfalfa $618

p ~~[illegible]~~ 211 of 323 Out of state fishing $400 per trip per person.

1 day of fishing. Guides say $462/day/person.

212 of 323 Break out of costs/expenditures

214 of 323 Rafters per trip 9.1

215 of 323 Gross revenue per acre - NM Alfalfa $618/acre

Walsenburg - ranchers fill up 400 gallon tanks in back of pickups at $.25 per 40 gallons. Has done for 52 years for in house plumbing. So do about 700 others
$.25 per 40 gallons is lower than cost to town residents
City/County conflict
Jim Hughes (1998) An End to Cheap Fills: Town may turn off Spigot. The Denver Post November 12, 1998 p. 1A, 12A.

Conifer area planning for water supplies - ...
3 year ground water study by USGS
Kieran Nicholson (1998) Conifer Growth Spu...
Plan Review The Denver Post Oct. 27...

Growth prompts call for more water storag...
Growth in El Paso County - Study by South...
Water Conservancy District. Study shows ...
135,000 to 155,000 acre feet. Price Ta...
James Amos (1998) ~~Help~~ Help - Growth Prompts Call...
Water Storage Space Needs, Pueblo Chief...

DeWeese Dam near Westcliff - Dam repa...
$850,000 for top 12 feet replacement, ...
group has offered $100,000 for its 100 acf...
There are 7,200 water shares [1 share = ...
If no repair, capacity cut 50%
Tracy Harmon (1998) DeWeese Shareholde...
to Make Dam Repairs Pueblo Chief...

Morrison CO $2.3M for reclamation of gravel pit and water treatment pit 585 acres / Project to sell 221 lots at $8,500 each for $1.9M
~~Den~~ Kieran Nicholson (1998) Reservoir Plan Buoys Morrison, The Denver Post November 15, 1998, 31A, 32A, 33A.

6·25·00

PUEBLO CHIEFTAIN
Pueblo, CO
(Pueblo County)
AM, 52,267; Sun, 55,674

Colorado Press Clipping Service
1336 Glenarm Place · Denver, CO 80204

Cement water lease OK'd

The Pueblo Board of Water Works approved a lease contract that would provide 250 acre-feet of water a year for the proposed Rio Grande Cement plant to be located south of Pueblo.

The 25-year lease agreement would provide the water from the St. Charles River through a series of exchanges that involves Oregon Steel. The agreement calls for Rio Grande to pay the board $132 per acre foot of water.