Water Supply

Water Diversion & Irrigation Methods

A primary purpose of many dams, both large and small, is to facilitate water diversions. Although existing water supplies can be stretched much further and new water infrastructure can be delayed using water conservation and efficiency strategies described below, people will continue to divert water from rivers and other surface sources for various purposes. Nearly 80 percent of water consumed in the United States comes from surface supplies—rivers, creeks and lakes.[1] In California alone, there are more than 25,000 points of diversion from streams.[2] Thus, there are at least 25,000 locations in the state at which fish and other river organisms can be harmed in the process of meeting our need for water. In many dam investigations, the question comes down to: could we still divert water if the dam is removed or modified, or not built at all? In many cases, the answer is yes. Several, more river-friendly alternatives to traditional permanent dam diversion methods are discussed below, including:

- Infiltration galleries and wells
- Screened pipe intakes
- Seasonal dams
- Consolidated diversions

Infiltration Galleries and Wells

As an alternative to a typical irrigation or smaller water supply dam, two general types of infiltration galleries have been employed to divert water from streams: vertical wells and horizontal infiltration galleries, also known as "Ranney wells."[3] Both types typically require pumps to draw water from the stream's gravel substrate through perforated pipes, but in certain sites infiltration galleries can function by gravity alone.[4]

1. U.S. Geological Survey. *Water use in the United States in 1995.* Washington, D.C.: GPO, 1998.
2. Scott McFarland, California State Water Resources Control Board, personal communication, 15 November 2001.
3. *Alternatives to Push-Up Dams.* Produced by the Bureau of Reclamation, Pacific Northwest Region. 10 min. 1999. Videocassette.
4. Glenn Ginter, Illinois Valley Soil and Water Conservation District, personal communication, 9 October 2001.

Vertical wells

Vertical wells draw water through perforated pipes placed vertically into the stream or floodplain substrate and water table maintained by the surface flow. Vertical wells can be located very near the stream or at some distance from the channel, depending on stream conditions. Pumps draw water up from the groundwater table.

Infiltration Galleries

Typical construction of an infiltration gallery involves placing perforated pipes in the streambed and connecting them to a collection area, or "sump" (see photo). Water seeps into the perforated pipes and flows to the sump where it is pumped out (or flows by gravity) for immediate use or storage. The size, length and depth to place the perforated pipes depends on a number of factors, including the size of the stream, rate of diversion needed, the nature of the gravel at the site and the depth to which bed scouring will occur during high flows. The perforated pipes are usually placed at least four feet deep within a bed of clean gravel at least 1.5 feet thick on all sides. The gravel, in addition to a fabric filter placed on top of the gravel layer, prevents the perforations from becoming clogged with sediment. If sedimentation is a problem, these wells can be designed with a reverse flushing feature. Depending on the site conditions and streamflow, infiltration galleries require approximately one square foot of perforated pipe surface for each gallon per minute of pumping.[5] Since 1996, the Natural Resource Conservation Service in Oregon has installed 22 infiltration galleries, some of which divert as much as 1400 gallons per minute (2.5 cubic feet per second).[6]

U.S. FISH AND WILDLIFE

INFILTRATION GALLERY DURING CONSTRUCTION ON SUCKER CREEK, OR

Advantages

Vertical wells and infiltration galleries offer a number of advantages over other diversion methods, including eliminating the impacts of dams on natural stream dynamics, avoiding the risk of fish entrainment, and reducing the visual impact of the diversion. The relatively low impact of this method can allow for diversions at any time of year.

Disadvantages

A significant challenge to infiltration galleries in certain streams is preventing the perforated pipes from becoming blocked with fine sediment. Although many infiltration galleries are equipped with a reverse pumping feature to flush out sediments, sediment can still pose problems. Caution must be taken to ensure that pumping rates do not reduce surface flows or water tables to the point of harming aquatic habitat or riparian vegetation. In addition, infiltration galleries will not work at all sites. Characteristics that could preclude the use of infiltration galleries include:[7]

5. Department of Agriculture, Natural Resource Conservation District. *Infiltration galleries of Oregon.* Washington, D.C.: GPO, 2000.
6. Greg Card, Natural Resource Conservation Service, personal communication, 17 October 2001.
7. Department of Agriculture, Natural Resource Conservation District. *Infiltration galleries of Oregon.* Washington, D.C.: GPO, 2000.

- "Armored" gravels on the streambed that would indicate poor percolation rates;
- Limited thickness or absence of gravel substrate that could prevent the placement of perforated pipes at depths adequate to protect them from scouring;
- Streambed made up of fine-grained soils such as clays, silts and sands that would continually clog the perforations; and
- Stream reaches with unstable banks that can migrate significant distances from their original locations, thus separating infiltration galleries from the water source.[8]

When relying on vertical wells, there is a risk that wells could dewater the stream where the subsurface water is connected to the surface water. This is a growing problem in states, such as California, where groundwater pumping is unregulated.

Costs

The cost of infiltration galleries depends primarily on the amount of water to be diverted, which would dictate the size of the perforated pipes, amount of excavation and gravel for backfilling and the cost of pumps, if needed. Costs can range from as little as $10,000 to more than $1 million depending on project characteristics.

8. Glenn Ginter, Illinois Valley Soil and Water Conservation District, personal communication, 9 October 2001.

Case Study, Infiltration Galleries and Wells

In 1998, U.S. Fish and Wildlife Service and the Illinois Valley Soil and Conservation District partnered to address the problems caused by a seasonal gravel diversion dam on Sucker Creek, a tributary to the east fork of the Illinois River, in Josephine County, Oregon. This irrigation dam, and others like it, block spawning habitat for salmon and trout, and increase water temperatures, sediment loads and turbidity in the creek or stream. To eliminate the problems and preserve the irrigation diversion for the landowner, an infiltration gallery was installed for $27,667. In addition to improving water quality, access to habitat was improved for coho salmon, fall chinook salmon and steelhead.

To learn more about the Sucker Creek irrigation project see U.S. Fish and Wildlife Service, Oregon office, pacific.fws.gov/jobs/orojitw/project/josephine/26-9502.htm.

Where you can go for help

- For more information, contact your state natural resources agency, such as the Department of Natural Resources or Department of Environmental Protection.
- "Irrigation Alternatives Infiltration Gallery." Oregon Department of Fish and Game, pacific.fws.gov/jobs/orojitw/technique/FishPassage/irrigation/gallery.htm.
- "Infiltration galleries of Oregon," USDA Natural Resources Conservation Service, June 2000.
- *Alternatives to Push-Up Dams* (video), U.S. Bureau of Reclamation, Oregon Department of Environmental Quality, *et al.*

Screened Pipe Intakes

Pumping water through pipes placed in rivers is a common diversion method today, but in many cases the pipe is used in conjunction with a dam—and often it is not screened to prevent fish from being entrained. When properly screened, screened pipe intakes can safely divert water to a distribution system for immediate use or into a surface or subsurface storage site away from the stream for later use. In cases where sufficient water depth consistently occurs, dams can be removed without affecting the diversion.

Where sufficient depth does not occur, "vaults" can be constructed to create enough depth to allow for screened pipe diversion. These "screened vault intakes" consist of a screened pipe placed in a pre-cast concrete vault set into the stream below the streambed elevation. The vaults are often located in a natural or constructed alcove at the edge of a stream to protect the structure from scouring and deposition. Even well protected vaults must be cleared of sediment and other debris on occasion. In addition, pipe diversions behind dams could be extended upstream to allow gravity to drive the diversion if possible, thereby allowing the removal of the dam.

Advantages

The primary advantage of screened pipe intakes is that in many cases they can function without a dam or other structure to control water levels. Thus, sediment and fish can pass without significant disruption, and flows are affected only by the amount of water diverted. When combined with off-stream storage of some kind, screened pipe intakes can provide water diversions and storage functions with minimal stream impacts.

Disadvantages

One concern with pipe intakes is fish entrainment. Intake screen technology has improved greatly in recent years, but entrainment continues to be a problem in certain cases. Another concern is that screens can be expensive to install and maintain. The chief limitation, however, to applying this strategy is that in certain streams, flows might not be sufficient to reliably pump water directly from the river during the diversion season(s). This problem could be minimized if pumping took place during higher flow periods and the water was stored off-stream, or if a natural pool can be safely utilized. Another drawback in certain cases where a dam is removed and the water level at the diversion point is lowered is that diverters may incur the cost of installing and operating pumps to make up for the lost water surface elevation.

Costs

The Idaho Department of Fish and Game has monitored numerous screening projects and found costs range from $2,200 to $6,400 per each cubic foot per second (cfs) the intake will divert.[9] Large diversions that involve sensitive fish species can be even more expensive. For example, the U.S. Bureau of Reclamation has completed a complex screen system on the Klamath River in Oregon to prevent endangered sucker fish from entering their 1000 cfs diversion canal.[10] The system cost $16 million to construct, which represents approximately $16,000 per cfs diverted.

9. Idaho Fish and Game, *Fish Screen Program*, ‹www.salmonidaho.com/screenshop/› (1 December 2002).
10. Bureau of Reclamation, *A-Canal Fish Screen Project*, ‹www.mp.usbr.gov/kbao/fish_screen/› (1 December 2002).

Case Study, Screened Pipe Intake

Foots Creek Dam on Foots Creek, a tributary to the Rogue River in Oregon, was a 5-foot high, 40-foot wide concrete dam that blocks passage for coho salmon and steelhead. A denil fish ladder installed in 1998 by the Oregon Department of Fish and Wildlife proved ineffective in providing consistent fish passage. Originally built for irrigation and recreational uses, water was being pumped from the impoundment to a pond that was used for fire protection and recreation. In 2000, the Rogue Basin Coordinating Committee (RBCC) began working with the landowner on a solution that would provide fish passage and still allow for the diversion rights. In order to meet their goal of continued water supply and adequate fish passage, RBCC and the landowner agreed on a plan that called for the removal of the dam and installation of a screened intake pipe that would continue to divert the necessary water to the nearby pond. The project was completed in 2001 with the breaching of the dam ($2,600) and installation of pump and pipe ($4,000). By removing this structure and using a screened intake pipe system to continue to supply water to the pond, six additional stream miles on Foots Creek are now open for migrating salmonids. [11]

To learn more about the Foots Creek project contact Chuck Korson with the U.S. Bureau of Reclamation at (541) 389-6541 or visit www.pn.usbr.gov/project/wat/publications/footscreek.pdf.

11. Bureau of Reclamation, *Partnerships in Watershed Restoration: Foots Creek Fish Passage Improvement*, March 2001, ‹www.pn.usbr.gov/project/wat/publications/footscreek.pdf› (9 June 2002).

Case Study, Screened Pipe Intake

The Doug James Diversion Rehabilitation project in Oregon's Illinois River valley replaced a gravel "push-up"[12] diversion dam with a screened intake vault and associated works for $32,500 in 1998. After five years the irrigator continues to be satisfied with the effectiveness of the new structure.

For more information, contact Glenn Ginter, Illinois Valley Watershed Council Coordinator, (541) 592-3731.

Where you can go for help

- For more information, contact your state natural resources agency, such as the Department of Natural Resources or Department of Environmental Protection.
- *Alternatives to Push-Up Dams* (video), U.S. Bureau of Reclamation, Oregon Department of Environmental Quality, *et al.*
- "Fish Screening Criteria for Anadromous Salmonids," National Marine Fisheries Service, swr.ucsd.edu/hcd/fishscrn.htm.

12. Gravel "push-up" dams are temporary dams that are formed by pushing up stream gravels with a bulldozer to form a dam.

Seasonal Dams

Seasonal dams are temporary structures that can be erected to store water for immediate or later diversion, or removed to allow flows and (in most cases) fish to pass. Inflatable dams and flashboard dams (also known as stop log dams) are the most common types of seasonal dams. When in operation, both types of dams raise the river level allowing water to be diverted through a channel or pipe.

Inflatable dams

Inflatable dams are made of thick, laminated rubber and nylon tubes that are anchored to a concrete foundation across the streambed. The tube can be filled automatically or manually with air or water to create a barrier, and subsequently deflated to lie flat on the foundation (see photo). The inflatable tubes usually last between 25 and 50 years.

ALAMEDA FLOOD CONTROL AND WATER CONSERVATION DISTRICT

ALAMEDA FLOOD CONTROL AND WATER CONSERVATION DISTRICT

INFLATED/DEFLATED DAM ON ALAMEDA CREEK, CA

Flashboard dams

Flashboard dams usually involve a concrete foundation and frame into which boards are inserted to block the stream flow and raise the water level to allow for diversion.

Advantages

Seasonal dams provide the flexibility to store and divert water or allow water, sediment and fish to pass when the dam is not in use. In certain cases, pools created by temporary dams can provide cool water habitat for species to over-summer in warm streams.[13] Seasonal dams are usually designed to deliver water by gravity, thus avoiding costs associated with pumping.

Disadvantages

Despite the flexibility of seasonal dams, they can cause significant problems for fish populations. For example, a dam operator might need to block the flow when fish are migrating to or from the ocean, thus delaying or entirely stopping their up or downstream movement. In addition, seasonal dams can block juvenile or adult fish from moving to cold-water refuges that help them survive high summer temperatures.[14] In some cases, the concrete structure that anchors flashboards or inflatable tubes can create barriers to fish passage even when the dam is not in operation, if scouring below the structures lowers the streambed elevation significantly, or if the water flowing over the foundation or tube is too shallow or too fast. These foundations inhibit the

13. Marty Gingras, California Department of Fish and Game, personal communication, 31 October 2001.
14. NOAA Fisheries and California Department of Fish & Game has increasingly denied requests for permits to operate seasonal dams, in part because they can prevent juveniles from accessing cold-water areas.

dynamic nature of the river, interfering with natural stream migration. This can modify sediment transport processes and cause problems with excessive scour or undesirable deposition. In addition, the pipe or channel diverting water from the temporary pool can entrain fish if not properly screened. Seasonal dams can affect streams negatively in other ways as well, including increasing water temperatures, harboring predator species, eliminating water flows and associated aquatic habitat downstream and inducing erosion of the bed and banks of streams and introducing major fluctuations in water levels upstream of the dam impacting biota, aquatic vegetation and riparian homeowners.

In recent years, operators have experimented with strategies to change the shape of the tubes used in inflatable dams to improve downstream passage while the tube is inflated. The most common strategy is to create a notch or to place a strap over the tube so that it cannot fully inflate at that location. These notches increase flow depth over the tube, which is safer and more appealing to out-migrating juveniles. These notches can sometimes also be used for adults migrating upstream if the jump is not too high.

Costs

The cost of inflatable and flashboard dams depends on many factors, including the size of the stream to be impounded, channel shape and material and the complexity of the required design. In 1989, the Alameda County Water District in California constructed a 300-foot long 13-foot tall air filled inflatable dam on Alameda Creek. The concrete foundation cost $1.6 million and the bladder cost $1.6 million.[15]

15. Steve Peterson, Alameda County Water District, personal communication, 13 December 2002.

Case Study, Seasonal Dams

The Susquehanna River in Pennsylvania is home to the Adam T. Bower Dam (popularly referred to as Sunbury Dam), which is the world's largest inflatable dam. Shikellamy State Park maintains the dam, inflating it with air each spring and deflating it each fall in order to create a seasonal three-thousand-acre compound called Lake Augusta. The lake, which is approximately eight feet deep at the dam, provides 13 miles for recreation such as boating and water skiing. The rubber bags measure twelve millimeters thick and sit flat upon cement casings when not in use.

This dam exemplifies in many ways, however, how inflatable dams can be misused. For example, during the 2003 season this dam was inflated in April to accommodate recreational and commercial interests and remained inflated until early fall, effectively blocking the Susquehanna during the entire migratory season (April – July) for American shad. Because of the pressures to inflate the dam early in the year, the state has agreed to let the dam operator meet migratory fish passage obligations through the construction of a fish ladder. The dam is currently providing no fish passage and has not provided any since its installation even though an inflatable dam was chosen over a more permanent structure entirely for the purpose of providing for fish passage.

To learn more about the Adam T. Bower Dam, visit www.visitcentralpa.org/OUTDOORS/Fabridam.htm.

Where you can go for help

- For more information, contact your state natural resources agency, such as the Department of Natural Resources or Department of Environmental Protection.
- "Rubber Dam Hydraulics: Hydraulic Design of Inflatable Flexible Membrane Dams." University of Queensland, Australia, www.uq.edu.au/~e2hchans/rubber.html

CONSOLIDATED DIVERSIONS

It is not uncommon for diverters to locate several diversion dams close together on a single stream. In certain cases, it is possible to consolidate the number of diversions to a single diversion point, allowing the elimination of some of the dams.

Advantages

Consolidating diversion points has the benefit of eliminating some or all of the diversion dams involved, and typically reduces the number of diversions that require screens to prevent fish entrainment.

Disadvantages

One potential drawback of this option is the need to relocate diversion pipes or canals to the new diversion point. Depending on circumstances, this could involve moving water over greater distances, require more materials, or an increase in pumping costs. It could also require some amount of cooperation or coordination among the diverters located together. Also, by consolidating multiple locations into a single diversion point, this diversion point may still create a barrier to migrating fish. While impacts on the stream will be less with fewer dams, there may still be negative impacts.

Costs

The costs of consolidating diversion points will vary greatly depending on distances between existing diversions, the size of diversions and the size and number of existing dams that would be removed. Costs can range from thousands to millions of dollars

Case Study, Consolidated Diversions

In the Touchet River basin near Walla Walla, Washington, a project to construct a fish screen, fish ladder and consolidate four irrigation diversions totaling 13 cfs that utilize three dams is expected to cost $883,000. The species that will benefit include steelhead, bull trout, whitefish and several species of native sculpin and minnow.

The Upper Salmon River Diversion Consolidation Program cost $2.28 million to consolidate four diversion points totaling 15 cfs by removing three dams and consolidating diversions to a single location and screening the remaining 10 diversions. [16]

To learn more about these projects, contact the U.S. Fish and Wildlife Service in Portland, OR at (503) 872-2763

16. Bonneville Power Authority, *Ongoing BPA Project Summary: Upper Salmon River Diversion Consolidation Program*, 24 July 1997, ‹www.efw.bpa.gov/Environment/EW/PROPOSALS/AIWP/1998/9600700.pdf› (3 January 2003).

APPLEGATE RIVER WATERSHED COUNCIL

SITE OF A FORMER IRRIGATION PUSH-UP DAM REPLACED WITH AN ALTERNATIVE DIVERSION STRUCTURE

Irrigation Methods

With agriculture responsible for the largest water usage in the United States and with irrigation dams being the most common type of water supply dam, it is important to examine the way this industry uses water and how conservation methods can be used to increase efficiencies and thus possibly decrease the need for dams. In addition to some of the alternative diversion techniques (described above) to supply water for irrigation, the U.S. EPA has compiled water-saving irrigation practices into three categories[17]:

- Field Practices
- Management Strategies
- System Modifications

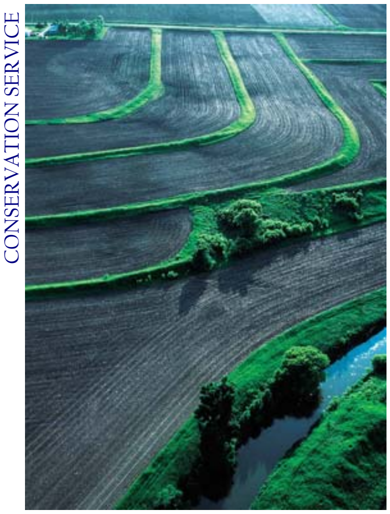
When these practices are combined with the alternative diversion strategies above, the need for a diversion dam for irrigation could be eliminated in some circumstances.

Field Practices

Field practices are techniques focused on keeping water in the field, distributing it more efficiently, or achieving better soil moisture retention. These techniques are typically less expensive than management strategies or system modifications. When traditional field practices fall short of expectations and the management strategies and systems modifications discussed below are out of reach, the field practices of dry-land farming and land retirement are another avenue to explore. Examples of field practices include:

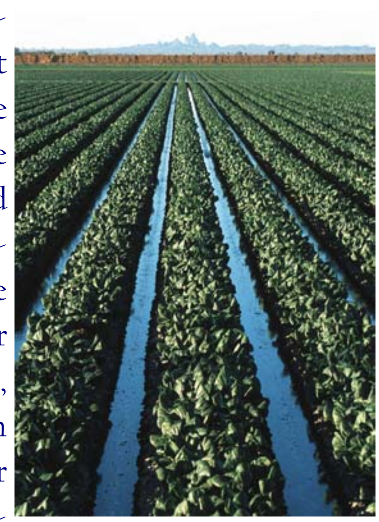
17. Environmental Protection Agency, *Cleaner Water Through Conservation*, April 1995, ‹www.epa.gov/water/you/chap3.html› (2 July 2003).

- The chiseling of extremely compacted soils;
- Furrow diking to prevent runoff;
- Land leveling for a more even water distribution
- Dry-land farming; and
- Land retirement.


LYNN BETTS, USDA NATURAL RESOURCE CONSERVATION SERVICE

LAND HAS BEEN TILLED AND TERRACED TO BETTER CAPTURE WATER

Farmers can develop land management practices that will decrease the demand on water supplies. More than half of land used for agriculture is still irrigated via a gravity-flow system. This system uses soil borders, furrows, or ditches in order to allow gravity to distribute water across fields. Gravity flow irrigation methods can result in up to 50 percent water loss due to evaporation, inefficiencies in water delivery to the crop-root zone and runoff at the end of the field.[18] The traditional gravity-fed system can be improved upon with the use of laser leveling or micro irrigation, though evaporation still leads to water loss. Laser leveling involves grading and precisely leveling the soil to eliminate any


JEFF VANUGA, USDA NATURAL RESOURCE CONSERVATION SERVICE

LAND THAT HAS BEEN LEVELED AND FURROW IRRIGATED

18. Department of Agriculture, Economic Research Service, *Irrigation and Water Use: Questions and Answers*, ‹www.ers.usda.gov/Briefing/wateruse/

variation in the gradient and reduce slope of the field. This helps control the flow of the water and allows for more uniform soil saturation.[19] Another method of preventing runoff is furrow diking. Furrow diking is the practice of building small temporary dikes across furrows to conserve water for crop production, which may also aid in preventing erosion.[20]

If the above land management practices are not decreasing water use enough and the system modifications described below are too cost prohibitive or not an appropriate technique for a particular crop, farmers can also consider converting to dry-land farming, switching to less water-intensive crops, or land retirement. Farmers practicing dry-land farming in arid regions use a variety of techniques and land management practices to minimize water loss and erosion. These techniques include coordinating seeding to the ideal soil moisture content, choosing crops more suited for arid conditions, and fallowing.[21] Fallowing refers to a number of practices used for well over a century, such as plowing a field in late fall or early spring to clear weeds and increase soil moisture. Initial plowing breaks up the land and allows the soil to absorb more water. It also eliminates moisture-sucking weeds and creates ridges in the land that limit runoff and better capture moisture from snow.[22] Fallowing can also involve choosing not to plant a certain field for one or more growing seasons.

19. Department of Agriculture, Economic Research Service, *Irrigation and Water Use: Glossary*, 30 March 2001, ‹www.ers.usda.gov/Briefing/wateruse/Questions/glossary.htm› (25 June 2003).
20. Texas A&M University, Blackland Research and Extension Center, *Environmental Policy Integrated Climate (EPIC)*, 20 May 1997, ‹www.brc.tamus.edu/epic/documentation/furrowdiking.html› (10 February 2004).
21. The Columbia Electronic Encyclopedia, *Dry Farming*, 2000, ‹www.infoplease.com/ce6/sci/A0816164.html› (30 May 2002).
22. River East School Division and University of Manitoba, *Summer Fallowing and Soil Moisture Conservation*, 1998, ‹timelinks.merlin.mb.ca/referenc/db0068.htm› (30 May 2002).

Land retirement refers to a common policy of permanently or temporarily suspending farming on a particular acreage of land in exchange for financial incentives. One of the best-known land retirement programs is the U.S. Department of Agriculture's Conservation Reserve Program (CRP). Through CRP, farmers are paid annual rent per acre and an additional sum for providing land cover. While CRP has typically been utilized to control the agricultural market and keep prices and quantities stable, the added value of conserving land and water resources has been given more consideration in determining compensation for land retirement since the late 1990s.[23] This type of financial incentive is common among land retirement programs.

Advantages

Practices such as chiseling, furrow diking, and land leveling allow the land to absorb water more efficiently and results in less waste. It is also one of the most inexpensive methods of agricultural water conservation discussed in this report. Depending on the amount of land in need of irrigating and the alternative chosen, it might be possible to remove an irrigation diversion dam, particularly if used in combination with one of the alternative diversion methods described above. Dry-land farming and land retirement, also discussed above, have the most to offer in terms of water savings, simply because they call for the use of little to no water, and the potential for dam removal.

23. Anderson, W. and R. Heimlich, "Agriculture Resources and Environmental Indicators, 2000", Department of Agriculture, September 2000, ‹www.ers.usda.gov/Emphases/Harmony/issues/arei2000/AREI6_2landretire.pdf› (30 May 2002).

Disadvantages

While chiseling, furrow diking, and land leveling help prevent runoff and allow the land to retain more water, they still do not address the over-watering that results from gravity-fed irrigation. Also, dry-land farming and land retirement practices can seem akin to suggesting that farmers go out of business. Discussions centering on these alternatives should take current use and compensation into consideration. Also, dry-land farming and land retirement practices are rarely, if ever, applied to the large agribusinesses that now dominate the industry.

Costs

As discussed above, furrowing and other land leveling practices are the least expensive irrigation alternatives discussed in this report. Actual project costs will vary depending on amount of acreage, topography of the land, and the region or country in which the farm is located. According to the 1998 Farm and Ranch Irrigation Survey, capital expenditures in the United States for farm improvements were $643 million for irrigation equipment and machinery, $138 million for construction and deepening of wells, $190 million for permanent storage and distribution systems, and $83 million for land clearing and leveling. [24]

In order for dry-land farming and land retirement to be feasible for farmers, it often must be accompanied by financial incentives like conservation easements, which involves the transfer of development and/or land use rights to a government agency or non-profit providing tax benefits or direct payment for retirement of the land.

Management Strategies

Management strategies allow the irrigator to monitor soil and water conditions to ensure water is delivered in the most efficient manner possible. By collecting this information, farmers can make informed decisions about scheduling, the appropriate amount of water for a particular crop, and any system upgrades that may be needed. The methods include:

- Measuring rainfall;
- Determining soil moisture;
- Checking pumping plant efficiency; and
- Scheduling irrigation.

Farmers have to rely on a number of factors to monitor soil moisture, including temperature and humidity, solar radiation, crop growth stage, mulch, soil texture, percentage of organic matter, and rooting depth. A variety of tools for monitoring soil moisture, such as Time Domain Reflectometry (TDR) probes or tensiometers, are also available to farmers.[25] The government of Queensland in Australia has done an effective job of compiling a fact sheet on a variety of irrigation scheduling tools, including the associated pros, cons, and costs of each. [26]

Ensuring that pumping plants are running at their most efficient also guarantees that water is being

24. Anderson, W. and R. Heimlich, "Agriculture Resources and Environmental Indicators, 2000", Department of Agriculture, September 2000, ‹www.ers.usda.gov/publications/arei/ah722/arei2_2/arei2_2irrigationwatermgmt.pdf› (13 February 2004).

25. Verhallen, A., P. Fisher, and R. Shortt, "Monitoring Soil Moisture", Ontario Ministry of Agriculture and Food, 1 November 2003, ‹www.gov.on.ca/OMAFRA/english/crops/hort/news/allontario/ao1103a1.htm› (10 February 2004).

26. Queensland Department of Natural Resources, Energy and Mines, *Irrigation Scheduling Tools*, 2002, ‹www.nrm.qld.gov.au/rwue/pdf/factsheets/sched_tools_02.pdf› (18 February 2004).

delivered to the plant and not wasted. Efficiency can be checked by examining the volume of water pumped, the lift, and the amount of energy used. A pump in need of repair or adjustment can not only waste water but also cost money.[27]

Advantages

The management strategies described above allow for the correct amount of moisture to be delivered to the plant. When combined with system upgrades like the ones discussed below, farmers can maximize the amount of water savings and the efficiency of their land. While this is not an automatic replacement for a dam, there could be an opportunity for removal or the ability to delay construction a new barrier, depending on the size of the diversion.

Disadvantages

Monitoring the water needs of crops in the most efficient manner possible requires technological upgrades that require an initial outlay of capital. In addition to the cost of implementing these system upgrades, there may be training required to integrate new computer systems and other technologies.

Costs

Depending on extensiveness of the system, costs can vary significantly for the management strategies discussed above. For example, the average price of a tensiometer ranges from $120 to $200, with the average field requiring a minimum of four stations containing two tensiometers each, while a c-probe system containing probes, training, and software can run as much as $9,120.

27. Peacock, W.L., "Energy and Cost Required to Lift or Pressurize Water", University of California Cooperative Extension *Grape Notes*, 21 February 2001, ‹cetulare.ucdavis.edu/pub/gra0201.pdf› (11 February 2004).

The Department of Natural Resources, Energy and Mines in Queensland, Australia has put together a comprehensive fact sheet (www.nrm.qld.govau/rwue/pdf/factsheets/sched tools 0.2.pdf) that provides cost estimates (in Australian dollars) for a wide range of irrigation scheduling tools.[28]

System Modifications

System modifications, often the most expensive of the three categories, require making changes to an existing irrigation system or replacing an existing system with a new one. Typical system modifications that allow for the most efficient delivery of water are:

- Add drop tubes to a center pivot system
- Retrofitting a well with a smaller pump.

TIM MCCABE, USDA NATURAL RESOURCE CONSERVATION SERVICE

A CENTER PIVOT IRRIGATION SYSTEM WITH DROP TUBES

28. Queensland Department of Natural Resources, Energy and Mines, *Irrigation Scheduling Tools*, 2002, ‹www.nrm.qld.gov.au/rwue/pdf/factsheets/sched tools 02.pdf› (18 February 2004).

Replacement irrigation systems include:

- Installing drip irrigation, microsprinklers, or solid set systems; or
- Constructing a tailwater recovery system.[29]


JEFF VANUGA, USDA NATURAL RESOURCE CONSERVATION SERVICE

DRIP IRRIGATION SYSTEM

Many farms still use inefficient irrigation techniques (*e.g.*, traveling gun, center pivot)[30] that apply more water than crops require.[31] Modern irrigation technology, such as drip irrigation, micro sprinklers and solid set systems can deliver water much closer to the actual plant and achieve much greater water efficiency.[32] These irrigation tools are the most efficient in terms of delivering water to crops. They use the latest technologies to determine the exact amount of water a crop needs in order to grow and delivers the water directly to the plant. However, they often prove most efficient when used with vegetable and fruit tree crops and less so with dense grain crops.

29. Kromm, D. E., and S. E. White, *Adoption of water-saving practices by irrigators in the High Plains*, Water Resources Bulletin 26(6):999-1012, 1990.

30. Center pivot irrigation uses water pressure flowing through a central pipe to propel the device across the area to be irrigated. On the other hand, traveling gun irrigation shoots water in wide arcs across the land. Both of these types of irrigation methods result in significant water loss and runoff problems.

31. Bureau of Reclamation. *Achieving Efficient Water Management: A Guidebook for Preparing Agriculture Water Conservation Plans.* Washington, D.C.: GPO, 1996.

32. Evans, Robert O. and others, "Irrigation Conservation Practices Appropriate for the Southeastern United States", Georgia Department of Natural Resources, 1998, ‹www.nespal.cpes.peachnet.edu/home/links/irrigation/Report/conserv.rpt980728.pdf› (17 December 2001).

Advantages

Because of the considerable amount of water used in agriculture, improving efficiency in this sector offers an opportunity to achieve significant reductions in water use. By using the latest technology available to maximize the efficient use of water, the need for some water diversions and dams can be eliminated.

Disadvantages

Switching to more efficient irrigation technologies is cost prohibitive for many farmers. Even though federal and state incentives exist, they are often inadequate to address the scope of the problem.

Costs

As mentioned above, initial costs of the latest irrigation technology can be quite high. For example, drip irrigation systems can cost on average $1,000 per acre to install necessary pumps and filters and $150 per acre per year for drip tubing.[33] A study done by Kansas State University Agricultural Experiment Station in October 2001 compared the costs of center pivot, flood and drip irrigation systems.[34] While the drip irrigation systems are typically more expensive to install, farmers are able to recoup some costs with savings from reduced water use.

33. University of California, Davis, *Management of Plant Parasitic Nematodes*, ‹ucdnema.ucdavis.edu/imagemap/nemmap/ent156html/204NEM/CHEM/EDRIP3› (18 February 2004).

34. O'Brien, D.M. and others, "Irrigation Capital Requirements and Energy Costs", *Kansas State University Farm Management Guide*, MF-836, October 2001, ‹www.oznet.ksu.edu/library/agec2/mf836.pdf+irrigation+costs&hl=en&ie=UTF-8› (28 January 2003).

Case Study, Irrigation Methods

Israel, a country with a semi-arid, Mediterranean climate, has developed a sustainable agriculture practice that allows them to stretch their limited water resources and meet both the growing demand for human consumption and increased crop production. Since the 1980s, Israel has been using drip irrigation and micro-sprinkler techniques to expand crop output (vegetables and fruit trees). Many of these irrigation systems are computerized and depend on plant moisture sensors to operate the system automatically. This technology, combined with the use of water-efficient crops and other dry farming techniques, has resulted in an irrigation efficiency of 90 percent, compared to the 64 percent efficiency of a furrow irrigation system. Between 1975 and 1998, water requirements fell from 2.85 acre-feet/acre to 1.78 acre-feet/acre. While water efficiency increased and water use continued to decrease, agricultural output increased twelve fold. [35] While these practices have not been used in Israel to replace water supply reservoirs, their implementation on a smaller scale in the United States could increase water efficiency to the level that the need for some dams could be eliminated.

To review the complete contributing paper on agriculture in Israel, visit www.damsreport.org/docs/kbase/contrib/opt159.pdf.

35. Shevah, Yehuda, "Irrigation and Agriculture: Experience and Options in Israel," *Prepared as a contributing paper to the World Commission on Dams,* 2001, <www.damsreport.org/docs/kbase/contrib/opt159.pdf> (5 June 2002).

Where you can go for help

- American Farmland Trust: www.farmland.org.
- U.S. Department of Agriculture, Natural Resources Conservation Commission: www.nrcs.usda.gov.
- U.S. Department of Agriculture, Economic Research Service: www.ers.usda.gov.

WATER SUPPLY

Water Management Alternatives

As communities face increasingly strained water supplies due to rapid development and pollution, decision-makers must continue to seek out sustainable water sources and irrigation methods that can meet both human and environmental needs. If there is a water supply dam in the community where the costs to the river outweigh the benefits to said community, or a new dam is being planned, there are several alternatives the community can implement to obtain and utilize needed water supplies in a less damaging manner, including:

- Urban design and infrastructure modification
- Rainwater harvesting
- Recycled (gray) water
- Conservation pricing
- Water-saving practices and devices
- Desalination plants

URBAN DESIGN AND INFRASTRUCTURE

Rain is a vital resource that fills our rivers and replenishes our surface and groundwater supply. Unfortunately, concrete and other impervious surfaces that make up much of today's (sub)urban landscape interfere with the hydrologic cycle and prevent the natural infiltration process from occurring. Many cities are also plagued with an aging infrastructure and leaky pipes. Municipalities can lose as much as 40 percent of treated water due to faulty pipes and other equipment.[1] This "lost" water exacerbates water shortages and can lead communities to invest in costly new water infrastructure (e.g., dams and river diversions). Communities such as Holliston, Massachusetts are planning to maximize green space for water recharge and are developing wastewater management systems that return high levels of treated water back to the community for local use rather than piping effluent 50 to 100 miles to an upstream town for treatment. [2]

1. NYCWasteLe$$ Business, *The Port Authority of New York and New Jersey at LaGuardia Airport, Water Conservation: Restrooms*, October 2001, ‹www.nycwasteless.com/gov-bus/Casestudies/lgacase2.htm› (24 January 2002).
2. Charles River Watershed Association, *Environmental Zoning Project: Sustaining Water Resources in Holliston*, ‹www.craw.org› (17 January 2002).

In addition, communities can utilize model ordinances to create stream buffers; street, schoolyard and parking lot designs; and residential landscape recommendations to increase the portion of rainfall that is absorbed and replenishes groundwater supplies.[3] When communities maximize their infiltration potential, they can reduce their reliance on traditional water infrastructure mechanisms, such as dams. A 2002 report by American Rivers, Natural Resources Defense Council and Smart Growth America entitled *Paving Our Way to Water Shortages*[4] recommends the following:

- Allocate more resources to identify and protect open space and critical aquatic areas;
- Practice sound growth management by passing stronger, more comprehensive legislation that includes incentives for smart growth[5] and designated growth areas;
- Integrate water supply into planning efforts by coordinating road building and other construction projects with water resource management activities;

VICTORIA TRANSPORT POLICY INSTITUTE

EXAMPLE OF PERMEABLE PAVEMENT

4. American Rivers, Natural Resources Defense Council, and Smart Growth America. *Paving Our Way to Water Shortages: How Sprawl Aggravates the Effects of Drought.* Washington, D.C.: American Rivers, 2002.
5. While smart growth has been used many different ways, in this context it is used to refer to ten principles of smart growth put out by Smart Growth America that range from infrastructure investments like roads and sewers to economic incentives to encourage revitalization of existing communities. A full list of the ten principles can be found at www.smartgrowthamerica.org.

- Invest in existing communities by rehabilitating infrastructure before building anew – a "fix it first" strategy of development;
- Encourage compact development that mixes retail, commercial and residential development;
- Replace concrete sewer and tunnel infrastructure—which convey stormwater too swiftly into waterways—with low-impact development techniques that replenish groundwater. These include on-site storage that allows the water to infiltrate permeable native soils or bioengineering techniques that facilitate evaporation and transpiration of stormwater; and

PORTLAND BUREAU OF ENVIRONMENTAL SERVICES

PARKING LOT SWALE FOR GROUNDWATER REPLENISHMENT AND CAPTURING RUNOFF

- Devote more money and time to research and analysis of the impact of development on water resources, and make this information accessible to the public.

Advantages

By carefully considering how to design communities sustainably and how to better plan for future growth and development, municipalities can implement innovative techniques that could extend the life of their water supply (*i.e.*, sustain groundwater aquifers and steady base flows for rivers) and reduce their reliance on water supply dams and river diversions.

Disadvantages

Determining the exact amount of groundwater and/or instream flow that can be recouped through wise planning is difficult given the variability in topographical and geological characteristics of landscapes. Many municipalities obtain water from watersheds other than their own. Even if such towns were to integrate smart growth measures into all future urban planning, this might have only limited impact on *their* water supply and could have a lesser effect on determining whether to remove an existing water supply dam or eliminate the need for a future dam.

Costs

Costs can vary widely depending on the type of project undertaken. For example, potential water savings from repairing leaks can be significant, but project costs depend on the extent of the problem and, often, geographic location. However, the estimates below on various pipe repair costs pulled together by the city of Olympia, Washington can serve as a rough example of potential expenditures. [6]

6. City of Olympia, Washington, *2004-2009 Adopted Capital Expenditures Plan*, ‹www.ci.olympia.wa.us/Admin/pdf/2004-2009FinalCFP/5 Water.pdf› (18 February 2004).

- Repair service leak (3/4" - 1"): $250
- Install service (meter) on a 3/4"-1" line: $600
- Install small main (2" line): $20 per linear foot
- Install 6" or larger main: $50 per linear foot
- Main line valve installation and replacement: $3,750
- Main line (2" - 8" line) leak repair: $600

Costs will also vary for some of the urban planning recommendations referenced above. However, the Center for Watershed Protection has produced a fact sheet that averages the costs for many of the urban planning projects discussed above, included are:[7]

- Bioretention areas: $6.40/cubic foot
- Narrower residential streets: $15/ square yard (savings of $35,000/ mile of residential street)
- Open space developments: $800/ home (infrastructure construction cost savings)[8]
- Wetlands: $289,000 for a ten acre-foot facility
- Porous pavement: $2-3/square foot ($45,000-100,000 per impervious acre)

7. Center for Watershed Protection, *Stormwater Manager's Resource Center Fact Sheets*, ‹www.stormwatercenter.net› (3 July 2003).
8. Average infrastructure cost savings when using open space design in developments range from 11 to 66 percent. Additionally, developments that utilize open space design often sell for 5 to 32 percent higher than houses in traditional subdivisions.

Case Study, Urban Design and Infrastructure

Over the past several years, the Center for Watershed Protection has organized a number of local site-planning roundtables in the Mid-Atlantic region. In the late 1990s, they convened a group of development, environmental, local government, civic, non-profit, business and other community

Case Study (cont.)

professionals as the Frederick County (Maryland) Site Planning Roundtable. Over the course of nine months, the group developed a series of model ordinances that would be used to steer the community toward more sound development practices that take watershed protection into account. The planning group examined issues dealing with stormwater management, impervious cover and preservation of green space. Recommendations put forth by the group, include:

- Shorter, narrower streets
- Fewer and smaller cul-de-sacs
- Smaller parking lots
- Increased stormwater infiltration/on-site capture and treatment
- More community open space
- Flexible sidewalk standards
- Increased vegetated buffers
- Enhanced native vegetation
- Limited clearing and grading

For more information on the Frederick County Site Planning Roundtable and to view a full copy of the report, contact the Center for Watershed Protection at 410-461-8323, center@cwp.org, or visit www.cwp.org/frederick.pdf.

Case Study, Urban Design and Infrastructure

For some of the more arid western states, recommendations like increasing vegetated buffers are often counter-intuitive. However, western states can implement some of the smart growth techniques referenced above to increase infiltration. For example, the Greater Wasatch Area of Utah has embarked on an ambitious strategy, known as Envision Utah, for future growth in the region. This area of northern Utah consists of 88 cities and towns, and is home to 1.7 million people, comprising 80 percent of the state's population.

Case Study (cont.)

The number of people living in the Greater Wasatch Area is expected to reach 2.7 million by 2020 and 5 million by 2050. Envision Utah aims to conserve and maintain the availability of the region's water resources by changing land use and increasing the rate of conservation. In addition to utilizing conservation water rates and offering incentives for the use of water-saving appliances, Envision Utah is also working with municipalities to encourage low-irrigation landscaping and drought-resistant plants; offering density bonuses to developers for building affordable housing and for creating walkable neighborhoods; using smaller land lots for building; preserving open space and creating greenways. Envision Utah plans to reduce water usage from the current 319 gallons per household per day to 267 gallons per household per day. Studies indicate that these measures will reduce water infrastructure costs from $2.629 billion to $2.087 billion, which is a savings of $542 million per year. One of the main reasons for undertaking these measures as stated in Envision Utah's strategic plan is to reduce the need for dams and other new diversions.[9]

For more information on Envision Utah and to view a full copy of the report, contact Ted Knowlton of Envision Utah at 801-303-1458, tknowlton@cuf-envision.org or visit www.envisionutah.org.

Envision Utah, *Envision Utah Quality Growth Strategy and Technical Review*, January 2000, <www.envisionutah.org/January2000.pdf> (27 May 2003).

Case Study, Urban Design and Infrastructure

TreePeople, a non-profit group, helped sponsor a watershed "makeover plan" for the greater Los Angeles basin that, if fully implemented, would cut water imports by up to 50 percent, reduce flooding and create up to 50,000 jobs. In 1997, TreePeople brought together dozens of urban planners, landscape architects, engineers, urban foresters and public agencies to devise the best management practices and a plan of action for the Los Angeles watershed. An example of a project already under way is Broadous Elementary School in the Los Angeles River watershed now collects all of its rainwater on site rather than it becoming runoff and is a living laboratory for the concept behind the bigger citywide plan. A team that included TreePeople, the school district, the Department of Water and Power and others, devised a comprehensive plan to reduce the school's flooding problems. More than 30 percent of the asphalt was removed from the schoolyard and replaced with landscaped areas sloped to catch runoff from remaining hard surfaces. The green area sits atop a state-of-the-art "infiltrator" system, which can store up to 93,000 gallons of rainfall until it is absorbed into the soil, where it replenishes groundwater. Some 220 new trees at the school also help intercept rainfall and slow runoff. The school's lawn now stores and provides more water than is required to maintain it. TreePeople's goal is to implement watershed techniques at the 400 Los Angeles schools being repaved under a school repair bond.

For more information on TreePeople's urban watershed work, visit www.treepeople.org/trees/.

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- Center for Watershed Protection: www.cwp.org.
- The Stormwater Manager's Resource Center: www.stormwatercenter.net.
- Nonpoint Education for Municipal Officials, University of Connecticut: www.nemo.uconn.edu.
- Natural Resources Defense Council, Stormwater Strategies: www.nrdc.org/water/pollution/storm/stoinx.asp.
- American Rivers, Natural Resources Defense Council, Smart Growth America, *Paving Our Way to Water Shortages: How Sprawl Aggravates the Effects of Drought*: www.amrivers.org/landuse/sprawldroughtreport.htm.
- Environmental Protection Agency, *Menu of Best Management Practices for Stormwater Phase II*: cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm.
- Sustainable Builder Sourcebook: www.greenbuilder.com/sourcebook/rainwater.html.
- California Urban Water Conservation Council: www.cuwcc.org.
- King County (WA) Department of Natural Resources, *Stormwater Topics*: dnr.metrokc.gov/wlr/stormwater.

RAINWATER HARVESTING

Though its roots are thousands of years old, rainwater harvesting is beginning to be used again in the United States. Harvesting rainwater involves the practice of collecting rain from roofs and other surfaces and storing it in cisterns[10] for later use. In residential and small commercial settings, it can be an economical and environmentally sound option to traditional water supply systems. Constructing a rainwater harvesting system can be a simple or complex endeavor. Water can be collected in a barrel directly from a roof to be used for keeping lawns green, or it can be passed through a series of filters to be used for drinking water.[11]

HTTP://USERS.EASYSTREET.COM/ERSSON/RAINWATR.HTM

RAINWATER COLLECTION SYSTEM AT A PORTLAND, OR HOME

Advantages

While rainwater harvesting alone may not replace or eliminate the need for a water supply dam, it is a good method for conserving water, as well as a good example of the kinds of techniques state and local governments can build into water conservation programs. In regions like the Eastern United States that receive regular rainfall, rainwater harvesting could represent a legitimate alternative to a water supply or irrigation dam. According to the March 2003 issue of *New Scientist*, the UN Environment Programme (UNEP) is launching an initiative to get Asian governments to invest in rainwater harvesting. A UNEP representative has been quoted as saying that cities in Asia could get at least one-third of their water from these types of systems. This would help up to two billion people in Asia, equaling the capacity of the Three Gorges Dam project in China, which will be the world's largest dam (stretching nearly a mile across and towering 575 feet with a reservoir that would stretch over 350 miles upstream) when completed. Other benefits to rainwater harvesting include decreasing the amount of stormwater runoff thereby reducing the risk of flooding and erosion of urban creeks and preventing polluted runoff from contaminating local water supplies.

10. A vessel or tank of some kind used for storing water.
11. Todd, Wendy P. and others. *Texas Guide to Rainwater Harvesting*, 2nd edition. Austin: Texas Water Development Board. 1997.

Disadvantages

The biggest disadvantage to utilizing a rainwater-harvesting unit is the maintenance required. If not correctly utilized and maintained, or if the water is not properly treated, there could be health impacts if the water is used directly for drinking water. [13]

Costs

Costs and savings vary depending on what function the rainwater harvesting system serves. In areas with sufficient rainfall and no municipal water source, rainwater harvesting systems are often more cost effective than traditional wells. The cost of operating and maintaining a well is estimated to be as much as $120 per month compared to the average one-time cost of $250 to $2,000 for a rainwater harvesting system of comparable capacity. Consumers in Atlanta, for example, could realize savings of up to $200 per year by collecting rainwater to use for landscaping and irrigating their lawns.[14] However, in the United States, it can take more than 30 years to realize savings using a "stand alone" system where municipal water is readily available.[15] For the most economical results, experts recommend maximizing storage capacity in your rainwater harvesting system, practicing water conservation, and using a municipal supply source for drinking water.[16]

13. Todd, Wendy P. and others. *Texas Guide to Rainwater Harvesting*, 2nd edition. Austin: Texas Water Development Board. 1997.
14. Gigley, Gretchen, The Southface Energy Institute, *Rainwater Harvesting* ‹www.southface.org/home/sfpubs/articles/rainwater.htm› (12 December 2001).
15. This is because municipal water suppliers do not charge the full cost of supplying water into their rates, allowing consumers to purchase water at artificially low rates.
16. ———*Texas Guide to Rainwater Harvesting*, 2nd edition. Austin: Texas Water Development Board. 1997.

Case Study, Rainwater Harvesting

The rainwater catchment unit pictured here was installed in January 1996. It was initially installed for non-potable use, but then the city of Portland, Oregon granted approval for a rainwater harvesting and purification system that could be used for all household purposes. Because the system provides drinking water as well, periodic testing is conducted for fecal coliform and other contaminants. The components of the purification system take up about six square feet of floor space, and the entire system costs less than $1,500, though the user incurs additional costs for periodic filter replacement. With Portland's average annual rainfall of three to four feet, the system captures approximately 27,000 gallons of water per year. One faucet is connected to the city's water and used to supplement rainwater supply during the drier summer months and for occasional cooking and drinking. [17]

For more information on the components of the system or links to setting up a system of your own, visit users.easystreet.com/ersson/ or email ersson.webpage@mailnull.com.

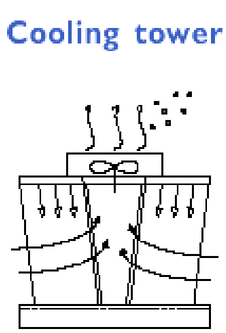
17. Experiments in Sustainable Urban Living, *Rainwater Harvesting and Purification System*, July 2003, ‹users.easystreet.com/ersson/rainwatr.htm› (8 Sept. 2001).

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Environmental Protection.
- Sustainable Building Sourcebook: www.greenbuilder.com/sourcebook/Rainwater.html.
- Texas Water Development Board. Texas Guide to Rainwater Harvesting. 1997. Second Edition: www.twdb.state.tx.us/publications/reports/RainHarv.pdf.
- United Nations, Rainwater Harvesting and Utilisation: www.unep.or.jp/ietc/Publications/Urban/UrbanEnv-2/9.asp.

RECYCLED (GRAY) WATER

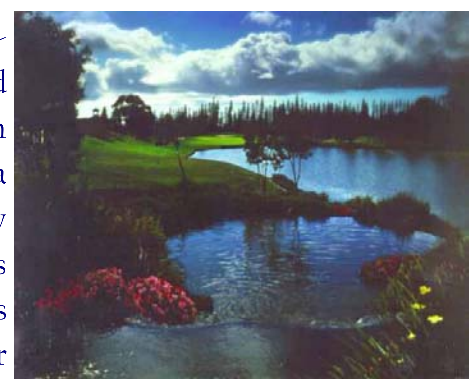
Another tool that can reduce the need for dams and other traditional water supply infrastructure is the recycling and reuse of water. Recycled water derives from residential and commercial wastewater that has been treated to produce a high quality source of water. Instead of this wastewater being dumped into rivers, it receives high level of treatment and is put directly back to use in the system. The level of treatment it receives and where it goes depends on its intended use. An Environmental Protection Agency (EPA) chart, available at www.epa.gov/region9/water/recycling/index.html, outlines treatment requirements for various uses of recycled water.[18] Recycled water used in irrigation can be stored in a cistern or tank of some kind and can be reused only once, while industrial (*e.g.*, power plants) water reuse pulls the water into a closed system and cycles the same water through the system continually. Recycled water can decrease the amount of water diverted from freshwater sources as well as the dependence on a water supply dam.



AMERICAN RIVERS IMAGE LIBRARY

FORT SAM HOUSTON WILL SAVE AN ESTIMATED 177 ACRE-FEET A YEAR BY USING RECYCLED WATER IN ITS COOLING TOWERS

Recycled water can be used for agricultural and landscape irrigation, toilet flushing and industrial processes. In fact, recycled water has the greatest potential when replacing freshwater in small-scale agriculture and landscape irrigation[19] (*e.g.*, public parks, golf courses and small farms) and cooling water for power plants and oil refineries because so much water is used in these processes.[20] Cycling through used water can significantly decrease water use in highly industrialized areas.[21] While individuals and industry can proactively implement water-recycling programs, participation increases significantly when a municipality develops a water-recycling program and offers incentives to the public. Many cities have undertaken large-scale water recycling programs in schools and government buildings to reduce waste and supplement current water supply systems during dry periods and droughts. Many municipalities not only offer incentives for voluntary water recycling using, but also use reclaimed[22] water to recharge groundwater aquifers and supplement water supply reservoirs. This is known as indirect potable reuse and is practiced in several locations throughout the United States (see case study below for example). By injecting recycled water into an aquifer or a water supply reservoir, cities and regions can raise water tables and increase water availability.[23]



EPA

POND AT THE KOELE GOLF COURSE IN HAWAII CONSISTING ENTIRELY OF RECYCLED WATER. RECYCLED WATER IS ALSO USED TO IRRIGATE THE COURSE.

18. Environmental Protection Agency, *Water Recycling and Reuse: The Environmental Benefits*, ‹www.epa.gov/region9/water/recycling/index.html› (16 September 2001).
19. Broembsen, Sharon L., "Capturing and Recycling Irrigation Water to Protect Water Supplies," *E-951 Water Quality Handbook for Nurseries*, ‹www.okstate.edu/ag/agedcm4h/pearl/e951/e951ch7.htm› (17 December 2001).
20. Cooling towers remove heat from the exhaust of industrial processes, and can account for up to 30 percent of a power plant's water use.
21. North Carolina Department of Environment and Natural Resources and others, *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities*, August 1998, ‹www.p2pays.org/ref/01/00692.pdf› (29 October 2001).
22. 'Reclaimed water' is often used interchangeably with 'recycled water.' However, many publications make the distinction between these two at point of use. 'Reclaimed' water usually undergoes more advanced treatment and is used for indirect potable use. Recycled water may not undergo as thorough a treatment and is generally used for nonpotable use.
23. Environmental Protection Agency, *Water Recycling and Reuse: The Environmental Benefits*, ‹www.epa.gov/region9/water/recycling/index.html› (16 September 2001).

Advantages

Recycled water can meet a variety of water supply needs and can reduce the impacts of water supply development on sensitive watersheds. Depending on the magnitude of the project and the watershed it is in, this water "savings" could offset the need for a water supply dam and reduce the amount of water diverted from rivers. An additional benefit is the reduction of the amount of pollutants flowing into rivers and oceans due to the decrease in the amount of treated wastewater being discharged into the environment.[24]

Disadvantages

While use of recycled water for nonpotable[25] purposes is generally an accepted practice, public misperceptions and concerns still exist about its use (both in regard to nonpotable and direct/indirect potable use). Certain municipalities, such as San Antonio and San Diego, are finding they have to undertake substantial public outreach campaigns to educate consumers and address their concerns about recycled water programs. While use of recycled water as a direct potable supply[26] has been explored in the United States in places such as San Antonio and has been safely used in Namibia (Africa), this is not yet considered acceptable practice in the United States.[27] Furthermore, when used in aquifer recharge, there could be a risk of contaminating groundwater and drinking water with inadequately treated wastewater.

Other barriers to use of recycled water include the initial costs (see below) associated with installing the wastewater reuse and distribution system, and also (depending on the type of system proposed) difficulty in obtaining permits from appropriate agencies.[28] However, it can actually be a cheaper alternative when compared to the cost of building a new dam or stormwater treatment facility.

Costs

Costs of water recycling systems vary widely depending on the use and the level of treatment required, ranging from a few hundred dollars to as much as $8,000.[29] However, many agencies sell recycled water at rates 60 to 85 percent that of their potable supply in order to encourage industry and local communities to participate.[30] The city of San Diego, for instance, offers rates of $0.80/HCF for recycled water and rates of $1.57/HCF for potable.[31] States like California that are forced to be progressive in dealing with water issues often provide funding or direct interested

24. WateReuse Association, Potable Reuse Committee, *Use of Recycled Water to Augment Potable Supplies: An Economic Perspective*, September 1999, ‹www.watereuse.org/Pages/information.html› (27 January 2003).
25. The terms potable and nonpotable refer to the level of treatment water receives in conjunction to its expected use. Potable water is used for drinking and receives a high level of treatment. Nonpotable water is used for irrigation and other household purposes (e.g., toilet water) and is typically treated to a lesser degree.
26. Product water is released directly into a municipal distribution system immediately after treatment.
27. Environmental Protection Agency, *Water Recycling and Reuse: The Environmental Benefits*, ‹www.epa.gov/region9/water/recycling/index.html› (16 September 2001).
28. ———*Water Recycling and Reuse: The Environmental Benefits*, ‹www.epa.gov/region9/water/recycling/index.html› (16 September 2001).
29. Green Nature, *Home Water Recycling: Greywater*, ‹greennature.com/article212.html› (21 August 2003).
30. Perkins, C. et al, *Memo to Mayor and City Council of Santa Monica on Resolution Setting Rate for Recycled Water*, October 2002, ‹www.santa-monica.org/cityclerk/council/agendas/2002/20021022/s2002102201-G.htm› (27 January 2003).
31. City of San Diego, *Water Department, Recycled Water Rates*, ‹www.sannet.gov/water/recycled/recycledrates.shtml› (2 July 2003).

parties to potential funding sources. For example, the San Diego County Water Authority has two sources of financial assistance available for setting up a recycled water system: the Financial Assistance Program and the Reclaimed Water Development Fund. Other sources of funding include the Metropolitan Water District of Southern California's Local Resource Program, the Bureau of Reclamation's Title XVI Grant Program, and the State Water Resources Control Board's low-interest revolving loan program.[32] In San Jose, the city will provide the design and construction to retrofit a facility for recycled water at no cost to the owner.[33]

8. City of San Jose, Environmental Services, *Retrofits for Recycled Water*, ‹www.ci.san-jose.ca.us/sbwr/Retrofits.htm› (2 July 2003).

Case Study, Recycled (Gray) Water

Around 1989, the cities of San Jose, Santa Clara and Milpitas in California launched the South Bay Water Recycling (SBWR) program to bring a reliable and sustainable water supply to the South Bay area. Recycled water is now used to irrigate golf courses, parks, school grounds and agricultural lands, and for industrial processes and cooling towers at over 360 locations in the three cities.[34] Using recycled water is often significantly cheaper for both the city and the end user. For example, as of December 2001, using recycled water for irrigation within the South Bay area costs 20 to 42 percent less than using potable water for irrigation.[35]

For more information about the South Bay Water Recycling program, contact Jennifer Durkin at Jennifer.durkin@ci.sj.ca.us or visit www.ci.san-jose.ca.us/sbwr/CustProfiles.htm.

34. City of San Jose, Office of Environmental Services, *Frequently Asked Questions… And Their Answers*, ‹www.ci.san-jose.ca.us/sbwr/FAQs.htm› (18 December 2001)..
35. City of San Jose, Office of Environmental Services, *Current Water Rates*, ‹www.ci.san-jose.ca.us/sbwr/WaterRates.htm› (18 December 2001). (Savings vary based on potable irrigation rates of the individual water retailers in the South Bay Water Recycling Service Area.)

Case Study, Recycled (Gray) Water

The Hueco Bolson Aquifer supplies much of the water to the arid town of El Paso. For the past 15 years, this aquifer has been successfully recharged with up to 3.27 billion gallons per year of reclaimed water treated to "drinking water standards". The reclaimed water has been introduced to the aquifer through a series of injection wells and infiltration basins. Subsurface storage of water has proved beneficial to the long-term management of the aquifer by supplying additional recharge, which offsets water level declines from the operation of its production wells. Prior to implementing this project, water tables were dropping at a rate of two to six feet per year. By 1990, the project had raised water tables eight to ten feet above what they would have been without the project.[36]

For more information about this project, contact Scott Reinerts, El Paso Water Utilities, at 915-594-5579.

36 *Water Recycling in the United States*, ‹www.watereuse.org/Pages/otherstates.html#uosa› (15 February 2002).

Where you can go for help

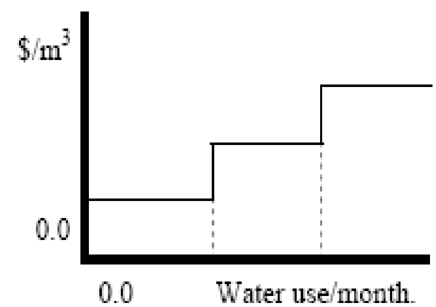
- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- Environmental Protection Agency Water Program: www.epa.gov/region9/water/recycling.
- Richardson, Tom and Bob Gross. *Use of Recycled Water to Augment Potable Supplies: An Economic Perspective.* WateReuse Association: www.watereuse.org/Pages/information.html.
- National Water Research Institute. *Water from Water: Recycling* (video) and *Issues in Potable Reuse*: www.nwri-usa.org.
- Legal Environmental Assistance Foundation (LEAF). *Aquifer Storage and Recovery Wells*: www.leaflaw.org/press/ASRposition2003.pdf.

Conservation Pricing

Conservation pricing is another method used to encourage consumers to reduce water consumption and thus reduce or eliminate the need for new or existing dams. It involves creating financial incentives for consumers to use less water, while at the same time not making water supply cost prohibitive for any particular user. The purpose is to expose consumers to the "full costs" of water and discourage waste by targeting their most precious resource: the pocketbook.[37] Municipalities in arid regions have been known to implement conservation pricing in the form of increasing block rates. Block rates are typically tiered for different usage levels so that users pay higher rates as they consume increasing amounts of water. Rates for customers who fall in the upper block can be three times the rates of users in the lower block.[38] Cities like Tucson, Arizona and Edmonton, Canada are creating rate structures that have resulted in the cutting of household water use by 10 to 15 percent.[39]

While conservation pricing can be used to reduce residential water consumption, the impacts are more noticeable in the industrial arena because industry uses more water and is normally more likely to obtain volume discounts. A study by Janice Beecher in 1994 found that a ten percent increase in price decreased residential demand by up to four percent and industrial demand by up to eight percent.[40] Experts suggest that rate plans be designed to consider the local population's ability to pay higher prices. While this may involve offering discounts or assistance to low-income families, it could allow for the targeting of highly wasteful industries. Eliminating volume discounts and using increased rates are methods of encouraging industry to implement some of the other conservation techniques discussed in this report.[41]

FIGURE 7 : INCREASING BLOCK RATE



NEW EAST CONSULTING SERVICES, LTD

INCREASING BLOCK RATE PRICING STRUCTURE

Advantages

Conservation pricing can reduce consumption without the capital expenditures associated with other water supply strategies. While conservation pricing may not result in the removal of a water supply dam, it is a tool that decision-makers could adopt to stretch existing supplies and delay or eliminate the need to construct new dams.

Disadvantages

While conservation pricing could preserve water resources, there are several institutional and public barriers to implementation. Many water systems are publicly owned and overseen by elected officials subject to the whims of politics. **These officials might resist implementing higher prices for fear of retaliation at the voting booth.**

37. Stallworth, Holly, "Conservation Pricing of Water and Wastewater," for *Environmental Protection Agency*, 10 April 2000, ‹www.epa.gov/owm/water-efficiency/water7.pdf› (20 August 2001).
38. Gerston, Jan, "Conservation Rates Affect Demand Management," for *Texas Water Resources Institute*, ‹www.twri.tamu.edu/twripubs/wtrsavrs/v3n4/article-2.html› (15 May 2002).
39. Ransel, Katherine. *Freshwater Scarcity and the Hydrologic Cycle*. Washington, D.C.: American Rivers, 2001.
40. ———"Conservation Pricing of Water and Wastewater," for *Environ-*

41. Stallworth, Holly, "Conservation Pricing of Water and Wastewater," for *Environmental Protection Agency*, 10 April 2000, ‹www.epa.gov/owm/water-efficiency/water7.pdf› (20 August 2001).

Setting higher rates could also be constrained by regulatory codes that vary across state and local jurisdictions. For example, at the federal level, the Clean Water Act determines how prices are set for wastewater treatment plants funded under the program.[42]

Costs

Capital costs are virtually nonexistent for municipalities looking to implement conservation pricing. Consumers, however, could see their water rates increase as the amount of water they consume increases. See the chart on the preceding page for an example on how these rate structures would work.[43]

42. ———"Conservation Pricing of Water and Wastewater," for *Environmental Protection Agency*, 10 April 2000, ‹www.epa.gov/owm/water-efficiency/water7.pdf› (20 August 2001).
43. Washington State Department of Health, *Description of Conservation-Oriented Rate Structures, Conservation-Oriented Rates for Washington Public Water*

Case Study, Conservation Pricing

From 1986 to 1992, the city of Santa Barbara, California experienced one of the most severe droughts in its history. This coastal community, which derives its water supply from a local aquifer and the Santa Ynez River, was forced to become more resourceful in meeting basic water needs. As part of a comprehensive water supply plan, they developed a desalination plant (discussed later), and increased the water rates three-fold through the course of the drought, switching to an increasing block rate structure in 1989.

While it is difficult to separate the impact of conservation pricing from the education campaign and other conservation measures undertaken, water use dropped to 46 percent of pre-drought levels at the height of the drought. Five years after the drought ended, water use still held at 61 percent of pre-drought levels.[44] If water savings such as this could be achieved in other watersheds, smaller, non-essential dams could be removed and the need for new dams diminished.

For more information, contact Stephen Renehan at the University of California, Santa Barbara School of Geography or download the full case study online at www.geog.ucsb.edu/~renehan/awra_article/article.html.

44. Loaiciga, H.A. and S. Renehan. "Municipal Water Use and Water Rates Driven by Severe Drought: A Case Study," *Journal of the American Water Resources Association* 33, no. 6 (1997): 1313-1326.

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- Chestnutt, Thomas. *Designing, Evaluating, and Implementing Conservation Rate Structures*, 1996. California Urban Water Conservation Council: www.cuwcc.com/publications.
- Gerston, Jan. *Conservation Rates Affect Demand Management*. Texas Water Resources Institute: twri.tamu.edu/twripubs/WtrSavrs/v3n4/article2.html. Fall 1997.
- Stallworth, Holly. *Conservation Pricing of Water and Wastewater*, April 2000 EPA: www.epa.gov/owm/water-efficiency/water7.pdf.

WATER-SAVING PRACTICES AND DEVICES

A key component of reducing the reliance on water supply dams is making the process of providing water as efficient as possible. While the minimum amount of water required by the average person for drinking, cooking, bathing and sanitation is considered to be 13 gallons per day, the average person in the United States uses between 65 and 78 gallons of water for those same purposes.[45] According to a study conducted by the Organization for Economic Cooperation and Development, the United States has the highest rate of per capita water consumption among its member countries.[46] Municipalities and industry have the opportunity to reverse wasteful water practices and improve efficiencies by encouraging and/or mandating conservation, while individuals can become part of the solution by implementing conservation practices in their own homes. Techniques for reducing indoor water use include installing low-flow water fixtures such as toilets, shower heads, washing machines and dishwashers; detecting and repairing leaky pipes and fixtures; and implementing educational campaigns to reduce wasteful practices such as running water when washing dishes or brushing teeth. Outdoor conservation can include using water-conserving landscaping methods such as drought tolerant planting and watering in the early morning or evening.

WATER SAVER HOME, WWW.H_2OUSE.ORG

WHEN SELECTING A NEW TOILET, BE SURE TO CONSIDER ALL OF YOUR OPTIONS. CHEAPEST MAY NOT BE BEST. NEW AND UP-AND-COMING MODELS INCLUDE COMPOSTING TOILETS, DUAL FLUSH, AND FLAPPERLESS TOILETS.

Many cities and states are undertaking intense conservation efforts to ensure water supplies for their growing populations.

- California has embarked on a major effort to retrofit toilets. Full implementation could save an additional 400,000 acre-feet per year—the size of a large California reservoir.
- With continued population growth in the city of San Antonio, Texas, officials have put an emergency aquifer management plan in place with a hotline for reporting incidences of water waste. The city also offers rebates for installing low-flow toilets and high efficiency washing machines.[47]
- Officials in Mexico City instituted a program to replace 350,000 toilets with newer high-efficiency versions that have already saved enough water to supply some 250,000 additional residents.[48]

While outdoor water consumption is the largest area of residential water use, bathroom fixtures consume the majority of indoor water in most households. The Energy Policy Act of 1992 established a national manufacturing standard of 1.6 gallons per flush for most toilets. By replacing one old toilet with a newer 1.6-gpf model, toilet water use can be reduced by up to 46 percent. The EPA estimates that use of these high- efficiency

45. Gleick, Peter *et al*. *The World's Water 2000-2001: The Biennial Report on Freshwater Resources*. Washington, D.C.: Island Press, June 2000.
46. Levin, Ronnie B. *et al*. "U.S. Drinking Water Challenges in the Twenty-First Century." *Environmental Health Perspectives* 110 (Feb. 2002).

47. San Antonio Water System, *Conservation*, ‹www.saws.org/conservation/› (1 Feb. 2002).
48. Gleick, Peter. "Making Every Drop Count," *Scientific American* 284, no. 2 (2001): 40.

toilets in new construction projects along with standard replacements will result in a savings of 7.6 billion gallons per day by 2020. Many municipalities are even offering incentives to replace old toilets with high-efficiency versions.[49]

The theory behind high-efficiency toilets can be applied to other areas. The average five-minute shower sends 40 gallons of water down the drain. By installing a low flow showerhead or flow restrictor, consumers can save up to 30 gallons per shower.[50] Fixing leaks can also save several thousand gallons of water. A slow-dripping, leaky faucet wastes 5,475 gallons per year.

To curb outdoor water use, homeowners, businesses, and city planners must find a solution that is appropriate for the climate they live in. One so-

AMERICAN RIVERS IMAGE LIBRARY

HOMEOWNER'S RAIN GARDEN

lution is xeriscaping, which is a comprehensive landscaping method that employs drought-resistant and water-efficient gardening techniques in an effort to conserve water. It was developed in response to a severe drought that devastated Colorado in 1981. Instead of using turf and grass, xeriscaping encourages the use of mulch, which is functional for water retention, long-term fertilization and weed control. Drought-resistant plants are

DENVER WATER, CHARLES MANN PHOTOGRAPHY

XERISCAPING HAS DRASTICALLY REDUCED WATERING

planted in groups, according to water needs, in order to utilize irrigation methods efficiently. In addition, placement is based on the optimal amount of sun exposure. Efforts are made to improve the soil, which subsequently allows for better absorption of water.[51] Homeowners who use xeriscape can expect to save a considerable amount of money on both maintenance and water use. Contrary to popular belief, automated sprinkler systems do not save water or money because owners rarely adjust them for weather or humidity variations. Manually operating a sprinkler system or using a hose where watering is needed is much more cost and water efficient.[52]

Advantages

The alternatives offered above are not new ideas and, in fact, have become commonplace. However, while there are laws mandating the use of high efficiency appliances in new building projects, there are few examples of large-scale efforts or incentives available for upgrades. As evidenced by some of the city and state programs referenced in the sidebar, efforts to increase water efficiency do work and could help fill the demand typically met by a water supply dam, especially in some of the smaller scale water supply systems that can be found in the Northeast and Mid-Atlantic regions of the country.

49. San Antonio Water System, *Conservation*, ‹www.saws.org/conservation/› (1 Feb. 2002).
50. American Water Works Association, *Water Statistics and Conservation*, ‹www.ci.south-bend.in.us/PUBLICWOrks/WATER/stats.htm› (8 September 2001).
51. Environmental Protection Agency, *Water Conservation*, ‹www.epa.gov/region4/water/drinking water/waterconservation.htm› (25 June 2003).

Disadvantages

Depending on the scope of the project, cost can be a factor when installing new equipment (*e.g.*, low-flow toilets) or replacing dilapidated pipes. There are also social considerations to take into account, such as resistance to low-flow toilets and showerheads because people feel like they are not getting adequate water. The biggest drawback of xeriscaping is the original cost of re-landscaping a yard. In addition, it takes an average of two to three years for the plants to reach full growth. Water conservation methods that rely on behavioral changes such as these may require ongoing educational efforts to maintain water-saving habits.

Costs

While the initial outlay for installing water-conserving fixtures can be substantial, these costs can be recovered - often rather quickly - through savings on water, energy and sewage. The Port Authority of New York and New Jersey at LaGuardia Airport implemented water conservation measures by renovating their restrooms. These measures included installing low-flow toilets, showerheads and faucets and implementing a leak detection and prevention program. Total cost for the equipment was $79,276, but they were able to recoup these costs within eight months through water and sewage savings.[53]

For an individual looking to take initial steps to make their home more water efficient, rebates and other incentives can make switching quite affordable. New low-flow toilets can start at $61-$80 and go as high as $700.[54] Low-flow showerheads range from $8-$50 depending on the number of features. While xeriscaping can also save water and money in the long run, the initial landscaping costs are not insignificant. For example, the Southern Nevada Water Authority has estimated the cost of converting 1,275 sq. ft. to xeriscape at $2,130. However, they also estimate that costs can be recovered in the first five years, with a savings of $1,500 or more after ten years.[55]

53. NYCWasteLe$$ Business, *The Port Authority of New York and New Jersey at LaGuardia Airport, Water Conservation: Restrooms*, October 2001, ‹www.nycwasteless.com/gov-bus/Casestudies/lgacase2.htm› (24 January 2002).

54. City of Austin, TX, *Frequently Asked Questions about Low Flow Toilets*, 2001, ‹www.ci.austin.tx.us/watercon/toiletq.htm› (3 July 2003).

55. Southern Nevada Water Authority, *Xeriscapes: Cost Benefits*, 2003, ‹www.snwa.com/publications/xeriscapes/xbook-cost.htm› (3 July 2003).

Case Study, Water-Saving Practices and Devices

Thanks to concerted citizen action, the Massachusetts Water Resources Authority (MWRA) undertook a coordinated effort to reduce water consumption to below the safe yield of the Quabbin Reservoir – thereby making a plan to divert the Connecticut River into the Quabbin unnecessary. The key to their success was demonstrating the cost and water savings potential of demand control measures, including a domestic retrofit program and a new retail water and sewer charge system. They also identified system leaks and unaccounted for water that were targeted for repair. Because of the consensus work of MWRA and the committee, metropolitan Boston decreased its consumption by 35 percent and was able to avoid additional diversions from the Connecticut River.

For more information, contact Eileen Simonson with the Water Supply Citizens Advisory Committee at 413-586-8861.

Case Study,
Water-Saving Practices and Devices

As part of their global water stewardship initiative, Unilever Home and Personal Care – USA wanted to demonstrate that conservation measures could have positive economic repercussions. In 1995, Unilever began implementing an extensive water efficiency program at its Cartersville, Georgia plant to prove just that. The company had put all aspects of the plan into effect by 2000, including:

- Heightened employee awareness of environmental and economic benefits of water conservation;
- Water reuse in non-contact cooling water, wash water and water from scrubbers and parts washing;
- Collection and use of rainwater in manufacturing process; and
- Automatic control of cooling water.

Since implementing this program, Unilever has reduced its wastewater effluent volume by 77 percent at a savings of $20,000 per year for potable water. By downgrading their usage status, they are also saving an additional $85,000 per year in permitting fees. A portion of this savings from the water efficiency program is added to employee bonuses.[56]

For additional information on the Unilever case study, please contact Ella Lott at 770-382-8660 or Judy Adler with the Georgia Department of Natural Resources Pollution Prevention Assistance Division at 404-651-5120.

56. Iott, Ella and Judy Adler, "Water Efficiency Makes Good Business $ense at Unilever Home and Personal Care – USA," for Georgia Department of Natural Resources, Pollution Prevention Assistance Division, ‹www.state.ga.us/dnr/p2ad/unilever.html› (13 May 2002).

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- Vickers, A. *Handbook of Water Use and Conservation*. WaterPlow Press, 2001.
- WaterWiser: The Water Efficiency Clearinghouse, www.waterwiser.org.
- Water Conserve: A water conservation portal, www.WaterConserve.info/.
- EPA Office of Wastewater Management. *Appendix A: Water Conservation Measures from Water Conservation Plan Guidelines*: www.epa.gov/OW-OWM.html/water-efficiency/wave0319/appendia.pdf.
- Niemeyer, Shirley. *Making Decisions: Household Water-Saving Equipment and Practices*. Cooperative Extension, University of Nebraska-Lincoln. NF 97- 338.
- EPA Office of Wastewater Management. *Water Efficiency Measures for Residences*, 1999: www.epa.gov/OW-OWM.html/water-efficiency/resitips.htm.
- H_2Ouse Tour: Water Saver Home. California Urban Water Conservation Council: www.h2ouse.org.

DESALINATION PLANTS

The desalination of ocean water or brackish groundwater is an alternative to obtaining water from fresh surface or groundwater sources, and could be used to replace the need for a water supply dam. Several different technologies exist to remove salt and other impurities from ocean water. The two most commonly used technologies are thermal distillation, which mimics the natural water cycle by using heat to create a vapor that is converted into freshwater, and reverse osmosis, which involves pushing water through a porous membrane that filters out salts and other impurities. Desalination is a process that is coming of age and is already used as a main source of potable water in the Caribbean, Mediterranean and Middle East.[57]

Advantages

For coastal states, desalination represents an opportunity to draw on oceanic water resources. If the appropriate conditions are present, a desalination plant has the potential to replace an existing or a planned dam.

Disadvantages

In order for a desalination plant to be a viable alternative to a water supply dam, the water users must be located fairly close to a coast. Desalination is also a technology that can have adverse environmental impacts of its own, as plants are very energy intensive and must dispose of a highly concentrated saline byproduct into the ocean or estuarine ecosystem. Additionally, desalination plants can be costly to construct and operate, and the facilities require large amounts of land.

TAMPA BAY WATER

OVERVIEW OF A TAMPA, FL DESALINATION PLANT

Costs

Desalination can be a very expensive process due to the high capital cost of desalination facilities and the large amounts of energy required to pump water through membranes to extract the salt or heat the water for distillation.[58] In the case study below, the desalination plant built in Tampa, Florida cost $110 million, of which the Southwest Florida Water Management District paid $85 million. The water produced in this plant is expected to sell for about $2 per 1,000 gallons, far below the desalination industry standard. The cost of regular groundwater sources is about $1.00 per 1,000 gallons. As technology continues to progress, the cost of desalination is expected to decrease, particularly when compared to many of the alternatives.[59]

57. Buros, O.K. *The ABCs of Desalting*. 2nd ed. Topsfield, MA: International Desalination Association, 2000.

58. The Surfrider Foundation, *Seawater Desalination Plants*, ‹www.surfrider.og/desal› (13 May 2001).

59. The U.S. Bureau of Reclamation (BuRec) commissioned a study of low-energy alternatives for desalination in 1995. The study found that using VARI-ROÔ technology would result in an energy cost-savings of $2.45 billion per year (compared to existing desalting technology) and a 7 percent reduction in water cost. VARI-ROÔ (VRO) technology involves the use of positive displacement pumping for greater energy recovery instead of the centrifugal pumps used in current reverse osmosis desalination. The study commissioned by BuRec specifically examined how the VRO system could be used to improve desalting plans in San Diego. Studies by the Middle East Desalination Research Center have also used VRO technology.

Case Study, Desalination

Tampa, Florida is home to the largest desalination plant in the United States. It is projected to produce 25 million gallons per day in order to meet 10 percent of the region's water needs. The saltwater undergoes osmosis and is then treated with lime and chlorine to ensure proper alkalinity. Historically, this region has derived its drinking water supply from groundwater. However, their new water plan calls for production cutbacks at the 11 existing northern Tampa Bay well fields to allow environmentally stressed areas to recover. To accommodate these cutbacks and still produce enough water for the region, Tampa Bay Water is turning to alternative sources for water, like desalination. Unlike other desalination plants in the United States, the Florida plant is not an emergency water source, but an economically sound, major source of a consistent water supply.[60]

For more information on the Florida desalination plant, visit Tampa Bay Water at www.tampabaywater.org/MWP/MWP Projects/Desal/TAMPABAYdesalinationproject_inro.htm.

60. Tampa Bay Water, *Tampa Bay Seawater Desalination*, December 2002, ‹www.tampabaywater.org/MWP/MWP Projects/Desal/TAMPABAYdesalinationproject_inro.htm› (15 July 2003).

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- International Desalination Association: www.idadesal.org/
- Water Treatment Engineering and Research Group, U.S. Bureau of Reclamation: www.usbr.gov/pmts/water/desalnet.html.