

# BEYOND DAMS

OPTIONS & ALTERNATIVES



A REPORT BY AMERICAN RIVERS & INTERNATIONAL RIVERS NETWORK.



American Rivers is a national non-profit conservation organization dedicated to protecting and restoring healthy natural rivers and the variety of life they sustain for people, fish, and wildlife.

# American Rivers

American Rivers delivers innovative solutions to improve river health, raise awareness among decision-makers, and serve and mobilize the river conservation movement.

By changing how dams operate and removing dams that are old, unsafe, and harm the environment, we bring back native fish and wildlife. By promoting natural alternatives to levees, dikes, and dredging, we restore natural functions of rivers and wetlands. We help keep enough unpolluted water in our rivers for the freshwater species and communities that depend on this water and its natural flow. We help communities protect their rivers from upstream water withdrawals, pollution, and the insidious effects of sprawl.

# International Rivers Network

We put special emphasis on protecting wild rivers and the rivers of Lewis and Clark, as the bicentennial of their expedition approaches.

International Rivers Network supports local communities working to protect their rivers and watersheds. We work to halt destructive river development projects, and to encourage equitable and sustainable methods of meeting needs for water, energy and flood management.

International Rivers Network seeks a world in which rivers and their watersheds are valued as living systems and are protected and nurtured for the benefit of the human and biological communities that depend on them. This vision can be achieved by developing worldwide understanding of the importance of rivers and their essential place in the struggle for environmental integrity, social justice, and human rights.

International River Network's mission is to halt and reverse the degradation of river systems; to support local communities in protecting and restoring the well-being of the people, cultures and ecosystems that depend on rivers; to promote sustainable, environmentally sound alternatives to damming and channeling rivers; to support the worldwide struggle for environmental integrity, social justice and human rights; and to ensure that our work is exemplary of responsible and effective global action on environmental issues.



# Acknowledgements

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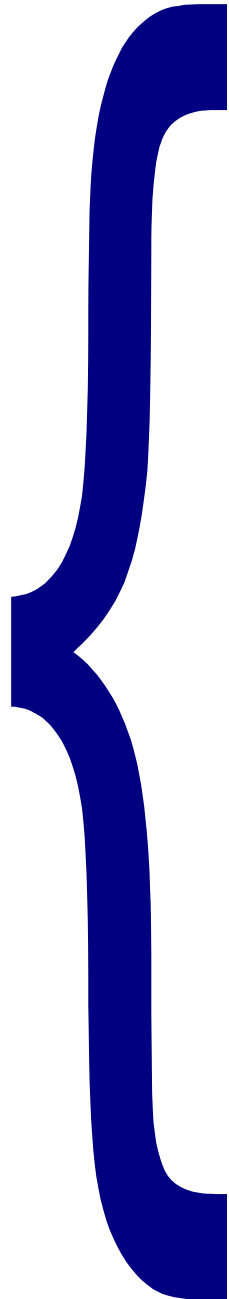
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# INTRODUCTION AND OVERVIEW

# Introduction



Rivers weave in and out of our lives, providing innumerable benefits to communities across the world. In the United States, we rely on our rivers for drinking water, irrigation, aquatic habitat, fisheries, energy, navigation, recreation and simply the natural beauty they bring to our landscapes. Humans have been building dams and other river blockages to harness and control water for centuries, attempting to secure its benefits for human use. Estimates put the number of dams in the United States anywhere between 76,000 to 2.5 million.<sup>1</sup>

However, as society has come to understand, dams can cause significant social and environmental impacts that outweigh the benefits they provide.

The consensus among river ecologists is that dams are the single greatest cause of the decline of river ecosystems.<sup>2</sup>

By design, dams alter the natural flow regime, and with it virtually every aspect of a river ecosystem, including water quality, sediment transport and deposition, fish migrations and reproduction, and riparian and floodplain habitat and the organisms that rely on this habitat.<sup>3</sup> Dams also require ongoing maintenance. For example, reservoirs in sediment-laden streams lose storage capacity as silt accumulates in the reservoir. In arid climates reservoirs also experience a high rate of water loss to evaporation.<sup>4</sup>

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1. The U.S. Army Corps of Engineers National Inventory of Dams lists 76,000 dams in U.S. rivers that have one of the following criteria: (1) high hazard (failure would likely cause loss of life and significant property damage); (2) greater than 6 ft in height and impoundment greater than 50 acre-feet; or (3) greater than 25 ft in height and impoundment greater than 15 acre-feet. The National Research Council has estimated the number of small dams in the United States may be as high as 2.5 million. National Research Council. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy*. Washington (DC): National Academy Press, 1992.

2. World Commission on Dams. *Dams and Development: A New Framework for Decision-Making*. Cape Town, 2000.

3. Raphals, Philip. *Restructured Rivers: Hydropower in the Era of Competitive Markets*. Berkeley: International Rivers Network, 2001.

4. Price, T. "Queen of the Dammed." *Outside Magazine*, November 2002.





Dams also can have significant economic impacts on dam owners, the surrounding community and society in general.<sup>5</sup> As dams age, maintenance costs and safety hazards often increase, resulting in an increasing financial burden and liability on the dam owner. Depending on the river and the fisheries being impacted by the dam, an owner may also be required to retrofit the structure with fish passage facilities or make other upgrades to comply with water quality standards.

The purpose of this report is to provide stakeholders and decision-makers with an overview of low-impact and non-structural alternatives to dams.

When dams diminish fisheries, communities can lose jobs and sustenance, or the source of their cultural or spiritual life. Because of these and other concerns, some dam owners and managers are finding that it makes more sense to remove certain dams, often benefiting the community ecologically and socially, rather than make costly repairs or upgrades. However, when such dams still provide valuable services, alternatives to replace the dams' functions should be considered.

The purpose of this report is to provide stakeholders and decision-makers with an overview of low-impact and non-structural alternatives to dams. It is designed as a reference for anyone interested in exploring options for replacing a function served by an existing dam or replacing a function to be served by a proposed dam.

5. The term *community* is often used in this report. The scope of this term depends on the particular circumstances of the dam. For example, for a small dam that does not affect many people or much fish and wildlife habitat, the local neighborhood directly affected by the dam may be the appropriate community. But for a large dam with many broad ecological, economic, and social impacts, the community may be a broader region or even the whole nation.

The primary motivation for preparing this resource is the frequency with which river restoration and protection advocates are asked, "What will people do for water, energy, etcetera, without a dam?" Clearly, there is no single solution that applies in every case. As rivers and dams vary, so do the best solutions. To restore or protect a free-flowing river, communities often rely on a combination of the alternatives presented here. Other communities may find that none of these alternatives is applicable to their situations.

The *Alternatives to Dams* report is divided into two sections. Section 1 presents an introduction and overview that outlines the dam functions that will be addressed in the report and their corresponding alternatives. It serves as the executive summary and will hopefully help audiences to better utilize the report.

Section 2 provides an in-depth description of options that can be used to replace the function of dams. Each alternative includes a discussion of the advantages and disadvantages of implementing the alternative, along with case studies in which these alternatives have been implemented. Both the advantages and disadvantages and the case studies attempt to look at the alternative from a variety of angles and often go beyond impacts associated with replacing an existing or proposed dam. An outline of potential costs also accompanies each alternative. When reviewing each section on cost, it is essential to note that these costs are only meant to serve as a starting point for your own research; many estimates reflect costs for a specific project. Costs may vary widely depending on the scope of the project, the characteristics of the river, the region of the country the project is in, and many other factors.





The report focuses on main functions that dams can serve and alternative means of fulfilling those uses: water diversion and supply, flood management, and energy.

**Water diversion and supply** – These alternatives focus on the use of water for irrigation and other agriculture, landscaping, drinking water and other municipal uses, and industrial use.

**Flood management** – Flood management examines alternatives to dams currently being used or proposed for the management of flooding and protection of life and property.

**Energy** – The energy section examines alternatives to hydropower dams.

This report does not address two functions dams can serve, recreation and navigation. We chose not to include recreation because, unlike the other functions addressed in the report, reservoir-based recreation cannot always be replaced by non-reservoir means (e.g., a free-flowing river does not provide a houseboat owner the same boating opportunity as a reservoir). Similarly, navigation is also excluded because it is an activity that could be replaced only by some type of land transportation such as rail or truck transport.

Deciding whether or not to remove a dam can be difficult. The complexity of the decision is compounded when the dam still serves a purpose, such as facilitating water diversions. Several tools exist to assist communities and decision makers in evaluating the option of removing a dam, such as *Exploring Dam Removal: A Decision-Making Guide*; *Tak-*


*ing a Second Look: Communities and Dam Removal*; *Dam Removal Success Stories*; *Dam Removal: A Citizen's Guide to Restoring Rivers*; and *Paying for Dam Removal: A Guide to Selected Funding Sources*.<sup>6</sup> While dam removal may not be the right decision for every situation, hundreds of dams have been removed from rivers and creeks across the country, and, when necessary, were replaced with one or more of the numerous non-structural and low-impact options described in this report.

Though dam building has slowed in the United States, dams continue to be thought of as a solution to many of our societal demands. This report is also designed to help those looking for alternatives to a proposed dam.

While this report offers numerous suggestions for lower impact and non-structural alternatives to dams, it is not intended to be a complete list. Certain sections of this report, such as water and energy conservation strategies, merely scratch the surface of an extensive body of literature and experience, while others, such as alternative diversion methods, cover much of what has been put into practice. It is important to remember that replacing something such as a large water supply dam may require implementing a number of alternatives to “make up the difference.”

The *real* alternative to many dams in the United States involves long-term policy and behavioral changes.

<sup>6</sup> These and other dam removal resources can be found at American Rivers' website [www.americanrivers.org](http://www.americanrivers.org), and at International Rivers Network's website [www.irn.org](http://www.irn.org).



As an Austin, Texas water conservation expert puts it, “We need a whole lot of one and two percent solutions to avoid having serious water problems in the future.” Whereas other alternatives may require one relatively simple solution, such as building an infiltration gallery to replace a diversion dam. However, in researching and writing this report, it became abundantly clear that the *real* alternative to many dams in the United States involves long-term policy and behavioral changes that reduce the fundamental demand for the services that dams can provide.

We hope this resource will provide readers with ideas, points of contact, and resources to identify alternatives for obtaining the benefits of water without forfeiting the benefits provided by healthy rivers. For more information or questions about any aspect of this report, please contact American Rivers or International Rivers Network at the below locations.

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# Overview



Dams are built to store water, irrigate crops, provide flood management, generate electricity, provide recreation or ease navigation. The most common purposes for building dams are flood management (25 percent) and water supply (18 percent). Table 1 illustrates the percentage of dams by use in the United States.<sup>1</sup> Below we discuss the functions of dams and briefly identify how those purposes might be met without a dam.

Table 1. Listed purposes of dams in the US Army Corps of Engineers' National Inventory of Dams.

<i>Purpose</i>	<i>Percentage</i>	<i>Number</i>
Recreation	31.3	23,185
Fire & farm ponds	17.0	12,557
Flood control	14.6	10,801
Irrigation	13.7	10,176
Water supply	9.8	7,226
Tailings & other	8.1	5,967
Hydroelectric	2.9	2,166
Undetermined	2.3	1,732
Navigation	0.3	243

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## WATER SUPPLY

For decades dams have been built in the United States to store or divert water for irrigation, residential use, industry, and a host of other consumptive uses. The common perception among water engineers was that any water flowing freely into the ocean was wasted. According to the U.S. Army Corps of Engineers' (Army Corps) National Inventory of Dams (NID), nearly 25 percent of the 76,000 dams listed are used for the primary purposes of water supply and irrigation. The NID does not include hundreds of thousands of small dams and weirs that block rivers and streams in the United States for one purpose or another.

1. International Commission on Large Dams (ICOLD). *World Register of Dams*. 1998.

## Alternatives, Water Supply

As communities face increasingly stressed water supplies, decision-makers must continue to seek out sustainable water sources and methods of use that can meet both human and environmental needs. If there is a water supply dam or diversion causing unjustifiable harm to the river ecosystem in your community, or a new storage facility is being planned, there are several alternatives your community can

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.

implement to reduce demand and secure water supplies in less damaging ways, including water conservation, infiltration galleries<sup>2</sup>, and desalination plants. Of course, lower-impact alterna-

tives cannot replace water supply structures in every case. For example, no infiltration gallery could single handedly replace dams that allow for the diversion of tens of millions of gallons each year from large rivers; nor could rainwater harvesting and gray-water systems replace the need for a water distribution system in many communities. However, the methods listed below and described in more detail in the second section of this report, can stretch existing water supplies, thereby reducing or eliminating the impacts of traditional water supply strategies; or they can delay or eliminate the need for new water supply structures.

- Alternative water diversion and irrigation methods

2. Infiltration galleries, or Ranney wells, involve placing perforated pipes under streambeds to allow water to be withdrawn by pumping or gravity flow.

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

## FLOOD MANAGEMENT

Floods are the most common and costly natural disturbances affecting the United States. Approximately nine of every ten presidential disaster declarations are associated with floods.<sup>3</sup>

Despite spending billions of dollars trying to control floods by building dams, levees, and other structures, floods took nearly 1,000 lives and cost over \$45 billion between 1990 and 1999.<sup>4</sup>

The relentless rise in flood costs despite increased spending on flood protection, punctuated by devastating floods in the Midwest in 1993, forced the United States to rethink long-held flood management policies that focused on dams and other engineered structures. The many technical evaluations of flood disasters unanimously call for a new response to the threat of floods.<sup>5</sup> The new approach calls for integrated management of the watershed, river, and floodplain, and incorporates non-structural strategies in addition to other traditional flood management structures.

3. Faber, S. “Flood policy and management: a post-Galloway progress report.” *River Voices* 8, no. 2 (1997).

4. Federal Emergency Management Agency, *FEMA Disaster Costs 1990 to 1999*, 19 February 2002, <[www.fema.gov/library/df\\_7.htm](http://www.fema.gov/library/df_7.htm)> (19 February 2002).

5. For example, see *Sharing the Challenge: Floodplain Management into the 21st Century* by the Interagency Floodplain Management Review Committee (1994); Final Report of the California Flood Emergency Action Team, available at <[rubicon.water.ca.gov/FEATReport120.fdr/featindex.html](http://rubicon.water.ca.gov/FEATReport120.fdr/featindex.html)>; or *Flood Risk Management and the American River Basin: An Evaluation by* the Na-

Flooding is part of the dynamic nature of healthy river ecosystems. Many species depend on seasonal droughts or pulses of water or nutrients as signals to start reproduction, migration, or other important lifecycle stages. High flows and floodwaters help shape rivers, produce rich agricultural soils, sustain riparian habitat, and import spawning substrate for fish. Inundated floodplains provide important habitat for numerous commercially significant fish, waterfowl, and wildlife species. In addition, floodplains serve as temporary flood water storage, thereby decreasing flood levels downstream.

The accumulated experience of the thousands of flood management dams in operation over many decades has produced a wealth of knowledge. Two important lessons underpin modern flood management strategies. First, our understanding of the frequency and magnitude of flooding, and therefore the measures necessary to protect life and property, is imperfect and evolving. Second, the traditional approach of building dams and other structural flood management measures has not prevented flood damage from increasing.

In the past five years alone, flood damage has exceeded \$40 billion in the United States. Even along rivers with extensive systems of dams and levees, devastating floods occur with disturbing frequency. Indeed, some scientists argue that flood management structures have increased flooding on certain rivers.<sup>6</sup> One fundamental cause of the rising toll of floods is that communities and businesses are lured onto floodplains by a false sense of security created by dams and levees, and enticed by regulatory and financial incentives such as publicly subsidized flood insurance. Today, nearly 10 million

homes are located in flood-prone areas in the United States, placing \$390 billion in property at risk. As the nation's population grows, shrinking availability of new land will intensify pressure to build in more flood-prone areas.

## ***Alternatives, Flood Management***


As watershed planners and government agencies like the U.S. Army Corps of Engineers continue to manage rivers for flooding, their decisions should take into account both structural and nonstructural methods that will allow a river to maintain its natural function. Relocating communities out of the floodplain is not always feasible, but strategic use of alternatives such as setting back levees, restoring river meanders, and flood proofing can reduce flood risk or protect against flood damage. The new flood management approach aims to reduce flood risk or flood damage without the construction of new dams by accomplishing the following three integrated goals, which are discussed in more detail in the second section of this report:

- Managing the watershed to decrease runoff and reduce peak flood flows;
- Increase the capacity of the river channel to store or slow peak flood flows; and
- Managing floodplains so that they can accommodate more floodwaters without threatening people or property.

## ***ENERGY***

Demand for power in the United States is increasing rapidly, with the Energy Information Administration (EIA) forecasting a 1.8 percent average annual growth in electricity sales through 2020. Total global hydroelectricity production exceeds 2 million gigawatt hours (GWh) annually, of which the United States and Canada account for more than 30

6. Pinter, N., Heine, R.A. (2001). *Hydrologic History of the Lower Missouri River*. Southern Illinois University, Carbondale.



percent. Hydropower supplies about 10 percent of U.S. electricity and hydropower dams account for approximately 2,500 of the 76,000 large dams in the United States. The Federal Energy Regulatory Commission (FERC) is the federal agency responsible for licensing the approximately 2,300 nonfederal hydropower dams in the United States.

Of these FERC-regulated dams, 80 percent generate less than 50 megawatts (MW) of power, which is enough electricity to power approximately 50,000 homes.<sup>7</sup>

The design and operation of hydropower dams have the potential to cause particularly serious impacts to rivers. Hydropower dams are designed to operate in either a “run-of-river” or peaking mode. Run-of-river hydropower dams generally operate such that the amount of water flowing into the reservoir is equal to the amount of water flowing out of the reservoir through generating turbines or other outlets.<sup>8</sup> Peak hydropower dams typically store water during “off peak” periods and release water through turbines to produce power during daily, weekly or seasonal periods of peak power demand. Hydropower operations can result in higher water temperatures, lower dissolved oxygen levels, altered pH levels, reduced habitat and species diversity and reduced macro-invertebrate and native fish populations and productivity.

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7. World Commission on Dams, *Dams and Water Global Statistics*, <[www.dams.org/global/namerica.htm](http://www.dams.org/global/namerica.htm)> (3 October 2001).

8. A true run-of-the-river dam is where instantaneous inflow equals instantaneous outflow, although dams with weekly, daily or hourly inflow equaling weekly, daily or hourly outflow may also be called run-of-the-river.

Daily peak-power flow fluctuations also can strand juvenile and adult fish, flush macroinvertebrates downstream and disrupt or prevent reproduction of a host of aquatic species, including federally listed amphibian and fish species.

## ***Alternatives, Energy***

The alternatives to hydropower dams examined in this report focus on two different aspects of energy: consumption and renewable energy sources. Energy experts believe energy consumption in the United States could be reduced through existing efficiency measures by 30 to 50 percent or more.<sup>9</sup> Given hydropower’s small percentage in the energy portfolio of many communities, minor adjustments to consumption could potentially (1) replace the need for a planned hydropower dam or (2) allow for the removal of a small-scale hydropower facility. Depending on the scale of the project, renewable forms of energy such as wind or solar power have the potential to greatly reduce the impacts of power generation and could allow for an existing hydropower facility to be decommissioned and removed. Environmentally sound alternatives to hydropower that are described in more detail in the second section of this report, include:

- End-use efficiency and demand-side management
- Wind power
- Solar power
- Fuel cells

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9. Pottinger, Lori. *River Keepers Handbook: A Guide to Protecting Rivers and Catchments in Southern Africa*. Berkeley: International Rivers Network, 1999.



## 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.<sup>1</sup> In California alone, there are more than 25,000 points of diversion from streams.<sup>2</sup> 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.”<sup>3</sup> 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.<sup>4</sup>

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.<sup>5</sup> 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).<sup>6</sup>

# 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.

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:<sup>7</sup>

# Disadvantages

U.S. FISH AND WILDLIFE



INFILTRATION GALLERY DURING CONSTRUCTION ON SUCKER CREEK, OR

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.<sup>8</sup>

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.

### 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](http://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](http://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.*

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



## 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.

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.

### Disadvantages

### 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.<sup>9</sup> 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.<sup>10</sup> 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/](http://www.salmonidaho.com/screenshop/)> (1 December 2002).

10. Bureau of Reclamation, *A-Canal Fish Screen Project*, <[www.mp.usbr.gov/kbao/fish\\_screen/](http://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.<sup>11</sup>

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](http://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](http://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"<sup>12</sup> 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](http://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.<sup>13</sup> Seasonal dams are usually designed to deliver water by gravity, thus avoiding costs associated with pumping.

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.<sup>14</sup> 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

## Disadvantages

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.<sup>15</sup>

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](http://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](http://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.

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

### Disadvantages

## 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.<sup>16</sup>

*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](http://www.efw.bpa.gov/Environment/EW/PROPOSALS/AIWP/1998/9600700.pdf)> (3 January 2003).



APLEGATE 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<sup>17</sup>:

- 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:

- 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.

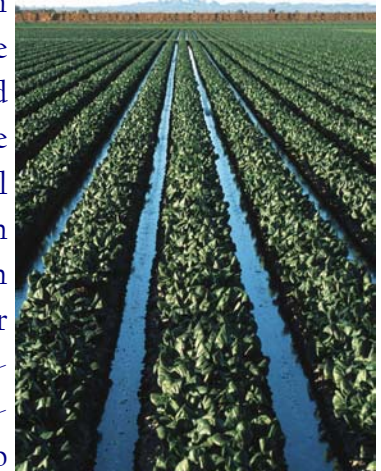
LYNN BETTS, USDA NATURAL RESOURCE CONSERVATION SERVICE



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.<sup>18</sup> 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



LAND THAT HAS BEEN LEVELED AND FURROW IRRIGATED

JEFF VANUGA, USDA NATURAL RESOURCE CONSERVATION SERVICE

17. Environmental Protection Agency, *Cleaner Water Through Conservation*, April 1995, <[www.epa.gov/water/you/chap3.html](http://www.epa.gov/water/you/chap3.html)> (2 July 2003).

18. Department of Agriculture, Economic Research Service, *Irrigation and Water Use: Questions and Answers*, <[www.ers.usda.gov/Briefing/wateruse/Questions/qa5.htm](http://www.ers.usda.gov/Briefing/wateruse/Questions/qa5.htm)> (30 May 2002).





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.<sup>19</sup> 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.<sup>20</sup>

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.<sup>21</sup> 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.<sup>22</sup> Fallowing can also involve choosing not to plant a certain field for one or more growing seasons.

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19. Department of Agriculture, Economic Research Service, *Irrigation and Water Use: Glossary*, 30 March 2001, <[www.ers.usda.gov/Briefing/wateruse/Questions/glossary.htm](http://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](http://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](http://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](http://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.<sup>23</sup> 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.

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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](http://www.ers.usda.gov/Emphases/Harmony/issues/arei2000/AREI6_2landretire.pdf)> (30 May 2002).



While chiseling, furrow diking, and land leveling help prevent runoff and allow the land to retain more water, they still do not address the overwatering 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.

## Disadvantages

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.<sup>25</sup> 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.<sup>26</sup>

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

## 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.<sup>24</sup>

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

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](http://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/aol103al.htm](http://www.gov.on.ca/OMAFRA/english/crops/hort/news/allontario/aol103al.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](http://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.<sup>27</sup>

## 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.

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.

## Disadvantages

The Department of Natural Resources, Energy and Mines in Queensland, Australia has put together a comprehensive fact sheet ([www.nrm.qld.gov.au/rwue/pdf/factsheets/sched\\_tools\\_0.2.pdf](http://www.nrm.qld.gov.au/rwue/pdf/factsheets/sched_tools_0.2.pdf)) that provides cost estimates (in Australian dollars) for a wide range of irrigation scheduling tools.<sup>28</sup>

## 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

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](http://cetulare.ucdavis.edu/pub/gra0201.pdf) (11 February 2004).

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](http://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.<sup>29</sup>

JEFF VANUGA, USDA NATURAL RESOURCE CONSERVATION SERVICE



DRIP IRRIGATION SYSTEM

Many farms still use inefficient irrigation techniques (e.g., traveling gun, center pivot)<sup>30</sup> that apply more water than crops require.<sup>31</sup> 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.<sup>32</sup> 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.

## 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.

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.<sup>33</sup> A study done by Kansas State University Agricultural Experiment Station in October 2001 compared the costs of center pivot, flood and drip irrigation systems.<sup>34</sup> While the drip irrigation systems are typically more expensive to install, farmers are able to recoup some costs with savings from reduced water use.

## Disadvantages

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](http://www.nespal.cpes.peachnet.edu/home/links/irrigation/Report/conserv.rpt980728.pdf) (17 December 2001).

33. University of California, Davis, *Management of Plant Parasitic Nematodes*, [ucdnema.ucdavis.edu/imagemap/nemmap/ent156html/204NEM/CHEM/EDRIP3](http://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](http://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.<sup>35</sup> 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](http://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](http://www.damsreport.org/docs/kbase/contrib/opt159.pdf) (5 June 2002).

## Where you can go for help

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

# Sustainable 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.<sup>1</sup> 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.<sup>2</sup>

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](http://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](http://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.<sup>3</sup> 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*<sup>4</sup> 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<sup>5</sup> 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

- 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.

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](http://www.smartgrowthamerica.org).



## 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.

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.<sup>6</sup>

6. City of Olympia, Washington, 2004-2009 Adopted Capital Expenditures Plan, [www.ci.olympia.wa.us/Admin/pdf/2004-2009FinalCFP/5\\_Water.pdf](http://www.ci.olympia.wa.us/Admin/pdf/2004-2009FinalCFP/5_Water.pdf) (18 February 2004).

## Disadvantages

- 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:<sup>7</sup>

- 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)<sup>8</sup>
- 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](http://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@cwpr.org](mailto:center@cwpr.org), or visit [www.cwpr.org/frederick.pdf](http://www.cwpr.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.<sup>9</sup>

*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](mailto:tknowlton@cuf-envision.org) or visit [www.envisionutah.org](http://www.envisionutah.org).*

Envision Utah, *Envision Utah Quality Growth Strategy and Technical Review*, January 2000, ([www.envisionutah.org/January2000.pdf](http://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/](http://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](http://www.cwp.org).
- The Stormwater Manager’s Resource Center: [www.stormwatercenter.net](http://www.stormwatercenter.net).
- Nonpoint Education for Municipal Officials, University of Connecticut: [www.nemo.uconn.edu](http://www.nemo.uconn.edu).
- Natural Resources Defense Council, Stormwater Strategies: [www.nrdc.org/water/pollution/storm/stoinx.asp](http://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](http://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](http://cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm).
- Sustainable Builder Sourcebook: [www.greenbuilder.com/sourcebook/rainwater.html](http://www.greenbuilder.com/sourcebook/rainwater.html).
- California Urban Water Conservation Council: [www.cuwcc.org](http://www.cuwcc.org).
- King County (WA) Department of Natural Resources, *Stormwater Topics*: [dnr.metrokc.gov/wlr/stormwater](http://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<sup>10</sup> 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.<sup>11</sup>

HTTP://USERS.EASYSTREET.COM/ERSSON/  
RAINWATR-HTML



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*, 2<sup>nd</sup> edition. Austin: Texas Water Development Board. 1997.



## Costs

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.<sup>13</sup>

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.<sup>14</sup> 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.<sup>15</sup> 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.<sup>16</sup>

## Disadvantages

### 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.<sup>17</sup>

*For more information on the components of the system or links to setting up a system of your own, visit [users.easystreet.com/ersson/](http://users.easystreet.com/ersson/) or email [ersson.webpage@mailnull.com](mailto:ersson.webpage@mailnull.com).*

17. Experiments in Sustainable Urban Living, *Rainwater Harvesting and Purification System*, July 2003, <[users.easystreet.com/ersson/rainwater.htm](http://users.easystreet.com/ersson/rainwater.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](http://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](http://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](http://www.unep.or.jp/ietc/Publications/Urban/UrbanEnv-2/9.asp).

13. Todd, Wendy P. and others. *Texas Guide to Rainwater Harvesting*, 2<sup>nd</sup> edition. Austin: Texas Water Development Board. 1997.

14. Gigley, Gretchen, The Southface Energy Institute, *Rainwater Harvesting* <[www.southface.org/home/sfpubs/articles/rainwater.htm](http://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.

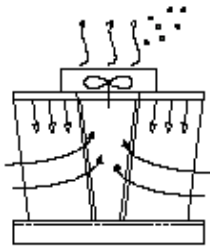
16. ——— *Texas Guide to Rainwater Harvesting*, 2<sup>nd</sup> edition. Austin: Texas Water Development Board. 1997.

## 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](http://www.epa.gov/region9/water/recycling/index.html), outlines treatment requirements for various uses of recycled water.<sup>18</sup> 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

### Cooling tower

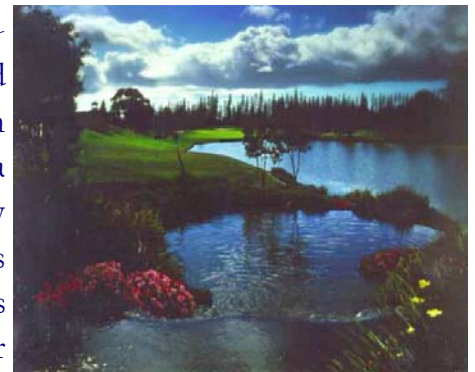


FORT SAM HOUSTON WILL SAVE AN ESTIMATED 177 ACRE-FEET A YEAR BY USING RECYCLED WATER IN ITS COOLING TOWERS

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<sup>19</sup>

(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.<sup>20</sup> Cycling through used water can significantly decrease water use in highly industrialized areas.<sup>21</sup> 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<sup>22</sup> 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 exam-

ple). By injecting recycled water into an aquifer or a water supply reservoir, cities and regions can raise water tables and increase water availability.<sup>23</sup>



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

EPA

18. Environmental Protection Agency, *Water Recycling and Reuse: The Environmental Benefits*, [www.epa.gov/region9/water/recycling/index.html](http://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](http://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](http://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](http://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.<sup>24</sup>

While use of recycled water for non-potable<sup>25</sup> 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<sup>26</sup> has been explored in the United States in places such as

## Disadvantages

San Antonio and has been safely used in Namibia (Africa), this is not yet considered acceptable practice in the United States.<sup>27</sup> 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.<sup>28</sup> 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.<sup>29</sup> 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.<sup>30</sup> The city of San Diego, for instance, offers rates of \$0.80/HCF for recycled water and rates of \$1.57/HCF for potable.<sup>31</sup> 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.htm](http://www.watereuse.org/Pages/information.htm)> (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](http://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](http://www.epa.gov/region9/water/recycling/index.html)> (16 September 2001).

29. Green Nature, *Home Water Recycling: Greywater*, <[greennature.com/article212.html](http://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](http://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](http://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.<sup>32</sup> In San Jose, the city will provide the design and construction to retrofit a facility for recycled water at no cost to the owner.<sup>33</sup>

8. City of San Jose, Environmental Services, *Retrofits for Recycled Water*, <[www.ci.san-jose.ca.us/sbwr/Retrofits.htm](http://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.<sup>34</sup> 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.<sup>35</sup>

*For more information about the South Bay Water Recycling program, contact Jennifer Durkin at [Jennifer.durkin@ci.sj.ca.us](mailto:Jennifer.durkin@ci.sj.ca.us) or visit [www.ci.san-jose.ca.us/sbwr/CustProfiles.htm](http://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](http://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](http://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.<sup>36</sup>

*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#uosar](http://www.watereuse.org/Pages/otherstates.html#uosar)> (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](http://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](http://www.watereuse.org/Pages/information.html).
- National Water Research Institute. *Water from Water: Recycling* (video) and *Issues in Potable Reuse*: [www.nwri-usa.org](http://www.nwri-usa.org).
- Legal Environmental Assistance Foundation (LEAF). *Aquifer Storage and Recovery Wells*: [www.leaflaw.org/press/ASRposition2003.pdf](http://www.leaflaw.org/press/ASRposition2003.pdf).

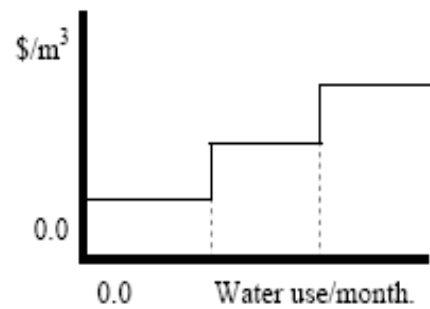
## CONSERVATION PRICING

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.<sup>37</sup> 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.<sup>38</sup> 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.<sup>39</sup>

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.<sup>40</sup> 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.<sup>41</sup>

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.

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.

## Disadvantages

37. Stallworth, Holly, “Conservation Pricing of Water and Wastewater,” for *Environmental Protection Agency*, 10 April 2000, <[www.epa.gov/owm/water-efficiency/water7.pdf](http://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](http://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](http://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.<sup>42</sup>

## 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.<sup>43</sup>

the drought ended, water use still held at 61 percent of pre-drought levels.<sup>44</sup> 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](http://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.

42. ———"Conservation Pricing of Water and Wastewater," for *Environmental Protection Agency*, 10 April 2000, <[www.epa.gov/owm/water-efficiency/water7.pdf](http://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

## 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](http://www.cuwcc.com/publications).
- Gerston, Jan. *Conservation Rates Affect Demand Management*. Texas Water Resources Institute: [twri.tamu.edu/twripubs/WtrSavrs/v3n4/article2.html](http://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](http://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.<sup>45</sup> 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.<sup>46</sup> 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

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.<sup>47</sup>
- 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.<sup>48</sup>



WATER SAVER HOME, WWW.H2OUSE.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.

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.

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/](http://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.<sup>49</sup>

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.<sup>50</sup> 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

49. San Antonio Water System, *Conservation*, <[www.saws.org/conservation/](http://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](http://www.ci.south-bend.in.us/PUBLICWORKS/WATER/stats.htm)> (8 September 2001).



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.<sup>51</sup> 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.<sup>52</sup>

## 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.

51. Environmental Protection Agency, *Water Conservation*, <[www.epa.gov/region4/water/drinking/waterconservation.htm](http://www.epa.gov/region4/water/drinking/waterconservation.htm)> (25 June 2003).





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.

## Disadvantages

make switching quite affordable. New low-flow toilets can start at \$61-\$80 and go as high as \$700.<sup>54</sup> 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.<sup>55</sup>

## 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.<sup>53</sup>

For an individual looking to take initial steps to make their home more water efficient, rebates and other incentives can

54. City of Austin, TX, *Frequently Asked Questions about Low Flow Toilets*, 2001, <[www.ci.austin.tx.us/watercon/toiletq.htm](http://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](http://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.

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](http://www.nycwasteless.com/gov-bus/Casestudies/lgacase2.htm)> (24 January 2002).



## 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.<sup>56</sup>

*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 Sense 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](http://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](http://www.waterwiser.org).
- Water Conserve: A water conservation portal, [www.WaterConserve.info/](http://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](http://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](http://www.epa.gov/OW-OWM.html/water-efficiency/resitips.htm).
- H<sub>2</sub>Ouse Tour: Water Saver Home. California Urban Water Conservation Council: [www.h2ouse.org](http://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.<sup>57</sup>

### 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.

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

### Disadvantages

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.<sup>58</sup> 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.<sup>59</sup>

58. The Surfrider Foundation, *Seawater Desalination Plants*, <[www.surfrider.org/desal](http://www.surfrider.org/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-ROO 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-ROO (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.

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



## 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.<sup>60</sup>

*For more information on the Florida desalination plant, visit Tampa Bay Water at [www.tampabaywater.org/MWP/MWP\\_Projects/Desal/TAMPABAYdesalinationproject\\_inro.htm](http://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](http://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/](http://www.idadesal.org/)
- Water Treatment Engineering and Research Group, U.S. Bureau of Reclamation: [www.usbr.gov/pmts/water/desalnet.html](http://www.usbr.gov/pmts/water/desalnet.html).

# FLOOD MANAGEMENT

## Reducing Runoff



As floodplain managers, state resource agencies and local communities wrestle with the problems associated with flood-control dams; cities around the country are implementing innovative techniques for managing floods without new dams. While many of these alternatives are not quick fixes, they are real solutions that can be implemented with long-term planning. The following are some alternative approaches to dams for flood management:

- Reducing runoff
- In-river flood management
- Separating the people and the threat

### ***REDUCING RUNOFF***

The principle behind runoff reduction measures is to increase the proportion of precipitation that infiltrates the soil and decrease the amount that runs off directly into rivers. On undeveloped land, typically less than 20 percent of the volume of rainfall becomes direct surface runoff that drains into rivers.<sup>1</sup> With development of buildings and paved impermeable surfaces, and the use of conventional piped drainage systems, direct runoff can increase to over 80 percent of the volume of rainfall. By reducing the amount of runoff, the streamflow levels during storm events will be reduced, thereby reducing flood risk and the need for structures such as dams.

### ***IN URBAN AREAS***

In urban areas, the types of techniques recommended to reduce runoff include:

- Infiltration trenches, which are rock-filled trenches in which stormwater is stored in the voids of the stones, and then slowly filters back into groundwater;

1. Dunne, T. and L.B. Leopold. *Water in Environmental Planning*. New York: W.H. Freeman and Company, 1978.





- Downspout diversion programs (i.e., allowing domestic gutters to discharge to lawns or other unpaved areas instead of being connected to the sewers);<sup>2</sup>
- Permeable or porous pavements for roads and parking lots;
- Swales (i.e., grass depressions that catch runoff from impermeable surfaces and slowly filter it back into groundwater) or grassed surface conveyance;
- Infiltration and treatment systems which



POROUS PAVEMENT

PERMEABLE PAVEMENT CORPORATION



STREET SWALE IN SEATTLE

SEATTLE PUBLIC UTILITIES

- can also serve as landscape features;
- Wide filter or buffer strips of natural vegetation: grass or woodland, usually located between paved areas and the watercourse to slow flows and remove pollutants;
- Small detention basins: grassy and vegetated depressions that hold and treat excess surface water for slow release;
- Infiltration basins that hold surface water, allowing it to infiltrate the soil gradually; and retention ponds or permanently wet

ponds that retain surface runoff and provide biological treatment through wetland and aquatic vegetation such as reeds.

## Advantages

These strategies are considered preventative measures that reduce the fundamental flood risk by reducing runoff and peak flood flows. Many of these strategies cost relatively little money compared to dams and levees and they can be squeezed into dense urban areas because most do not require large amounts of space.

One drawback to these strategies is that in order to significantly reduce runoff, these strategies must be implemented in many locations. In addition, the dispersed and incremental nature of this approach poses a challenge to quantify the impacts and maintain the effectiveness of the measures. Although many of the measures listed above require little space, large infiltration or detention basins could be difficult to site within urban areas. In addition, care must be taken to ensure that detention basins do not increase flood peaks.<sup>3</sup>

## Disadvantages

## Costs

Costs will vary greatly depending on the measure chosen, ranging from less than \$100 to install downspout diversions to hundreds of thousands of dollars for elaborate infiltration basins. The good news is that many of these techniques cost less than traditional stormwater drain systems. For an additional project cost-savings example, see the case study below.

2. Downspout diversion programs have helped to maintain a consistent flow of higher water quality into urban streams. UNITED STATES studies have shown that downspout diversion programs can reduce mean flow volumes in the sanitary sewer network by 25 to 62 percent (Kaufman and Wurtz, 1997).

3. For example, a detention basin in the lower area of a watershed might delay inflow to a creek such that it occurs when the flood wave is arriving from the upper watershed, thereby potentially increasing flood levels.



## Case Study, Reducing Urban Runoff

In 1992, the Oregon Museum of Science and Industry (OMSI) relocated to a former industrial site on the Willamette River and in doing so decided to take steps to ensure their impact on the environment was minimal and that they addressed some of the environmental issues plaguing the watershed. In order to reduce runoff and capture stormwater on their 10-acre parking lot, OMSI chose to build 2,300 feet of bioswales rather than the traditional parking lot islands. These bioswales are linear wetlands that contain a variety of native plants and trees. While still not considered inexpensive, these bioswales did cost \$70,000 less than a traditional stormwater drainage system and has resulted in little stormwater discharge during a normal storm event.

OMSI also chose to protect and rebuild the banks of the Willamette from erosion by planting native riparian shrubs in the buffer. FEMA cited this project as an excellent example of the use of bioengineering, and during the floods of 1996 and 1997, the bank stabilization survived.

To learn more about the Oregon Museum of Science and Industry's project, visit [www.fish.ci.portland.or.us/pdf/pdc1.pdf](http://www.fish.ci.portland.or.us/pdf/pdc1.pdf).

## Case Study, Reducing Urban Runoff

As Atlanta, Georgia's population continues to expand, the Big Creek watershed is facing increasing threats from development interests. Presently, the watershed is 16 percent impervious cover; with negative effects from stormwater runoff beginning at about ten percent impervious cover. The resulting impacts from excess runoff include degraded water quality, erosion, increased flood damage and habitat degradation, as well as the construction of

## Case Study (cont.)

dams and levees and stream channelization.

A reconnaissance study was undertaken to develop recommendations to reduce the adverse impacts of urbanization on the watershed, which included stormwater management, riparian buffers and restoration. Stormwater management recommendations included the creation of stormwater ponds and natural detention and infiltration facilities that would improve water quality and capture and store runoff and floodwater. The riparian buffers and corridors will also store and extend the discharge of floodwaters, as well as decrease erosion and remove pollutants from stormwater runoff. By allowing runoff to be absorbed into the earth and undergo a more natural hydrologic process, flood impacts could be significantly reduced in the Big Creek watershed and flood management infrastructure, such as dams and levees, could be removed.<sup>4</sup>

To learn more about the Big Creek reconnaissance study in Atlanta, Georgia, visit [www.forester.net/sw\\_0011\\_assessing.html](http://www.forester.net/sw_0011_assessing.html).

4. Fischenich, J.C., R.B. Sotir, and T. Stanko, "Assessing Urban Watersheds: The Case of Big Creek," *Stormwater: The Journal for Surface Water Quality Professionals*, [www.forester.net/sw\\_0011\\_assessing.html](http://www.forester.net/sw_0011_assessing.html) (11 June 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.
- Stormwater Managers Resource Center: [www.stormwatercenter.net/](http://www.stormwatercenter.net/).
- 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](http://www.amrivers.org/landuse/sprawldroughtreport.htm).

## IN AGRICULTURAL AREAS

Where land adjacent to rivers has been developed for intensive cultivation of crops, the volume and speed of runoff usually increases, contributing to the risk of flooding downstream and the possibility of pollution by herbicides, pesticides and agricultural waste products. Possible methods for minimizing these risks include:

- Adopting less intensive agricultural practices (e.g., farming outfits that continually increase production each season with longer growing seasons, using a sand and clay substrate) and controlling irrigation rates and contour levels so that water is retained on the land;



LYNN BETTS, USDA NATURAL RESOURCE CONSERVATION SERVICE

VEGETATED BUFFER STRIPS

- Creating vegetated buffer strips or wetlands between cultivated land and watercourses to slow surface water runoff and remove pollutants; and

- Directing agricultural runoff to infiltration ponds, retention ponds and wetland areas to slow runoff and improve water

quality. These may also provide features for wildlife.



GARY KRAMER, USDA NATURAL RESOURCE CONSERVATION SERVICE

WETLANDS RESTORED FOR FLOOD MANAGEMENT

## Advantages

These measures share the same benefits of those listed for urban areas. Detention basins are usually quite shallow and require a large area to provide significant flood storage. However, because they are normally dry and will not be needed in most years, they can be put to use in the meantime. For example, the detention basins of the Lincoln, Nebraska flood alleviation scheme are farmed, and farmers receive compensation for damage to their crops when the basins are used for flood management. One option considered for the Red River watershed in Canada and the United States was that of micro-storage, using the agricultural fields between the raised roads as flood storage.

Implementing these measures in rural areas can present challenges similar to those in urban settings, such as the fact that these strategies may need to be implemented in many locations. If the area is composed of many smaller farms, one farmer working to reduce runoff will not impact flooding enough to lead to the removal of a dam. In addition, changing agricultural practices might be impractical for the crops under cultivation or the characteristics of the area.

## Disadvantages

## Costs

The cost of runoff control measures will vary greatly depending on the size and type of measure applied. The cost of detention basins can range from \$0.10 to \$2.50 per cubic foot of detained water.<sup>5</sup> A relatively small detention basin that would hold the volume of a typical backyard pool, 20,000 gallons, would likely cost between \$2,000 and \$10,000.

5. Schueller, T.R. *Controlling Urban Runoff: a practical manual for planning and designing urban BMPs*. Metropolitan Council of Governments, 1987.



## Case Study, Reducing Agricultural Runoff

The Lake Thompson Watershed, located in southeastern South Dakota, has lost the majority of its wetlands over the years to increase agricultural production, for which 90 percent of the land is now used. As a result of increased agricultural production and the loss of wetlands and other retention space, the region experienced severe flooding around several lakes from 1984 to 1986 that led to crop, property, and road damage. In an effort to reduce the frequency and duration of major flooding, both governmental and non-governmental organizations created a wetland restoration plan within the watershed that included restoring drained wetlands on public lands; acquiring new land to restore wetlands; developing conservation practices on private lands; and offering incentives to prevent further drainage projects. In addition to decreasing the threat of flooding, many of the restored sites once again function as wildlife habitat.<sup>6</sup>

To read the entire Lake Thompson case study, visit [www.ramsar.org/lib\\_wise\\_18.htm](http://www.ramsar.org/lib_wise_18.htm). For more information about this project you may also contact Tom Dahl with the U.S. Fish and Wildlife Service at 608-783-8425.

6. Dahl, Thomas E., "Wetland drainage and restoration potential in the Lake Thompson watershed, South Dakota, USA," *Towards the Wise Use of Wetlands*, 1993, <[www.ramsar.org/lib\\_wise\\_18.htm](http://www.ramsar.org/lib_wise_18.htm)> (11 June 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.
- Dosskey, M.J., R.C. Schultz, and T.M. Isenhardt. *Riparian Buffers for Agricultural Land*. Dosskey. USDA Natural Resources Conservation Service: [waterhome.brc.tamus.edu/projects/afnote3.htm](http://waterhome.brc.tamus.edu/projects/afnote3.htm).
- Buffer Strips: Common Sense Conservation, USDA Natural Resource Conservation Service, [www.nrcs.usda.gov/feature/buffers/](http://www.nrcs.usda.gov/feature/buffers/)
- Haeuber, R. and W.K. Michener. "Natural Flood Control", *Issues in Science and Technology*, Fall 1998. [205.130.85.236/issues/15.1/haeube.htm](http://205.130.85.236/issues/15.1/haeube.htm).
- Buffers for Agriculture, Connecticut River Watershed: [www.crjc.org/buffers/Buffers%20for%20Agriculture.pdf](http://www.crjc.org/buffers/Buffers%20for%20Agriculture.pdf).





# Riparian and In-River Flood Management Measures



Rivers themselves can serve a flood management function by providing “live storage.” The open space of floodplains adjacent to rivers and streams store and slowly release floodwaters, reducing peak flood flows downstream. Wetland areas act as large sponges, soaking up floodwaters in addition to filtering water and adding to groundwater supplies.

Many flood management measures constructed in the past reduced the natural live storage capacity of river channels. When engineers cut off meanders to straighten rivers and increase flow velocities, the storage provided by the longer, meandering river channel is lost. Levees constructed to keep rivers within their channels prevent floodplains from storing and slowly releasing flood flows. As a result, in some cases peak flood flows have increased and caused greater flood risk downstream of highly controlled river reaches. This transferring of the flood creates a feedback loop of escalating flood risk and flood management actions that propagates downstream.<sup>7</sup> By restoring the natural flood-carrying capacity of rivers and/or their riparian buffer regions, the need for a new or existing dam is reduced.

In more recent efforts to restore natural river functions, including providing instream storage, the trend has reversed. The most common measures recommended today, which are discussed below, include:

- Breaching or setting back levees;
- Restoring meanders;
- Constructing bypass channels; and
- Restoring vegetated banks and wetlands.<sup>8</sup>

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7. Mount, J.F. *California Rivers and Streams: the conflict between fluvial process and land use*. Berkeley: University of California Press, 1995.

8. Interagency Floodplain Management Review Committee. *Sharing the Challenge: Floodplain Management into the 21st Century*. Washington, D.C.: GPO, 1994.



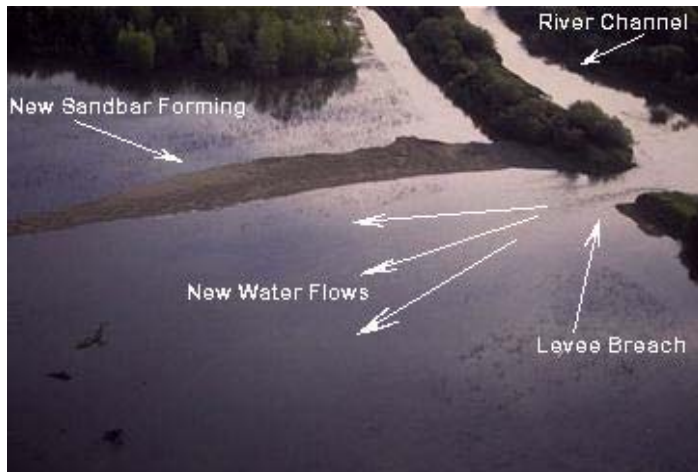
## BREACHING LEVEES

Many river restoration and flood management projects involve breaching or removing portions of levees to allow the river to reconnect with its floodplain, thereby recreating the temporary flood storage function and important floodplain habitat.

### Advantages

Breaching levees can be a relatively inexpensive measure in many cases, involving only several hours of operating a backhoe or bulldozer. Temporarily flooding old floodplains will produce many secondary benefits such as increasing groundwater infiltration, improving water quality, restoring natural floodplain forming processes (e.g., sediment transport and deposition) and improving fish and wildlife habitats.

THE NATURE CONSERVANCY



SUCCESSFUL LEVEE BREACH FOR FLOOD MANAGEMENT

In many cases the area to be inundated again with a levee breach has been developed, requiring other levees to limit the area to be flooded. Many levees today also have secondary functions, such as an active roadbed, that would have to be accommodated somehow before breaching.

### Disadvantages

### Costs

Costs will vary from thousands to millions of dollars depending on the size of the levee, the amount to be removed, whether the opening must be protected with engineered structures, whether the breach is to be open continuously or operated in response to certain events, and whether other measures are needed to control the flooding allowed by the new

### Case Study, Breaching Levees

The Cosumnes River Project in California was started in 1987 after The Nature Conservancy (TNC) and its partners established the Cosumnes River Preserve with the goal of restoring and protecting the river system. As part of the project, TNC scientists breached a riverside levee along the Cosumnes River in California during the winter of 1995-6, allowing the river to flow through a 50-foot long gap into a former farm field.<sup>9</sup> More levees have since been breached or have been set back to create a larger floodplain.<sup>10</sup> As a result of the levee breaching, the natural process of flooding has resumed, allowing restoration of plant, fish and wildlife populations, as well as restoring a floodplain for excess water storage.<sup>11</sup>

To learn more about this project, visit The Nature Conservancy at [www.tnccalifornia.org/our\\_proj/cosumnes/](http://www.tnccalifornia.org/our_proj/cosumnes/) or Cosumnes River Preserve at [www.cosumnes.org](http://www.cosumnes.org) or contact Ramona Swenson with The Nature Conservancy at 916-684-4012.

9. Cosumnes River Preserve, *Cosumnes River Project and Mission*, <[www.cosumnes.org/](http://www.cosumnes.org/)> (11 June 2002).

10. The Nature Conservancy of California, "Cosumnes Preserve Gets New Partners, New Lands—More than Doubles in Size," *California Newsletters*, 1999, <[www.tnccalifornia.org/news/newsletters/newsletter\\_summer\\_1999.asp](http://www.tnccalifornia.org/news/newsletters/newsletter_summer_1999.asp)> (11 June 2002).

11. ———, *Cosumnes River Project and Mission*, <[www.cosumnes.org/](http://www.cosumnes.org/)> (11 June 2002).



THE NATURE CONSERVANCY



INITIAL BREACH ON THE CONSUMNES LEVEE IN OCTOBER 1995

THE NATURE CONSERVANCY



CONSUMNES FLOOD ABSORPTION AREA IN 1996

THE NATURE CONSERVANCY



CLOSEUP OF THE LEVEE BREACH

## 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.
- Florsheim, J. and J. Mount. *Intentional Levee Breaches as a Restoration Tool*. University of California at Davis: [watershed.ucdavis.edu/crg/product.asp?var="06"](http://watershed.ucdavis.edu/crg/product.asp?var=).
- Florsheim, J.L. and J.F. Mount (2002), Restoration of floodplain topography by sand splay complex formation in response to intentional levee breaches, Lower Cosumnes River, California: *Geomorphology*, v. 44, p. 67-94.



## SETTING BACK LEVEES

Many river projects also involve moving levees away from rivers (setting back levees) to provide more floodplain area to store floodwaters and to restore some of the habitat complexity characteristic of natural rivers.

### Advantages

Setting levees back can serve the dual purpose of creating more favorable habitat for fish and wildlife and increasing the channel's flood capacity, thereby reducing flood water levels. Depending on the river system and the amount of storage capacity created, this could eliminate the need for new or existing flood management dams.

The principal drawback of levee setbacks is often the cost, as moving large amounts of the material that makes up levees can become expensive. The planning and engineering design for the reconfigured channel can also be costly. In addition, setting levees back far enough to have a meaningful impact on flood flows can require a significant area, which can conflict with current land uses.

### Costs

The cost of levee setbacks will vary from thousands of dollars to many millions, depending on the size of the river and setback to be implemented.

### Disadvantages

## Case Study, Setting Back Levees

The California cities of Marysville and Yuba City are situated near the confluence of the Sacramento, Feather, and Yuba rivers, and, as a result, have experienced numerous devastating floods. Regional stakeholders have developed a plan to set back several miles of levees along both banks of the Feather River, rather than build new dams or other flood management structures. Project modelers predict flood water levels will decrease up to four feet in certain areas once the project is completed.<sup>12</sup> The project is expected to cost more than \$20 million.<sup>13</sup>

*For more information, contact Janet Cohen with the South Yuba River Citizens League at 530-265-5961.*

12. Sacramento River Portal, *Sacramento River Project Reports*, <[www.sacramentoriverportal.org/modeling/hydro\\_index.htm](http://www.sacramentoriverportal.org/modeling/hydro_index.htm)> (19 June 2003).

13. Janet Cohen, Executive Director, South Yuba River Citizens League, personal communication, 14 March 2003.





## Restoring River Meanders

Restoring meanders to impounded and/or straightened streams is becoming an increasingly accepted choice in flood management across the

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NATURAL FLOOD MANAGEMENT:  
RIVER MEANDERS AND VEGETATED BUFFERS

country. Many rivers have been so altered by flood management projects that significant restoration work may be required. The University of Mississippi, in conjunction with the U.S. Department of Agriculture, has conducted successful research using vegetation of specific densities and patterns to encourage streams to alter their courses and sediment deposition, recreating “natural” meanders. Once a dam or other flood management project is removed, however, many rivers will naturally recreate an appropriate meandering channel relatively quickly without any assistance. Either way, increasing the natural capacity of the river can decrease the need for an existing or new dam.

## Advantages

Restoring meanders to rivers that have been straightened not only restores river habitat degraded by past flood management projects, but also increases the in-stream storage capacity and slows the downstream propagation of the flood peak, thereby decreasing downstream

flood risk and the need for flood management dams.

Restoring meanders often requires large areas of land adjacent to the river, which could inhibit or eliminate existing uses of that land. In addition, it may be difficult to convince members of the community that flooding will not increase when a dam is removed. This is often the case, even when the dam provides no meaningful flood protection.

## Disadvantages

## Costs

As discussed above, restoring rivers and stream meanders can cost anywhere from several thousand to many millions of dollars depending on the size of the project. For example, a project to restore natural meanders on the Soque River in Georgia cost \$55,000 and involved the use of rock vanes and strategically placed vegetation.<sup>14</sup> On the other end of the spectrum, restoring the Omak Creek in Washington State to its original stream was more complex. The total project cost was \$788,000, which included moving the stream back to its original channel, creating instream habitat, revegetation, and more.<sup>15</sup>

14. Environmental Protection Agency, *Natural Restoration on the Soque River, Georgia*, [www.epa.gov/region4/water/wetlands/projects/soqueepa.html](http://www.epa.gov/region4/water/wetlands/projects/soqueepa.html) (15 March 2004).

15. Alvarez, S.M. and B. Ridolfi, *Omak Creek Relocation Project: Forming a Stream Team to Rebuild Steelhead Runs*, [www.ridolfi.com/omak/](http://www.ridolfi.com/omak/) (15 March 2004).





## Case Study, Restoring River Meanders

North Richmond, California was established on the floodplains of Wildcat and San Pablo creeks on San Pablo Bay near San Francisco. Although this was a suitable location for the shipbuilding industry, the community frequently suffered from flooding in the winter months. After years of costly and ineffective flood management projects that damaged the environment, the County Board of Supervisors approved a community supported alternative flood management plan in 1985. The goal of the plan in this highly developed watershed was to use the creek's natural character as much as possible to handle 100-year flood flows, and to properly manage environmental stressors from these flows in order to allow the functioning of the ecosystem.

Restoration techniques included restoring a meandering channel pattern that mimicked natural streams and riparian tree planting. The natural channel provides various aquatic habitats with its designed pools, riffles and glides while also transporting sediments away from vulnerable marshes and accepting higher flows onto floodplains. Trees were planted along the stream to guide channel formation, to prevent erosion, to lower the water temperature and to provide woody debris beneficial to river organisms. Not only was flood management achieved and riparian and habitat restored, but the project provided public education and aesthetic enhancement.<sup>16</sup>

To learn more about the North Richmond alternative flood management plan, visit [www.epa.gov/OWOW/NPS/Ecology/chap6wil.html](http://www.epa.gov/OWOW/NPS/Ecology/chap6wil.html).

16. Environmental Protection Agency, *Ecological Restoration: A Tool To Manage Stream Quality; Wildcat Creek, California*, July 2002, <[www.epa.gov/OWOW/NPS/Ecology/chap6wil.html](http://www.epa.gov/OWOW/NPS/Ecology/chap6wil.html)> (17 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:
- U.S. Department of Agriculture: [www.usda.gov/stream\\_restoration/newlnk.htm](http://www.usda.gov/stream_restoration/newlnk.htm).
- Rinaldi, M. and P.A. Johnson. "Characterization of Stream Meanders for Stream Restoration." *Journal of Hydraulic Engineering* 123(6): 567-570.
- Shore, D. and P. Wadecki. "Born Again River: Remeandering the Nippersink." *Chicago Wilderness*. Winter 2001: [chicagowildernessmag.org/issues/winter2001/bornagainriver.html](http://chicagowildernessmag.org/issues/winter2001/bornagainriver.html).
- National Technical Information Service. *Stream Corridor Restoration - Principles, Processes, Practices*: [www.ntis.gov/products/bestsellers/stream-corridor.asp?loc=4-2-0#order](http://www.ntis.gov/products/bestsellers/stream-corridor.asp?loc=4-2-0#order).



## CONSTRUCTING BYPASS CHANNELS

Bypass channels, which are alternate channels that a river or stream will utilize above certain flow levels, have been constructed to increase the discharge capacity of many rivers where flooding has been a problem. In the past, these were frequently no more than concrete-lined canals designed to carry flows with the least frictional resistance. More recently however, bypass channels are being designed to mimic natural channels and provide seasonal or permanent habitat for fish and wildlife. In some cases, rivers are being allowed to reclaim secondary channels that had been converted to agriculture or other uses.

CALIFORNIA DEPARTMENT OF FISH AND GAME



THE YOLO BYPASS

## Advantages

Whereas a dam is constructed to “catch” or impound floodwaters, a bypass channel replaces this function by creating an alternative overflow or “storage” channel for floodwaters. In addition to increasing flood capacity of a system, bypass channels can provide temporary fish and wildlife habitat. They can also serve other functions, such as providing additional farmland or parkland, when not needed to convey floodwaters.

## Disadvantages

Bypass channels often require a large amount of land, a challenge in many areas. In addition, if the channel must be constructed or greatly improved, such projects can become expensive. In situations where farmland is to be used, it might be difficult to purchase the land or obtain a flood easement to allow occasional flooding. Finally, the potential exists for designing a project that is over engineered and does more harm to the environment (i.e., creation of concrete box channels or culverts).

## Costs

Depending on the type of bypass project, costs vary widely and can reach into the millions of dollars. Along the Guadalupe River in San Jose, California, a 3,000-foot long bypass channel will be constructed to double the flood capacity in a heavily developed stretch of river at a cost of \$225 million. This cost is on the high end of the spectrum because it includes relocating numerous businesses and residences.<sup>17</sup>

17. “Flood control project to resume in San Jose.” *San Jose Mercury News*. 21 June 2002.

### Case Study, Constructing Bypass Channels

Constructed in the early 1930's, California's Yolo Bypass serves to convey floodwaters for the Sacramento and Feather Rivers. The Army Corps of Engineers developed a network of weirs and bypass channels that would mimic the natural hydrology of the Sacramento River. As soon as the combined flow from the Sacramento River and Feather River reach a certain trigger point, floodwaters are diverted to the Yolo Bypass. While the maximum flow capacity for the main channel of the Sacramento River is 110,000 cfs, the Yolo Bypass can



## Case Study (cont.)

convey 490,000 cfs. Though the Sacramento River has exceeded its flow capacity every other year on average from 1956 to 1998, the Yolo Bypass has yet to exceed its capacity. In addition to its flood management benefits, the bypass and area wetlands serve as critical habitat for migrating fowl, steelhead, chinook salmon, and delta smelt.<sup>18</sup>

*To learn more about the Yolo Bypass, contact Ted Sommers with the Department of Water Resources at 916-227-7537 or [tsommer@water.ca.gov](mailto:tsommer@water.ca.gov) or Elizabeth Soderstrom with the Natural Heritage Institute at 530-478-5694 or [esoderstrom@n-h-i.org](mailto:esoderstrom@n-h-i.org).*

18. Sommer, T. and others, "California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture," *Fisheries* 26, no. 8 (2001), <[www.fisheries.org/fisheries/F0108/F0801p6-16.PDF](http://www.fisheries.org/fisheries/F0108/F0801p6-16.PDF)> (5 July 2002).



THE YOLO BYPASS WILDLIFE AREA

# Separating the People and the Threat



Regardless of the risks involved, people do and will continue to live in the floodplain, both upstream and downstream from dams. And, as scientists and river managers have discovered, many of the dams constructed for flood management are no longer or have never fully achieved that objective. Floodplain management encompasses a wide variety of regulatory, planning and structural measures aimed at reducing the risk of loss of property and human lives in the event of a flood. Flood management measures include zoning, flood proofing, building standards, and warning systems.

An important component of floodplain management is controlling the development of floodplains to place people and flood intolerant land uses in areas with relatively lower flood risk (*i.e.*, land at higher elevation or greater distance from the river). Land with greater flood risk is used for more flood tolerant activities, such as agriculture, parks and parking lots. This type of zoning or resettlement has the biggest impact on the need for an existing or new dam aimed at flood management.

If property and people cannot be located out of flood prone areas, flood proofing or some of the “natural” flood management measures discussed above can prevent floodwaters from reaching areas at risk. While it is not likely that flood proofing alone will lead to the removal of a dam designed for flood management or delay a proposed flood management dam, it can be a useful tool when used in conjunction with the alternatives discussed above.

## *FLOOD PROOFING*

Structures may be modified in a variety of ways to reduce the risk of floodwater penetration and damage, including: waterproofing walls, fitting openings with permanent or temporary doors, gates or other closure devices, fitting one-way valves on sewer lines and building boundary walls around the house structure.



The internal design of buildings may also be altered to reduce flood damage. For example, electrical circuits and sockets may be permanently routed and located at high rather than low levels.



DAVE PALMER

FLOOD WALL BEING ERECTED FOR PRIVATE LANDOWNER

In extreme cases, buildings may be raised on piers and occasionally buildings will be built on raised mounds or with important areas above likely flood levels. Further measures may include sump pumps that begin operating in basements when water levels rise, and contingency plans for when a flood is anticipated.



EXAMPLE OF FLOOD PROOFING THROUGH ELEVATION

FEDERAL EMERGENCY MANAGEMENT AGENCY

## Advantages

The benefit of flood proofing is that it allows existing or new structures to be located within an area prone to flooding if the structure cannot be moved or located in a flood-free area. Flood proofing could also allow areas that are now prevented from receiving floodwaters to flood in the future, providing all the benefits of re-flooding areas described above. Also, depending on the area, these practices can replace a dam, levee, or other traditional flood management structure.

Retrofitting homes and other structures to protect them from flood damage can be expensive and disruptive to families or businesses. In addition, although a structure might be protected from flood damage, a degree of risk and inconvenience remains for the people or operations occupying the structures sitting in floodwaters.

## Costs

Costs for flood proofing vary depending on the combination or complexity of tactics pursued.

- Lifting a house to install a taller foundation or piers could cost as little as \$30,000 or more than \$200,000.<sup>19</sup>
- Preventive measures for sewer pipes and the flooding of basements or first floors include installation of back-up valves or gates, standpipes, sewage ejector pumps, and overhead sewers and can range anywhere from \$100 to \$6,000.<sup>20</sup>

## Disadvantages

19. Mack Construction, *Homepage*, <[www.stevemack.com/lifting.html](http://www.stevemack.com/lifting.html)> (19 March 2003).

20. City of Hammond, Indiana Sewer Department, *A Property Owner's Guide to Flood Proofing*, <[hmdin.com/sewer/FloodProofingGuide.htm](http://hmdin.com/sewer/FloodProofingGuide.htm)> (16 March 2004).





- The average price range for materials, labor, and installation of a Floodguard flood wall is \$100 to \$140 per lineal foot.<sup>21</sup> A flood wall can also be incorporated into the actual wall of the house by retrofitting the structure with a waterproof veneer (appropriate in areas where flood depth is generally two feet or less). The average cost for retrofitting a house or building with waterproof veneer is \$10 per square foot of exterior wall.<sup>22</sup>

21. Chehalis River Council, *Personal Flood Wall Facts*, <[www.crewater.org/issues/fludwall.html#90](http://www.crewater.org/issues/fludwall.html#90)> (16 March 2004).

22. City of Wood River, Illinois, *Protecting Your Property from Flooding: Exterior Walls*, <[www.woodriver.org/FloodInfo/ProtectProperty/ExteriorWalls.htm](http://www.woodriver.org/FloodInfo/ProtectProperty/ExteriorWalls.htm)> (16 March 2004).

## Case Study, Flood Proofing

Mandeville, Louisiana, has a number of old homes and businesses of historical value on the shore of Lake Pontchartrain in Louisiana. Southerly winds and tidal influence back up water into these developed areas, with occasional strong winds and heavy rainfall responsible for the majority of flooding. For many citizens relocating out of the floodplain or elevating their homes is not an option, and flood proofing has been used to prevent excessive flood damage. To flood-proof their homes and businesses, Mandeville citizens sealed all openings below flood level on building exteriors and covered walls, doors, windows, vents and other building openings with waterproofing compounds and impermeable sheeting. Due to the pressure from the water on the structure, flood proofing only protects buildings when flood depths are no more than three feet.

## Case Study (cont.)

Two historic area restaurants, Bechac's and RIP's, had experienced flooding problems in the past and faced restrictions on what could be done to the structure by the State Historic Preservation Office. Bechac's, valued at \$1.5 million, had a total of \$35,175 in flood damage from four past floods, and RIP's, valued at \$700,000, had \$94,055 in flood damage from eleven past flood events. Final costs of dry flood proofing came to \$190,000 for Bechac's restaurant and \$200,000 for RIP's restaurant. Since then, both businesses have avoided damages during at least two floods.<sup>23</sup>

To read the complete Mandeville case study, visit [www.fema.gov/pdf/fima/performance.pdf](http://www.fema.gov/pdf/fima/performance.pdf).

23. Association of State Floodplain Managers and Federal Emergency Management Agency, "Louisiana: City of Mandeville, Louisiana," *Mitigation Success Stories*, 4<sup>th</sup> ed., January 2002, <[www.http://www.floods.org/MSS\\_IV.pdf](http://www.floods.org/MSS_IV.pdf)> (11 June 2002).

## Where you can go for help

- Protecting Your Home From Future Flood Damage: [www.fema.gov/nwz97/prothom.shtm](http://www.fema.gov/nwz97/prothom.shtm).
- Above the Flood: Elevating Your Floodprone House: [www.fema.gov/hazards/floods/fema347.shtm](http://www.fema.gov/hazards/floods/fema347.shtm).
- Homeowner's Guide to Retrofitting: Six Ways to Protect Your House from Flooding: [www.fema.gov/hazards/hurricanes/rfit.shtm](http://www.fema.gov/hazards/hurricanes/rfit.shtm).
- Federal Emergency Management Agency and the Federal Insurance Administration. *Guide to Non-Residential Floodproofing—Requirements and Certification for Buildings Located in Special Flood Hazard Areas: Guide to Non-Residential Floodproofing*.



## RESETTLEMENT

In many cases, because floodplains are largely developed, separating people and property from flood risk requires resettlement. The relocation of property either from high-risk to low-risk floodplain land, or from floodplain to flood-free land, is a strategy that is used when frequent and severe flooding occurs. Given that the threat to life and/or property is the driving reason many dams are built for flood management, eliminating both of these from the floodplain has the largest impact on the need for new or existing dams.

FEDERAL EMERGENCY MANAGEMENT AGENCY



AERIAL PHOTO OF GREAT MISSISSIPPI FLOOD

## Advantages

The main benefit of resettlement is that the resettled people and property are removed from flood prone areas permanently, eliminating the risk of flood damage. Once a community is resettled, the dam or other flood management structure could be removed or avoided and the river reconnected to its natural floodplain.

The drawbacks to resettlement include the great cost and inconvenience of moving families and businesses. In addition, adequate and affordable high ground might not be available in an area acceptable to the community to be resettled.

## Costs

Resettlement is an expensive proposition in the short term, but often is less expensive when the costs of future floods avoided are considered. For example, in Arnold, Missouri, the total amount of federal disaster assistance granted after the 1993 floods was close to \$1.5 million dollars. After the floods of 1995, the fourth largest flood in Arnold's history, the damage was less than \$72,000 as a result of non-structural mitigation—the acquisition of flood-prone or flood-damaged properties and relocation of structures.<sup>24</sup>

## Disadvantages

24. Federal Emergency Management Agency, *Success Stories from the Missouri Buyout Program*, 2002, <[www.fema.gov/mit/cb\\_agres.htm](http://www.fema.gov/mit/cb_agres.htm)> (19 February 2002).



## Case Study, Resettlement

The Great Midwest Flood of 1993 resulted in \$15 billion in damages, including the displacement of tens of thousands of families, loss of life and demonstrating the failure of traditional flood management measures, such as levees.<sup>25</sup> Rather than face the threat of continued flooding, some citizens chose to resettle on higher ground. Approximately 20,000 Midwesterners decided to move out of the floodplain, resulting in the relocation of more than 8,000 homes and business. This is the largest voluntary relocation after a flood in U.S. history. Furthermore, farmers voluntarily converted more than 50,000 acres of flooded farmland to wetlands.<sup>26</sup> Relocation efforts in a town near St. Louis led to a 99 percent drop in federal disaster relief costs, dropping from \$26.1 million in 1993 to less than \$300,000 in 1995. This is in stark contrast to another town near St. Louis that chose a more structural flood management approach, enlarging its levees in order to permit development of the floodplain. Despite the upgrades, this town suffered more than \$200 million in damages, one of the highest bills for flood-related damage, as a result of the 1993 floods.<sup>27</sup>

To read more about the Great Midwest case study, visit [www.greenseissors.org/water/floodcontrol.htm](http://www.greenseissors.org/water/floodcontrol.htm).

25. Larson, L.W., "The Great USA Flood of 1993," Presented at the International Association of Hydrological Sciences Conference, Anaheim, CA, June 1996, <[www.nwrfc.noaa.gov/floods/papers/oh\\_2/great.htm](http://www.nwrfc.noaa.gov/floods/papers/oh_2/great.htm)> (5 July 2002).

26. "Wetland Destruction Leads to Devastating Floods," *Affinity*, 15 April 1997, <[www.greenlink.org/affinity/41597/flooding.html](http://www.greenlink.org/affinity/41597/flooding.html)> (11 June 2002).

27. Taxpayers for Common Sense, "Rotten to the Corps: Army Corps of Engineers Flood Control Construction \$1.25 billion," *Greenseissors: Cutting Wasteful and Environmentally Harmful Spending*, 2002, <[www.greenseissors.org/water/floodcontrol.htm](http://www.greenseissors.org/water/floodcontrol.htm)> (11 June 2002).

## Where you can go for help

- Federal Emergency Management Agency, *Hazard Mitigation Grant Program*: [www.fema.gov/fima/hmgrp/](http://www.fema.gov/fima/hmgrp/).
- American Rivers, *Programs to Help You Restore Your Floodplain*: [www.amrivers.org/floodplainstoolkit/programs.htm](http://www.amrivers.org/floodplainstoolkit/programs.htm).
- The Trust for Public Land, *Flood Control/Hazard Mitigation*: [www.tpl.org/tier3\\_cdl.cfm?content\\_item\\_id=1102&folder\\_id=72](http://www.tpl.org/tier3_cdl.cfm?content_item_id=1102&folder_id=72).





Concerns over the environmental and societal impacts of fossil fuel burning and nuclear power, and questions of energy security mean that identifying viable energy alternatives is a widespread concern affecting everyone, not just those interested in river restoration or hydropower dam construction. About 2,400 hydropower dams generate roughly ten percent of the nation's electricity. While many of those dams will continue to operate profitably, some dams no longer produce enough power to justify their benefits. By taking a look at the longer-term alternatives presented below, we can begin to consider options that eliminate the ecological concerns raised by hydropower dams and other traditional energy sources. The utilization of one or a combination of the following alternatives can help a community or government eliminate the need for an existing or proposed dam:

- End-use efficiency
- Investment in and use of emerging power generating technologies

### *END-USE EFFICIENCY*

It has long been recognized that programs designed to reduce energy needs represent an environmentally beneficial and, in many cases, cost-effective alternative to seeking new or eliminating existing sources of power. Such programs can motivate people to be more careful about the way they use energy, offer financial assistance in making homes and businesses more energy efficient (for example, by improving insulation or by installing high-efficiency appliances), or find ways to shift energy usage from on-peak to off-peak periods. Together, these types of measures have come to be known as demand-side management or (more recently) end-use efficiency.

End-use efficiency represents an opportunity to reduce the need for electrical generation and consequently the need for obsolete or new hydro-





power dams.<sup>1</sup> Energy efficiency measures can reduce pollution and greenhouse gas emissions, save money and create jobs. Many efficiency measures and technologies are cost-effective at today's electricity prices, and the use of full-cost environmental and social accounting of electricity supply options makes them even more so. According to the Rocky Mountain Institute, up to 75 percent of the electricity used in the United States today could be saved with cost-effective energy efficiency measures.<sup>2</sup>

Since 1973, the United States has acquired more than four times as much new energy from end use efficiency as from all expansions of domestic energy supplies put together. The energy savings already achieved have cut Americans' energy bills by more than \$200 billion a year, compared to what they would collectively be spending if they used energy at the same rate as in 1973.<sup>3</sup> Most hydropower dams in existence today produce very little power; 80 percent of FERC-regulated dams produce less than 50 MW of power, which is enough electricity to power approximately 50,000 homes.<sup>4</sup> In fact, it has been said that the energy produced by Edwards Dam that was removed from the Kennebec River in Maine could have been met by replacing 75,000 standard light bulbs with energy efficient bulbs.<sup>5</sup> The current and potential energy savings combined with the low output of many hydropower projects lessens the need for existing and potential hydropower dams.

Despite the demonstrated effectiveness and promise of implementing these measures, actual investments in energy efficiency and the savings from them continue to be small, and have declined in recent years.<sup>6</sup>

In the late 1980s, new regulatory tools were designed to create incentives for utilities to invest in demand side management strategies. Complex mechanisms for cost recovery, lost revenue recovery and shareholder incentives were implemented, and, as a consequence, many utilities began investing heavily in energy efficiency as a means to balance supply and demand. With the advent of retail competition, however, these mechanisms became increasingly obsolete. Indeed, the mere threat that utilities might eventually have to face competition caused their demand side management spending to plummet nearly as fast as it rose.<sup>7</sup>

End-use efficiency programs may include a number of strategies, including the following:

- Offering financing for energy efficient homes and buildings in the form of energy efficient mortgages;
- Offering rebates to consumers for purchasing efficient equipment and to manufacturers for designing and producing it;
- Setting energy efficiency standards;
- Implementing consumer education programs about conservation and efficiency measures available to them;

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1. World Commission on Dams. *Dams and Development: A New Framework for Decision-Making*. London: Earthscan Publications Ltd, Nov. 2000.

2. Rocky Mountain Institute, *Efficiency is Still the Best Bet*, <[www.rmi.org/sitepages/pid510.php](http://www.rmi.org/sitepages/pid510.php)> (22 Oct 2001).

3. Pottinger, Lori. *River Keepers Handbook: A Guide to Protecting Rivers and Catchments in Southern Africa*. Berkeley: International Rivers Network, 1999.

4. World Commission on Dams, *Dams and Water Global Statistics*, <[www.dams.org/global/namerica.htm](http://www.dams.org/global/namerica.htm)> (3 October 2001).

5. McPhee, John. *The Founding Fish*. New York: Farrar, Strauss and Giroux, 2002.

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7. Raphals, Philip. *Restructured Rivers: Hydropower in the Era of Competitive Markets*. Berkeley: International Rivers Network, May 2001.

8. Pottinger, Lori. *River Keepers Handbook: A Guide to Protecting Rivers and Catchments in Southern Africa*. Berkeley: International Rivers Network, 1999.



## Advantages

- Implementing programs like the EPA Energy Star program, in which products, homes and other buildings are identified and promoted if they meet energy-efficiency standards; and
- Improving efficiency on the supply-side, such as reducing losses through distribution systems.<sup>8</sup>

Programs around the world have demonstrated that efficiency measures can significantly decrease electricity demand, thereby reducing the need for hydroelectric dams and other generation sources. In most cases, these demand reductions can be achieved at less cost than constructing new power sources, and provide more jobs in the long run.

The principal drawback of depending on efficiency to decrease energy demand is the perceived incremental and diffuse nature of an approach that depends on changing the behavior of many individuals, or on retrofitting many relatively small devices. These characteristics can prove challenging for energy planners who prefer more quantifiable and predictable approaches.

## Costs

Many simple strategies implemented by consumers are very low cost, such as \$5-\$15 for a compact fluorescent light bulb. Larger programs that provide incentives to consumers for replacing inefficient large appliances can cost millions – up front. In most cases, however, the cost of the measure is paid back many times

## Disadvantages

over its lifetime. Replacing an old refrigerator with a newer, energy-efficient model may cost \$700 to \$1,500 up front but could save as much as \$180 a year on a homeowner's energy bill.

### Case Study, End-Use Efficiency

Energy conservation in the Northwest has saved enough energy to power two cities the size of Seattle during the last 22 years, and the potential exists to acquire more conservation savings by 2025, according to the Northwest Power Planning Council. The council put forth a plan that will save the equivalent of 5,800 MW of electricity through energy efficiency and conservation by the year 2025 (by comparison, the nation's largest hydropower dam – Grand Coulee – produces 6,800 MW). This figure includes 2,600 MW the region has already conserved since Congress passed the Northwest Power Act in 1980. The power act directs the council to prioritize low-cost conservation before it encourages the development of generation plants.

Building codes that promote energy-efficient design, weatherizing the home, and compact fluorescent lights are among the developments that have helped to reduce electricity demand since the council's first 20-year power plan in 1983. In laying out a power plan for the next 20 years, council analysts say the region should be able conserve 3,200 MW. The region has defied long-term projections with its end-use efficiency programs. In the 1970s, power planners projected a Northwest energy shortfall, prompting many of the region's utilities to embark on an ill-fated nuclear power program. Deep shortages never panned out, however, due largely to conservation.

*For more information on this Pacific Northwest energy efficiency case, see the Northwest Power Planning Council at [www.nwccouncil.org](http://www.nwccouncil.org).*

8. Pottinger, Lori. *River Keepers Handbook: A Guide to Protecting Rivers and Catchments in Southern Africa*. Berkeley: International Rivers Network, 1999.



## Case Study, End-Use Efficiency

Before the deregulation of the energy sector, California was long a leader in increasing energy efficiency, spending at its peak in 1993 as much as \$416 million per year on utility efficiency programs. Thanks to this strong effort, California's demand grew at about one percent per year over a decade, which is half the rate of the rest of the country.

Since 1975, a combination of state energy efficiency standards for buildings and appliances and utility energy efficiency programs dramatically reduced energy consumption in California – enough to heat and power the entire state for over two years. In 1998 alone, the savings from building and appliance standards totaled \$1.4 billion, with utility programs adding a similar amount. The displaced energy from both standards and programs was roughly the equivalent of ten 1000-MW power plants. The combined impact of all the efficiency programs in California in one year is equal to 15 percent of the total statewide electricity consumption. Had efficiency programs been continued at mid-'90s levels, the state could have saved an additional 1,100 MW – enough to avoid some of the problems during the state's 2001 energy crisis.

According to a study by the RAND Corporation, improvements in energy efficiency since 1977 caused the state's economy to be three percent larger in 1995 than it would have been otherwise, and resulted in savings of between \$875 and \$1300 per capita. In addition, the efficiency improvements resulted in a 40 percent reduction in air emissions, compared to what would have resulted if energy intensity had remained at 1977 levels and the mix of energy uses remained constant (i.e., energy intensive industry continued to dominate the economy).

*The above case study is excerpted from a report by the Energy Foundation. To see the entire report: [www.ef.org/california](http://www.ef.org/california)*

## Where you can go for help

- Natural Resources Defense Council: [www.nrdc.org/air/energy/genenergy.asp](http://www.nrdc.org/air/energy/genenergy.asp).
- Sierra Club: [www.sierraclub.org/energy](http://www.sierraclub.org/energy).
- Alliance to Save Energy: [www.ase.org](http://www.ase.org).
- Energy Efficiency and Renewable Energy Network, U.S. Department of Energy: [www.eren.doe.gov](http://www.eren.doe.gov).
- American Council for an Energy Efficient Economy: [www.aceee.org](http://www.aceee.org).

# Emerging Technologies



While end-use efficiency has huge potential throughout the United States and the world, new sources of energy supply are often still required. Renewable portfolio standards (RPS), in which the government issues tradable credits to retail electricity companies for electricity produced from new renewable resources, promote the development and use of sources that are less damaging than dams, fossil fuels or nuclear power. In order to meet RPS requirements, each company must hold a given amount of credits each year. In 2002, twelve states had enacted their own RPS programs and the U.S. Senate passed a federal RPS. The Senate RPS required that major electric companies gradually increase sales of renewable energy sources to 10 percent by 2020, although this provision has met stiff opposition in the House and is far from becoming law.<sup>9</sup> Qualifying renewable resources must be new, so existing hydropower plants are not included. However, provision was made for inclusion of “incremental hydropower,” which is defined as adding hydropower capacity to existing hydropower generation facilities.

However, definitions of “renewable” vary among different incarnations of the RPS. Some programs define “incremental hydropower” as renewable, others grant credit to “small” dams (e.g. less than 30 MW), while others exclude dams from the list of qualifying renewable resources. The retail electricity price impacts of RPS are projected to be small because the price of buying renewable credits and building the required infrastructure is projected to be relatively small when compared with total electricity costs.<sup>10</sup> Finding sources that are less damaging than dams is highly site specific and variable. Options include wind power, solar power, fuel cells and microturbines, geothermal power, biogas, ocean power,<sup>11</sup> and others. Discussed below are three of the most promising and economically viable technologies, including:

- Wind power
- Solar power
- Fuel cells and microturbines

9. Union of Concerned Scientists, *Fact Sheet: The Senate Renewable Electricity (Portfolio) Standard*, September 2002, <[www.ucsusa.org/clean\\_energy/renewable\\_energy/page.cfm?pageID=838](http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=838)> (10 Sept. 2002).

10. Energy Information Administration, *Analysis of a 10-percent Renewable Portfolio Standard*, May 2003, <[www.eia.doe.gov/oiaf/servicerpt/rps2/pdf/sroiaf\(2003\)01.pdf](http://www.eia.doe.gov/oiaf/servicerpt/rps2/pdf/sroiaf(2003)01.pdf)> (June 2003).

11. Pottinger, Lori. *River Keepers Handbook: A Guide to Protecting Rivers and Catchments in Southern Africa*. Berkeley: International Rivers Network, 1999.



## WIND POWER

Wind power is the world's fastest growing energy source, with an average annual growth rate in the 1990s of 24 percent. It is likely to continue to grow at a breakneck rate through this decade as costs continue to drop and pressure grows to cut greenhouse gas emissions. In some areas, wind power is already cost competitive with fossil fuels. Wind power now contributes directly to the economies of 46 states, and often provides job opportunities in poor farming communities.<sup>12</sup> Ac-

DAVID BARENBERG,  
RENEWABLE NORTHWEST PROJECT



21ST CENTURY WIND TURBINES

According to the American Wind Energy Association (AWEA), total installed wind power in the United States stood at 4,685 MW as of January 2003. However, growth in the United States was still slower than elsewhere around the world. AWEA estimates that wind projects are capable of providing six percent of the nation's electricity by 2020. Right now wind makes up about half of one percent of the U.S. energy mix. AWEA says government support is crucial for wind energy development, especially through incentives like the production tax credit (PTC).

12. American Wind Energy Association, *Wind Energy and Economic Development: Building Sustainable Jobs and Communities*, <[www.windonthewires.org/windFactsJobs.cfm](http://www.windonthewires.org/windFactsJobs.cfm)> (2003).

Wind power has benefited from a 1.8 cent per kWh credit since 1992, but Congress failed to extend the credit when it expired under law in 2001. The PTC was renewed in March 2002 when Congress passed the current economic stimulus bill but has since expired. Several pending bills in Congress aim to extend the law for several years.

## Advantages

Wind power is non-polluting, easy to install in increments that match demand, and can blend with other land uses such as farming or grazing, thereby minimizing the amount of land consumed by power generation. It is competitively priced, and does not pose a fuel-price-escalation risk. It also creates more jobs per unit of energy produced than other forms of energy, according to AWEA. Furthermore, according to the EWEA and Greenpeace, the potential penetration of wind power into the total national energy grid is about 20 percent.<sup>13</sup> Depending on the location of a wind farm in relation to a hydropower dam, the potential to replace an existing or delay a new hydropower may exist.

The major drawback to wind power is its intermittency – at even the best sites the wind blows at different speeds, and sometimes not at all. While it has been said that the Mid-West could produce enough wind energy to power the entire country, the problem lies in delivering the power to the eastern and western seaboard. Transmission lines may not exist in rural areas where

## Disadvantages

13. Marsh, P. "Wind Power Systems Poised to Triple Over Next Five Years," *Financial Times*, 23 January 2001.





farms would need to be sited and would take three to five years to install even a regional network. Relying on a variety of wind farm sites to power the grid can help minimize the problem.<sup>14</sup> Another drawback is that local opposition occasionally arises due to concerns such as noise, property values and hazards to bird populations. Location and portability also play a role in the ability of a wind farm to replace hydropower output given the characteristically different geographic needs (plains versus steeper grade) of wind farms and hydropower dams.

## Costs

The cost of energy from wind projects fell by 80 percent between the early 1980s and late 1990s. Real, level costs are now about three to six cents per kW without any tax credits. This is competitive with many new coal or natural gas facilities. Costs for individual projects depend on financing, transmission infrastructure, and wind quality. The most cost-effective wind farms usually have at least 35 turbines and a total capacity of 25 MW or more.<sup>15</sup> Average cost to construct a 25 MW wind farm can range \$25 to \$35 million.<sup>16,17</sup>

14. American Wind Energy Association. *Global Wind Energy Market Report, 2001*, <[www.awea.org/faq/global2000.html](http://www.awea.org/faq/global2000.html)> (June 2003).

15. Reliable Northwest Project, *Wind Technology*, <[www.rnp.org/RenewTech/tech\\_wind.html](http://www.rnp.org/RenewTech/tech_wind.html)> (19 March 2003).

16. Renewable Northwest Project, *Vansycle Ridge Wind Farm*, <[www.rnp.org/Projects/vansycle.html](http://www.rnp.org/Projects/vansycle.html)> (16 March 2004).

17. Energy Information Administration, *Renewable Energy Annual, 1997*, <[www.eia.doe.gov/cneaf/solar/renewables/renewable.energy.annual/backgrnd/chap10h.htm](http://www.eia.doe.gov/cneaf/solar/renewables/renewable.energy.annual/backgrnd/chap10h.htm)> (16 March 2004).

## Case Study, Wind Power

In order to meet growing energy demands, the city of Austin, Texas created the GreenChoice program in 1999 after the city council decided that five percent of their electricity must come from renewable

## Case Study (cont.)

sources (Renewable Portfolio Standards). To meet the RPS, the city chose to offer customers wind power as their renewable source. The program gave customers the option of replacing the standard fuel charge on electric bills with the GreenChoice charge (about one cent/kWh higher rate) or to buy the renewable electricity in fixed blocks for a fixed price. The GreenChoice charge is fixed at the sign-on rate for ten years, making the plan ultimately cheaper as fuel prices rise. To date, more than 6,000 residential customers and more than 150 businesses and government agencies have signed up for GreenChoice. In fact, business customers have committed to purchasing a majority (85 percent) of the renewable power available. Austin Energy expanded their production, such that Austin's King Mountain wind farm is becoming one of the nation's largest wind development projects. By increasing its wind power purchases and by using renewable energy sources, Austin Energy will meet 53 percent of its projected load growth between 2000-2003 through savings from its energy-efficiency programs.<sup>18</sup>

To view the entire GreenChoice case study, visit [www.greenpowergovs.org/wind/Austin%20case%20study.html](http://www.greenpowergovs.org/wind/Austin%20case%20study.html).

18. International Council for Local Environmental Initiatives, *Case Study: Austin, Texas; Local Government Renewables Portfolio Standard*, <[www.greenpowergovs.org/wind/Austin%20case%20study.html](http://www.greenpowergovs.org/wind/Austin%20case%20study.html)> (11 June 2002).

## Where you can go for help

- American Wind Energy Association: [www.awea.org](http://www.awea.org).
- National Association of State Energy Officials: [www.naseo.org/energy\\_sectors/wind/default.htm](http://www.naseo.org/energy_sectors/wind/default.htm).
- U.S. Dept. of Energy, wind page: [www.eere.energy.gov/wind](http://www.eere.energy.gov/wind).
- National Renewable Energy Lab: [www.nrel.gov/wind](http://www.nrel.gov/wind).



## SOLAR POWER

Two types of technologies dominate the solar power industry at this time: solar photovoltaics (PVs), the panels that turn sunlight directly into electricity; and solar thermal, which involves focusing reflected sunlight on boilers that produce steam to turn electric generators.

PVs are the world's second fastest growing source of power, but some of the largest solar generating facilities use solar thermal technology. The use of PVs around the world grew by an annual average of 17 percent a year through the 1990s, although solar generation is still only a minuscule fraction of the world's electrical supply.

SACRAMENTO MUNICIPAL UTILITY DISTRICT



ONE OF THE SACRAMENTO MUNICIPAL UTILITY DISTRICT'S "BORROWED" SOLAR ROOFTOPS.

## Advantages

Solar power has incredible potential; it has been estimated that 100 square miles of open space covered with efficient solar panels in a location such as Nevada could generate all the electrical power needs of the United States.<sup>19</sup> It is an emissions-free energy source that can be incorporated easily into existing or planned

19. Murphy, Pat, "Solar Power: the great untapped energy source." *National renewable Energy Laboratory*, 2000, <[www.enn.com/enn-features-archive/2000/06/06072000/solarpower\\_12849.asp](http://www.enn.com/enn-features-archive/2000/06/06072000/solarpower_12849.asp)> (16 June 2003).

structures. Depending on the location of the dam and the amount of power it produces, PVs have the potential either by themselves or in combination with other alternatives to alleviate the need for an existing or proposed hydropower dam.

Like wind, solar power is intermittent – it cannot generate at night and production is cut during overcast days. Because battery technology is still relatively inefficient and expensive, it is not feasible to store large amounts of power.

## Costs

In remote homes or industries, relying on solar power can be as little as one-tenth the cost of grid power because it can be fully cost competitive. In grid-connected homes and industries, solar power can be two to five times the cost of grid power.<sup>20</sup> According to BP Solar, the world's biggest manufacturer of solar cells, the cost of making PVs fell from \$30 a watt in 1990 to seven dollars a watt a decade later. But the costs of PVs are still high, and will have to fall another 50-75 percent to be fully competitive with fossil fuels for grid-connected power. BP believes that this will take another five to ten years.<sup>21</sup> However, many states such as California offer rebates for home PV systems, which brings the technology within range of standard grid power.<sup>22,23</sup>

## Disadvantages

20. Solarbuzz.com, *Solarbuzz.com Online*, <[www.solarbuzz.com/StatsCosts.htm](http://www.solarbuzz.com/StatsCosts.htm)> (21 January 2003).

21. McCully, Patrick. *Silenced Rivers: The Ecology and Politics of Large Dams*. Berkeley: Zed Books, 2001.

22. See California Energy Commission website link to their "Buy Down" program.

23. Windmill Tours, *Windmill Tours Online*, <[www.windmilltours.com](http://www.windmilltours.com)> (26



## Case Study, Solar Power

The Dangling Rope Marina on Lake Powell in Utah began the operation of 384 solar panels on August 30, 1997 in an effort to decrease the pollution of the desert air. The electricity that runs the gas pumps for the 250,000 boaters that visit the remote reservoir each year now comes from the sun rather than diesel fuel. According to the EPA, this is the largest solar power generating facility within a national park and the second-largest standalone solar facility in the nation. The project cost \$1.5 million and is projected to save \$2.3 million over the projected 20-year lifespan of the solar panels. Furthermore, the solar power will reduce 540 tons of carbon dioxide, 27,000 pounds of nitrogen oxides, and 5,183 pounds of carbon monoxide emissions annually.

To learn more about the Dangling Rope Marina visit the EPA at [www.epa.gov/globalwarming/greenhouse/greenhouse1/utah.html](http://www.epa.gov/globalwarming/greenhouse/greenhouse1/utah.html).

## Case Study, Solar Power

The city of Sacramento, California has established a strong solar power program. The Sacramento Municipal Utility District (SMUD) purchases, installs, owns and operates two to four kW residential rooftop PV systems on the "borrowed" rooftops of willing customers. Since the beginning of the PV Pioneer program, more than 550 PV systems have been installed.<sup>24</sup> They operate two 1-MW photovoltaic generating plants, PV1 and PV2, the largest of their kind in the United States. Operating in a 20-acre field near the closed Rancho Seco Nuclear Generating Plant, PV1 and PV2 produce enough energy in the summer to power over 700 homes.<sup>25</sup>

For more information on SMUD programs, visit [www.forth.com/Content/Stories/SMUD.htm](http://www.forth.com/Content/Stories/SMUD.htm).

24. SMUD, *Solar PV Pioneer Programs*, 2002, [www.smud.org/pv/index.html](http://www.smud.org/pv/index.html) (18 June 2003).

25. Sprung, Gary, *Solar Power Generation with Express*, February 2001, [www.forth.com/Content/Stories/SMUD.htm](http://www.forth.com/Content/Stories/SMUD.htm) (18 June 2003).

## Case Study, Solar Power

In November of 2001, voters in San Francisco, California approved a \$100 million revenue bond for renewable energy and energy efficiency. The measure pays for itself entirely from energy savings at no cost to taxpayers. This bond aimed to increase use of solar energy, leading to lower solar energy costs and increased demand. Because solar energy is initially expensive, the bond delegated \$50 million for solar projects, while delegating the rest of the money to wind projects and energy efficient technologies. The energy efficiency projects have extremely short payback periods, and wind energy is already commercially viable and affordable. When these projects are bundled together, the costs for solar are effectively lowered, as is San Francisco's emissions of greenhouse gases. San Francisco's success has established a model for funding the nation's transition to solar and renewable energy and away from hydropower and fossil fuels.<sup>26</sup>

For more information on the San Francisco case study, visit "Vote Solar" at [www.votesolar.org/index.html](http://www.votesolar.org/index.html).

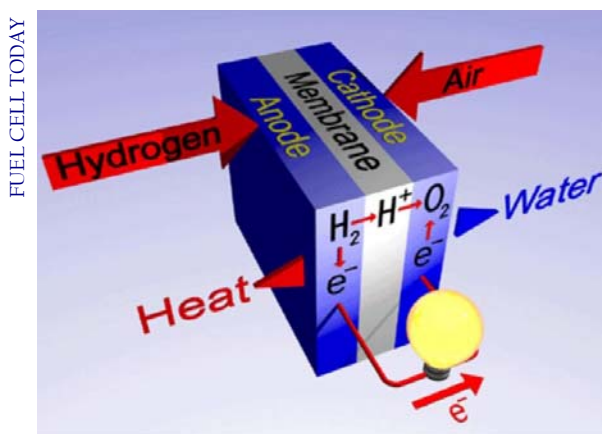
26. Vote Solar, *Vote Solar*, [www.votesolar.org](http://www.votesolar.org) (18 June 2003).

## Where you can go for help

- American Solar Energy Society: [www.ases.org](http://www.ases.org).
- Solar Energy Industries Association: [www.seia.org](http://www.seia.org).

## FUEL CELLS AND MICROTURBINES

Fuel cells and microturbine engines are highly efficient, small-scale technologies at the forefront of a movement toward distributed generation, which reduces the dependency on grid power and thus hydropower and fossil fuels. They are completely distinct technologies that are each at different phases of their development; however, they do share similarities in terms of scale and application.



FUEL CELL

With microturbines and fuel cells, individual apartment buildings, hotels, residential care facilities, small factories, supermarkets, and office blocks can generate their own electricity, heat and cooling. “Cogeneration,” or combined heat and power, is the most efficient application for microturbines, fuel cells, and other heat-producing electricity generating methods. In a cogeneration system, heat produced in generating electricity that would normally be wasted is used to heat water and/or buildings.

A fuel cell is an electrochemical device that combines hydrogen with oxygen via a chemical reaction. A fuel cell produces electricity, heat, and water (a byproduct) without combustion. Because hydrogen can be produced by electrolysis of water,

fuel cells are theoretically an almost totally clean and renewable source of electricity. However, since the electrolysis of hydrogen requires electricity, in the short and medium term most non-vehicle fuel cells utilize natural gas to fuel hydrogen production. When used to generate combined heat and power, or when running on hydrogen produced without the use of fossil fuels, fuel cells can reduce carbon dioxide emissions by 40 to 100 percent compared with conventional power plants or engines. In early 2000 there were nearly 50 MW of fuel cell demonstrations under way or planned in Japan, the United States, and Europe.

The microturbine engine, a downsized version of jet-engine-based gas turbines now common in electrical generation, is a commercially viable technology. A 30 kW microturbine is about the size of a refrigerator and generates enough energy to power a small business. Microturbines are mostly powered by natural gas, but can also be powered with other fuels including biomass, the most abundant fuel source in rural areas of developing countries. Advantages over traditional combustion engines include fewer moving parts, compact size, lighter weight, greater efficiency, lower emissions, lower electricity costs, and opportunities to utilize waste fuels. They have the potential to be located on sites with space limitations. Waste heat recovery used with microturbine engines can achieve efficiencies greater than 80 percent. This compares with efficiencies of 45 percent for the newest coal-burning technology and of around 60 percent for state-of-the-art combined-cycle gas turbines.





## Advantages

The primary benefit of fuel cells is that they have the potential to be virtually pollution-free. With cogeneration, microturbines can offer efficiencies over 80 percent compared to many older hydropower dams, which may operate at only 60 percent efficiency. Once these technologies become commercially available and are able to saturate the market, they will have the potential to lessen the need for a hydropower dam, particularly when used in combination with other alternatives.

At this point, fuel cells are still experimental (though microturbines are commercially available), and are likely to remain costly for a number of years after they appear on the market. Fuel cells and microturbines are currently dependent primarily on natural gas, which produces greenhouse gas emissions. While fuel cells have the potential to be emissions free, the combustion engine of a microturbine, though more efficient than conventional energy production methods, will always require a non-renewable fuel source. In addition to these disadvantages, the difficulties in translating these alternatives to large-scale projects inhibit their ability to truly replace a hydropower facility.

## Costs

Today, the most widely marketed fuel cells cost about \$4,500 per kilowatt; by contrast, a diesel generator costs \$800 to \$1,500 per kilowatt and a natural gas turbine can be even less. High capital cost is also a deterrent to wide scale adoption of cogeneration. While it is possible to purchase and install a 60kW

## Disadvantages

microturbine for less than \$100,000, integrating a microturbine into a large facility can double or even triple the cost of the installation and raise the project complexity by an order of magnitude.

### Case Study, Fuel Cells and Microturbines

In the mid-1990s, the U.S. Department of Defense (DoD) launched a Fuel Cell Demonstration Program that involved the installation and operation of 200 kW phosphoric acid fuel cell power plants at 30 government locations across the United States. The goal of this program was to determine how fuel cells could fit into the DoD's future energy strategy and to stimulate the fuel cell industry. By January 1, 2000, the demonstration showed the fuel cell power plants generated 91,720 MWh of electricity, and decreased electrical and thermal costs by \$3.6 million. The power plant installed at Edwards Air Force Base in California created a net savings of \$96,000, which included \$122,000 in electrical savings, \$3,000 in thermal savings, and \$29,000 in natural gas costs.<sup>27</sup>

To learn more about the Fuel Cell Demonstration Program case study visit [www.dodfuelcell.com/IOPCpaper.pdf](http://www.dodfuelcell.com/IOPCpaper.pdf) or the DoD Fuel Cell Demonstration website at [www.dodfuelcell.com](http://www.dodfuelcell.com).

27. Binder, M.J., F.H. Holcomb, and W.R. Taylor, *Cogeneration Case Studies of the DoD Fuel Cell Demonstration Program*, [www.dodfuelcell.com/IOPCpaper.pdf](http://www.dodfuelcell.com/IOPCpaper.pdf) (11 June 2002).

### Where you can go for help

- Fuel Cells 2000: [www.fuelcells.org](http://www.fuelcells.org).
- Scientific America article "Beyond Batteries" December 23, 1996: [www.sciam.com/article.cfm?articleID=000103AE-74A1-1C76-9B81809EC588EF21&pageNumber=2&catID=4](http://www.sciam.com/article.cfm?articleID=000103AE-74A1-1C76-9B81809EC588EF21&pageNumber=2&catID=4).
- Technical magazines include: Energy Policy, Power Engineering and Renewable Energy World.

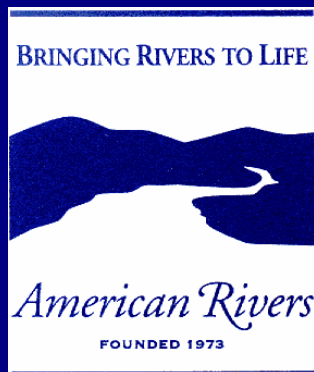




# CONCLUDING THOUGHTS

Deciding whether or not to remove a dam can be difficult. The complexity of the decision is compounded when the dam still serves some purpose, such as facilitating water diversions. While dam removal may not be the right decision for every situation, hundreds of harmful dams have been removed across the country, and when necessary replaced with one or more of the numerous non-structural and low-impact options described in this report. In researching and writing this report, it became abundantly clear that the *real* alternative to many dams in the United State involves policy and behavioral changes that reduce the fundamental demand for the services that dams can provide. It is our hope that practitioners, decision-makers, and interested citizens will use this report not only as a resource to help replace a function of an existing harmful dam, but also as a stepping point to begin the larger dialogue about how better to manage our rivers and other limited resources.





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