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PEAK WATER

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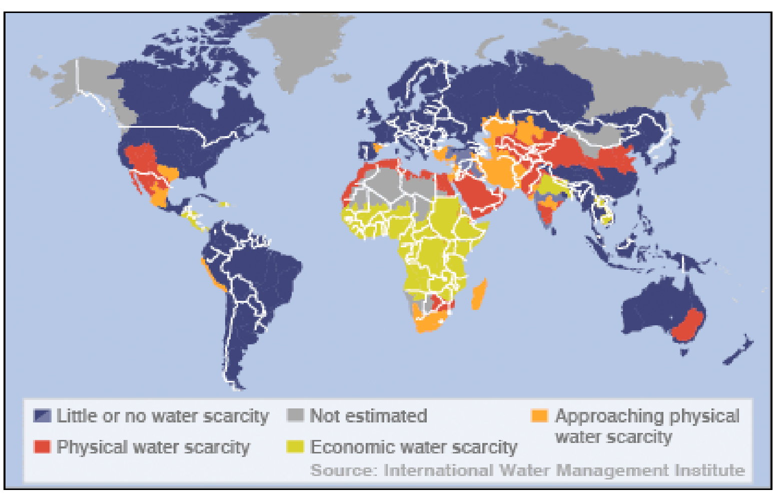
To judge from recent media attention, the finite supply of freshwater on Earth has been nearly tapped dry, leading to a natural resource calamity on par with, or even worse than, running out of accessible, affordable oil. The Christian Science Monitor asks, "Is Water Becoming the New Oil," and the Washington Post tells us to "Get ready for peak water, and even peak food." Wired Magazine reminds us that aquifers and rivers are running dry, and others talk about how Peak Water is going to reshape civilization.

Undoubtedly, we are in a water crisis worldwide. Per-capita water availability is declining as our population grows from 6 to 8 to 11 billion people or even more. Billions of people still lack access to the most basic of water services: over a billion people lack access to safe and affordable drinking water; and 2.5 billion lack access to adequate sanitation. We're facing water scarcity in many parts of the world. Many rivers no longer flow to the sea: the Colorado, Yellow, Nile, Others are too polluted to sustain life.



Talking about the water crisis in Salt Lake City, Utah, at the heart of the American Southwest, is very appropriate. In fact, the American media coined the term Peak Water to reflect the real limits on water availability in precisely this corner of America.

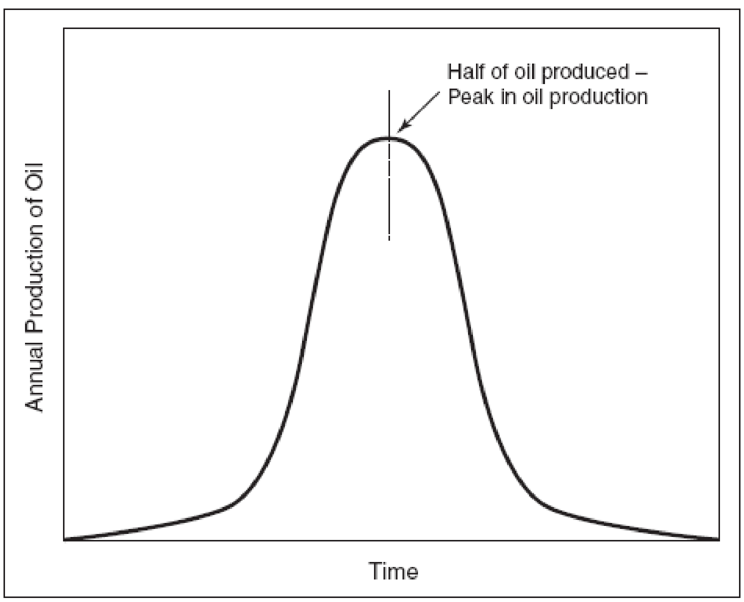
Looking at this map of water scarcity, the areas in red are defined as facing *physical water scarcity*, where more than 75% of river flows are being used by humans. Areas in orange are *Approaching physical water scarcity***.** And areas in green are facing *Economic water scarcity:* where you have enough water to meet demand, but malnutrition exists.

In a large area covering much of the American Southwest, you see a large swatch of red, as there are real limits on water availability. Seventy five percent of river flows are already being used and with projected population growth in this area, this is expected to get worse. **So we are having the right conversation about Peak Water in the right place at the right time.**

To begin, I will explore Peak Oil to provide some context. Based on this, oil and water will then be compared to understand whether the concept of Peak Water is possible, and in what ways it would be useful. I will then discuss a new paradigm and a new direction in water management, called the Soft Path for water.

Peak Oil

The theory of peak oil was introduced in the 1950s by the geologist M. King Hubbert and his colleagues who suggested oil production would follow a bell-shaped curve. This curve plots oil production on the y-axis and time on the x-axis. First, you have discovery and rapid increase in production. Second, as the stock of oil starts to be consumed, costs rise, and production levels off. Finally, since the easiest sources oil become already tapped, oil becomes more scarce and extraction becomes increasingly difficult and expensive. As a result, production drops precipitously. In this last phase, we would also see the substitution of alternatives.



The phrase “peak oil” refers to the point at which about half of the existing stock of petroleum has been depleted and the rate of production peaks.

In 1956, Hubbert predicted that oil production in the United States would peak between 1965 and 1970. And in fact, in 1970, U.S. oil production reached its height and began to decline. This bell-shaped oil production curve has been proven for a well, an oil field, a region, and is thought to hold true for the world. We don’t know when global peak oil will hit or if it has already. But in Spring 2008, when the price of oil went to $120 a barrel, the concept of global peak oil began to feel very tangible.

The concept of peak oil is now being applied to water, which begs the questions, does the production or use of water follow a similar bell-shaped curve? As we confront the global water crisis, is the concept of “peak water” valid and useful to planners, water managers, and users?

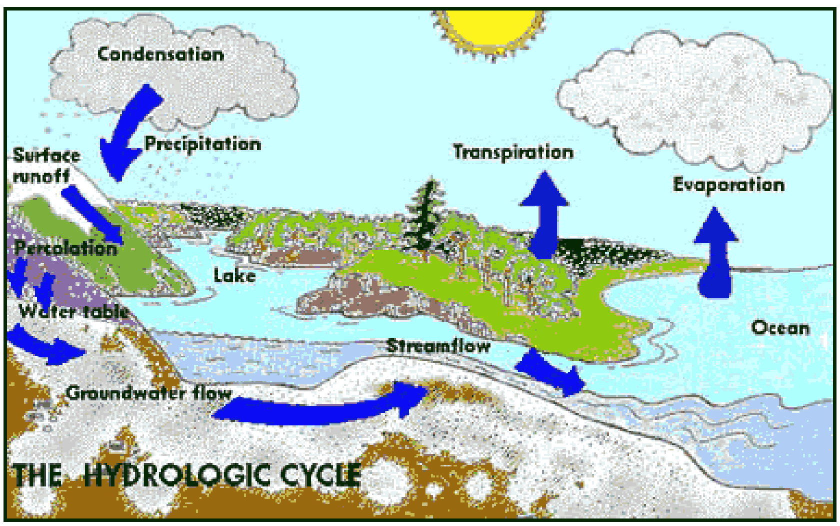
I'll go through the different characteristics of oil and water to evaluate whether a peak in the production of water is relevant, and in what contexts it may be possible.

First, we look at the limits on total water availability. Both water and oil are finite resources. While it is clear that we will certainly run out of oil (or, to be more precise, economically and environmentally-accessible oil), will we ever run out of water? Considering this question on a planet covered with water may seem silly, but when we look at where water exists on our planet, we get a much more interesting answer.

While the supply of oil on earth is diminishing over time, there is an unchanging stock of 1.4 billion cubic kilometers of water on earth. Ninety seven percent of this is salt water in oceans, which leaves 35 million cubic km of freshwater—70% of which is locked in ice. Total human appropriations are a small fraction of this, at 3700 cubic km per year. But, shockingly, while it is a small fraction of the total stock, we are already using nearly 50% of all the renewable supply of water. So, are we running out of water? No, we will never "run out" of water on earth, but we are very close to using much of the renewable supply.

Renewability

One of the key differences between oil and water is their renewability. Oil is non-renewable or stock limited. Oil was accumulated over millions of years on earth, and the total stock of oil will only continue to be depleted over time.



Water, on the other hand, is a renewable resource—the total amount of water on earth is unchanging, water only changes its form and location on earth. The hydrologic cycle illustrates water's movement from the oceans to the clouds through evaporation, from the clouds to the land through precipitation, and from the land to the sea through rivers.

An important point to note is that in some ways, water is also stock limited. We see lake levels falling, or rivers drying up, or groundwater levels falling over time. This water has not disappeared; it has just changed form and location. The same amount of water still exists; it just may not be in the same region, or as easy to access. When we over-pump a groundwater aquifer or a surface reservoir, that water is no longer available for us in that location—so certain stocks of water can actually be "used up" and run out. This illustrates that in some ways, water is also stock limited.

Consumptive vs. Non-consumptive Water Use

We also need to understand what happens to the resource after we use it. Pretty much every use of petroleum is consumptive, converting high quality energy into lower quality heat.

Some uses of water are consumptive, making water temporarily unavailable in the watershed, such as when water is incorporated into crops, or consumed by humans or animals. However, most uses are non-consumptive, such as water used for cooling in industry or water used in washing. And even water that has been "consumed" is not lost to the hydrologic cycle or to future use – it is simply recycled by natural systems.

The Transportability of Water

With the fact that water is renewable and not consumed in its use, we know that we're never going to run out of water, so concerns about water scarcity must be about something other than actually running out. And, of course, they are.

The water challenges we face today are the result of the tremendously uneven distribution of water on earth, due to human and environmental reasons; the difficulty in accessing some of the largest volumes of freshwater, like deep groundwater and ice in Antarctica; human contamination of some readily available stocks; and the high costs of moving water from one place to another.

The "transportability" of water is very relevant to the concept of peaking. Oil is transported around the world, because it has a high economic value compared to its cost of transportation. As a result, there is effectively a single global stock of oil that can be depleted.

In contrast, water is very expensive to move any large distance compared to its value. As a result, there is no single, fungible global stock of water, and regional constraints become a real concern. As a result, all of the media attention to the concept of "peak water" has focused on local water scarcity and challenges, for good reason. Most water problems are local, not global, for physical and economic reasons.

Once a region's water use exceeds its renewable supply, it begins tapping non-renewable sources like groundwater aquifers. Once we start depleting these, we move to the long term options. These are to reduce demand for water to renewable levels, or move to increasingly expensive sources, such as desalination or bulk water transport.

Substitutes for Oil and Water

According to the concept of peak oil, once we feel we are "running out" of oil, we began seriously considering alternative energy sources to replace the role that oil plays. The energy provided by the combustion of oil can be provided by a wide range of alternatives, from solar to natural gas to biofuels.

But, unlike oil, fresh water is the *only* substance capable of meeting certain needs. So, while other energy sources can substitute for oil, water has no substitutes for many uses. The basic amount of water we need for drinking and growing food are **irreplaceable** uses of water. There is nothing else on earth that we can drink to sustain ourselves or that we can use to grow our food.

But, there are also many ways that we use water that are unnecessary or highly inefficient. For example, using water to flush our toilets and transport human waste is a **choice** but not a necessary use of water. There are many other ways that we could perform sanitation as a society that would require little or no water. We are even finding ways to wash clothes without using any water.

Climate Change

Another factor that ties together oil and water is climate change. Petroleum, as a fossil fuel that produces carbon dioxide when burned, is one of the major culprits driving global warming. And, among the most significant consequences of climate change will be impacts on the hydrologic cycle. Such changes are already being experienced.

As the climate changes, hydrologic impacts will include changes in the intensity and duration of precipitation, the loss of snowpack and glaciers, and a risk of both more floods and more droughts. Further, with reductions in snowpacks, less spring snowmelt to depend on, and a reduction in water availability, the latest climate models forecast more water insecurity for the American Southwest.

Does Global Peak Water Exist?

A "peak" in production exists when we use up half of supply, and for resources that are limited in supply and non-renewable. Globally there are huge stocks of water, it is renewable, and it is not consumed in its use. Further, while a peak in global oil production is possible, most water constraints are very local.So, no. There is no such thing as global "peak water."

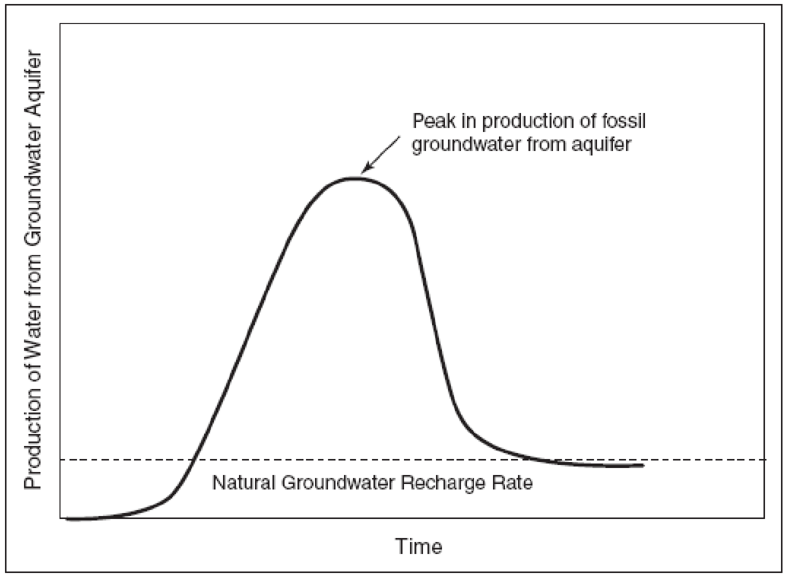
But, the concept of a "peak" in water can be useful in some key ways. The following are a few examples of when and how the concept of "peak water" can be useful:

- For example, we can have a peak water type effect when we are depleting water from a slow recharge groundwater aquifer.
- We also introduce a new term, which can be useful in watersheds called "peak ecological water."
- One of the most important outcomes of the concept of "peak water" is that it helps signal the end of cheap and easy to access water.
- This recognition of the value of water can drive us to an important and needed paradigm shift in the way water is managed and priced—towards a soft path for water, that improves the productivity, equity, and efficiency of water use.

Fossil Groundwater

First let's talk about fossil groundwater. In most watersheds, there are renewable flows of water, such as rainfall, stream flows, and snow melt. There are also *effectively* non-renewable stocks of water, such as fossil groundwater. Fossil groundwater is groundwater in an aquifer, accumulated over many thousands of years, which has a very slow recharge rate. Because it is effectively a non-renewable supply of water, it can follow a peak water type curve similar to production from an oil well or field.

The chart to the right shows the production of water from a groundwater aquifer. The dashed line is the natural groundwater recharge rate. Once withdrawals from the groundwater aquifer pass the natural recharge rate for the aquifer, the production of water from the aquifer can continue to increase until a significant portion of the groundwater has been harvested.



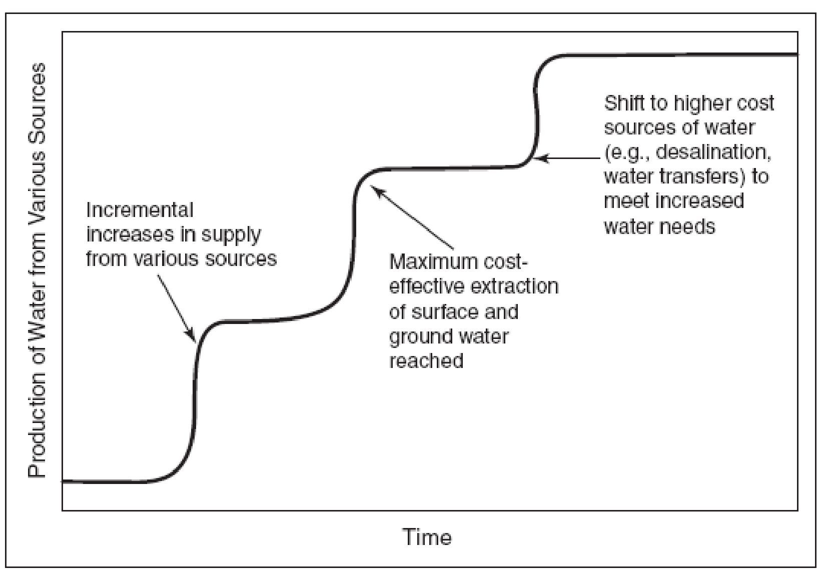
After this point, deeper boreholes and increased pumping will be required to harvest the remaining amount of water, potentially reducing the rate of production of water. Eventually extraction will drop until it reaches the renewable recharge rate where sustainable pumping is possible. A key point here is that it doesn't drop to zero, but back to the renewable recharge rate.

"Peak Ecological Water"

For many watersheds, a more immediate and serious concern than actually "running out" of water is exceeding a point of water use that causes serious or irreversible ecological damage.

Water provides many services. Not only does it sustain human life and commercial and industrial activity, but it is also fundamental for the sustenance of animals, plants, habitats, and environmentally-dependent livelihoods.

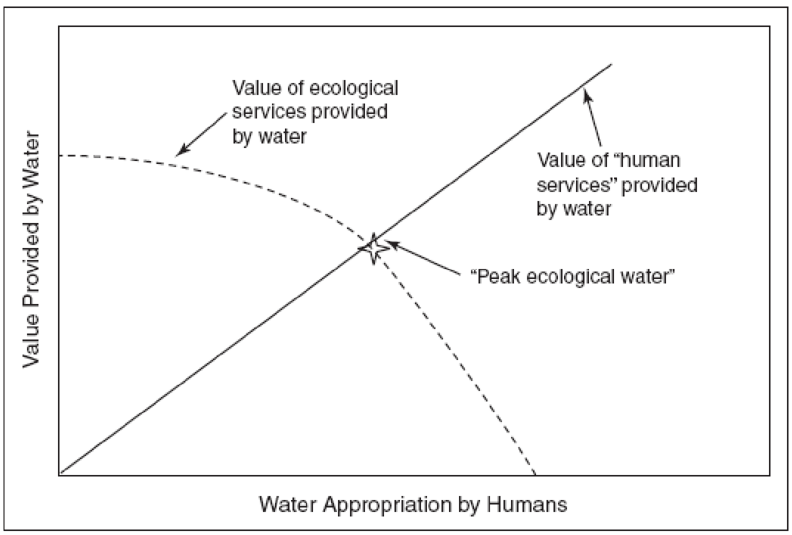
The figure to the right shows a potential water production or supply scenario in a watershed or region. On the y-axis you have increasing water production.



Over time, as demand increases, incremental supply projects, such as dams, reservoirs, groundwater pumping, increase water supply. Once the maximum cost-effective extraction of these water sources is reached, we need to shift to a higher cost “backstop” supply of water like desalination or large scale water transfers. Every new supply project that appropriates water for human use and consumption removes this water from the environment, decreasing the ecological services that this water was providing.

This water we take out of the environment has environmental impacts. Since 1900, half of the world’s wetlands have disappeared. The number of freshwater species has decreased by 50% since 1970, faster than the decline of species on land or in the sea.

We must remember that where the river goes, so do we. So, ecological disruptions will eventually affect human societies. In this next figure we present a simplified graph of the value provided by water, on the y axis, as the amount of water we take out increases, on the x-axis.



Because we are unable to appropriately value ecological services in dollar terms, we’ve just labeled the y-axis “value provided by water.” As we take on increasing supply projects, appropriating more water, the value provided to humans by this water increases. But as we take water from the watershed, the ecological services and value that this water was providing (for plants and animals) declines.

At a certain theoretical point, which we call peak ecological water, the value of ecological services provided by water is equivalent to the value of human services provided by water. After this point, taking more water for human use causes ecological disruptions far worse than the value it adds for us.

At the point of “peak ecological water,” society will maximize the ecological and human benefits provided by water. As shown in the figure on the left, the overall value of water, combining ecological and social benefits, rises to a peak and then declines as human appropriation increases.

Of course, determining the point of “peak ecological water” is entirely subjective based on different evaluations of the value of each unit of water in ecosystems and to humans. Despite the challenge of determining “peak ecological water,” human societies make decisions all the time as to what level of ecological disruption is acceptable to meet human needs.

Again, we must remember that where our rivers go, we will eventually go; humans are so interdependent on watersheds, that ecological disruptions will eventually harm human society.

The End of Cheap Water

The thing that is most exciting for me about the idea of peak water, despite its flaws, is that it signals we are at the end of the age of cheap, easy water. In the same way that Peak oil has meant the end of cheap, easy to access sources of petroleum, Peak Water means we are going to have to go further, spend more, and expect less in the realm of freshwater. “Peak water” reminds us that water, which we used to think was widely available and inexpensive, can no longer be taken for granted.

A New Water Paradigm: The Soft Path for Water

Where does this leave us? In many regions of the world including in the American Southwest we are facing real limits on water availability, with growing populations, climate changes, and insecure water supplies, and growing water use. How do we solve this water crisis? Do we do more of the same? More dams and reservoirs? More overpumping of our groundwater aquifers? Or…do we do something different?

As Robert Frost wrote a few decades ago:

> “I shall be telling this with a sigh
> Somewhere ages and ages hence:
> Two roads diverged in a wood, and I,
> I took the one less traveled by,
> And that has made all the difference.”

We are at a crossroads—here in Utah and Salt Lake City, in Las Vegas, in Los Angeles, and in cities and villages throughout the world. The choices we make now will determine the future of water on this planet and in our lives.

The Hard Path and the Soft Path

Business as usual we are calling the hard path. The “hard” path relies almost exclusively on centralized infrastructure and decision-making: dams and reservoirs, pipelines and treatment plants, water departments and agencies. It delivers water, mostly of potable quality, and takes away wastewater.

The hard path is the path of engineers. As a water/wastewater engineer, I know the role that engineers have played in making this path a reality.

The second path—the “soft” path—also relies on centralized infrastructure, but complements it with extensive investment in decentralized facilities, efficient technologies, and human capital. It strives to improve the overall productivity of water use rather than seek endless sources of new supply. It delivers diverse water services matched to the user’s needs, and works with water users at local and community scales.

Several elements of the Soft Path are relevant to what we are facing in the American Southwest. We need to meet water related needs, not just supply water. People want to take a shower, make food, grow gardens, they do not want 200 gallons of water per day. We need to match the quality of water we are providing to the need that must be served. It is pointless to waste drinking water to flush our toilets or water our flowers. We need to quantify the amount of water generated from the investments we make in decentralized facilities—in many cases, they can provide the same amount of water more cheaply and efficiently than larger facilities. We must rethink the concept of supply and consider effective “soft” supply options such as reclaiming wastewater, reusing grey water, and harvesting rainwater. We need new economic tools that help us value water effectively, this means block water pricing so that a certain basic amount of water is free, but luxury uses of water to wash our cars and water huge grassy fields is charged appropriately.

And, we need to ensure that communities are involved and engaged in decisionmaking around water. An educated and informed citizenry will the best stewards of water for current and future generations.

Myths About Efficiency

First, I will discuss the importance of conservation and efficiency, which is often called “demand management” in the water sector,
There are a lot of myths about efficiency, including:

- Myth 1: Efficiency opportunities are small.
- Myth 2: Water demand is relatively unaffected by markets and prices.
- Myth 3: Conserved water is not “real.”
- Myth 4: Efficiency improvements are speculative and risky.
- Myth 5: Efficiency improvements are not cost effective.
- Myth 6: Demand management is too complicated

Water managers assume that water demand increases as the population and economy grow. In fact, in many parts of the United States, demand for water has not increased, despite a growing population, and a growing economy. In the U.S. and California we used less water in 2000, for everything, than we did in 1980. This is true in many parts of the world. Since 1980, water use in the U.S. has gone down, while the economy (represented by GNP here) has continued to rise. We have broken the link between economic growth and water use. In many cases, now, even as population goes up *total* water use is actually going down. Examples of this decoupling include:

- New York City: residential water use per person has dropped from 200 gallons per day to 140 gallons per day. A 1/3 drop in water use in 15 years
- In California, with steadily rising population, significant increases in the gross state product, total water withdrawals have actually dropped
- Albuquerque, New Mexico, and Seattle, Washington also show significant reductions in per capita water use

Efficiencies are possible and have already occurred in every industry. In the 1930s, it used to take 200 tons of water to make one ton of steel; in 2002, it only took 2 tons of water. In semi-conductors, over 20 years, we’ve reduced water use from 30 gallons per square inch to 2 gallons.

And, in our homes, water conservation and efficiency does not mean brown landscapes and shorter showers. It means doing everything we want, but using less water. For example, in 1980, most toilets used 6 gallons per flush (gpf). Newer toilets now use about 1.3 gallons per flush. Old showerheads pumped out 5-7 gallons per minute, newer models use as little as 1.5 gpm.

And there are other innovative techniques to make the water we use go further, including:

- Grey water from baths and washing is a valuable resource as distinct from black water that comes out of our toilets.
- Dual plumbing systems allow this grey water to be used for landscaping, watering outdoor gardens, and flushing toilets.
- We need to think about matching water quality to water need. High quality drinking water is wasted when we use it to water our lawns or flush our toilets.
- Grey water reuse is in place in a number of places throughout the world, and is mandated in some places.
- Using Rainwater Harvesting, we can capture and store rainwater which can be used for toilets and gardens, or to recharge groundwater aquifers. This is already in use in China, Brazil, India, and the United States.In India, many states require that ALL structures collect rainwater and direct it to groundwater recharge pits.

Moving forward on the Soft Path will require:

- Identify the Potential
  - Who is going to require water?
  - For what purpose or goal is water needed?
  - What kind of water?
  - How much water?
- Identify Barriers
  - Behavioral
  - Technological
  - Information and data
- Making Social Choices
- Implementing Options using
  - Economic tools
  - Technological
  - Regulatory tools
  - Education

While the hard path depended on engineers to lays pipes, build dams and reservoirs, and manage water systems for huge populations, the soft path depends on planners, architects, and communities.

Planning commissions and cities can enforce building codes or retrofit on resale ordinances that reduce water demand by requiring every dwelling to be fitted with the most water efficient cost effective technologies, including low flow showerheads, toilets, and washing machines. Planners can build in dual plumbing systems in communities, or grey water systems in households so that wash water can be used to water landscaping.

We can require every dwelling to develop a rain water harvesting structure and develop our cities to promote infiltration of storm water to recharge our groundwater aquifers.

Conclusion

To summarize, the take home lessons are:

- We will never “run out” of water.
- In the Southwest, we face real limits on water availability. These will worsen with growing populations and climate change.
- In these places we have already reached a point at which human water use is affecting the environment, (and eventually us).
- We are seeing the end of the age of cheap and easy to access water.
- The good news is we can do everything we need and use far less water.
- This requires community engagement, smart planning, and comprehensive implementation.
- The hard path belonged to Engineers, the soft path will be engineered by Planners.

In conclusion, we have a choice of two paths before us. Every choice we make as planners, community members, engineers, architects, and policymakers will affect our water future and the future of our cities. Every choice we make affects the path we follow.

Peak Water reminds us that as we reach the limits of our water supplies, our focus must shift to a new way of thinking about water. Water is a precious, scarce, and vital resource and our use of it must be thoughtful, sustainable, and carefully planned. The future is ours for the making. Thank you.

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