Freshwater—Is It the Petroleum Problem of the 21st Century?

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1. Introduction – Freshwater As A Resource

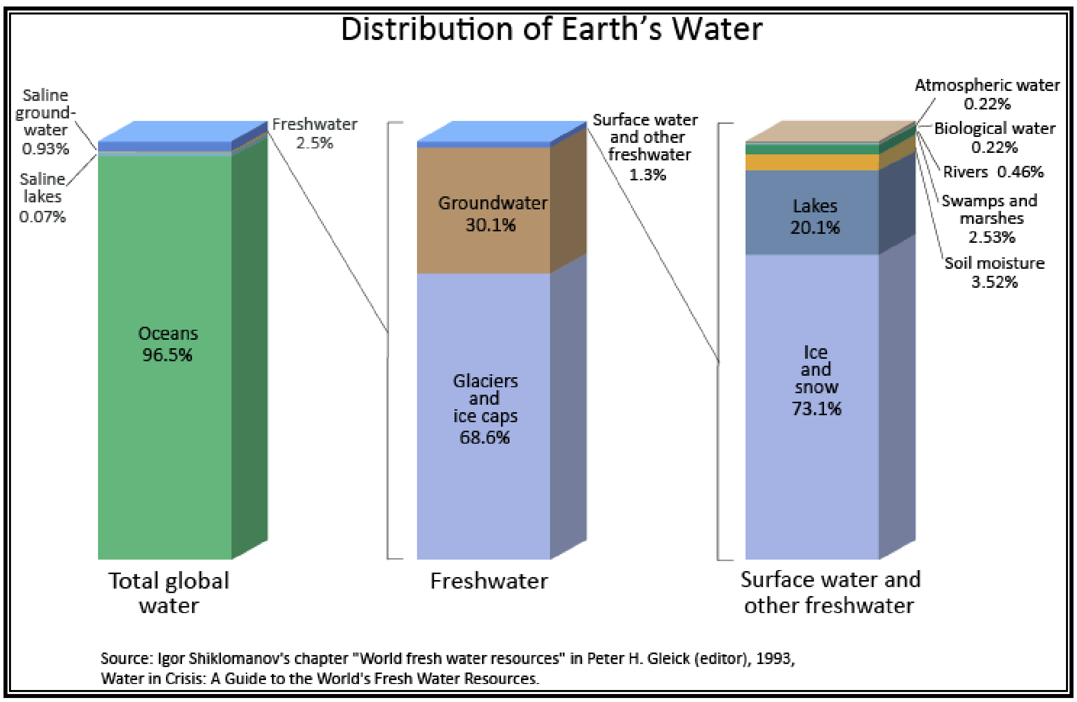
1.1. Supply of Water

Water is a necessity for life. The importance of water is vividly clear to us; it must not be overlooked. Now more than ever, water is being judged as a resource. The current ways we use water is being questioned and its future supply is dwindling. Approximately 70% of the Earth's surface is covered by water. Water seems abundant, but actually the amount of freshwater is quite small. Of that 70%, 97.5% of it is salt water, which leaves only about 2.5% freshwater. That being said, 1.75% of the entire Earth's water is freshwater. Approximately 70% of the world's 1.75% freshwater is frozen in the ice caps in places such as Antarctica and Greenland. When such instances are considered, we are left with about .5% freshwater that is actually available to us. Therefore, the (current world population at submission time) people that inhabit the earth must allocate and share less than 1% of the world's total freshwater supply. More specifically, a study done at the University of Michigan in 2000 considers there to be about .007% of all the water on Earth to be accessible for "direct human uses."Mainly, this amount is that found in lakes, rivers, reservoirs, and underground resources that can be easily tapped at an affordable cost. Only lakes, rivers, reservoirs, and underground resources are regularly replenished by forms of precipitation and can be considered available on a sustainable basis. (University of Michigan)

1.2. Distribution of Water

The Earth's freshwater supply is minute. Next, we will discuss the distribution of the resource. As previously stated, less than 1% of the world's water is considered to be usable by humans "as is." Distribution of the worlds freshwater is as follows: 68.6% is Glaciers and Ice

Caps, 30.1% is Groundwater and 1.3% is surface water and other freshwater. Again, as stated previously, only about 1% of the earth's freshwater is readily available. We can then again examine the breakdown of that 1% even further. The breakdown within that 1% is as follows: 73.1% Ice and Snow, Lakes 20.1%, 3.52% Soil Moisture, 2.53% Swamps and Marshes, .46% Rivers, .22% Biological Water, and .22% Atmospheric Water. The breakdown of the distribution of water worldwide is easily depicted and viewed in the following graph: (USGS)

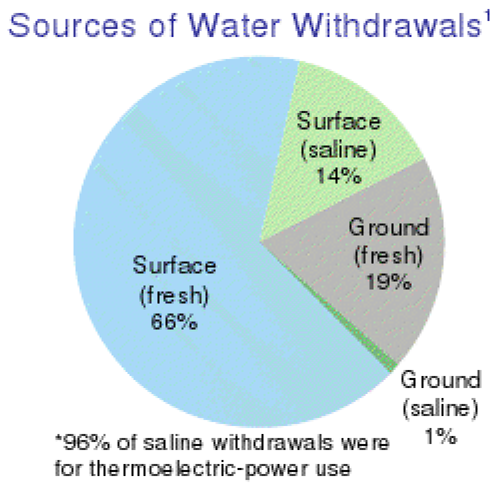


The following table organizes the data not by percentages of supply but by volume in cubic miles. To fully understand the table, we must comprehend that 1 cubic mile = 1.10×10^{12} gallons. From these figures, we can get estimates of the actual amount by volume of the water that is readily available to us. It is important to note that there are approximately 56,000 community water systems providing water to the public in the United States. Those 56,000 systems process about 38 billion gallons of water a day. (City of Lawton)

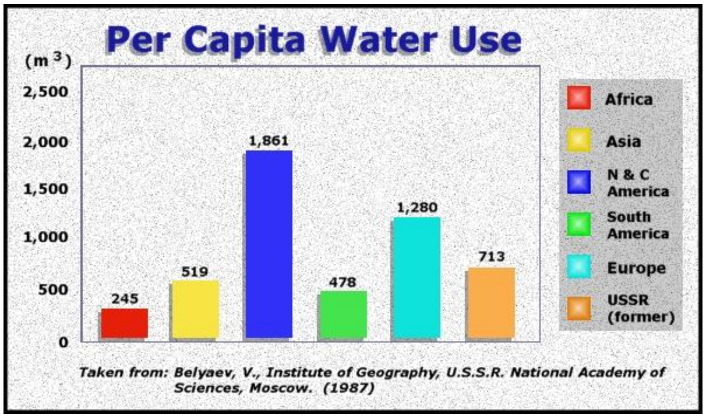
One Estimate of Global Water Distribution				
Water source	**Water volume, in cubic miles**	**Water volume, in cubic kilometers**	**Percent of freshwater**	**Percent of total water**
Oceans, Seas, & Bays	321,000,000	1,338,000,000	--	96.5
Ice caps, Glaciers, & Permanent Snow	5,773,000	24,064,000	68.6	1.74
Ground water	5,614,000	23,400,000	--	1.7
Fresh	2,526,000	10,530,000	30.1	0.76
Saline	3,088,000	12,870,000	--	0.93
Soil Moisture	3,959	16,500	0.05	0.001
Ground Ice & Permafrost	71,970	300,000	0.86	0.022
Lakes	42,320	176,400	--	0.013
Fresh	21,830	91,000	0.26	0.007
Saline	20,490	85,400	--	0.007
Atmosphere	3,095	12,900	0.04	0.001
Swamp Water	2,752	11,470	0.03	0.0008
Rivers	509	2,120	0.006	0.0002
Biological Water	269	1,120	0.003	0.0001
Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources (Oxford University Press, New York).				

1.3. Overview of US Consumption of Water

More specifically, we intend to examine the United States levels of supply and consumption of freshwater. In addition, we will examine the implications, laws and regulations that surround water as a resource and take note of the economic effects of water scarcity. Nationally, consumption can be credited in the categories within the following graph:



From this graph, one can see that we are exhausting our surface freshwater supply at a much higher percentage in comparison to saline surface water, or groundwater that is either considered freshwater or saline. (UM Sustainable Center) It is also important to understand that the United States consumes more water than any other region in the world. For example, an American that takes a five minute shower uses more water than the average person in a developing country's slum uses for an entire day. (Pacific Institute) The US consumes an enormous amount of water in comparison to the rest of the world and it is something that must be recognized. The following graph depicts per capita water use separated by regions of the world.



North and Central America consume approximately 581 m^3 more a day than the rest of the world. This is an enormous amount. It is more than Asia, South America and the former USSR combined.

1.4. Water Scarcity and Sanitation

By gaining knowledge about the supply and distribution of the world's water, we can now easily agree that water is a valuable resource. Moreover, we can label water as a *scarce* resource even in the United States. However, some believe that the problem of water scarcity is "overblown," because they believe the problem rests with sanitation. Approximately 2/5 of the world's population lacks access to modern sanitation. Of that 2/5, 80% of those people live in rural and not urban areas. In addition, it is known that poor countries suffer more than wealthy ones. Unsanitary drinking water causes wide spread illness and kills more than two million people each year. Sadly, many of those deaths occur in developing nation and are listed in an age group of less than five. Surprisingly, the world's leading pollutant is human and animal excrement. With the lack of sewer systems, many countries dump raw sewage directly into their water supplies. (Joynt and Poe) Sanitation is, indeed, an increasing problem for the world's water. It leads to many deaths each year that could potentially be prevented. However, our focus is more on the future implications of a dwindling water supply.

2. Water Resources

2.1. Groundwater Resources

The hydrological cycle dictates our distribution and thus supply of freshwater. Of all the water on our planet less, than one percent is freshwater, and even less of 1% is available for human use. Water resources are commonly thought of as being an entirely renewable resource. While fluctuations in water resources such as periods of drought are common in the world, we sustain a notion due to our understanding of the water cycle that it is impossible to run out of water as a resource. The hydrological cycle is indeed a cycle, and our point of harvest for water use is a mere section of a large conveyor. It is unlikely that our worldwide source of freshwater will ever vanish and escape our atmosphere leaving our planet a desert wasteland, but a more practical threat of concern regards to water resources are how anthropogenic processes change usable water into unusable water.

2.2 Surface Water Resources and Its Uses

During a the last major evaluation of water resources by the USGS in 2005, 80% of all withdrawals came from surface water and 20% came from groundwater resources. The main uses of water were thermoelectric (49% of water withdrawals), irrigation (31% of total water withdrawals) and the public supply utilizing only 11% of the total surface water supply. Of the groundwater used, 67% went to irrigation and 18% was used for the public supply. Water demand has remained relatively stable in all sectors except public supply, which have been increasing since 1980 (Kenny 2005). Public supply can include water being supplied for industrial, domestic, or commercial use.

2.3 Anthropogenic Changes to Water Use

Innovations in irrigation methods and drought tolerant crops have led to the small increase of use by irrigation despite increases in total agricultural acreage. An area of greater concern is towards the public supply and domestic use of water resources. Of the 11% total water withdrawn for public use, 67% of freshwater withdrawals were from surface water (Kenny 2005). Increases in the US population, per capita withdrawal, and decreases in the self-supply population have lent to increases in the public supply withdrawal from our water resources. While public supply is only the third most utilized of our water resources, it arguably is one of the most important in regards to human health and the proper functioning of society. Public water supply is also one of the most costly water uses due to extraction, and because it must adhere to government health standards. Public water withdrawals differ from categories such as irrigation in the sense that a public supply is in constant demand, whether an area is in times of drought or flooding, the general public requires constant supply of potable water. Additionally, a collapse in public supply water resources would have a drastic immediate effect on more individuals than a collapse in say mining, aquaculture or even irrigation. Two important components to public water supply are its constant availability from its resource, whether it be surface water or ground water, and its characteristics or water quality.

It is important to distinguish that surface and ground water resources are interconnected, and some surface water will eventually recharge aquifers, that we will later be utilized for water needs. Likewise, some aquifers discharge into surface water resources, only to be incorporated again later into groundwater sources at a different location. Because of this connectedness between resources, anthropogenic impacts on one source will likely affect the other. These impacts can include any way in which humans change the composition of water or affect the cyclical nature by withdrawals.

2.4. Where does our Wastewater go after use?

Treating water to meet national and federal standards is an expensive and energy-consuming task. Water utilities in the U.S. treat 34 billion gallons of water per day (EPA 1999). Surface water requires more treatment (and is thus more expensive) than that of groundwater because of the large amount of contaminants due to surface runoff. Ground water is subjected to filtration during recharge provided by natural geological processes and is less expensive to treat. In this sense, groundwater takes longer to re-establish after being withdrawn but typically has lower levels of contaminants. Surface water is relatively easier to extract and replenishes more quickly but has higher amounts of contaminants. By utilizing natural geological and biological processes to treat water, we have the ability to increase the quality of our surface and groundwater resources.

2.5. Solutions to Water Quality and Degradation

Healthy ecosystems have the potential to play a vital role by increasing the quality of surface and groundwater, thus decreasing the costs associated with water treatment for public use. The most notable ecosystems that provide services to our water resources are riparian habitats and wetlands that filter pollutants, sediments, act as flood regulators, and water storage (Pielou). Many waterways in the U.S. have been manipulated away from their natural state to one that appears to be more suitable for human uses. The implementation of concrete levees and supports to combat erosion are in fact eliminating the potential service a natural riparian ecosystem could be providing. Riparian ecosystems provide a regulating service for water purification, erosion control, and flood control (Ellis). Because of the interconnectedness between surface water and groundwater, concrete channeling ultimately can slow the rate of recharge for groundwater resources. Implementing and maintaining a healthy riparian corridor along a surface water resource ultimately conserves water by lowering the ambient temperature, minimizing evaporation (Ellis).

Implementation and maintenance of riparian ecosystems by firms utilizing freshwater resources have the ability to reduce costs, comply with permit requirements, earning of credits to offset pollution discharge (Cochran et. Al.). In the 2011 study by Cochran et. Al, research showed that thermoelectric pollution in the form of heat could be reduced by the implementation and maintenance of a riparian corridor. Multiple electricity companies utilize the Tualatin River in Northwestern Oregon for thermoelectric power. Firms utilizing the river planted 1.6 million native trees and shrubs along the Tualatin River, providing shade, and 295 kcal/day of credits towards thermal pollution. This alleviated energy companies from installing mechanical chillers, and produced a 25% reduction in pollution credits (Cochran et. Al). In an agricultural setting, pesticide, herbicide and excess fertilizers can be largest sources of pollution (Pielou). Creating biological diversity in agricultural settings by implementing landscape complexity can reduce groundwater pollution by 90% (Kedziora 2010).

Besides channeling, dams are another human implementation utilized for managing surface water. Most dams are built for hydroelectric power generation, to facilitate navigation, provide a reservoir for water supply, and control flooding. There are however negative implications with constructing dams. There is always the possibility for dams to fail, accidents do happen and a dam breach can be catastrophic. Though dams are a mechanism for increasing the surplus water supply, large amounts of water are lost due to evaporation from stagnant water. Vital nutrients for crops and riparian habitats are constrained and prevented from being distributed across a valley or flood plain. Dams also facilitate the channeling of water into arid regions, causing excess salts to accumulate into making cropland unproductive (Pielou). For many developing nations with vast water resources such as China and Brasil, mega-electric dams are being constructed at astonishing rate to meet electrical demands. While these dams seemingly are the answer for meeting electrical demand, they have high implications regarding water quality and social costs. Political and government intervention in these countries facilitate the construction of mega-dams despite the environmental and social costs. The Mekong River for instance provides 2.6 megatons of fish to its outlying residents annually. Because countries such as Brazil and China do not undergo a rigorous IRP (Interest Rate parity) cost and risk methodology before undergoing these massive projects, they are in fact costing themselves more in an attempt to meet growing population's demand for electrical power (Totten 2010).

With our global water demand on the rise, it is vital that our water resources not be compromised by the dismembering of geologic and ecological processes that naturally increase the quality of our water. The issue of "running out" of water does not deserve as much attention as running out of viable water for human consumption and use at a manageable price.

Maintaining the integrity of our environmental services translates to maintaining a self-sufficient process for cleaning our water as well maintaining our environmental integrity.

3. Water Desalination

Desalination is the process of removing excess salt and other minerals from saline water. Water is desalinated all over the globe to produce potable water from bodies of inconsumable salt water. The two most common types of water desalination methods today are distillation and membrane desalination.

3. 1. Distillation

Distillation is a method of separating mixtures of liquid based on their relative boiling points. This can be done in a variety of different methods, the most popular being Multi-stage flash distillation and Multiple-effect distillation.

3.2. Multi-stage Flash Distillation

The multi-stage flash distillation process is currently the most popular method of desalination, producing over 80 percent of all desalinated water in the world today (*Multi-Stage Flash Distillation (MSF)*). Multi-stage flash distillation, or MSF, is done by "condensing steam on tubes moving sea water through a brine heater (*Multi-Stage Flash Distillation (MSF)*)". This process is depicted in figure 1.

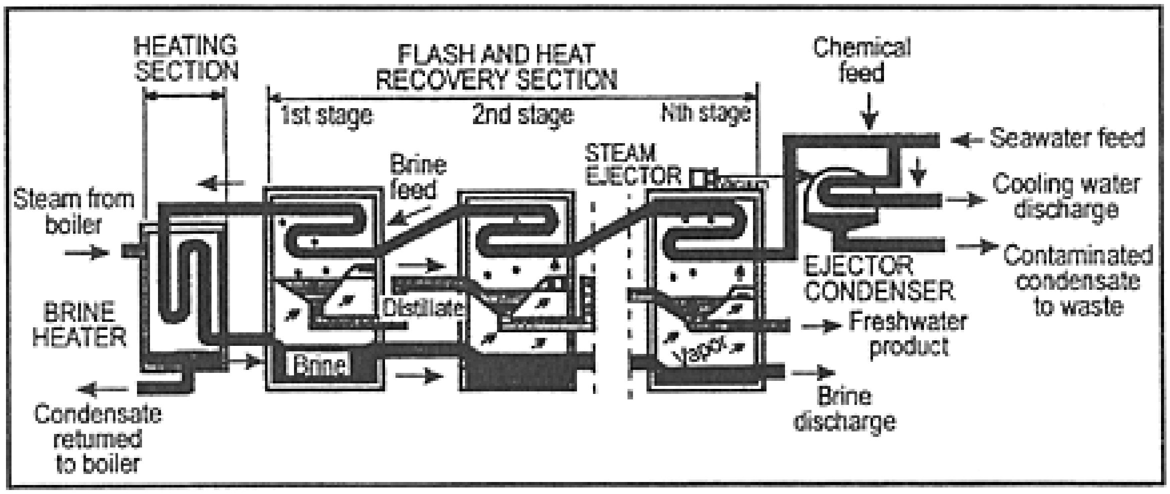


Figure 1

Heated water is passed to an additional container identified as a "stage", where the surrounding pressure is lesser than that in the brine heater. It is the abrupt introduction of this water into a lower pressure "stage" that makes it boil so quickly as to flash into steam. As a rule, only a minute percentage of this water is transformed into steam. Consequently, it is usually the case that the water that is left behind will pass through a succession of additional stages, each having a lower ambient pressure than the preceding "stage." While steam is produced, it is condensed on tubes of heat exchangers which run all throughout every stage. (*Multi-Stage Flash Distillation (MSF)*)

MSF is an extremely common method of distillation because it allows desalination plants to recycle a large portion of their energy. As displayed in figure 1, the MSF process is designed to recover and recycle the heat used to distill brine by running the cold, sea-water intake parallel to this process.

3.3. Multiple-effect Distillation

Multiple-effect distillation, ME for short, is a less common method of water desalination. Seen below in figure 2, this method utilizes a number of condensation/distillation chambers called "effects" to separate solutions.

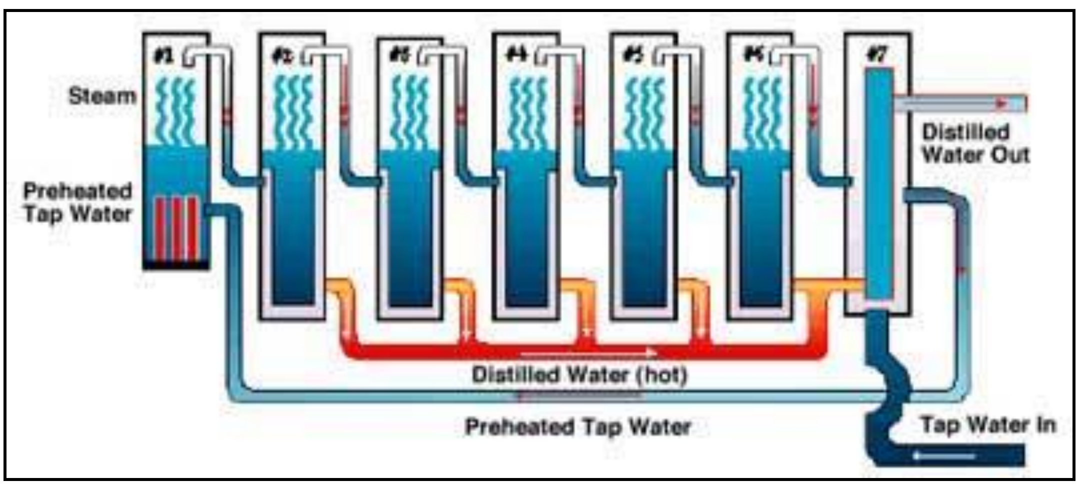


Figure 2

Water is boiled in a sequence of containers, each maintained at a lower pressure than the previous. Since the boiling point of water decreases as pressure decreases, the vapor boiled off in one container can be used to heat the next, and only the first vessel requires an external source of heat. (*Multi-Stage Flash Distillation (MSF)*)

This process is utilized for a number of reasons. One such reason is that it requires less electricity to desalinate water than MSF (*Multiple Effect Distillation (MED)*). This method can also be run at low temperatures (**70°C) -** This is important because lower temperatures reduce corrosion of the elements (*Multiple Effect Distillation (MED)*). A ME process can also be run 24 hours a day with little maintenance, because it has no moving parts (*Multiple Effect Distillation (MED)*).

The ME process of desalinating water is most commonly applied to industrial uses such as power plants, petrochemical complexes, chemical plants, and oil refineries (*Multiple Effect Distillation (MED)*). These industries don't require the use of potable water- instead, they simply require desalinated water. The ME distillation process excels at producing water of an industrial purity, often utilizing only four elements to do so (*Multi-Stage Flash Distillation (MSF)*). This method is also well suited to industrial applications as it can utilize heat produced by industrial processes (*Multiple Effect Distillation (MED)*). If run in this manner, an ME apparatus has a very low operation cost

3.4. Membrane Desalination

Membrane desalination is the process utilizing a permeable membrane to remove excess salt and other minerals from saline water. There are currently two widespread methods of membrane desalination: reverse osmosis and electrodialysis reversal.

3.5. Reverse Osmosis

Reverse osmosis, RO for short, is the process of "applying hydrostatic pressure on seawater or brackish water surrounding a semi-permeable membrane (Weintraub)". The membranes utilized are permeable to water but relatively impermeable to dissolved electrolytes. The hydrostatic pressure placed on the brackish water surrounding the membrane causes water molecules to proceed across the concentration gradient, through the membrane.

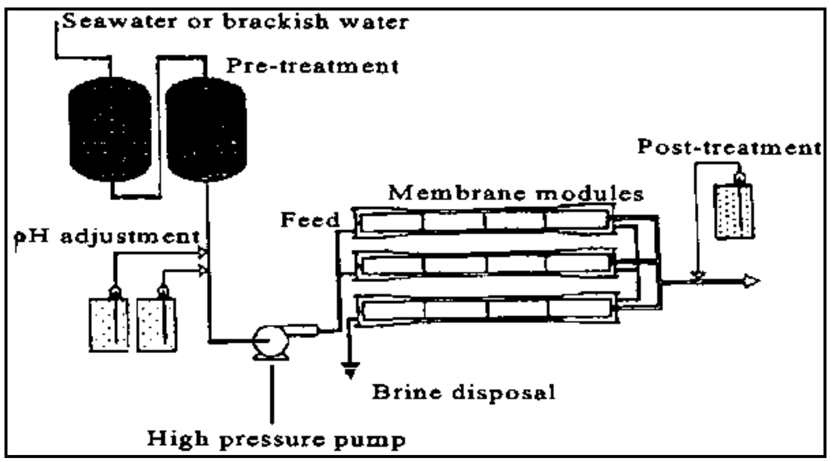


Figure 3

In doing so, the brackish solution is separated into two solutions. The solution which has not passed through the membrane is composed of water and the electrolytes which could not pass through the semipermeable membrane. The second solution which has passed through the semipermeable membrane is highly pure, potable and relatively free of salt and other electrolytes.

Reverse osmosis is widely touted as "the most economical way to desalinate water (Weintraub)". Reverse osmosis is utilized all over the world. Cutting edge reverse osmosis plants in Israel near Ashdod project an output of 180,000 m3 per day at a price of about 0.50 $/m3 (Weintraub).

The operations cost in a reverse osmosis plant relatively are low. The bulk of the cost associated with sustained operation come from the cost of replacing damaged membranes and treating incoming brackish water (Bradshaw).

The membranes utilized in reverse osmosis are "sensitive to abuse" (Weintraub). Pressure must be within the membrane's operational limits. Excess pressure can result in damage to the membrane. In addition, the incoming water must be pretreated both to remove bacteria and particulates. The particles found in brackish water can damage the semi-permeable membrane when pressurized.

3.6. Electrodialysis Reversal

Electrodialysis reversal operates much in the same way as reverse osmosis. The primary difference between the two is that electrodialysis reversal, or EDR, utilizes an electrical current to move ions in brackish water along a concentration gradient as opposed to the hydrostatic pressure used in reverse osmosis.

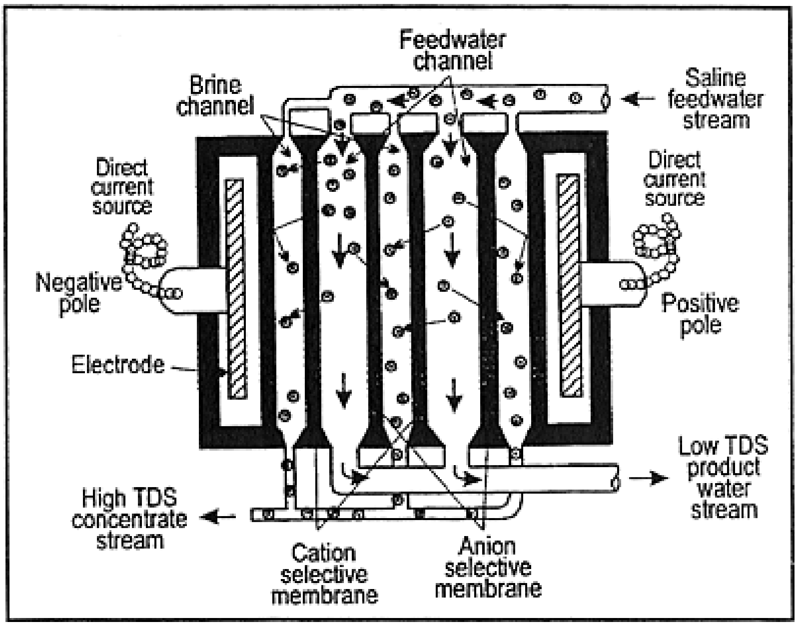


Figure 4

This process is widely utilized for both wastewater treatment and for producing potable water. The cost of this process varies between $0.30 and $0.40 per cubic meter of treated water (Roquebert).

3.7. Necessary Infrastructure

If the United States is to transition to water desalination as its primary means of producing water, extensive infrastructure development will be necessary. First, vast expanses of water desalination plants will need to be constructed along the coasts of the United States. Second, massive pipelines will have to be constructed to transport water to non-coastal regions. While the costs associated with construction and development are high, there are currently a number of countries relying heavily on water desalination and water pipelines to produce and distribute water.

Australia is currently investing $13.2 billion on desalination plants and the necessary pipeline infrastructure to provide potable water to five of its largest cities (ONISHI). Libya has long relied on water pipelines to supply its people and economy with water. In 1983, Libya spent $27 billion on 2174 miles of water pipeline (Suppes). This pipeline transports water from a Saharan aquifer to cities on the coast of the Mediterranean Sea.

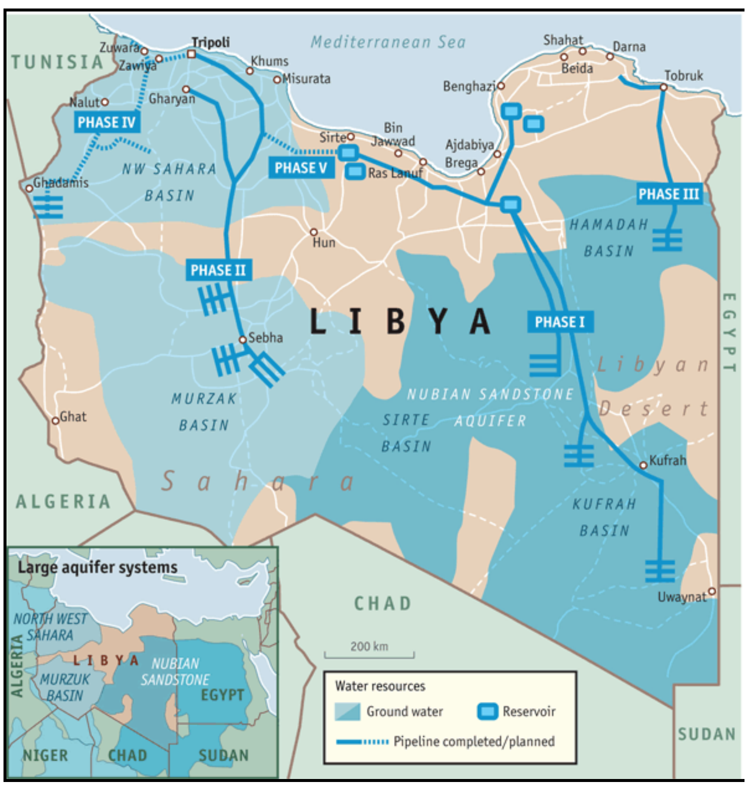


Figure 5

4. Water Laws and Regulations

4.1 Main Laws and Regulation

Legislation regarding water policy and regulation has been one of the most important components of American law since the late 18th century. The original water laws focused on establishing property rights for land owners in contact with water, while legislation in later years has started to focus on water purification and environmental concerns. As America expanded westward in the 19th and 20th centuries certain water rights and water allocation arrangements developed in correlation with the differing traditions and conditions. The law of water rights varies from region to region and state to state in an effort to establish fair and equal allocation. Areas that have surplus water reservoirs tend to need less complex legislation than other areas where demand exceeds supply. The eastern United States, which is generally more water rich than western America, adopted the classic riparian rights system; while, the western United States choose the appropriation doctrine style of legislation (Colorado).

4.1.1. The Riparian Rights System

The riparian rights system of the American east (roughly east of Kansas City) holds that if a landowner's property comes in contact with any body of water then he or she has the right to enjoy the benefit of a reasonable use of said water. Riparian rights also require that anyone else who has property connected to that same body of water must be allotted equal access and use of the water. Over the years there have been some changes in the fine print of the riparian rights. Early on the law stated that landowner must keep the natural flow of the river undisturbed to make sure that each riparian owner downstream was able to have the same natural water flow of water onto his or her property. The rule eventually mutated over time to a clause of "reasonable use" which allows each riparian owner to use the water as he or she sees fit. This means that the riparian owner can use the water without any concern for the natural flow as long as there is no unreasonable harm committed to any other riparian owner. This basic system of regulation worked well for many years until the population in the East boomed and water distribution became more of a struggle. To ease the water distribution struggle state governments began to superimpose the simple riparian rights with complex administrative schemes like permit systems. An example of modern riparian rights can be seen in Maryland's water laws and regulations. The following is an excerpt from Maryland's Court of Appeals describing the riparian regulation inside its borders;

> It is well established that the title to land under navigable water is in the State of Maryland, subject to the paramount right of the United States to protect navigation in the navigable waters. The owner of the fast land, however, has a common law right to land formed by accretion adjacent to the fast land and has the right of access to the navigable part of the river in front of his fast land, with the right to make a landing, wharf or pier in front of his fast land, subject, however, to general rules and regulations imposed by the public authorities necessary to protect the rights of the public. When the statutory law grants the right to a riparian owner to extend his lot or to improve out to the limits prescribed by the public authorities, the riparian owner receives a 'franchise-a vested right, peculiar in its nature but a quasi property of which the lot owner cannot not be lawfully deprived without his consent.' When the lot owner makes improvements in front of his lot, complete title then vests in him in the improvements provided it is in front of his lot and does not appropriate the riparian rights of his neighbors (Schwenk).

Many see this new aged superimposed riparian rights system as the key to safe and fair water regulation in the eastern United States (Colorado).

4.1.2. The Appropriation System

Unlike the riparian method, the appropriation system used in the western territories does not correspond with land ownership. The appropriation came about as a product of country's harsh conditions. The pioneers of the West originally viewed the Great Plains and as an uninhabitable desert because all of the barren land in relation to the little water resources. In an effort to solve the irrigation crisis and provide water for themselves the pioneers created a law of appropriation that is based off the concept of diverting water from its source for use in a beneficial manner. Generally speaking the first person who appropriated the water to whatever need he or she saw fit received the full right that that water supply, followed closely by the second person to use the water, and so on and so forth. This law even holds in times of water shortage; the oldest rights prevail. There are several hitches in the system to make sure that corruption does not leave the rich with water and the poor without it. One of these regulations is the clause that states public waters must be functioned in useful or beneficial purposes. Another is the claim that the appropriator can only use the exact amount he or she needs, and that he or she must revert any waste or return flow back to the original stream. The third and most important hitch in the appropriation system is that the appropriation rights are subject to abandonment. In other words, the rights transfer to the next in line once the water is stopped being used or is being used in an incorrect fashion. Colorado's water rights system is a great example of the appropriation system in working order. Colorado water law states that water usage is based on the priority of one's appropriation of a definite amount of water, at a certain location, for specified uses. In order to acquire an appropriation one must present a survey paired with an existing intent to make good use of the water. From there the appropriation slot is confirmed and the priority is determined in a proceeding within the state Water Court. In the state Water Court an application for a water right is processed by the appropriate segment of the seven water divisions covering Colorado. The applications include a legal description of the requested diversion and are then placed in order behind other claims requested in earlier years. The only exception to this process is held for federally owned lands including state parks for which water is reserved to supply the exact needs of those lands first. This system of appropriation works well for the water tight regions across the western United States and will hopefully continue to do so as conditions get worse is the future. Both the riparian and appropriation systems of water right regulation are keystones of state legislation. While they tend to focus mainly on property rights, the federal government's water laws and regulations focus on public health and protecting the environment (Colorado).

4.1.3. The Clean Water Act

There are numerous federal laws and directives that have come to fruition over the last century that have lead to better health and a better environment for the American people. Science and the adoption of the germ theory of disease led the Federal Government to protect its citizens against water born diseases including Typhoid fever and Cholera by purifying and regulating the nation's water supply. The Clean Water Act (CWA) is seen by many as the flagship piece of legislation in cleaning up America's water. Officially Passed by Congress in 1972, the CWA received its bearings from the Federal Water Pollution Control Act of 1948 which was the nation’s first federal attempt to clean American water. The CWA regulates industrial waste disposal into American waterways and implements numerous other regulatory actions to make sure millions of Americans have access to clean water. One of the biggest achievements of the CWA was the creation of the National Pollutant Discharge Elimination System (NPDES) which makes it illegal to dump any pollutant from a point source into navigable waters without a permit. Notably, the CWA does not pertain to groundwater nor water quantity issues. Groundwater quality and the quality other water sources that are not classified as navigable waterways are protected by other federal legislation (Summary).

4.1.4. The Safe Water Drinking Act

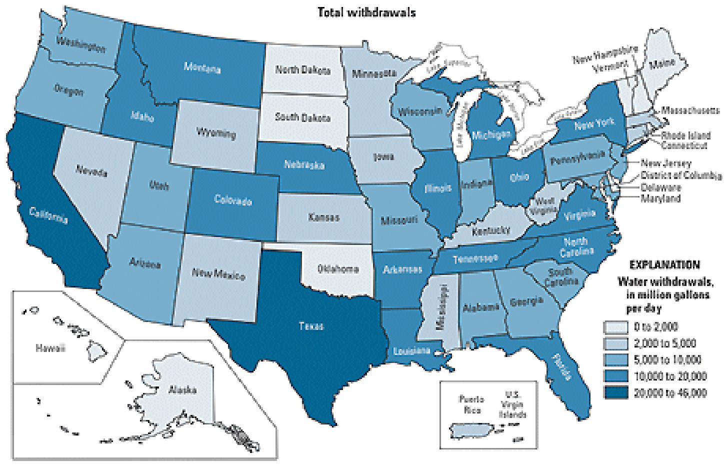
The Safe Drinking Water Act (SDWA), passed by Congress in 1974, is an example of legislation spreads to regulate the nation’s entire water supply including ground water. The law covers all major bodies of water but does not extend to private wells which serve fewer than 25 individuals. It requires that “all public water systems must have at least 15 service connections or serve at least 25 people per day for 60 days of the year”(Understanding). To ensure the drinking water is safe the SDWA protects against water contamination through source water protection, various treatments, and public information. The act was amended in 1996 to update the law and provide the public with a more transparent picture of the American water supply. The Amendment outlined the inclusion of consumer confidence reports, cost-benefit analysis, a drinking water state revolving fund, and a operator certification clause to name a few. Overall, the SDWA has been a very beneficial and productive piece of legislation that has saved millions of people’s lives (Understanding).

4.2 Fracking Law

4.2.1. The Federal Energy Policy Act of 2005

A big point of discussion currently under debate in the Senate and state court rooms across the country is hydraulic fracturing or fracking legislation. As of right now there is legislation in the federal Energy Policy Act of 2005 that has become known as the Haliburton Loophole which exempts gas drilling and extraction companies from following some of the requirements defined in the SWDA (Fracking). This loophole has allowed natural gas companies to use absurd amounts of freshwater from certain aquifers across the country and contaminate countless other freshwater sources. Congressional Investigations launched towards well know fracking firms have found that "32 million gallons of diesel fuel have been illegally injected into the ground as a fracking chemical in 19 different states from 2005 to 2009" (Fracking). That appalling statistic illustrates how widespread the use of fracking is in America and gives insight into how damaging it is to fresh water supplies. With no help in sight stemming from the federal government, states are beginning to step up and crack down on fracking. The Great Lake states recently passed the Great Lakes Compact which limits large water withdrawals, and there are over 100 bills from 19 different states that have been introduced since October 2010 that all deal with hydraulic fracturing for natural gas (Pless).

5. Water Use in the United States



(Image 1)

Are future generations of humans guaranteed water? In 2005, the United States Geological Survey estimated that Americans' withdrew around 410,000 million gallons of water total each day (Kenny). Water use in the United States is inefficient and not sustainable. Water should be viewed as the greatest recourse, not like a never-ending product. The necessary resource should always display diminishing waste. More firms and citizens have to get-involved in the preservation of the nation's water, so life can be extended. However, some states need greater reform than others such as: California, Texas, Idaho, and Florida which accounted for about a quarter of the every drop consumed in all fifty states (Maupin). For example, image one above conveys the obvious discrepancy between the States regarding water use. Additionally, most of the water withdrawn in America was for thermoelectric power, but industry, irrigation, public, domestic, mining, livestock, and aquiculture uses contribute to the absurd amount of water being consumed and wasted. The following piece will clarify, explore water withdrawals, and expose inefficiencies among water practices in the United States of America.

However, water use has been historically inefficient. Before the late-twentieth century, water was not regulated in America. The 1970's gave way to the Environment Protection

Agency, and many environmental bills like the Clean Water Act. The CWA remains to be the leading federal law battling water pollution (U.S. Congress). As the United States economy exploded so did water usage, but when the nation transformed from a manufacturing economy to a service dominated economy in the twentieth century water withdrawals diminished. For example, in 1985 industrial uses of water used about 25,800 million gallons per day, but by 2000 industries withdrew 19,700 million gallons a day (Helsel). The previous statement proves that the United States is using less water overtime. In fact, total industrial water withdrawals were 8 percent less in 2005 than during 2000 (Maupin). Besides, the natural drop off in the manufacturing sector, there were greater environmental regulations placed on firms requiring more efficient uses of water by United States industries.

5.1

Moreover, Industries that manufacture metals, wood products, chemicals, and petroleum products are major users of water. For example, most of the United States' manufactured products use water during some part of the production process. Water use in the industrial sector includes fabricating, processing, washing, diluting, cooling, and transporting. In addition, United States' industries used approximately 18,200 million gallons of water per day (total withdrawals of both saline and fresh water from 2005), and those figures calculate an annual water use estimate of 6,643,000 million gallons (Kenny). Industrial withdrawals were about four percent of America's total withdrawals, and Texas accounted for about 70 percent of the saline surface-water withdrawals for industry (Maupin). Furthermore, Louisiana, Indiana, and Texas accounted for almost 38 percent of total industrial withdrawals across all fifty states; whereas the largest fresh surface-water withdrawals were in Louisiana which has a very large coastline (Maupin).

5.2 Power Generation

Nevertheless, creating electricity for the nation via stream-controlled generators uses a significant amount of the water used. According to 2005 data, the process of generating electivity consumes just under half of the overall water withdrawals for the nation (Kenny). Moreover, water withdrawal for power generation is made up of 99 percent surface water, so about one percent ground water is used, and about 28 percent of the water designated to power plants is saline (U.S. Department of Energy). On average, about 195,000 million gallons of water per day is used for thermoelectric power (U.S. Department of Energy). Surprisingly, about only eight percent of the cooling systems in power plants across America have close looped systems, and 92 percent of these thermoelectric plants do not even reuse or clean the contaminated water (U.S. Department of Energy). Furthermore, about 85 percent of the power plants are located in the Eastern States, and the most of these plants are near the coast-line because so much water is needed for cooling thermoelectric generators (Kenny). Throughout the history of the United States water has not been seen as a non-renewable resource. Thus, the nations' gigantic thermoelectric power plant system erupted; inefficiently, banking off the abundance of surface water in America via two oceans, large lakes, and various rivers.

5.3 Irrigation

Furthermore, irrigation is the second highest user of water lower only too power plants which dominate overall use. In 2005, water used in America for irrigation totaled about 128,000 million gallons a day (Kenny). These uses included irrigation systems for both agricultural and recreational purposes, but did not include personal sprinklers. Watering systems are used on about half of all irrigated land in the nation, and three quarters of that land is located in the

Western States; where water is obviously highly demanded (Dickens). However, like the use of industrial demand for water over time the water use for irrigation has decreased. For example, in 2000 almost 137,000 million gallons of water were used for irrigation practices (Maupin). Despite increases of irrigated land and population, water uses have been diminishing in the United States.

5.4 Mining

Mining may be the most questionable sector that uses water in the United States, because as the demand for domestic oil increases, the demand to frack also skyrockets. For example, fracking shale rocks for petroleum can use up to eight million gallons of water per frack (Dickens). Mining can demand water for multiple uses such as: extracting substances like natural petroleum, gasses, and metals. This sector includes quarrying, crushing, filtering, fracking, and any other use for water associated with mining demands. Data from 2005 shows that water withdrawals for mining were about five million gallons per day (Kenny). However, mining water use can be forecasted to increase overtime. On the other hand, only about half of the water used for mining was fresh water, and the amount of water used was significantly less than thermoelectric water use.

5.5 Municipal Supply

Another form of water use in America is municipal supply; referring to water withdrawn by public and private water suppliers that distribute water to at least 25 places or have at least 15 connections (MacKichan). In 2005, municipal supply allocated an estimated ten percent of the total water used in the United States. Users of this water were families, businesses, and publicly paid officials. These uses included things such as: pools, parks, public buildings, firefighting and the dispensing of certain water lines. According to 2005 data 44,200 million gallons a day had been withdrawn for the use of the public sector (Kenny). Also it is one of the only sectors of water use that consumes more groundwater than surface water.

5.5 Rural Domestic Use

Also, domestic water uses are mostly groundwater, and these uses include all residential functions for water like showering and other natural reasons. Most of the 43 million people using this water are located in rural areas which have not been linked to any municipal water supply systems (Kenny). These people use wells and or any other private means to attain useable freshwater. This privately supplied water totaled about four thousand million gallons per day in 2005 (Kenny). Moreover, the greatest domestic withdrawals are in two states, California and Michigan (Dickens). These two States consume an estimated 15 percent of the total domestic withdrawals for the United States (Dickens). Although some States like Maine and Vermont have large rates of their total population using rural domestic water, but this domestic water use as a percentage of overall use appears obsolete.

5.7 Livestock and Aquiculture Use

Finally, livestock and aquiculture water withdrawals together make up about less than three percent of the total water withdrawals (MacKichan). Livestock uses could consist of water for animals, animal food, and dairy firms. Throughout 2000, water withdrawals for livestock were less than once percent of the total water used in the United States (Dickens). While Texas, Oklahoma, and California made up about half of the total one percent used. Furthermore, aquaculture uses include all water needed for the supply of water-living creatures. For example, in 2000 the amount of freshwater withdrawn for aquaculture was about 3,700 million gallons per day (Dickens). Idaho used the most water for aquaculture, and the State used about half of the total aquaculture water withdrawn in America (MacKichan).

In conclusion, even though American water use has been diminishing since the late-twentieth century, water use is unsustainable due to the vision of certain citizens and corporations whom take for granted the value of the precious resource. Water use needs to be consulted for the thermoelectric and irrigation sectors because, the smallest about of change for these two uses of water will positively impact overall water use the most. Also, mining and domestic water use must be regulated harsher in the future to confirm that freshwater will be around for future citizens of the United States of America. Moreover, the answer to the overlying question about the water supply is determined by the actions of Americans today.

6. The Economic Affects on Water Scarcity

With any scarcity, demand grows when there is a lack in comparable alternatives. Water scarcity is no different. As demand grows however, new production processes are developed and potable water is produced in many different ways. New production processes though often run a trial and error period before all production issues are settled; this leads to growing concerns as to where our water is coming from and how it is being produced or filtered. Currently less fresh water is becoming available everyday, but more is being demanded as a direct result of population growth. As a result, without an ample supply of funding for new clean water production processes, water quality may decrease and lead to questionable paths from where our water originated.

6.1 Quality Issues

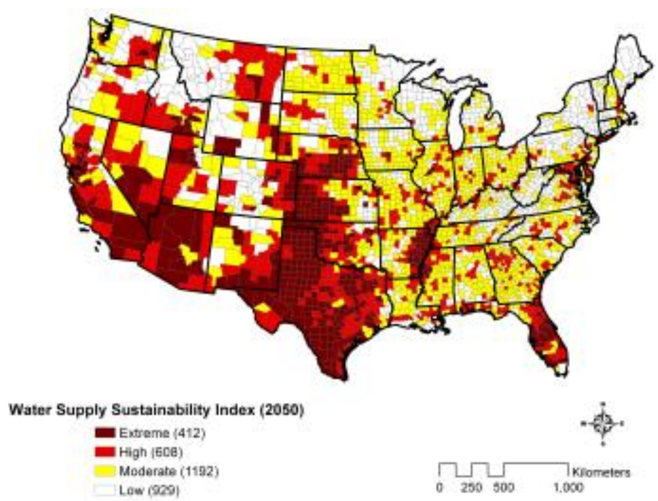
When a good is scarce, especially one that is used to sustain life many risks will be taken to consume a healthy quantity. This being said some would be willing to consume questionable water if costs for safe water are too high. Unsafe or properly filtered potable waters may "cause more diseases, thus increasing health concerns and human loss". (*Global Water Shortages Will Pose Major Challenges*)

Having to concern ones self with the origin of his or her water seems almost unthinkable. From most Americans earliest years they are taught that the earths natural water cycle will produce enough fresh water to sustain life. Consequently, a very small minority are concerned with fresh water and where it is coming from. The water cycle however with the introduction of metropolitan areas, energy production facilities, and mass agriculture production has been greatly altered to the point that many areas currently lack stable fresh water supplies or will very soon. Most quotes we have found on water scarcity so major concern for 2050, but the one below is much more appropriate for todays problem.

> "In 2003, the General Accounting Office, an investigative arm of the U.S. Congress, published a survey that found water managers in 36 states "anticipate water shortages locally, regionally or statewide within the next ten years."' (Schneider)

Being now one year away from the time cut-off quoted we can safely say 36 states are not at harm of immediate water scarcity risks; however, many do have rapidly approaching issues.

As stated earlier most water scarcity articles discuss the major concern surfacing around 2050. Sources predict as many as “70 percent of counties in the United States may face climate change-related risks to their water supplies by 2050” (Woody) Below we have inserted a graph from *Environmental News Service* to really show the issues we could face if change is not made.



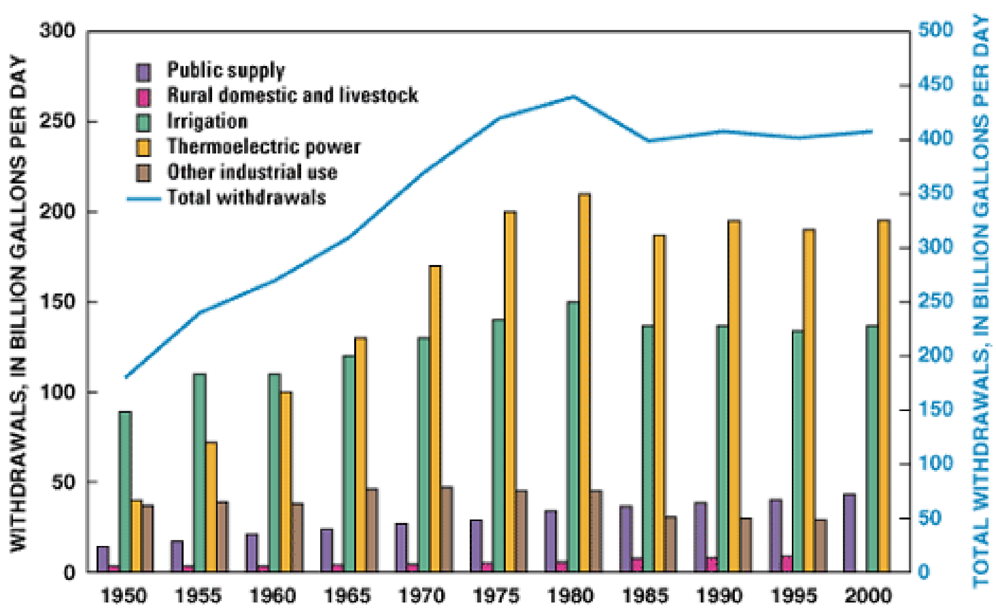
This chart shows “That 14 states face an extreme or high risk to water sustainability, or are likely to see limitations on water availability as demand exceeds supply by 2050.” (“Risk of Water Scarcity Increasing for 1,100 U.S. Counties.")

The major cause of increased water consumption and demand is population growth. With a steadily growing population and a rapidly increasing use of energy by said population everyday, water is being relied upon more and more to provide in every aspect of life. The use of fossil fuel power plants uses immense amounts of water every day, and because of there long standing dependable nature federal government data is predicting that the “U.S. will continue to use thirsty fossil-fuel power plants to generate electricity." (Woody) Data though seems to be very controversial on this subject with strong arguments for and against continued dependence on large coal-fired power plants. One statistic we found stood out more than the others: "About half the 410 billion gallons of water the U.S. withdraws daily goes to cooling thermoelectric power plants, and most of that to cooling coal-burning plants, according to the U.S. Geological Survey." (Boaz)

Renewable or green energy is not light on water use either. While most renewable energy plants cut down on overall emissions, which is also a cause for global warming and the disappearance of much fresh water by glacial melting, the start up costs are incredibly high. In 2009, "The U.S. dedicated 23 million acres of public lands in six states for new solar electricity-generating plants as part of its economic stimulus package, which apportioned nearly 100 billion dollars for clean energy projects." (Boaz) The plan was to build solar electricity-generating plants with water-cooled solar panels. The plan was great from an emissions standpoint, but terrible from the cost and water use standpoints. Furthermore the plan was intended for the United States Southwest region that is already known as an area strained by limited water resources while also currently under development pressures. Furthermore, while most reports state that coal-fired power plants use the most water of energy production processes, the National Park Service's Pacific West Region stated that "Solar generating plants that use conventional cooling technology use two to three times as much water as coal-fired power plants". (Boaz) This is just one of numerous examples of the negative cost implications that building new facilities may have on an already monetarily strained U.S. economy. While it may seem as new sustainable energy plants are not beneficial from a cost or water use view in the short run, it is not fair to say that with future freshwater production systems it will not be the best route for the future.

6.2 Energy and Water Consumption

Energy production is the major concern with water use today as a result of mans fixation on technology and advancement, but agriculture and irrigation are not far behind when it comes to water used. The agriculture sector uses the majority of ground water consumed and as shown below is second in total water consumption behind the aforementioned energy sectors. ("Water Use in the United States.")



6.3 Waters Effect on Agriculture

Agriculture growth is being seriously slowed as a result of water loss and its now higher costs to obtain. Because irrigation is so reliant on ground water and that is an ever lessoning source farmers are trying to find new methods and in general are having to spend more for the same or even less crop production than in previous years. One source stated,

> "In the future, irrigation may not be possible at all as the levels continue to drop past the well intakes of farmers. More likely, before the pumping stops, the cost of drilling and maintaining deeper wells may exceed the value of what can be grown, severely limiting the farmland's value." (Schneider)

Food must come from somewhere, and without a stable U.S. production imports will have to go up to support demand, likely increasing prices yet in another aspect of everyday life. (*Global Water Shortages Will Pose Major Challenges)*

6.4 Privatization of Water and the Cost/Quality Effects

While the major causes of the impending water problem have been determined it seems there is no real answer to fix or in many ways even slow inevitable scarcity from coming. That being said several methods have been tried, although only working with mixed results. The two major methods attempted to this point for slowing water scarcity have been water privatization and tariff systems. Water privatization has been big in many European countries and has attempted to expand into the U.S.; tariffs have been implemented in several areas nationally on small scales but because of a lack in success have been abandoned in most instances.

Water privatization is a big issue in the movie *Blue Gold*. The idea presented in the movie is that much like an electric company water will be bought from a company with all water consumed in that household coming directly from on of these suppliers facilities. This system was originally implemented in Georgia with limited success. The direction of water from the source to a specific facility and then to the house of consummation added additional costs along with quality degradation. Having to pay a higher cost for water ultimately lowered household's consumption but the lowered consumption came at an ultimately higher end cost. (Bozzo) The other method attempted has been to place a tariff on water consumption. The goal was to incentivize consumers to not waste or only use water if necessary by charging higher prices as water consumption rose. The major issue with the tariff system however was that it was difficult to apply costs based on use as apposed to a simple flat rate tariff. The only way to accurately charge for this specific case was to install use monitors that much like water privatization cost more to implement and enforce than actually achieved the intended goal of water and cost savings. (Smout)

6.5 The Water Cost Domino Effect

Water loss and rising costs with no real sign of slowing down could cause an incredibly negative domino affect both for individuals and the U.S. economy as a whole. Less water as seen increases costs in every sector of economic production. Water is not only essential for the human body but for the life of the economy through almost if not all production process. With a rise in the cost of water production costs for all economic sectors will rise and those costs will be directly imposed on the consumer. Higher everyday costs directly affect household's disposable incomes and their ability to support economic growth by recycling that income back into the economy. The affect of less monetary support in all aspects of the U.S. economy bars stimulation and future growth.

6.6 Positive Economic Effects

While most issues surrounding water scarcity are negative, several positives have arisen. People are now attempting to use less water in order to stretch the finite supply as long as possible, water saving technologies and products are one the rise that make everyday life more water efficient, and lastly new companies are beginning to surface with the goal of water savings and efficiency on their mind along with attempting to make up for the economic loss of other industries. (*Global Water Shortages Will Pose Major Challenges)* That being said, one could have an optimistic take on water scarcity because of the positive impacts on new production process's. The overall negative cost implications are much more likely to be of focus though when it comes to water scarcity and the future of the U.S. economy.

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IMAGE 1- http://www.treehugger.com/natural-sciences/good-news-water-use-in-the-us-less-in-2005-than-1975.html

FIGURE 1 - http://www.unep.or.jp/ietc/publications/techpublications/techpub-8d/F80122.gif

FIGURE 2 - http://www.aquatechnology.net/multieffectdiag.jpg

FIGURE 3 - http://www.oas.org/DSD/publications/Unit/oea59e/p110.GIF

FIGURE 4 - http://www.unep.or.jp/ietc/publications/techpublications/techpub-8d/F80123.gif

FIGURE 5 - http://4.bp.blogspot.com/-Y0CmpZZVlQs/TiwPq3aSdHI/AAAAAAAAB5I/As4yAi6ejqA/s1600/libya-water.gif