"Water, water, everywhere, nor any drop to drink"
- Rhyme of the Ancient Mariner, by Coleridge.

Without water there would be no life on Earth. We use it to maintain our health, agriculture, industry, and economic vitality. In fact, one of the main struggles of civilizations has been harnessing fresh water resources for the public good. It is ironic that, of all the water that exists on the planet, three percent is freshwater found in ice, lakes and rivers, and underground aquifers.

In the 21st century, global water supply has become a more serious issue every day, and this is even true in developed nations like the United States, where an abundant supply of freshwater is sometimes taken for granted. In 1800, the 5.3 million citizens of the United States enjoyed virtually unlimited supplies of clean fresh water. In 2009, the growing population of over 300 million is pushing the limits of the geography's natural resources. The U.S. currently finds itself in a state of water stress, using more fresh water than can naturally be replenished by the water, or hydrologic, cycle. This is true especially in areas that rely on groundwater found in aquifers, which accounts for 99% of all usable freshwater, but only accounts for 20% of human water withdrawals (Center for Sustainable Systems).

Take for example, the town of Orne, Tennessee. The town's usually reliable mountain water spring has been drying up earlier and earlier every summer, and the public water has to be rationed to only three hours a day during this season. Also in the Southeast, Atlanta's quickly drying reservoir has led to legal disputes between the states of Florida, Georgia, and Alabama. Another problem, according to Postel, is the over-pumping in northwest Texas that has caused groundwater supplies to shrink by 25%. Water concerns elsewhere in the country include groundwater resource pressure in the Midwest and the historically dry conditions of the Southwest. A study by The Canadian Centre for Climate Modeling and Analysis shows that climate induced changes in water supply should also be used in determining future water policy. Their data indicates decreasing average precipitation rates in the Southwest as the century progresses. If these model projections hold up, local populations will have even less fresh water than previously considered.

The first strategy that must be taken to combat this water problem is to accurately measure and account for all the water resources available in the United States. Since 1950, the United States Geological Survey (USGS) has issued a series of reports every five years estimating the water withdrawals by state, the amount of water allocated by each sector, and the sources from which the water was withdrawn.

Secondly, to allow for more effective water management, the usage of these water resources in relation to the demands of all aspects of American society must be known. The USGS reports on eight main categories of water usage in the U.S. The largest sector is thermoelectric power production, followed by irrigation, public supply, industry, aquaculture, mining, domestic, and livestock, respectively. Water use in the United States has changed along with the evolution of technology, population, and economic conditions. Since 1950, water use for thermoelectric power has increased by about 500%, and irrigation has increased by about 50%. It would follow that the most drastic reductions in water consumption should come from advancement in these two areas.

Current research has shown that total water withdrawals peaked around 1980, and have since leveled off despite a steadily increasing population. The U.S. Department of the Interior reports that overall water consumption is lower than in 1975 and 1980, even though the population has augmented by 30% and American household (domestic) use and public water usage have increased steadily since 1950. The USGS has also underscored the importance of knowing the limitations of the drinking water supply for our growing population. Continuing technological improvements in irrigation and energy production for water use is of the utmost importance, but in order to reduce water consumption even further, advancements must be made in public and domestic use.

In addition to improving water management practices, the looming water shortage situation has necessitated the investigation into expanding sources from which the U.S. obtains its water. Fresh water development would transpire through new treatment technologies, preventing water pollution, taking new approaches to water storage, and creating social and economic tools to optimize spending and encourage acceptance of new management techniques.

In this paper, we will seek to incorporate this knowledge and these strategies to solve the nation's water constraints in the most cost-effective means possible. This will develop through efficiency in management, conservation, policies, and innovative technologies. We will seek to continue existing programs that serve to stabilize water consumption in the face of rapid population growth and high maintenance lifestyles, expand desalination and similar approaches to gaining new fresh water sources, and incorporate new methods to minimize the environmental, economic, physical, and cultural effects of these programs.

"When the well is dry, we learn the worth of water"

--Benjamin Franklin

General Assumptions for all Models:

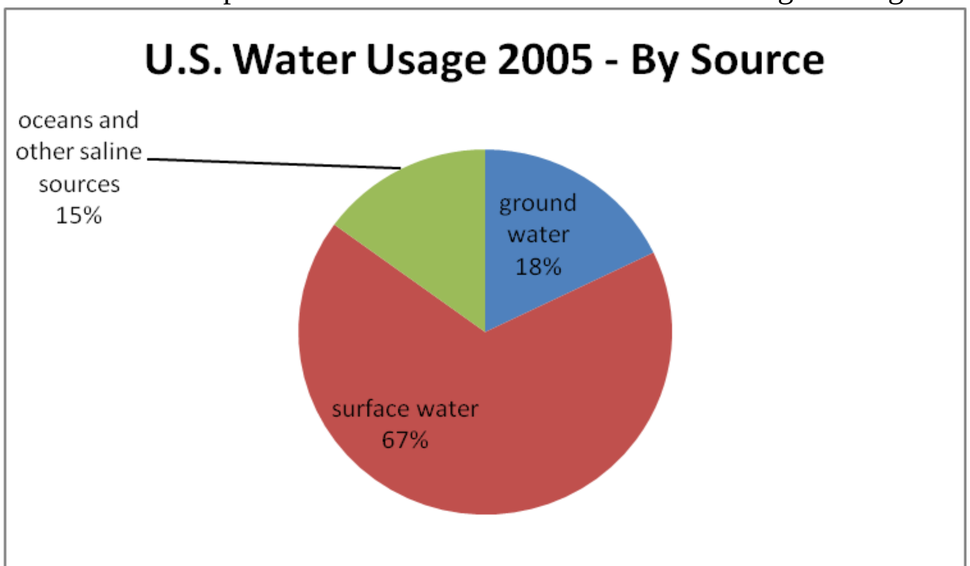
1. The population of the United States will increase at current rates and will reach about 353 million by the year 2025 (US Census Bureau)
2. Total water consumption equals the total consumption from the following eight categories as defined by the U.S. Geological Survey: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and aquaculture.
3. Current water management methods are not sufficient to allow for long term U.S. sustainability.
4. New technologies for water management, desalinization, transport, storage, etc. will become cheaper over time.
5. Utilizing water stored in icecaps and glaciers is not an economically feasible method of obtaining fresh water. The best option for expanding fresh water resources, therefore, lies in saline water.
6. Groundwater sources are basically non-renewable on a short-term basis. Groundwater provides 31 percent of the water used in U.S. agriculture and is, on average, being depleted 25 percent in excess of recharge rates (New Water Supply Coalition)

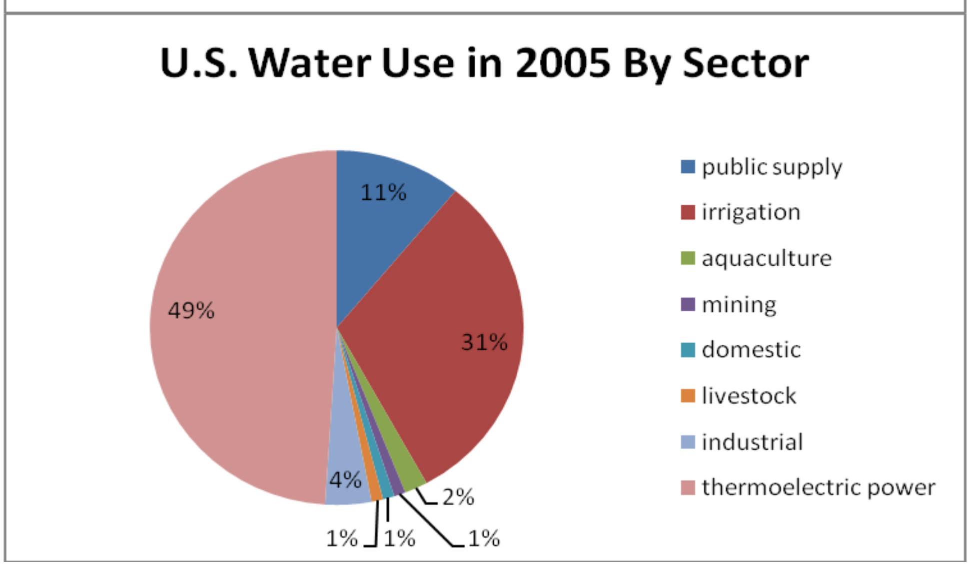
Determining current water withdrawal:

Our first approach in solving this problem was to research the current situation in terms of national water use.

The USGS reports that the total freshwater and saline water withdrawals were 410,000 million gallons per day, or 408 billion gallons per day. Surface water withdrawals made up approximately 67.15% of the total (273,972 Mgal/day), groundwater withdrawals made up about 18.15%, or 74,052 Mgal/day , and the remaining 15% (61,200 Mgal/day) consisted of saline water withdrawals in the form of seawater and brackish costal water.

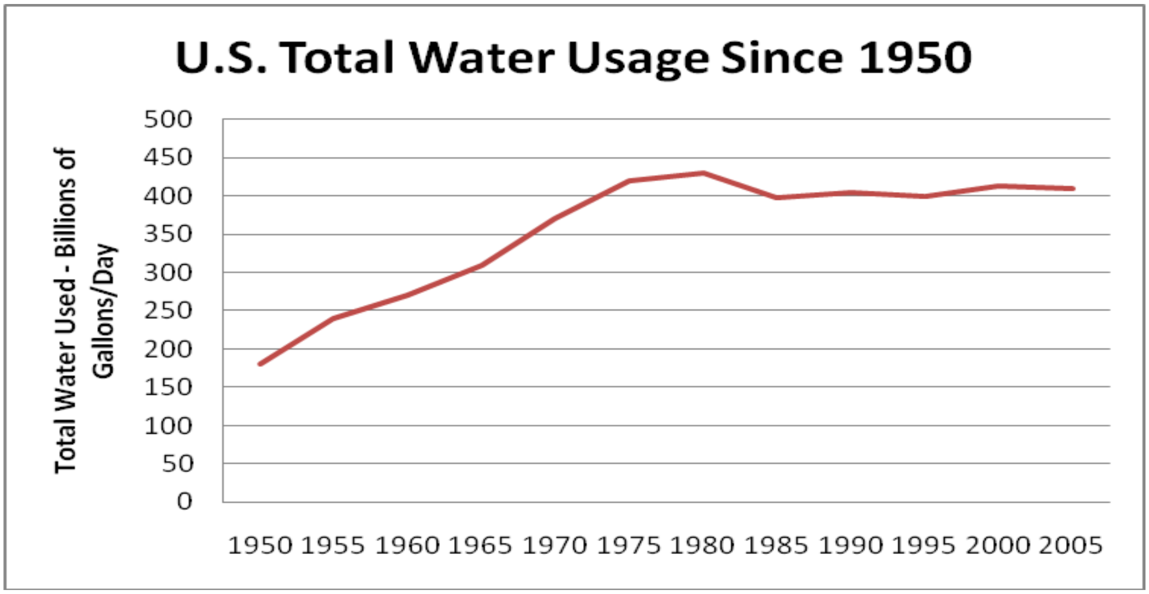
The USGS also reports the current distribution of water through the eight main sectors.



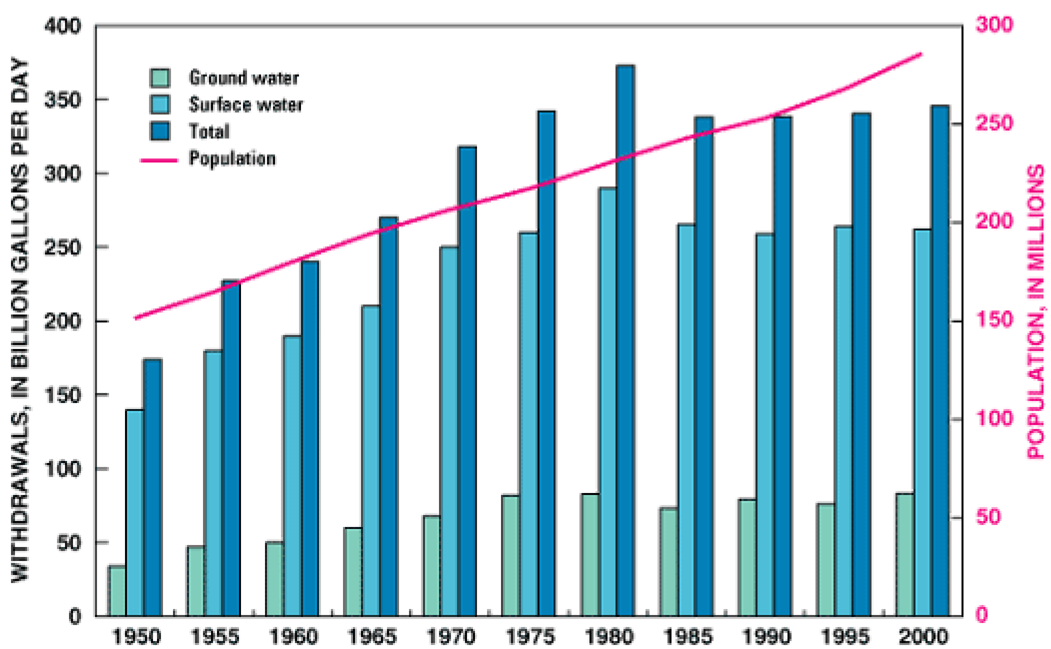


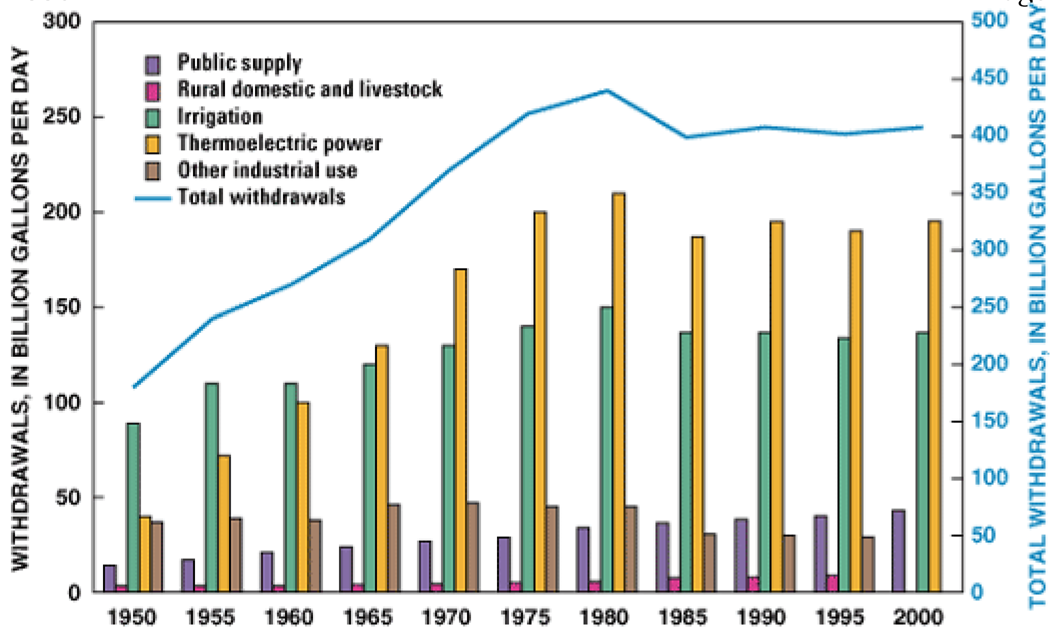
Calculating/estimating water consumption in 2025:

Using USGS reports from 1950, we were able to see the overall trend in water usage.

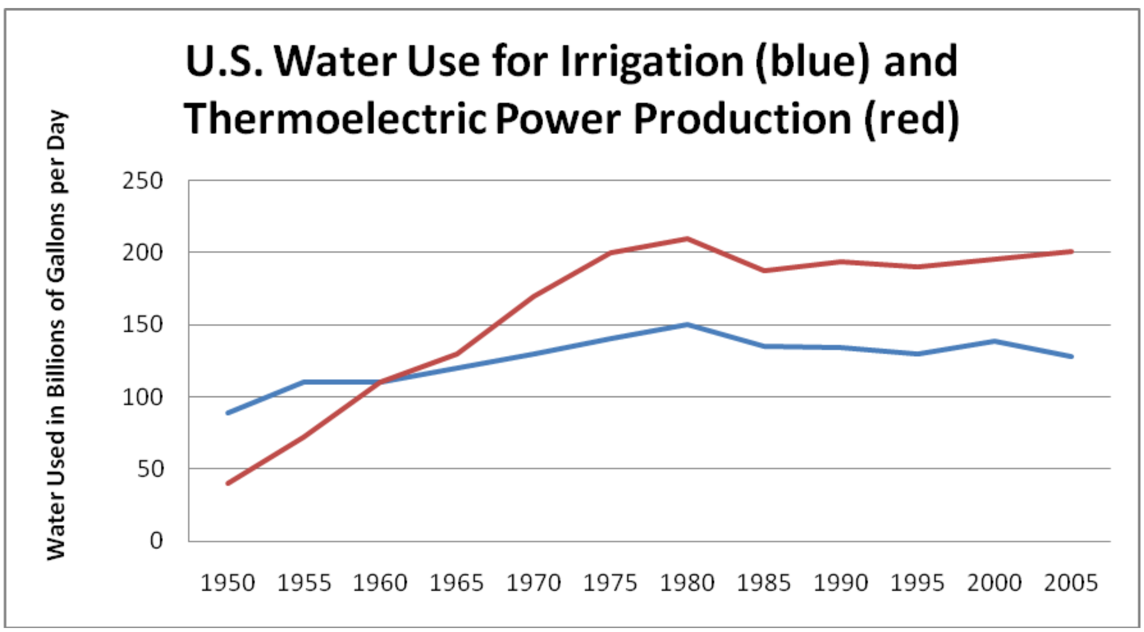


Withdrawals seemed to have peaked in 1980, and since 1985, withdrawals have remained relatively constant. At the same time, population has been increasing at a steady rate.

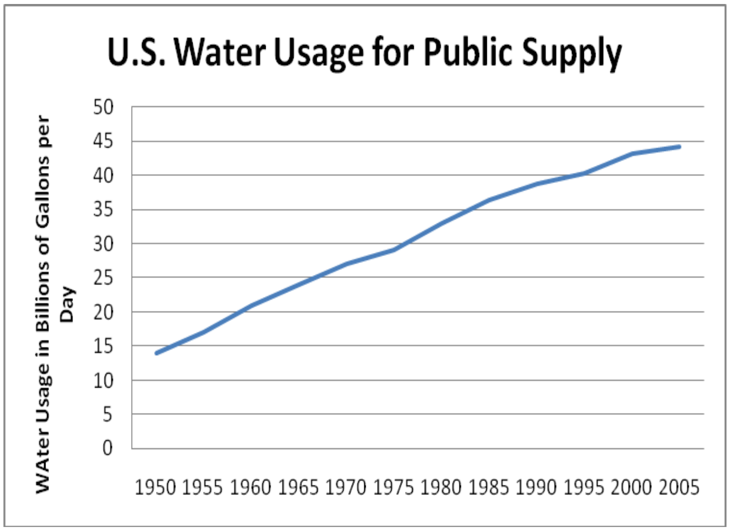


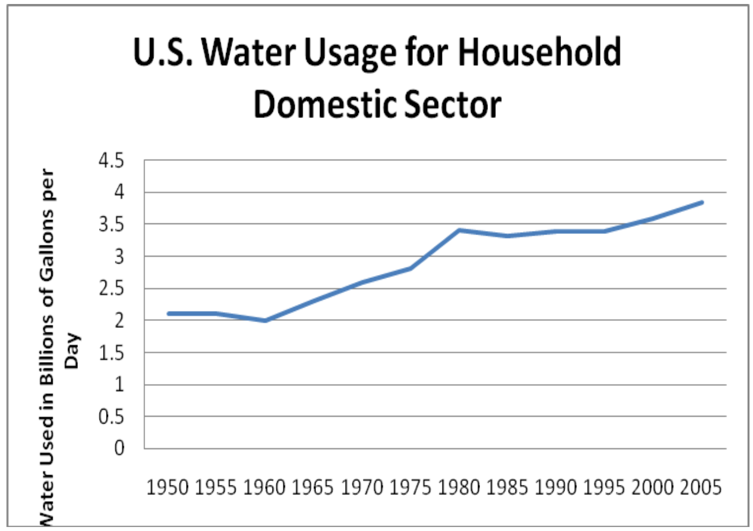


Water usage in different sectors has exhibited different growth over the years. For example, irrigation and thermoelectric power water use has steadied in recent years due to better management practices and more efficient technologies:



Meanwhile, water use in the public sector and household domestic use has steadily increased since 1950, necessitating the need for better conservation practices:





From these trends, we can calculate that the total water usage in the year 2025 will be equal to approximately 497.8 billion gallons per day, or **181,681** billion gallons of water per year.

<u>Strategies for our models:</u>

Our models seek to implement several strategies:

- Water conservation through public supply and domestic use.
- Reduce reliance on groundwater by 2025. This goal is driven by the fact that groundwater is essentially non-renewable on a short term basis.
- Increase reliance on desalinized saline water
- The remaining groundwater sources that are not replaced with desalinized water will be compensated for by expanding surface water resources.
- Be reasonable – we can’t spend hundreds of billions of dollars on desalinization projects.

Our Modeling Goals: Reducing Groundwater, Minimizing Costs

Background:

"If we could ever competitively, at a cheap rate, get fresh water from salt water, that would be in the long-range interests of humanity which would really dwarf any other scientific accomplishments."

--John F. Kennedy, 1962

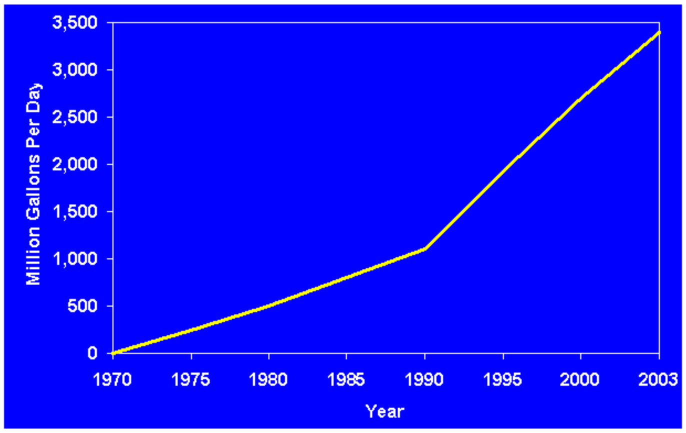
Our models seek to reduce reliance on groundwater and surface water by the year 2025. It analyzes two variables: water withdrawal and cost. We aim to model the projected cost of reducing groundwater and surface water consumption for various amounts. Our first goal is to greatly expand desalinization technologies to effectively replace groundwater usage.

Worldwide, desalination plants produce over 3.5 billion gallons of potable water every day. The most obvious source of saline water for use by these technologies is the oceans, but there are also vast reserves of naturally brackish water that could potentially be utilized. The lower concentrations of salts in brackish water would offer a more economically feasible proposition than pure seawater. The economics of desalinization are daunting, however. Processes that rely on boiling water use a significant amount of energy which makes large scale manufacturing prohibitive. New techniques such as using multiple chambers and decreasing pressure to reduce the water's boiling point have helped, but this has been almost entirely limited to wealthy and energy-rich nations on the Arabian Gulf.

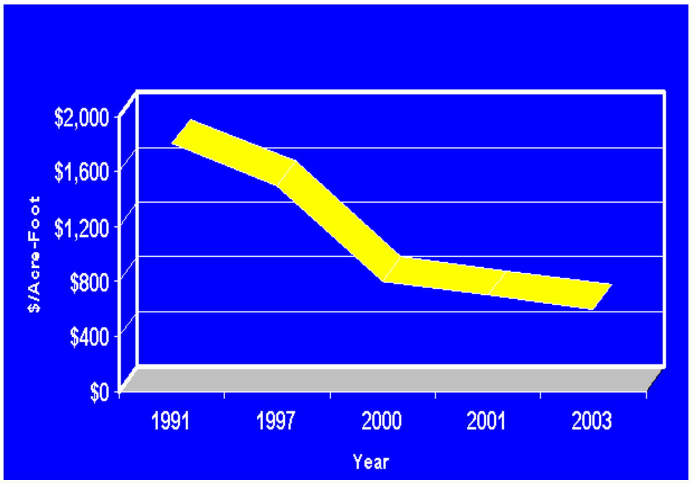
Another method of desalinization that requires low technology and low energy is solar distillation, but the vast area requirements and facility locations make this process exorbitant. The future hope of desalinization technologies lies in membrane technologies such as reverse osmosis (RO). This process is now widely used in decontamination, purification, and recycling, and its potential for desalination is rising. Put simply, membranes allow the passage of water molecules while excluding the passage of contaminants such as salt.

The world's largest RO facility is in Ashkelon, Israel, which produces approximately 87 million gallons of desalinized water per day. In the United States, current projects include the Carlsbad Desalination Project in San Diego, which produces about 50 million gallons of desalinized water per day and the Tampa Bay Seawater Desalination Plant in Florida, which is designed to produce and output of 50 million gallons.

This graph indicates how breakthroughs in membrane technology have resulted significant increases in RO desalination plant production worldwide.



Cost remains the main problem that we must overcome. RO remains an energy intensive method, but far less so than any thermal distillation plants typically found in the Middle East. Developments in desalination technology, the transition to construction of large capacity plants, and the collocation of power generation facilities and desalination plants has resulted in a dramatic decrease in the cost of fresh, desalinized water.



The trend of desalinated cost of water based on recent seawater RO desalination projects in the US, Israel, Cyprus, Singapore and the Middle East (Poseidon Resources Corporation).

Assumptions specific for Model 1:

1. Brackish water costs \$1.64 per 1000 gallons to desalinize and seawater costs \$2.50 per 1000 gallons to desalinize.
2. Of current desalinization programs in the U.S., approximately 55% utilize brackish water sources and 45% utilizes seawater sources. These proportions will remain constant through the year 2025. Using these proportions and the costs from assumption 1, we can assume that desalinizing all types of saline water will cost an average of, (.55)(1.64) + (.45)(2.50) = \$2.03 per 1000 gallons.
3. The prices of extracting and utilizing groundwater and surface water are \$0.50 and \$0.90 per 1000 gallons, respectively. These prices will remain constant through the year 2025.
4. Reductions in groundwater withdrawal will result in a direct increase in saline water withdrawal in respect to the correct proportions mentioned in assumption 2. Additionally, increases in total water usage will be compensated for only with increases in saline water withdrawal. The amount of available groundwater is decreasing, and the cost of desalinization is decreasing, making an increase in saline water withdrawal an economically and conservatively attractive option for long-term sustainability.
5. All current desalination plants will work to current potential through 2025. We can validate this because most of these plants have been built in the past 15 years.
6. New desalination plants will have a lifespan that extends past 2025, and will operate to full potential.
7. The 2005 surface water extraction (in gallons) will remain constant through 2025.
8. All water plants will be able to store water for use in peak times.

9. The rate of increase of groundwater (r) usage will remain constant through 2025. A negative “r” will indicate a decrease in usage.
10. The rate at which groundwater withdrawal reduction is constant for all aquifers across the U.S.
11. The average cost of a desalination plant will account for the low number of high-production plants and the high number of low-production plants.
12. The costs of extraction for each type of water source as stated in assumptions 1 and 3 incorporate power, operation, extraction, maintenance, etc., but not the initial plant construction costs.
13. No new surface water or groundwater facilities will be built through 2025.

Model 1 Equation and Calculations:

$$C_T = 575.7584 - 394.052(1+r)^{15}$$

Where C_T equals the total cost of water withdrawal and processing for the year 2025, recognizing that groundwater resources will need to be changing at a rate "r".

Step 1:

The total amount of water withdrawal in the United States is given proportionally as:
67.15% surface water, 17.85% groundwater, and 15% saline water.

We first define C_T as the total cost of groundwater withdrawal "x", surface water withdrawal "y", and saline water withdrawal "z".

Based on USGS data, we can predict the total water usage in the year 2025 as 497.8 billion gallons per day, or **181,681** billion gallons of water per year. From this value, we can determine the 181,681 = x + y + z.

We defined the amount of water withdrawn from surface sources "y" as constant. This value will be equal to the proportion of usage from surface water (as given in our assumptions) times the total projected gallons in 2025, or y = (.6715)*(181681) = **121,998.79** billion gallons per year.

We defined that "x", the amount of groundwater withdrawal, will decrease each year in accordance with the goals of our model. We can describe "x" by the equation,
$x = N_o(1+r)^{15}$, where N_o= the original groundwater withdrawal in 2025 as defined by the USGS in 2005, and r = the rate of increase of groundwater withdrawal. Our exponent of 15 comes from the number of years (2025 – 2010). We assume that N_o will remain constant from 2005 through 2025, and we can calculate N_o = (.1785)(181681) = **32,430.06** billion gallons per year. "r" will be a negative number because the rate is decreasing over time.

Our goal in this model is to gradually replace groundwater with saline water ("x" with "z"). We can therefore define "z" as z = 181,681 – y – x. We substitute our values for "y" and "z" to derive the equation $z = 181{,}681 - 121{,}998.79 - 32{,}430.06(1+r)^{15}$, which simplifies to
$\mathbf{z = 59{,}682 - 32{,}430.06(1+r)^{15}}$**.**

Using our assumed costs for water consumption from different sources (assumptions 2 and 3), we derive total cost as, $\mathbf{C_T = .5x + .9y + 2.03z}$, where the coefficients represent the costs per 1000 gallons. Substituting in our equations representing "x", "y", and "z", we can define
$C_T = .5(32430.06(1+r)^{15}) + .9\,(121998.79) + 2.03(59682 - 32430.06(1+r)^{15})$, which simplifies to
$\mathbf{C_T = [230{,}953.37 - 49{,}617.99(1+r)^{15}]/1{,}000.}$

<u>Step 2:</u>

We expand upon this equation by noting that new desalination equipment will need to be constructed in order to meet our needs. Our new equation, therefore, is $\mathbf{C_T = .5x + .9y + 2.03z + C_m(m)}$.

C_m is defined by the average cost of a desalinization plant. It is important to note that these costs are different for seawater and brackish water plants, so we use C_m = .55(Brackish average cost) + .45(Saltwater Average cost) = .55(22.95) + .45(326.5) = **$0.15955 billion.**

"m" is the number of desalination plants needed for 2025. We can therefore define "m" as the difference in gallons of saline water between 2025 and 2010, divided by the average output of each machine. Thus, $m = \frac{z_{25} - z_{10}}{O}$, where "O" is the average output (found to be 17.28 billion gallons per year) and "z_n" = the gallons of saline water production.

With O = 17.28 billion, $z_{25} = 59{,}682 - 32{,}430.06(1+r)^{15}$ as defined in part 1, and z_{10} = (the 2010 proportion of saline water usage)*(the 2010 total water usage in billions of gallons per year) = (.15)(148920), we can determine that $m = [(59682-32430.06(1+r)^{15}) - .15(148920)]/17.28$, and more simply,

$$\mathbf{m = (37344 - 32430.06(1+r)^{15})/17.28}$$

We therefore rewrite the cost equation obtained in part 1 to include $C_m(m)$.

$$C_T = [230953.37 - 49617.99(1+r)^{15}]/1000 + 0.15955[(37344 - 32430.06(1+r)^{15}]/17.28)$$

Simplification in terms of "r" and a constant value allow us to derive at our final model of

$$\mathbf{C_T = 575.7584 - 394.052(1+r)^{15}}$$

<u>Model 2:</u>

$$\mathbf{C_T = 1{,}840.061 - 349.052(1+r)^{15} - 1264.3(1+S)^{15}}$$

Where C_T equals the total cost of water withdrawal and processing for the year 2025, acknowledging that surface water resources will be changing at a rate "S".

We build upon Model 1 by acknowledging that the current surface water usage "y" will likely not remain the same through 2025. We will define this rate of change as "S".

From Model 1, we have:

$\mathbf{x = 32{,}430.06(1+r)^{15}}$ and

Now, we derive $\mathbf{y = 121{,}998.79(1+S)^{15}}$

Remembering that 181,681 = x + y + z and z = 181,681 – x – y, we will define "z" in Model 2 as

$\mathbf{z = 181{,}681 - 32{,}430.06(1+r)^{15} - 121{,}998.79(1+S)^{15}}$**.**

Our total cost equation from Model 1 part 1, $C_T = .5x + .9y + 2.03z$, will now be redefined as $C_T = .5[32{,}430.06(1+r)^{15}] + .9[121{,}998.79(1+S)^{15}] + 2.03[181{,}681 - 32{,}430.06(1+r)^{15} - 121{,}998.79(1+S)^{15}]$, which can be simplified to

$\mathbf{C_T = 368{,}812.43 - 49{,}617.992(1+r)^{15} - 137{,}858.6313(1+S)^{15}}$

Recalling from Model 1 part 2, we must now redefine $C_m(m)$ to be included in our cost equation $C_T = .5x + .9y + 2.03z + C_m(m)$.

C_m, the average cost of a desalination plant from Model 1, is still **\$0.15955 billion**.

"m", the number of new desalination plants needed for 2025, remains defined as

$m = (z_{25} - z_{10})/O$. We substitute in our new value of "z" to obtain

$$\mathbf{m = [181{,}681 - 32{,}430.06(1+r)^{15} - 121{,}998.79(1+S)^{15} - 22{,}338]/17.28}$$

Multiplying our new values for "m" and "C_m" together, we develop that

$$\mathbf{C_m(m) = 1{,}471.249 - 299.4338(1-r)^{15} - 1{,}126.442(1-S)^{15}}$$

Substituting this back into our original cost equation of $C_T = .5x + .9y + 2.03z + C_m(m)$, we obtain our final equation for Model 2 as:

$$\mathbf{C_T = 1{,}840.061 - 349.052(1+r)^{15} - 1264.3(1+S)^{15}}$$

<u>Model 3:</u>

$$\mathbf{C_T = 1{,}840.061 - 349.052(1+r)^{15} - 1264.3(1+S)^{15} - C[181{,}681 - 32{,}430.06(1+r)^{15} - 121{,}998.79(1+S)^{15}]}$$

Where C_T equals the total cost of water withdrawal and processing for the year 2025, recognizing that the cost of desalinization will decrease by a value "C" by the year 2025.

We recognized in our assumptions that the price of desalinization technologies will decrease through the year 2025, and Model 3 seeks to incorporate this change in expansion of Model 2.

Recalling our total cost equation of $C_T = .5x + .9y + 2.03z + C_m(m)$, we will now define the coefficient of "z" to be (2.03 – C), where "C" is the reduction of cost by the year 2025.

Only looking at (2.03 – C)z, we can substitute our value for "z" obtained in Model 2 to receive **$(2.03 - C)[181{,}681 - 32{,}430.06(1+r)^{15} - 121{,}998.79(1+S)^{15}]$.**

Identifying that, in distributing our new variable "C" into "z", we can simplify calculations to have an extra term decrease the final equation obtained in Model 2. Thus, we derive

$$\mathbf{C_T = 1{,}840.061 - 349.052(1+r)^{15} - 1264.3(1+S)^{15} - C[181{,}681 - 32{,}430.06(1+r)^{15} - 121{,}998.79(1+S)^{15}]}$$

Testing and Analyzing our Model:

We realize that our Model 3 is the most realistic of our approaches. We aimed to decrease reliance on ground water sources and surface water sources, while increasing the amount of saline water sources implemented through desalination techniques. We will test our equation from Model 3 with the following goals:

- Reduce groundwater withdrawal by 10% by 2025.
- Reduce surface water withdrawal by 5% by 2025.
- Consolidate for these reductions with stepped-up desalination.

In order to reduce groundwater by 10%, we need to define “r”. We can set $(1+r)^{15} = .9$, to find

r = 0.007.

In order to reduce surface water by 5%, we need to define “S”. We can set $(1+S)^{15}=.95$, to find

S = 0.00341

We will also incorporate a decrease in average desalinization costs of $1 per 1000 gallons, giving

C = 1.

Results:

Analyzing first the values “C_m” and “m”, we calculate that to meet our set goals,

- **m = 828.06**. This is the number of new desalinization plants operating at average productivity that needs to be built. This would have to be rounded up to **829.**

- C_m, calculated in model 1, remains $0.15955 billion. Multiplying this with “m”, we determine that $C_m(m)$ = Total cost of plant construction = **$131.64 billion**
- Examining the whole equation given to us in Model 3, we calculate that our plan will cost a total of **$288.21 billion.**

<u>Conclusion and Position Paper:</u>

Addressing the United States Congress:

Without water there would be no life on Earth. We use it to maintain our health, agriculture, industry, and economic vitality. In fact, one of the main struggles of civilizations has been harnessing fresh water resources for the public good. It is ironic that, of all the water that exists on the planet, three percent is freshwater found in ice, lakes and rivers, and underground aquifers.

In the 21st century, global water supply has become a more serious issue every day, and this is even true in developed nations like the United States, where an abundant supply of freshwater is sometimes taken for granted. In 1800, the 5.3 million citizens of the United States enjoyed virtually unlimited supplies of clean fresh water. In 2009, the growing population of over 300 million is pushing the limits of the geography’s natural resources. The U.S. currently finds itself in a state of water stress, using more fresh water than can naturally be replenished by the water, or hydrologic, cycle.

The first strategy that we took to combat this water problem was to accurately measure and account for all the water resources available in the United States. The USGS has issued reports on the statistics of U.S. water usage every 5 years since 1950, and with this data we were able to predict trends in water use through to the year 2025. Mathematically, we strove to create a model that would accurately predict the costs of various water management practices.

Our main approach was to limit national reliance on the current majority sources of fresh water – ground water and surface water – and to expand desalination methods to compensate for these reductions. We aim to model the projected cost of reducing groundwater and surface water consumption for various amounts, and our first goal is to greatly expand desalinization technologies to effectively replace groundwater usage.

Worldwide, desalination plants produce over 3.5 billion gallons of potable water every day. In the United States, current projects include the Carlsbad Desalination Project in San Diego, which produces about 50 million gallons of desalinized water per day and the Tampa Bay Seawater Desalination Plant in Florida, which is designed to produce and output of 50 million gallons. The strengths of our model are that it allows us to set our own terms, whether that be monetary constraints, groundwater reduction, or surface water reduction. We recognize that meeting water resource needs for the future is the most important goal of our model, and from this constraint we can determine our overall financial needs.

Our math strove to meet the following three goals: 1. Reduce groundwater withdrawal by 10% by 2025; 2. Reduce surface water withdrawal by 5% by 2025; 3.Consolidate for these reductions with stepped-up desalination.

Anticipating reductions in the cost of desalination technologies, we have derived the following results:

1. The United States needs to build approximately 829 new desalination plants across the country, retaining a ratio of 55% for seawater desalination and 45% for brackish water desalination.

2. The estimated cost of construction of these new plants is $131.64 billion.
3. Adding in the cost of withdrawal and utilization of groundwater, surface water, and desalinized saline water, we have produced a final necessary cost of $288.21 billion. Divided by the 15 year timeframe of the plan, we ask that the government allocate about $25 billion a year for our model.

Currently, it is becoming more evident around the world that desalinization remains our best hope for a sustainable fresh water future. In the United States, a dramatic increase in proposed desalinization plants such as this one are running into increasing opposition from environmental and economic groups. We have addressed the financial concerns with a proposal that we believe is realistic and economically feasible, but the environmental concerns remain unaddressed.

We strongly advise that desalination sites should be designed, operated, and planned to minimize environmental impacts. The outflows of brine (the waste of desalination plants) need to avoid sensitive marine areas and incorporate adequate dilution. We propose that improvements be made in technology to use less energy, or couple desalination plants with thermoelectric plants. Also, safe disposal of the residual salts and other chemicals is of the utmost importance. A case study in Greece has shown a zero-discharge plant is feasible through that coupling desalination plants with solar salt works (Laspidou, 2009) that . Intake wells of these plants must also be carefully designed so as not to harm the ocean ecosystem from which they are taking water.

Desalination inherently creates an increased demand for energy. Presently, a majority of the U.S. energy is generated from coal-fired power plants which release large amounts of carbon dioxide and pollutants such as sulfur and mercury recognized to have a negative effect on the environment. For this reason, we advise desalination plants pair with renewable energy resources such as wind, hydropower, and solar power. However, new technologies which reduce the energy need of desalination processes and utilize novel desalination methods such as solar distillation, geothermal, and the Passarel process should be researched and developed to reduce cost. We also recommend that fewer, larger desalination plants be built, as opposed to the large number of average production plants proposed in our model. We have provided a list of the most strategic locations for new desalination plants.

<u>Proposed Desalination Plant Locations</u>

1 – Seattle, Washington – to provide for the Pacific Northwest

2 – San Jose, California – to meet demands due to population growth and agriculture in the arid Southwest

3 – Los Angeles, California – to provide water for one of the nation's largest cities

4 – San Diego, California – same as #2

5 – Corpus Christi, Texas – for transportation inland for crop irrigation (to counteract reduced groundwater withdrawals)

6 – Port Arthur, Texas – same as #5 and to provide water for Dallas and Houston

7 – Gulfport, Mississippi – for agriculture, industrial, and domestic use in the Southeast

8 – Panama City, Florida – to provide water in a region where saltwater intrusion has affected groundwater resources

9 – Savannah, Georgia – same as #7

10 – Boston, Massachusetts – to provide water for the Northeast

Current Plants:

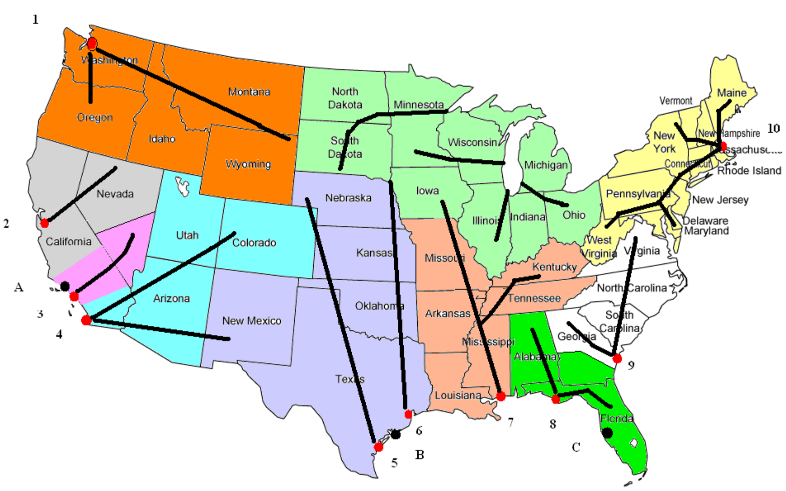
A – Los Angeles, California

B – Houston, Texas

C – Tampa Bay, Florida

Proposed Transport and Storage Methods:

The issue of transporting vast amounts of desalinized freshwater lies not with within the states, but rather with getting the resources to the inland states from the coast. We analyzed possible water transportation methods and concluded that pipelines would be the most cost-effective and environmentally friendly method. Our main goal was to build pipelines from our main plant locations listed above to all the necessary states inland.



We calculated that half the distance between Corpus Christie, TX and Seattle, WA would be the essential length of pipeline extending from each plant. We can determine the total cost of this transport through the equation

(distance)*(number of plants)*(gallon flow for each plant)*(cost per gallon per kilometer) = Cost

1879.762km*10*(18.1681 million per year)*.0106 = **$3.62 billion per year**

The total distance used by pipes is 1879.762 km, even though they are broken up unevenly to reach all states. This distance was calculated using Mapquest directions.

This is the cost for transporting the water, and we add to this the cost of building all of the pipes. This cost is calculated to be (distance)*(# of plants)*(price per km) = 1879.762*10*(0.0044703) = $84.03 billion. It should be noted that this is a one-time cost, unlike our yearly proposal for plants and transport. Also, there is a substantial amount of existing pipeline already in place that would decrease this cost drastically. Most pipelines are state-run, but our proposal to Congress is building federal inter-state pipelines for water transport.

Water storage will be left to existing in-state facilities because although more water is being pumped into states, most of the storage in aquifers and other natural sources increases to compensate for this increase; we did not factor this into our costs.

Effects of Our Model:

Cultural effects include legislation made by politicians that affects domestic decreases in water use and public supply reductions. The EPA mandates federal laws such as the Marine Mammal Protection Act, the Safe Water Drinking Act, the Clean Water Act, the Endangered Species Act, and the Wetland Protection Act, and the National Environmental Protection Act (NEPA). These policies restrict the amount of environmental degradation that came be imposed on certain areas of the environment, therefore, the strategic placing of our desalinization plants could not break any of these laws. Also, there are mandates that impose that certain restrictions desalinization plants, such as regulations on the quality of drinking water and limitations on the placement of output sources. Other cultural effects include humans conserving water through raised awareness.

One of the largest uses of freshwater is agriculture. The country can immediately conserve its water supply by instituting several changes to irrigation techniques in farming. First, convert farmland which currently uses inefficient surface systems (flood, furrow, and corrugate) to much more efficient micro-irrigation, center pivot sprinkler, and moving lateral sprinkler systems. Research indicates these methods can increase application efficiency to 85-95%. Furthermore, the government should encourage farmers to avoid planting water-thirsty crops in desert regions and time irrigation to avoid watering during the hottest hottest/windiest waters of the day to reduce water loss due to evaporation. These described methods will also preserve water quality and save money.

The physical effects of our model mostly deal with the difficulties that arise with transportation. Mountain ranges and other geographical altitude changes cause problems when trying to transport, and more energy is required to overcome these geographical obstacles. However, regions reap the benefits of our model through the placement of out desalination plants and transportation pipelines. The water is being transported mostly to regions with high agriculture rates that are currently depleting aquifers at an alarmingly rapid rate. By supplying them with fresh water, our model gives the aquifers time to restore by natural processes, and if not that, they will sustain aquifer levels.

Our model serves as the best approach to outline the nation's water usage policy until 2025 because of its minimal environmental impacts and reduced economic constraints compared to recent legislation, and it meets the overall goal of our country by supplying the population with water in an effective and feasible way. Our final cost estimate to Congress is $110 billion for the first year, followed by $25 billion for the proceeding fourteen years. This cost encompasses all water needs, transportation, and storage, as well as quickly reducing dependence on ground and surface water.

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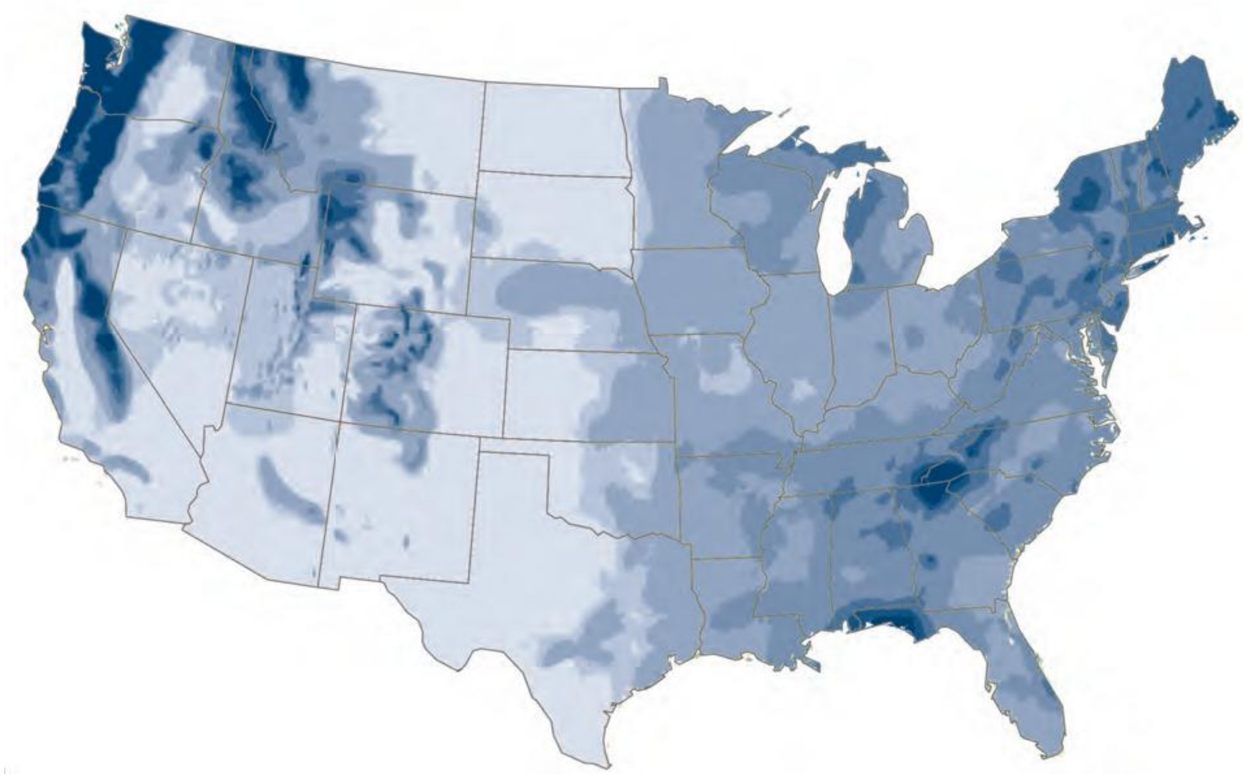
<u>Appendix:</u>

Other graphs and tables obtained from research and not mentioned in the paper.

Figure 1: Estimated mean annual natural ground-water recharge in the conterminous United States (data from Wolock, 2003a).



Explanation: Dark shaded areas indicate high mean annual ground-water recharge and lighter shaded regions indicate lower mean annual ground-water recharge.

Figure 2: Principal Aquifers of the United States (modified from Principal Aquifers, U.S. Geological Survey, 2003).